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The attributable risk of chronic obstructive pulmonary disease due to ambient fine particulate pollution among older adults

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A R T I C L E I N F O

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A B S T R A C T

Background: The linkage between ambient fine particle pollution ($PM_{2.5}$) and chronic obstructive pulmonary disease (COPD) and the attributable risk remained largely unknown. This study determined the cross-sectional association between ambient $PM_{2.5}$ and prevalence of COPD among adults ≥50 years of age.
Methods: We surveyed 29,290 participants aged 50 years and above in this study. The annual average concentrations of $PM_{2.5}$ derived from satellite data were used as the exposure indicator. A mixed effect model was applied to determine the associations and the burden of COPD attributable to $PM_{2.5.}$
Results: Among the participants, 1872 (6.39%) were classified as COPD cases. Our analysis observed a threshold concentration of 30 μg/m^3 in the $PM_{2.5}$-COPD association, above which we found a linear positive exposure-response association between ambient $PM_{2.5}$ and COPD. The odds ratio (OR) for each 10 μg/m^3 increase in ambient $PM_{2.5}$ was 1.21(95% CI: 1.13, 1.30). Stratified analyses suggested that males, older subjects (65 years and older) and those with lower education attainment might be the vulnerable subpopulations. We further estimated that about 13.79% (95% CI: 7.82%, 21.62%) of the COPD cases could be attributable to $PM_{2.5}$ levels higher than 30 μg/m^3 in the study population.
Conclusion: Our analysis indicates that ambient $PM_{2.5}$ exposure could increase the risk of COPD and accounts for a substantial fraction of COPD among the study population.

1. Introduction

Chronic obstructive pulmonary diseases (COPD) have been an increasingly important global public health problem. It is estimated that there are about 70 million COPD patients worldwide (Bazargani et al., 2014). It is particularly a problem in low and middle-income countries, where about 90% of COPD deaths occur and effective prevention and control measures are usually lacking (Ferkol and Schraufnagel, 2014). Despite the widespread concern, the relationship between COPD and some important risk factors, especially environmental factors, has not been adequately studied (Zhao et al., 2017).

Ambient air pollution is one potential environmental factor for COPD. While compelling evidence has shown an etiology association between tobacco smoking, indoor air pollution and COPD (Kurmi et al., 2010; Salvi, 2014), the relationship between COPD and outdoor air pollution, such as $PM_{2.5}$ has only been evaluated in a few studies with mixed results. A significant association was observed in two longitudinal studies (Naess et al., 2007; Pinault et al., 2016) and one cross-sectional study in China (Liu et al., 2016). Conversely, non-significant associations were reported in one Canadian cohort study (Gan et al., 2013), an English cohort (Atkinson et al., 2014), and some other studies (Atkinson et al., 2014; Wong et al., 2015). These inconsistent findings indicated the necessity to conduct more studies.

Furthermore, it would be of great importance to estimate the

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attributable risk of COPD due to air pollution exposure. This could provide more important information by showing how much of the disease is preventable if we have effective public health and prevention measures (Burnett et al., 2014).

Additionally, most existing evidence was obtained from developed countries. Very few studies have been available in low- and middle-income countries, where high air pollution generally exists. Here we reported the results on the cross-sectional effects of ambient $PM_{2.5}$ on the risk of COPD among older adults in six low- and middle-income countries. We further estimated the COPD burden attributable to ambient $PM_{2.5}$ using a health risk assessment framework.

2. Methods

2.1. Study participants

We used the baseline survey data of the World Health Organization (WHO) Study on global AGEing and adult health (SAGE), the details of the survey have been introduced elsewhere (Wu et al., 2015). Briefly, SAGE is a longitudinal study in six low- and middle-income countries: China, Ghana, India, Mexico, Russia and South Africa. The participants were selected using a multi-stage stratified cluster sampling approach. The relevant information was collected from each participant by trained investigators using a standardized questionnaire during 2007–2010.

2.2. COPD

Participants were recognized as COPD cases if they met one of the following criteria: 1) Participants who have been diagnosed with COPD by a clinician; 2) who self-reported receiving treatment for COPD during the past 12 months. This diagnosis approach has previously produced a comparable prevalence rate with a large population-based survey in China (Zhong et al., 2007).

2.3. Ambient $PM_{2.5}$

We retrieved the annual concentrations of ambient $PM_{2.5}$ which were estimated based on the aerosol optical depth (AOD) information in the remote sensing data of NASA (Van Donkelaar et al., 2015). The AOD is an indicator to reflect the transparency for electro-magnetic radiation and particulate matter concentration in the troposphere (NASA (National Aeronautics and Space Administration), 2013). The $PM_{2.5}$ concentrations were firstly estimated in a 10*10 km resolution in consideration of local weather conditions; and they were then refined into a $1 * 1$ km resolution (Van Donkelaar et al., 2015). Previous studies have observed that the estimated $PM_{2.5}$ concentrations were highly correlated with the actual monitored concentrations (Wong et al., 2015). The estimation served as a proxy of exposure level of ambient $PM_{2.5}$. The participants' residential community centroid was geo-coded and used to match the estimated $PM_{2.5}$ concentrations. The mean concentrations of the prior three years before the survey were used as the exposure in the main model (Filleul et al., 2005; Lin et al., 2017b).

2.4. Covariates

A series of covariates were considered in the analysis, including demographic factors [sex, age, marital status, and body mass index (BMI)], socioeconomic factors (education attainment, and annual household income), and lifestyle factors (smoking, alcohol consumption, occupational pollution exposure, physical activity, and domestic cooking-related air pollution). We categorized marital status into three groups: married, unmarried and widowed. Those who were never married, separated, or divorced were classified as unmarried. Household income was grouped into low and high categories using median as the cut point. Assessment of lifetime tobacco smoking has been described elsewhere (Wu et al., 2015). Three smoking variables were used for this study: status of smoking (never or ever), duration of smoking (never, and less or > 20 years), and amount (never, fewer or > 10 cigarettes/day).

Two variables were used to assess indoor air pollution, namely fuel type and ventilation in cooking spaces. Fuel type was classified into two categories: solid fuels and liquid and gas fuels. The former included coal, wood, dung and agricultural residues; the latter included electricity, liquefied petroleum gas and natural gas. Ventilation was defined as whether there was any ventilation apparatus in the cooking area, such as chimney, extraction hood, or fan. Occupations were classified as air pollution related occupations, including mining, construction, cleaning, renovation, mechanic-related work; and others without occupational air pollution exposure, such as administrative, office work, service, academic, sales, fishery, unemployed, etc. (Neupane et al., 2010). Physical activity was classified into three levels: low, moderate, and high according to the time spent on each activity and its total energy consumption (Wu et al., 2015).

2.5. Statistical analysis

Since the participants residing in the same community may not be independent from each other due to the shared environment, and facilities, violating the independence assumption of regression models (Fleischer et al., 2014), we applied a mixed effect model with the $PM_{2.5}$ exposure and other covariates at the participant level as a fixed effect term, and community as a random effect term (Lin et al., 2017a).

We first examined the dose-response relationship between $PM_{2.5}$ and COPD using a natural spline smoothing function (Tian et al., 2016). Our initial analysis observed the existence of a threshold concentration, above which there was a linear effect. We then identified the threshold based on the Akaike Information Criterion (AIC), a method described previously by Zhang et al. (Zhang et al., 2016). In brief, we examined several potential thresholds. For example, a visual inspection of the concentration–response curve may suggest that the potential threshold might be 25 and 35 $\mu g/m^3$. We thus fitted two models with the cut-off varying within the concentrations (by each 1 $\mu g/m^3$). The model that minimizes the sum of the AICs will be selected as the threshold (Zhang et al., 2016).

We then investigated the linear association between ambient $PM_{2.5}$ and COPD above the identified threshold concentration. Multivariate models were conducted to control for some important covariates in the models, which were selected according to two criteria: 1) variables that are potential risk factors for COPD; and/or (2) variables that changed the association between $PM_{2.5}$ and COPD by > 10% when added to the model. Using these criteria, the variables included in the final model were sex, age, BMI, education, smoking, alcohol drinking and occupational exposure.

2.6. Stratified analysis

To identify the potential effect modifiers, stratified analyses were conducted by a few potential variables: sex (males and females), age group (< 65 years and ≥65 years), smoking (ever-smokers and never-smokers), education (low and high levels) and season of the survey (warm and cold seasons, with warm season defined as April to September, and cold season as January to March and October to December). The statistical significance of the difference between the stratum was tested by using the 95% confidence interval: $(\beta_1 - \beta_2) \pm 1.96\sqrt{(SE_1)^2 + (SE_2)^2}$. β_1 and β_2 represented the regression coefficients in each stratum, and SE_1 and SE_2 were the corresponding standard errors (Wu et al., 2014).