

# Control of chronic obstructive pulmonary disease in urban populations: findings from a cross-sectional prevalence survey in Shenzhen, China

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## Research

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# Abstract

**Background:** The prevalence of chronic obstructive pulmonary disease (COPD) among urban populations is generally lower than rural residents, but the disease burden is still high. Limited evidence on the patients' characteristics has been offered to guide the control of the disease in city settings.

**Methods:** We conducted a cross-sectional prevalence survey of COPD among residents aged  $\geq 40$  years in an emerging city Shenzhen, China. The multi-stage stratified random sampling method was applied to enroll eligible participants from September, 2018 to June, 2019. Tested by spirometry, individuals were diagnosed with COPD if the post-bronchodilator FEV1/FVC ratio was less than 0.7. Patients' demographic and clinical characteristics, as well as estimates of the exposure to air pollutants, were included in the univariable and multivariable logistic regression models to assess the risk factors for COPD.

**Results:** A total of 4157 individuals were invited to participate in this survey and 3591 who had available spirometry results and epidemiological data were enrolled in the final analysis. The estimated standardized prevalence of COPD among residents over 40 years old in Shenzhen was 5.92% (95% confidential intervals 4.05-8.34). Risk factors for COPD included elder age (adjusted odds ratio 1.206, 95% CI 1.120-1.299 per 10-year increase), smoking over 20 pack-years (1.968, 1.367-2.832), history of chronic bronchitis (1.733, 1.036-2.900) or asthma (4.920, 2.425-9.982), and exposure to higher annual minimum concentrations of ambient SO<sub>2</sub> (1.156, 1.053-1.270 per 1- $\mu\text{g}/\text{m}^3$  increase). Among 280 spirometry-diagnosed patients, most (221, 78.93%) patients were classified as mild COPD (GOLD stage I). The COPD assessment tests showed 24.7% (58/235) patients had severe symptoms with a total score  $\geq 10$ , and 82.6% (194/235) were clinically symptomatic with a total score  $\geq 2$ .

**Conclusions:** This survey found a low prevalence of COPD in Shenzhen and most patients had mild symptoms, thus recommended screening using spirometry in primary health care to detect early-stage COPD. Increased risk from the exposure to air pollutants also indicated the urgent need for environmental improvement in city settings.

## Background

Chronic obstructive pulmonary disease (COPD) is a preventable and curable respiratory disease characterized by persistent respiratory symptoms and airflow limitation (Vogelmeier et al. 2017). COPD is one of the leading causes of death in the world, and the success of its treatment largely depends on the correct implementation of various recommendations, especially effective intervention for early-staged mild diseases (Y. Zhou et al. 2017). As forecasted by the World Health Organization (WHO), the prevalence of COPD will further increase in the future 40 years because of the increasing smoking rates in developing countries and the aging population in high-income countries [3]. The number of patients who will die from COPD and related diseases would exceed 5.4 million cases globally by 2060 (Halpin et al. 2021). Variations were observed between the prevalence of COPD in rural and urban areas, but limited evidence was provided to design the targeted measures for different situations.

COPD has been one of the major fatal diseases in China during the past 30 years. Followed to stroke and ischemic heart diseases, the number of patients dying from COPD ranked third in 2017 (M. Zhou et al. 2019). A countrywide survey in China during 2014–2015 (Fang et al. 2018) showed that the prevalence of COPD among residents aged > 40 years old is 13.6%, which is significantly higher than that in 2007 (8.2%) (Zhong et al. 2007). Shenzhen is an economically developed coastal city in southern China, with a better environment than rural areas. A large number of young internal migrants come to this city for more work opportunities and higher income. A pilot survey (Chen et al. 2017) in a district of Shenzhen showed a COPD prevalence of 9.6% among residents over 40 years old. People who have related symptoms or exposure to risk factors would be suggested to take the spirometry test every year; however, seldom migrants actively take the examination due to mild symptoms or restricted access to medical service. To make recommendations of control strategies for similar city settings, we conducted a cross-sectional survey in all the ten districts of Shenzhen to estimate the overall prevalence of COPD, to assess associated demographic factors as well as environmental exposure, and to analyze patients' clinical characteristics.

## Methods

### Study site

Shenzhen is a coastal city in southern China and its economy has continuously and prosperously developed over the past 40 years of reform and opening up. A large number of internal migrants have poured into this special economic zone, constituting nearly two-thirds of the 15 million residents in 2020 (Shenzhen Statistics Bureau; NBS Survey Office in Shenzhen 2019). This migration resulted in a relatively young residential population in Shenzhen, with an average age of 32.5 years (Shenzhen Statistics Bureau; NBS Survey Office in Shenzhen 2019). The city has a tropical oceanic climate with warm and humid air throughout the year. The average temperature in 2019 is 24°C, and only one day in the whole year had a temperature below 10°C (Shenzhen Meteorological Bureau 2020). Shenzhen also has good environmental conditions with 43.4% land of the green area and was titled “the National Forest City” in 2018. The annual average value of PM<sub>2.5</sub> is 19 µg/m<sup>3</sup>, and the comprehensive air quality index ranks in the top ten cities in the country (Shenzhen Municipal Ecological Environment Bureau 2020).

### Sampling methods

In this COPD prevalence survey from September 2018 to June 2019, we enrolled eligible participants ≥ 40 years old with residence at least six months in Shenzhen using the multi-stage stratified cluster random sampling method. The numbers of communities of each district were determined based on the number of resident populations. A total of 40 communities from ten districts were selected, and about 120 households were selected from each sampled community. The Kish Grid method was used to randomly select one resident over 40 years old from each household for investigation. Excluded were patients with mental illness or cognitive impairment, cancer, high paraplegia, pregnant or breastfeeding women and other subjects who cannot cooperate to complete the epidemiological investigation.

This survey assumes that the prevalence rate is 9.6% based on the previous survey in Shenzhen(Chen et al. 2017). Under the condition that the statistical error probability ( $\alpha$ ) is 0.05 and the allowable error is 80%, the sample size of each group is estimated to be 1852. Stratified by gender and considering the non-response rate of 15%, the total sample size of the survey is estimated to be 4260.

### **Spirometry test and parameters**

Qualified subjects would undergo the pulmonary function test by spirometry and take a structured questionnaire survey after signing the informed consent form. The trained and certified staff used the spirometer (BTL Science and Technology (Shenzhen) Co., Ltd.) to perform pulmonary function examination and bronchodilation test on all the included subjects. The measurement indicators mainly include the forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and one-second rate (FEV1/FVC). Each respondent should successfully complete three pre-bronchiectasis pulmonary function tests, and then perform a bronchodilation test by repeating the pulmonary function test 15 minutes after inhaling 400 mg of the bronchodilator salbutamol aerosol. Subjects allergic to salbutamol or resting heart rhythm higher than 100 bpm were excluded.

According to the 2017 Global Chronic Obstructive Pulmonary Disease Action (GOLD) guidelines(Vogelmeier et al. 2017), we defined the diagnostic criteria for COPD as the post-bronchodilator FEV1/FVC ratio < 0.7. The severity of limitation of lung function among patients of spirometry-confirmed COPD were classified according to the percentage of FEV1 in the predicted value (pv): mild (GOLD stage I: FEV1/pv  $\geq$  80%), moderate (GOLD stage II: 50%  $\leq$  FEV1/pv < 80%), severe (GOLD stage III: 30%  $\leq$  FEV1/pv < 50%), and extremely severe (GOLD stage IV: FEV1/pv < 30%). Patients who were diagnosed with COPD would have further chest X-ray examination and COPD Assessment Test (CAT)(P W Jones et al. 2009).

### **Epidemiological investigation and exposure assessment**

Face-to-face surveys were conducted using a structured questionnaire to obtain patients' basic demographic information, knowledge of COPD, respiratory disease history, family disease history, and respiratory symptoms, exposure of smoking and other risk factors. According to the GOLD document(Vogelmeier et al. 2017), the main types of risk factors for COPD are as follows: "indoor biofuel exposure" is defined as households using biofuels for cooking or heating; "coal exposure" as the households using coal fuel for cooking or heating; and "workplace exposure to dust or chemicals" as the exposure in the workplaces for at least 12 months to dust in the air or harmful chemical gases.

The exposure levels of the air pollutants were detected by the 2018 environmental air quality monitors in each district. The indicators included the air quality index (AQI) and the ambient concentrations of six air pollutants including PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub>, CO, and O<sub>3</sub>. The original monitoring data was obtained from the China National Environmental Monitoring Center, including the daily 24h measurement values of 11 monitoring points throughout 2018. The means of the 8:00-20:00 measurement values were regarded as the daily measurement values and were used to calculate the average of the indicators throughout the

whole year, as well as their annual minimum and maximum values, which were respectively assessed on their impact for COPD in regression models.

## Data processing and statistical analysis

The original questionnaire data is entered into EpiData, exported to Excel format, and saved after data cleaning. Weighted by the gender-age ratio in the 2017 Shenzhen Population Survey (Shenzhen Statistics Bureau and NBS Survey Office in Shenzhen 2017), the standardized prevalence and 95% confidence intervals (CI) were estimated overall and for subgroups. The chi-square test was used to compare the differences in prevalence between groups, and the Cochran-Armitage trend test was used for trend analysis. Univariable logistic regression was used to assess the impact on COPD of demographic characteristics, personal and family disease history, and exposure of risk factors. Variables with a p value < 0.2 were included in the multivariable regression, and stepwise regression was used to include the variables. In the final model, variables with a p value < 0.05 were regarded to have significant correlation with COPD. Statistical analysis was performed using SPSS (version 20.0).

## Results

### Basic characteristics

A total of 4,157 people were investigated in the survey and 3591 (86.48%) were included for analysis who had available data of both epidemiological data and pulmonary function tests. The participants included 1603 (44.6%) males, the average age was  $55.25 \pm 9.46$  years, the average body mass index (BMI) was  $24.44 \pm 3.20$  kg/m<sup>2</sup>, and the average annual exposure to PM<sub>2.5</sub> was  $24.24 \pm 2.08$  µg/m<sup>3</sup>. Low proportions of participants reported ever being diagnosed with other lung diseases, including 150 (3.27%) with chronic bronchitis, 50 (0.80%) with asthma, 66 (1.29%) with tuberculosis, and 88 (2.70%) who were hospitalized for lung diseases during childhood. Regarding exposure to smoking, a total of 556 (20.19%) people were current-smokers, of which the vast majority (531, 95.50%) were men and only 25 (4.50%) were women; 102 (2.13%) participants reported that their mother smoked during pregnancy. In regard to the exposure to other risk factors, 669 (18.75%) people were exposed to dust or chemicals in workplaces, 9 (0.23%) people to biofuels at home, and 12 (0.41%) people to coal at home. The basic demographic characteristics and family history of the study population were listed in [Table 1](#).

### Prevalence of COPD

Measured by spirometry, 280 people were diagnosed with COPD, and the crude prevalence rate of COPD among residents over 40 years old was 7.79% (95% CI 6.94-8.72) in Shenzhen city. Adjusted by the age and gender, the standardized prevalence of COPD was estimated to be 5.92% (4.05-8.34) ([Table 2](#)), and about 172,100 (117,800-242,300) residents over 40 years old suffered from COPD in Shenzhen ([Figure 1](#)). The age-standardized prevalence rate among men over 40 years old was 6.51% (4.48-9.09), which was higher than that among women of 5.39% (3.67-7.62), and the difference was statistically significant (p<0.001). The prevalence showed an upward trend as the age increased (trend test, p<0.001). The

gender-standardized prevalence of COPD among residents aged 40-49, 50-59, 60-69 and over 70 years old were 4.30% (2.77-6.20), 7.28% (5.20-9.75), 12.72% (9.31-15.16), and 14.95% (7.28-19.19), respectively (**Table 1**).

The prevalence of COPD also showed difference in different areas of Shenzhen. The crude prevalence in the central area was the highest, reaching 9.34% (7.89-10.95), and lowest in the eastern region (5.44%, 3.14-8.69), of which the prevalence in Pingshan District was the lowest of only 3.51% (**Figure 2A**). Residents in central area were elder than in northern or eastern areas, which probably lead to the higher crude prevalence of COPD. However, standardized estimates still indicated the discrepancy among COPD prevalence in different areas. The standardized prevalence in central, northern and eastern areas were, respectively, 7.59% (5.02-10.93), 5.60% (3.80-7.93), and 3.86% (0.85-11.61) (**Figure 2B**).

### **Risk factors for COPD**

To evaluate the impact on COPD of the air conditions including AQI and the ambient concentrations of six major air pollutants, we performed univariable logistic regression to include the annual average as well as the minimum and maximum values of each indicator (**Table 3**). The results showed that the maximum value of PM<sub>10</sub>, the average and minimum value of SO<sub>2</sub>, and the average value of CO were significantly correlated with COPD. After standardization by gender and age, the effect of the maximum value of PM<sub>10</sub> and the minimum value of SO<sub>2</sub> remained statistically significant. The risk of COPD increased by 3.8% (0.5-7.1) as the maximum concentration of PM<sub>10</sub> increased every 10 µg/m<sup>3</sup>. For every 1 µg/m<sup>3</sup> increase in the minimum concentration of SO<sub>2</sub>, the risk of COPD increased by 11.8% (2.4-22.1).

The results of univariable logistic regression on other risk factors showed that smoking, education level, medical insurance type, lung disease history, and environmental exposure were significantly correlated with COPD (**Table 4**). In the final multivariable logistic regression model, the risk of COPD increased by 1.206 (1.120-1.299) times as every 10 years of age increased, by 1.156 (1.053-1.270) times per every 1 µg/m<sup>3</sup> increase of the annual minimum air SO<sub>2</sub> concentration; people who smoked greater than 20 pack-years (OR 1.968, 95% CI 1.367-2.832), whose mother smoked during pregnancy (OR 1.881, 95%CI 1.039-3.405), or who had been diagnosed with chronic bronchitis (OR 1.733, 95%CI 1.036-2.900) or asthma (OR 4.920, 95%CI 2.425-9.982) significantly had higher risk of COPD (**Table 4**).

### **Clinical features of COPD patients**

Among the 280 patients diagnosed with COPD, most (221, 78.93%) patients were classified as mild COPD (GOLD stage I), 46 (16.43%) patients were moderate COPD (GOLD stage II), and only 13 cases (4.64%) were severe COPD (GOLD stage III/IV). Among 235 patients who underwent COPD assessment test (CAT), 15 patients (6.4%) reported no related symptoms, and the other 220 patients (93.6%) reported either the respiratory symptoms (cough, sputum, sputum, chest tightness, wheezing, restricted activity) or non-respiratory symptoms (restricted going-out, poor sleep, and fatigue). The above eight symptoms were evaluated on a scale of 0-5, and the results showed that the median CAT score of these patients was five

points (interquartile range 2-9 points). Among the investigated patients, 24.7% (58/235) had a total CAT score of  $\geq 10$  points and were regarded to have severe symptoms, as defined by GOLD(Singh et al. 2019). Lowering the thresholds to detect symptomatic patients, we found that 55.7% (131/235) patients had a total score of over five points, and 82.6% (194/235) had a total score of over two points, where patients were clinically considered to be symptomatic (**Figure 3A**).

Among patients with COPD of GOLD stage I, II, III or above, the proportions of patients with severe symptoms (CAT score  $\geq 10$ ) were 18.6%, 38.5%, and 69.2%, respectively. About half of mild (52.5%) and moderate (59.0%) COPD patients gained a CAT score of  $\geq$  five points, while most (92.3%) severe patients could be detected under this threshold. The proportions of patients who were clinically considered to be symptomatic (CAT score  $\geq 2$ ) were 79.8%, 89.7%, and 100.0%, respectively (**Figure 3B**). Nearly half of the patients (44.3%, 104/235) reported at least four symptoms. The proportions of patients reporting  $\geq$  four symptoms among mild, moderate and severe COPD were 42.6%, 43.6%, and 69.2%, respectively (**Figure 3C/D**). The most frequently reported symptoms are cough (138, 58.7%), expectoration (134, 57.0%), poor sleep (131, 55.7%), and fatigue (123, 52.3%) (**Figure 3E**). Among the above four most common symptoms, patients with any of them accounted for 88.5% (208/235).

## Discussion

This cross-sectional survey estimated that the standardized prevalence of COPD among urban residents over 40 years old in Shenzhen is 5.92% (95% CI 4.05–8.34), which was greatly lower than the average level of 13.6% across China(Fang et al. 2018). Risk factors including elder age, smoking, history of lung diseases, and exposure to higher ambient concentrations of SO<sub>2</sub> were found significantly associated with the diagnosis of COPD. Most of the diagnosed patients had mild symptoms and were classified as GOLD stage I. Considering that the early intervention for mild COPD patients would have the most benefits(Y. Zhou et al. 2017), we suggest in resourceful city settings to screen COPD using spirometry in primary-care facilities to promptly detect early-stage patients and effectively control the disease progression or COPD-related mortality.

In our study, the prevalence of COPD among the urban populations over 40 years old in Shenzhen was far lower than the prevalence rate of 13.6% obtained from the 2014–2015 national epidemiological survey(Fang et al. 2018), and also lower than the global estimate in 2010 of 11.7%(Adeloye et al. 2015). The prevalence of COPD in other cities in China showed similar levels, such as 6.5% in Shanghai(Zhong et al. 2007), 5.5% in urban areas of Shanxi Province(Zhong et al. 2007), or 6.0% in Heilongjiang Province(Han et al. 2015). More young populations in cities could be one of the reasons for the lower overall prevalence of COPD. Besides, we also observed a significant decrease in COPD prevalence among different age groups, especially among elderly populations – 12.7% and 14.9% in Shenzhen versus 21.2% and 35.5% nationally among people aged 60–69 and aged  $\geq 70$  years, respectively(Wang et al. 2018). We assume that better air quality and improved indoor environment in cities have long-term benefits and prevent people from chronic lung diseases including COPD(Faizan and Thakur 2019). As statistics in our study, 18.75% of investigated people reported exposure to dust or chemicals at workplaces, and only

0.23% and 0.41% were, respectively, exposed to biomass or coal during cooking or heating in households. These figures were all extraordinarily lower than the national levels (46.6%, 40.7%, and 34.3%, respectively)(Fang et al. 2018). Smoking(Biener, Decker, and Rohde 2019), the well-known risk factor for pulmonary diseases, also showed a lower level in Shenzhen than nationally (28.3% versus 40.2%).

Of note, shown were differences in the prevalence of COPD in various regions of Shenzhen. The standardized prevalence in the central region (7.6%) was almost twice that in the eastern coastal areas (3.9%). The lower population density, fewer cars, and better air quality in the eastern region probably led to this difference. Though  $PM_{2.5}$ , the main indicator for air quality, did not show a significant impact on COPD in our data, we found that exposure to higher ambient concentrations of  $SO_2$  increased the risk of COPD and its annual minimum value presented the most sensible impact. This result agreed with a recent observation from an Australian cohort, where the exposure to higher concentrations of  $SO_2$  was associated with the incidence of COPD in women of different age groups(Hendryx et al. 2019).  $SO_2$  is one of the components of air pollutants resulting from industrial processes or fossil fuel combustion, which might resource from the crowded traffic in city centers or dense factories in Shenzhen. The spatial analysis in Mongolia showed that the ambient concentrations of  $SO_2$  and other traffic-related pollutants were higher in city centers or near main roads(Huang et al. 2013). Other air pollutants might also increase the risk of COPD, as presented by a study in UK that higher concentrations of  $PM_{2.5}$ ,  $PM_{10}$ , and  $NO_2$  were found significantly associated with higher prevalence of COPD(Doiron et al. 2019). Vehicle emissions could be the main sources of air pollution and potential reasons for respiratory diseases in city settings. To improve the environment in cities, policies have been implemented including constrain of vehicle population and optimization of transportation structure(Sun et al. 2020), and comprehensive strategies for the development of healthy cities were also urgently announced(Guan et al. 2016).

Most of the patients (78.93%) diagnosed in this survey were mild COPD and classified as GOLD stage I. The proportion was even higher than that obtained from the national survey in 2014–2015 (56.4%)(Wang et al. 2018). COPD patients detected by screening in other countries are mainly moderate-level patients. For example, 30.6% and 51.4% of COPD patients diagnosed in a survey in Poland were classified as mild-(GOLD stage I) and moderate-level (GOLD stage II), respectively(Bednarek et al. 2008). Early diagnosis and treatment of patients with mild COPD can more effectively control their lung function status and significantly reduce their progression and deterioration(Guirguis-Blake et al. 2016). As recommended by GOLD(Vestbo et al. 2013), spirometry is considered a necessary tool for screening mild COPD patients, which is a basic tool for COPD diagnosis as well as the grading of lung function. In our survey, the proportion of people who have undergone spirometry before our investigation was very low, and even among COPD patients, the proportion was still less than 10%. This indicated that the current screening in Shenzhen is insufficient to timely detect COPD patients in an early stage. For the purpose of early diagnosis and effective control, it is necessary to include spirometry in the routine examinations of people over 40 years old, which helps to find early-stage COPD patients and to promptly intervene, as suggested in Health Regulations in Shenzhen Special Economic Zone(Standing Committee of Shenzhen Municipal People's Congress 2020).

The CAT score can be used to effectively screen high-risk groups with respiratory symptoms or restricted daily activities(P W Jones et al. 2009), but the total CAT score of the diagnosed patients in this survey was generally low. Half of the patients obtained less than five points, suggesting that the threshold of CAT score should be lowered in screening COPD patients. For example, if the CAT total score is two or above, 82.6% of mild COPD patients would be recommended to further examinations for confirmation. Other studies(Houben-Wilke et al. 2018; Paul W Jones, Tabberer, and Chen 2011) agreed the CAT score useful in the COPD screening of patients with COPD, and Kon S. and his colleagues(Kon et al. 2014) also proposed that a reduction of over two points could evaluate the effect of the intervention in COPD patients. However, there were still some patients who had no self-reported symptoms or who had a total CAT score of fewer than two points. These patients can only rely on spirometry for screening.

This study only involved residents in one specific city of China where a large number of young people migrant from rural areas to this well-developed metropolis. Further studies are needed to characterize the prevalence of obstructive pulmonary diseases in other cities. Cost-effectiveness analysis will also support the implication of different screening strategies in different settings.

## Conclusions

This cross-sectional survey found a relatively low prevalence of COPD among urban populations over 40 years old in Shenzhen. Spirometry and a low threshold of a two-point CAT score are recommended for COPD screening, and further effort including optimization of transportation and the industrial process is needed to improve environmental conditions in cities.

## Abbreviations

COPD: Chronic obstructive pulmonary disease; CAT: COPD assessment test; IQR: Interquartile range; OR: odds ratio.

## Declarations

### Ethics approval and consent to participate

The epidemiological investigation and related tests and evaluations were conducted after receiving the signed informed consent from all the participants. This survey was reviewed and approved by the Ethics Committee of Shenzhen Center for Chronic Disease Control (No. SZCCC-2020-018-05-PJ).

### Consent for publication

Not applicable.

### Availability of data and materials

The dataset analyzed during this study are included in this published article. The raw data of individuals used of this study are available from the corresponding author on reasonable request.

### Competing interests

The authors declare that they have no competing interests.

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### Authors' contributions

LJ, HG, and WT designed and managed the study. LJ and CL collected, processed and cleaned the raw data; JY and QJ did the data analysis and interpretation. JY drafted the manuscript; LJ, LW, and QJ prepared the final article; all authors contributed to and reviewed the final version.

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## Tables

**Table 1. Demographic characteristics and exposures of study participants**

	Total (n=3591)	Men (n=1603)	Women (n=1988)
Age, m ± sd	55.25 ± 9.46	55.11 ± 9.75	55.37 ± 9.22
Age, n (%)			
40-49 years	1189 (65.89)	571 (67.55)	618 (63.90)
50-59 years	1140 (20.62)	464 (20.43)	676 (20.86)
60-69 years	1012 (8.55)	445 (7.67)	567 (9.60)
≥70 years	250 (4.94)	123 (4.35)	127 (5.64)
Education level, n (%)			
Primary school or less	735 (14.07)	225 (10.17)	510 (18.79)
Middle and high school	2097 (57.66)	986 (59.60)	1111 (55.32)
College and higher	757 (28.27)	392 (30.24)	365 (25.89)
Years of residence in Shenzhen, n (%)			
1-10	1049 (23.19)	433 (21.86)	616 (24.79)
≥10	2539 (76.81)	1168 (78.14)	1371 (75.21)
Residence Region, n (%)			
Central Region	1446 (40.10)	595 (38.79)	851 (41.68)
Eastern Region	294 (7.19)	159 (7.40)	135 (6.95)
Northern Region	1851 (52.71)	849 (53.81)	1002 (51.37)
Disease history, n (%)			
Mother smoked during pregnancy	102 (2.13)	44 (1.98)	58 (2.31)
History of chronic bronchitis	150 (3.27)	69 (3.48)	81 (3.00)
History of asthma	50 (0.80)	26 (0.79)	24 (0.81)
History of tuberculosis	66 (1.29)	39 (1.86)	27 (0.60)
Childhood hospitalization for pulmonary diseases	88 (2.70)	40 (3.11)	48 (2.21)
Risk factors for COPD, n (%)			
Exposure to dust or chemicals	669 (18.75)	350 (22.08)	319 (14.73)
Indoor exposure to biomass	9 (0.23)	3 (0.22)	6 (0.23)
Indoor exposure to coal	12 (0.41)	2 (0.15)	10 (0.72)
Smoking history, n (%)			
Never smoker	2690 (71.52)	745 (50.11)	1945 (97.31)
Former smoker	337 (8.29)	323 (14.73)	14 (0.54)
Current smoker	556 (20.19)	531 (35.17)	25 (2.16)
Smoking (pack-years), n (%)			
None	2690 (79.01)	745 (60.28)	1945 (97.92)
One to less than 20	189 (7.94)	178 (14.35)	15 (1.47)
20 or more	447 (13.04)	432 (25.37)	11 (0.60)
BMI, m ± sd	24.44 ± 3.20	24.91 ± 3.11	24.91 ± 3.11
History of spirometry test, n (%)			
Yes	271 (7.56)	147 (9.73)	124 (4.95)
No	3201 (92.44)	1396 (90.27)	1805 (95.05)
Annual mean PM <sub>2.5</sub> exposure (µg/m <sup>3</sup> ), m ± sd	24.24 ± 2.08	24.20 ± 2.14	24.27 ± 2.03

Note: Continuous variables were expressed as mean ± standard variation (m ± sd), and category data as counts (proportion).

**Table 2. Standardized prevalence of COPD in population aged 40 years or older**

	Total	Men	Women
Total	5.92 (4.05-8.34)	6.51 (4.48-9.09)	5.39 (3.67-7.62)
Age (years)			
40-49	4.30 (2.77-6.20)	3.79 (2.23-5.36)	4.94 (3.23-6.65)
50-59	7.28 (5.20-9.75)	7.75 (5.32-10.19)	6.71 (4.82-8.60)
60-69	12.72 (9.31-15.16)	15.86 (12.46-19.25)	9.70 (7.26-12.13)
≥70	14.95 (7.28-19.19)	20.53 (13.39-27.67)	9.76 (4.60-14.92)
p for trend	<0.001	<0.001	0.030
Education level			
Primary school or less	8.89 (6.83-10.94)	12.50 (8.18-16.82)	6.53 (4.38-8.67)
Middle and high school	5.78 (4.78-6.78)	5.72 (4.27-7.16)	5.87 (4.49-7.25)
College and higher	5.60 (3.96-7.24)	5.23 (3.02-7.43)	6.13 (3.67-8.59)
p for trend	0.040	0.010	0.47
Region			
Central city	7.59 (5.02-10.93)	8.76 (4.82-14.42)	6.65 (3.58-11.23)
Eastern Region	3.86 (0.85-11.61)	4.26 (0.59-16.59)	3.16 (0.20-16.92)
Northern Region	5.60 (3.80-7.93)	5.70 (3.25-9.18)	5.41 (3.01-8.97)
p for difference	0.012	0.022	0.046

**Table 3. The impact of ambient air quality and the exposure to six air pollutants on COPD**

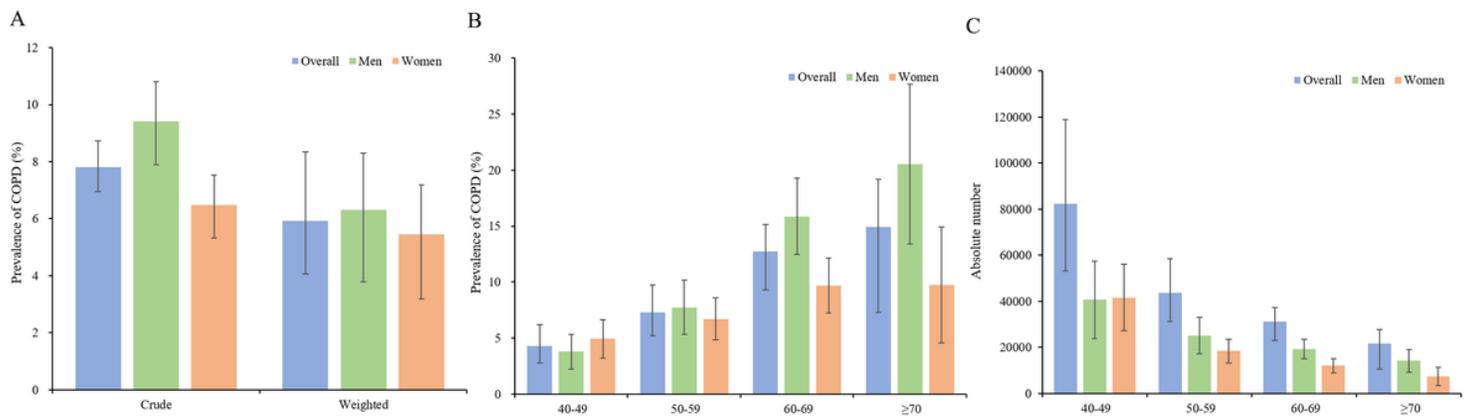
	COPD cases	Non-COPD cases	Univariable regression		Age-gender-adjusted regression	
			OR (95%CI)	P value	Adjusted OR	P value
AQI_mean	46.45 ± 4.28	46.56 ± 4.30	0.944 (0.709-1.256)	0.692	-	-
AQI_min	13.83 ± 1.45	13.90 ± 1.42	0.692 (0.288-1.662)	0.410	-	-
AQI_max	170.47 ± 8.81	166.17 ± 41.69	1.026 (0.996-1.057)	0.096	1.024 (0.993-1.056)	0.132
PM <sub>2.5</sub> _mean	27.70 ± 3.21	27.66 ± 3.25	1.039 (0.715-1.511)	0.840	-	-
PM <sub>2.5</sub> _min	4.64 ± 0.98	4.62 ± 1.03	1.310 (0.400-4.290)	0.656	-	-
PM <sub>2.5</sub> _max	131.38 ± 31.44	127.78 ± 33.75	1.033 (0.996-1.072)	0.085	1.031 (0.993-1.072)	0.112
PM <sub>10</sub> _mean	46.60 ± 5.11	46.75 ± 5.10	0.941 (0.739-1.198)	0.621	-	-
PM <sub>10</sub> _min	10.20 ± 2.35	10.12 ± 2.40	1.137 (0.687-1.881)	0.618	-	-
PM <sub>10</sub> _max	184.33 ± 38.67	178.65 ± 39.11	1.037 (1.006-1.070)	0.020	1.038 (1.005-1.071)	0.022
SO <sub>2</sub> _mean	7.37 ± 1.13	7.20 ± 1.22	1.123 (1.014-1.245)	0.026	1.098 (0.986-1.222)	0.090
SO <sub>2</sub> _min	2.82 ± 1.45	2.49 ± 1.34	1.184 (1.088-1.288)	<0.001	1.118 (1.024-1.221)	0.013
SO <sub>2</sub> _max	19.23 ± 4.73	18.69 ± 4.87	1.023 (0.998-1.048)	0.077	1.024 (0.998-1.050)	0.076
NO <sub>2</sub> _mean	31.30 ± 5.52	31.11 ± 5.50	1.006 (0.984-1.029)	0.579	1.014 (0.992-1.038)	0.219
NO <sub>2</sub> _min	6.55 ± 3.24	6.27 ± 3.42	1.024 (0.989-1.060)	0.181	1.025 (0.988-1.064)	0.192
NO <sub>2</sub> _max	114.91 ± 45.90	110.33 ± 47.02	1.002 (0.999-1.005)	0.117	1.003 (1.000-1.005)	0.053
O <sub>3</sub> _mean	66.73 ± 4.00	67.22 ± 4.18	0.972 (0.944-1.001)	0.057	0.976 (0.947-1.007)	0.126
O <sub>3</sub> _min	5.98 ± 2.58	6.14 ± 2.59	0.977 (0.932-1.025)	0.346	-	-
O <sub>3</sub> _max	190.84 ± 10.36	191.58 ± 10.45	0.993 (0.982-1.005)	0.252	-	-
CO_mean	0.64 ± 0.02	0.64 ± 0.02	1.089 (1.018-1.164)	0.013	1.062 (0.996-1.133)	0.067
CO_min	0.26 ± 0.09	0.26 ± 0.09	0.999 (0.986-1.012)	0.896	-	-
CO_max	1.39 ± 0.31	1.38 ± 0.31	1.001 (0.997-1.005)	0.740	-	-

Note: The unit of each air pollutant is  $\mu\text{g}/\text{m}^3$ . The odds ratios (OR) were calculated as AQI, PM<sub>2.5</sub>, PM<sub>10</sub> increased every 10 units, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub> every 1 unit, and CO every 0.01-unit change.

**Table 4. Risk factors for COPD in age-and-gender adjusted logistic regression and the multivariable model**

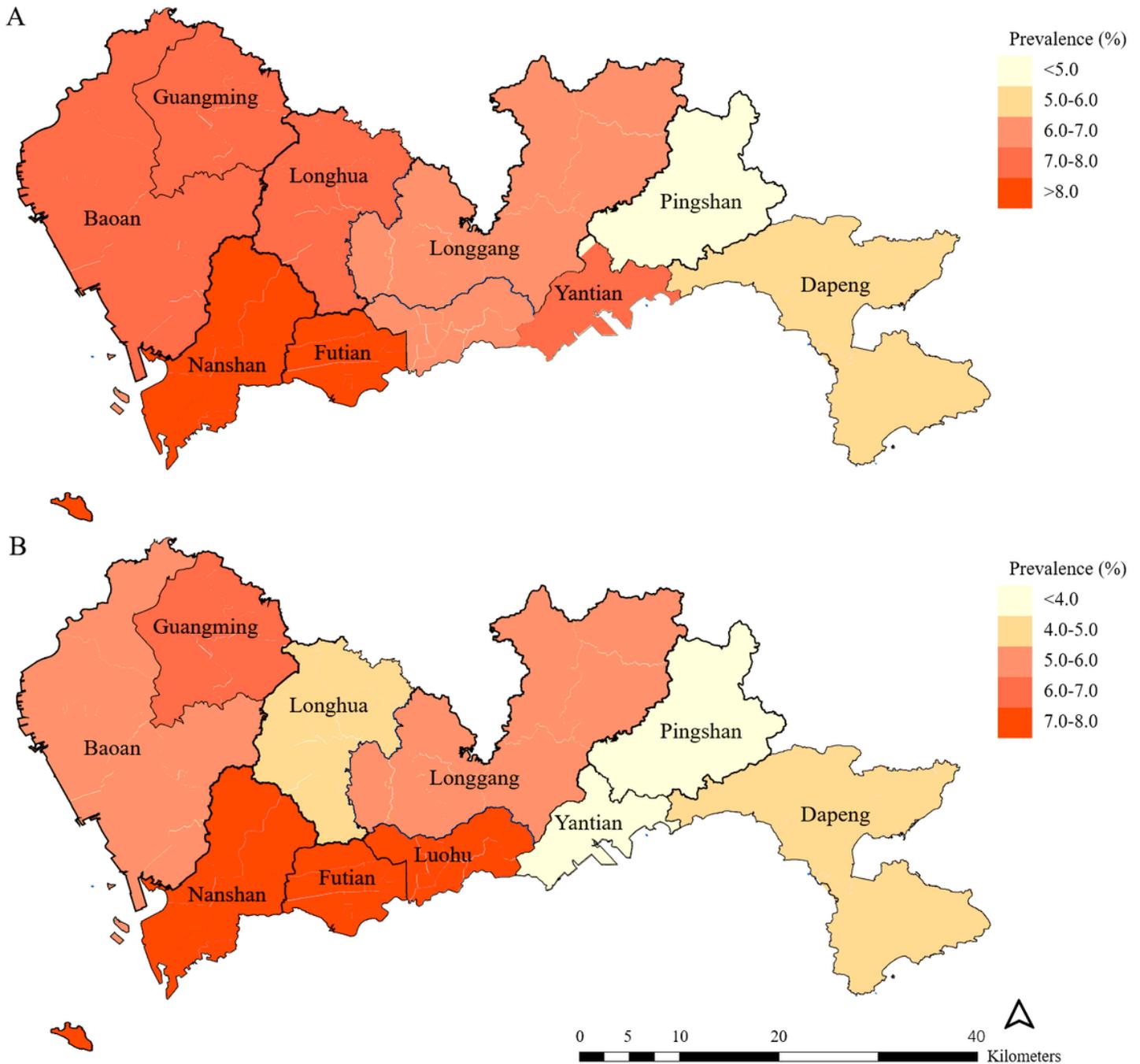
	COPD cases (n=280)	Non-COPD cases (n=3311)	Age- and sex-adjusted regression		Multivariable regression	
			OR (95%CI)	P value	OR (95%CI)	P value
Male	151 (53.9)	1452 (43.9)	1.514 (1.183-1.937)	0.001	1.270 (0.941-1.712)	0.118
Age (per 10 years)	59.2 ± 9.2	54.9 ± 9.4	1.269 (1.186-1.356)	<0.001	1.206 (1.120-1.299)	<0.001
Air SO <sub>2</sub> minimum exposure	2.82 ± 1.45	2.49 ± 1.34	1.120 (1.026-1.224)	0.012	1.156 (1.053-1.270)	0.002
Mother smoked during pregnancy	16 (6.1)	86 (2.7)	2.084 (1.194-3.638)	0.010	1.881 (1.039-3.405)	0.037
History of chronic bronchitis	30 (10.8)	120 (3.7)	2.638 (1.717-4.053)	<0.001	1.733 (1.036-2.900)	0.036
History of asthma	20 (7.2)	30 (0.9)	6.607 (3.639-11.996)	<0.001	4.920 (2.425-9.982)	<0.001
Smoking ≥ 20 pack-years	68 (24.3)	488 (14.8)	2.080 (1.481-2.921)	<0.001	1.968 (1.367-2.832)	<0.001

## Figures



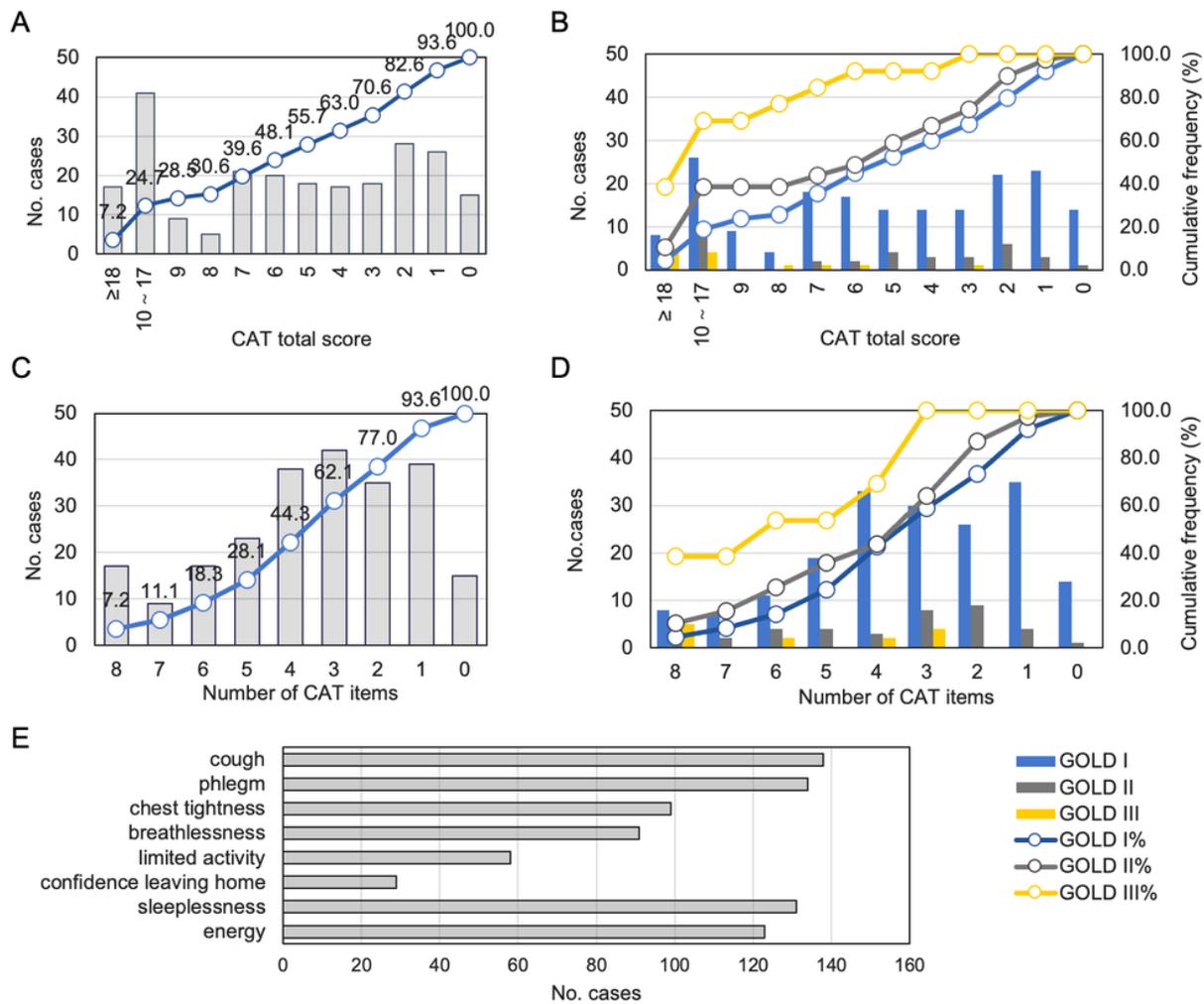
**Figure 1**

The prevalence of COPD and the estimated number of patients by gender and age group. (A) Total prevalence and standardized prevalence of people over 40 years old; (B) Standardized prevalence of different age groups Disease rate; (C) Estimated number of patients in different age groups.



**Figure 2**

Crude prevalence (A) and standardized prevalence (B) by district. The central region Nanshan, Futian, and Luohu districts; the northern region includes Baoan, Guangming, Longhua, and Longgang districts; the eastern region includes Yantian, Pingshan, and Dapeng districts. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



**Figure 3**

Related symptoms and COPD Assessment test (CAT) score of COPD patients. The total proportion of symptomatic patients whose CAT score and total score are higher than each threshold (A) and the stratification by GLOD level (B); cumulative proportions of patients reporting different numbers of CAT items (C) and the stratified by GLOD levels (D); (E) the number of people reporting various CAT items.