

# Asthma and Asthma-Related Symptoms among Adults of an Acid Rain-Plagued City in Southwest China: Prevalence and Risk Factors

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## Abstract

There is increasing evidence for a possible association between asthma and asthma-related symptoms and indoor environmental quality in developing countries. Data on the prevalence of asthma and asthma-related symptoms and its association to personal, occupational, and environmental risk factors among adults in the acid rain-plagued city of Zunyi in southwestern China have not been widely available. A multistage cluster random sampling method was performed in populations aged 18 years and above in 11 inner-city areas of Zunyi in Guizhou province in winter (from October 2011 to March 2012). A modified adult questionnaire of the European Community Respiratory Health Survey II translated into Chinese was administered to adults in order to collect data on asthma and asthma-related symptoms and selected home environmental factors. The overall prevalence of adult asthma, asthma and asthma-related symptoms were 1.8% and 13.1%, respectively. Coal (OR = 1.893; 95% CI, 1.157-3.097), cooking oil fumes (OR = 2.218; 95% CI, 1.466-3.356), current smokers (OR = 4.201; 95% CI, 2.647-6.667), secondhand smoke (OR = 3.654; 95% CI, 1.341-4.343) and pets keeping (OR = 2.170; 95% CI, 1.424-3.308) were independently associated with the occurrence of adult asthma and asthma-related symptoms. The prevalence of adult asthma was lower than those reported by European and American studies, but closer to those of previous Chinese studies. The risks of asthma and asthma-related symptoms in this population were associated with exposure to coal, cooking smoke, cooking oil fumes, and secondhand smoke and pets, among other risk factors.

**Keywords:** environmental risk factors, asthma, asthma-related symptoms, adult resident

## Introduction

Asthma is a common chronic respiratory disease that has been a growing public health concern internationally, induced by increasing prevalence rates in adults and children. Asthma usually arises from an interaction between host factors and environmental factors. A rapid increase in asthma in recent years cannot be ascribed to changes in genetic factors;

the focus of interventions for the increased prevalence of asthma should be on environmental factors. Although the role of indoor environmental exposure in the development of asthma morbidity and exacerbations are largely unknown, there is strong evidence that indoor risk factor exposure, including fuel combustion [1], environmental tobacco smoke (ETS) [2], and allergens [3, 4], play a key role in triggering and exacerbating adult asthma morbidity.

Epidemiologic surveys have shown varying prevalence rates for asthma and asthma-related symptoms across coun-

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tries and regions: inner-city areas of China may have generally lower prevalence of asthma and asthma-related symptoms than western countries. Little is known about the prevalence of asthma and asthma-related symptoms among adults living in an acid rain-plagued area of China in relation to the combination of various indoor environmental risk factors to which the residents are exposed.

Indoor air pollution is an important issue in China. Air pollution originating from cooking and heating represents a major environmental exposure that affects the health of adults in most Asian countries, including China. For instance, in China, in four cities (namely Chongqing, Guangzhou, Lanzhou, and Wuhan), approximately 51-71% of households used coal for heating or cooking [5]. Moreover, tobacco smoking is common in China. In mainland China in 2010, 26% of its urban adult population and 30% of its rural adult population were current smokers, with about 70% of its adult population exposed to second-hand smoke (SHS) in a typical week [6]. China is undergoing industrial development and urbanization at an unprecedented rate. Although this has improved living conditions for some people in modern cities, many people are faced with deteriorating indoor environmental conditions.

Our study area, Zunyi city, possesses abundant coal reserves and is known as the city most seriously polluted by acid rain and records high levels of air pollution (Fig. 1). These conditions prompted us to investigate the extent of asthma and asthma morbidity and their relation to the potential risk factors. The objective of this study was to assess the prevalence of asthma and asthma-related symptoms in relation to personal, occupational, and environmental indoor risk factors in inner-city areas of Zunyi city, Guizhou Province in southwest China.

## Methods

### Study Design

A population-based, cross-sectional epidemiological survey of asthma and asthma-related symptoms was conducted in Zunyi. The study was conducted in winter (from

October 2011 to March 2012). Data on health variables related to asthma and asthma-related symptoms, plus information on personal, occupational, and home environmental factors was collected by self-administered questionnaires distributed to selected adult participants.

### Study Location

Zunyi is the biggest city in northern Guizhou Province. Both urban districts of the city, Huichuan and Honghuagang, were selected. Honghuagang district comprises of 8 inner-city areas, namely, Laocheng (LC) road, Wangli (WL) road, Zhonghua (ZH) road, Nanmenguan (NMG) road, Yanan (YA) road, Zhoushuiqiao (ZSQ) road, Zhongshan (ZS) road, and Beijing (BJ) road, while Huichuan district consists of 3 inner-city areas, namely Shanghai (SH) road, Xima (XM) road, and Dalian (DL) road. Therefore, the inner-city area in Zunyi comprises of 11 areas, covering a wide range of geographic areas in the city (105 km<sup>2</sup>) and a total population of more than 403 million. These 11 inner-city areas are homogeneous in terms of lifestyle, education, employment and income, housing, geographical origin of residents, and air pollution implication. The heads of 11 selected inner-city areas were contacted, and all agreed to participate.

Zunyi is a traditional industrial city. It is known as the city most seriously polluted by acid rain in China. The frequency of acid precipitation in Zunyi was above 80%, with the lowest pH value of acid precipitation ever reached being 3.2, a result of excessive coal consumption by local industries and households. Coal and liquid petroleum gas are the major sources of fuel for cooking, baking, and heating in the local households in winter. Cooking is mainly done either indoors with an open-fire traditional cooking stove in a small kitchen without effective ventilation, or in an open or closed kitchen adjacent to the living room within the house (Fig. 2).

### Study Population and Selection Process

The study population was selected by a simple random sampling technique. At the first stage of sampling, given the number of community members ranging from eight to



Fig. 1. Map of the selected area (Zunyi city) in Guizhou Province, China.

twelve in each inner-city area in Zunyi, two study communities were selected from each inner-city area by simple random sampling. Therefore, a total of 22 communities were selected. At the second stage of sampling, one residence community (cluster unit) was randomly selected for investigation in each community using the same sampling technique, therefore, a total of 22 residence communities were selected. At the final stage of sampling, in each selected residence community, the first family was selected by simple random sampling of residential address numbers.

Taking into consideration that adult residents in one family do not usually sleep in one bedroom, and their pulmonary physical responses to the exposure to indoor air pollution might be potentially different, hence all family members present at the residence who met the inclusion criteria were selected. After that, neighbors living in a residence next door who met the inclusion criteria were recruited and interviewed. If no one was at home, the interviewer returned up to three times before skipping to another family next door. If the selected family refused to participate or could not be found, neighbors living in the next residence who met the inclusion criteria were recruited. This procedure was repeated in every house in the selected houses until the targeted number of participants was recruited. The residents were asked to complete the consent form and questionnaire at home. In each inner-city area, the number

of investigated residents was decided based on the percentage of the number of residents in each area over the total number of residents in inner-city areas.

Inclusion criteria for the studied community: No factories/plants stood within the selected community. For eligible residents: 18 and above-year-olds for men and women; living more than three years within the inner-city area in Zunyi. Exclusion criteria: asthmatics with concomitant diagnoses of chronic bronchitis or emphysema were ineligible. The available health records of subject were taken to confirm his/her chronic bronchitis or emphysema disease.

## Definition

### Asthma and Asthma-Related Symptoms

We focused on asthma and asthma-related symptoms, which were treated as outcome variables.

Asthma is defined as doctor-diagnosed asthma (including asthma diagnosed by Chinese medicine practitioners) with a positive answer to the question of "Did you ever have this disease with a diagnosis from a doctor in the last 12 months?"

Asthma-related symptoms are defined as subjects who reported wheezing with breathlessness or wheezing in the

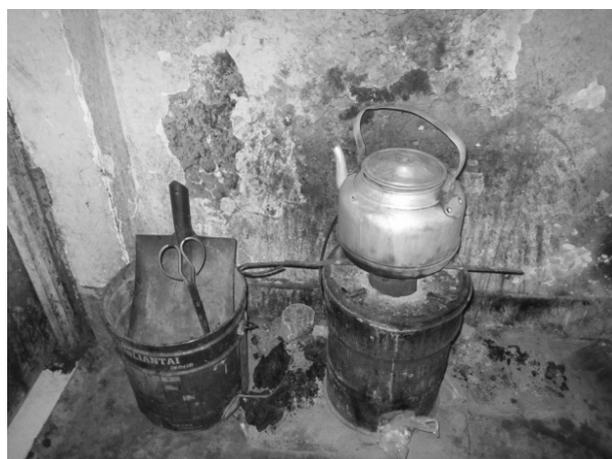


Fig. 2. Cooking or heating in winter season in inner-city areas of Zunyi.

absence of colds and any one of these conditions: chest tightness upon waking up in the morning or waking up from sleep with chest tightness, or waking up from sleep with coughing within the past winter. The presence of these symptoms was coded positive for having asthma-related symptoms [7]. (Asthma-related symptoms include: wheezing with breathlessness + chest tightness upon waking up in the morning, wheezing with breathlessness + waking up from sleep with chest tightness, wheezing with breathlessness + waking up from sleep with coughing, wheezing in the absence of colds + chest tightness upon waking up in the morning, wheezing in the absence of colds + waking up from sleep with chest tightness, and wheezing in the absence of colds + waking up from sleep with coughing).

### Questionnaire

Data on health variables related to asthma and asthma-related symptoms, and information on personal, occupational, and home environmental factors were collected by self-administered questionnaires distributed to the selected adult participants.

The questionnaire used is a modified questionnaire based on the adult questionnaire of the European Community Respiratory Health Survey II (ECRHS II). It contains standardized questions on doctor's diagnosed asthma, current asthma, and other asthma-related symptoms, as well as household environmental factors, etc. The modified ECRHS II questionnaire was translated from English to Chinese and translated back to English. Both original and newly translated English versions were compared in terms of meaning before the Chinese version questionnaire was finalized. The ECRHS II questionnaire related to asthma and asthma-related symptoms in adults has been validated in epidemiologic studies in Norway [8], Japan [9], and Sweden [10].

Self-administered questionnaires were distributed to the selected adult residents. They were guided in answering the questions by a researcher. The questionnaire consists of three parts.

The first part of the questionnaires is to gather subject's personal and sociodemographic data, including: sex, age, height, weight, and education. The population was divided into 3 age groups (18-39, 40-59,  $\geq 60$ ) so that the author can observe the trend of prevalence of asthma and asthma-related symptoms within the various age groups. Height and weight reported by participants was used for assessing body mass index (BMI), defined as the individual's body weight (in kg) divided by the square of his or her height (in meter). The subjects were categorized into underweight ( $\text{BMI} < 18.5 \text{ kg/m}^2$ ), normal weight ( $18.5 \leq \text{BMI} < 23 \text{ kg/m}^2$ ), and overweight ( $\text{BMI} \geq 23 \text{ kg/m}^2$ ) according to the re-defined WHO criterion for obesity in the Asia Pacific Region. Education status falls into two groups: compulsory education and non-compulsory education. The Chinese government stipulates that compulsory education includes the education of primary and secondary schools; non-compulsory education includes high school, college, or university.

The second part of the questionnaire elicits the information on subjects' experiences of asthma and asthma-related symptoms in the last winter. The following questions from the questionnaire were used to screen asthma and asthma-related symptoms including asthma, wheezing with breathlessness, wheezing in the absence of colds, chest tightness, and cough of each subject during the past winter months.

- Q1. Have you had wheezing or whistling in your chest at any time this winter?
- Q2. Have you woken up with a feeling of tightness in your chest in the morning at any day this winter?
- Q3. Have you woken up with a feeling of tightness in your chest at any time this winter?
- Q4. Have you been awoken by an attack of coughing at any time this winter?
- Q5. Have you ever had chronic bronchitis in the last 12 months?
- Q6. Have you ever had emphyzema in the last 12 months?
- Q7. Have you ever had asthma?
- Q8. Have you had an attack of asthma this winter?

Subjects were excluded from this study if he/she had a positive answer to questions 5 or 6.

The third part of the questionnaire is the major part of this study. The goal was to gather information regarding the risk factors of asthma and asthma-related symptoms in the residential environment. These questions are generated from an extensive literature review. The questions in this part are to obtain information on resident's kitchen and bedroom exposure characteristics and current and ever exposure to environmental tobacco smoke as well as occupational exposure. Coal and propane are the most popular fuel for cooking, heating, and water heating in Zunyi. The burning of fuels may emit air pollutants such as nitrogen dioxide, carbon monoxide, and particulate matter, which can irritate the respiratory airways. The question concerning cooking fuels was: What kind of stove do you mostly use for cooking this winter? The exposure of cooking oil fumes when cooking was based on this question: When cooking, are there cooking oil fumes present? Furry pets are the ideal places for dust, insect wastes, insects, and all known allergens. Exposure to these particulates can trigger asthma and asthma-related symptoms. The question concerning the exposure of furry pets was: Did you keep a pet (cat, dog, or bird) this winter? Active smoking and environmental tobacco smoking exposure have been found to be associated with respiratory symptoms. Questions concerning the exposure of active and passive smoking were as follows: Have you ever smoked for as long as 6-month continuous period, do you smoke cigarettes now, have you smoked at least 100 (5 packs) cigarettes in your lifetime, have you at any point within the winter months regularly spent time in the same room with smoker/s smoking cigarettes for more than 15 minutes (or the time for about one cigarette) at least three times per week? Occupational airborne exposure (i.e. dust or gas) also has been proven to be closely related to respiratory disorders. The questionnaire also included a question concerning occupational dust or gas exposure: Do you have dust or gas exposure in your work site?

## Data Analysis

Data analysis was carried out using Statistical Package for Social Sciences (SPSS) Version 15.0. Pearson's chi-square ( $\chi^2$ ) test was used to compare the prevalence of asthma and asthma-related symptoms between groups for each selected kitchen, sleeping area characteristic, and ETS.

A p-value of less than 0.05 is considered the level of statistical significance. Because our response variable-prevalence of asthma and asthma-related symptoms is dichotomous, we use logistic regression to estimate the effects of coal, cooking smoke, irritating cooking smoke, secondhand smoke, and pets' exposure on the prevalence of asthma and asthma-related symptoms in adults with other sociodemographic factors (age, sex, BMI, education, etc.) as controls. Results are presented in the form of odds ratios (ORs) with 95% confidence intervals (95% CI).

## Ethics

An ethical clearance was obtained from the Universiti Kebangsaan Malaysia Medical Centre Research and Ethics Committee. All respondents were given briefings before the conduct of the study and later requested to give their consent form.

## Result

### Profile of the Adult Residents

In total, 1,269 subjects were surveyed with a response rate of 95.1% (1207/1269). A total of 62 subjects were excluded from our study due to refusal to participate or inadequate information. Overall, 1,207 people aged  $\geq 18$  years in 11 inner-city areas in Zunyi city took part in the present study, with an overall response rate of 100.0%. Table 1 shows the distribution of adult residents by selected background and indoor environmental exposure characteristics. Consistent with our recruitment method, the distribution of subjects by their inner-city areas of residence was fairly uniform. Among the adult residents analyzed, the mean age of this population was  $45.5 \pm 15.9$  years, and 51.3% of the subjects in the sample were females. The proportion of adult subjects declined by age, as expected. Compared with underweight (17.6%) and overweight (19.7%) subjects, 62.7% had normal weight. Less than half of all subjects (36.1%) had education beyond high school. Approximately 22% of subjects had childhood asthma, and 22.4% had a familial history of asthma. Thirty-nine percent of the adults lived in households using coal, 21.8% lived in households using cleaner fuels (electricity or electromagnetism), and the remaining 39.4% lived in households that used a mix of coal and liquid petroleum gas or kerosene and cleaner fuels. Slightly more than one-third reported the presence of cooking oil fumes. The percentages of current smokers, ex-smokers, and non-smokers in the study population were 29.2, 13.8, and 57.0%, respectively. In addition, 18.4% of adult residents lived in households where some-

one else smokes. Males and females differed in their exposure to environmental tobacco smoke (second-hand smoke), 15.5% of males but 21.2% of females exposed to ETS (data not shown). Almost one-fourth of adult subjects were exposed regularly to dust or gas at work. About 31% reported keeping pets in the house.

As shown in Table 1, there were more elderly persons and those with lower education levels in the group with asthma and asthma-related symptoms than in the group without asthma and asthma-related symptoms ( $p < 0.01$ ). More overweight subjects (25.9% vs 9.2%) were found in the group with asthma and asthma-related symptoms than in the control group. Exposure to coal, cooking fuel smoke, cooking oil fumes, secondhand smoke, and pets were significantly associated with asthma and asthma-related symptoms by chi-squared analysis (Table 1).

### Prevalence of Adult Asthma and Asthma-Related Symptoms

Asthma is a serious problem among people in China. According to one report by Zhong et al., almost 15-20 million people suffered from asthma in China [11]. In the present study, among the 1,207 adult subjects, 22 had a diagnosis of asthma by physicians and were classified as having definite asthma. Within this group, all 22 subjects suffered from asthma-related symptoms in the past winter season. A total of 136 subjects who had no definite asthma, but noted asthma-related symptoms on the questionnaire were grouped as having asthma-related symptoms during the past winter. Subjects with concomitant diagnoses of chronic bronchitis or emphysema were excluded from the asthma group. We excluded subjects by using items in the same questionnaire for patient history and symptoms of chronic bronchitis and emphysema. A total of 158 subjects (13.1%) either had a diagnosis of asthma by physicians or reported suffering from asthma-related symptoms on the questionnaire. Twenty-two of the 158 subjects had asthmatic attacks in the past winter. Therefore, the prevalence of asthma during winter was 1.8%.

As can be seen in Table 2, asthma and asthma-related symptoms were significantly more prevalent in the middle-age group from 40 to 59 years old (6.1%). Adults with asthma in childhood and familial history of asthma were more likely to have a higher prevalence of asthma and asthma morbidity. By type of the fuel used for cooking or heating, adults living in households using coal (11.9%) are about two times more likely to suffer from asthma and asthma-related symptoms than are those living in households using cleaner fuels (6.4%). Among those exposed to cooking oil fumes, the prevalence of asthma and asthma-related symptoms was significantly higher compared to those without such exposure ( $p < 0.05$ ). Adults smoke (6.6%), but not ex-smokers, were also much more likely to suffer from asthma and asthma-related symptoms than were those who had never smoked (3.0%). Adults who were exposed to SHS were less likely to suffer from asthma than was those without such exposure. The prevalence also was somewhat lower among adults who kept pets (6.0%) than those without (7.0%).

Table 1. Comparison of frequency distribution of demographic data and indoor environmental risk factors between asthma and asthma-related symptoms cases and non-asthma-and-asthma-related symptoms group.

Variables (No. of cases, %)	Asthma and asthma- related symptoms case (n=158)	Non asthma and asthma- related symptoms (n=1049)	p value #
Gender			
Male (588, 48.7)	90 (15.3)	498 (84.7)	<0.05*
Female (619, 51.3)	68 (11.0)	551 (89.0)	
Age distribution (years)			
18-39 (493, 40.8)	41 (8.3)	452 (91.7)	<0.01**
40-59 (485, 40.2)	74 (15.3)	411 (84.7)	
≥60 (229, 19.0)	43 (18.8)	186 (81.2)	
BMI (kg/m <sup>2</sup> )			
Underweight (BMI < 18.5 kg/m <sup>2</sup> ) (212, 17.6)	29 (13.7)	183 (86.3)	>0.05
Normal weight (18.5≤BMI<23 kg/m <sup>2</sup> ) (757, 62.7)	88 (11.6)	669 (88.4)	
Overweight (BMI≥23 kg/m <sup>2</sup> ) (238, 19.7)	41 (17.2)	197 (82.8)	
Education			
≥Senior high school (771, 63.9)	72 (16.5)	364 (83.5)	<0.01**
< Senior high school (436, 36.1)	86 (11.2)	685 (88.8)	
Asthma in childhood			
Yes (268, 22.2)	92 (34.3)	176 (65.7)	<0.01**
No (939, 77.8)	66 (7.0)	873 (93.0)	
Familial history of asthma			
Yes (375, 22.4)	93 (24.8)	282 (75.2)	<0.01**
No (832, 77.6)	65 (7.8)	767 (92.2)	
Stove used for cooking or heating			
Cleaner fuel <sup>a</sup> (476, 39.4)	36 (7.6)	440 (92.4)	<0.01**
Fuel mix <sup>b</sup> (263, 21.8)	45 (17.1)	218 (82.9)	
Coal (468, 38.8)	77 (16.5)	391 (83.5)	
Cooking oil fumes			
Yes (388, 32.1)	82 (21.1)	306 (78.9)	<0.01**
No (819, 67.9)	76 (9.3)	743 (90.7)	
Keep pets			
Yes (270, 31.1)	73 (27.0)	197 (73.0)	<0.01**
No (937, 68.9)	85 (9.1)	852 (90.9)	

Table 1. Continued.

Variables (No. of cases, %)	Asthma and asthma- related symptoms case (n=158)	Non asthma and asthma- related symptoms (n=1049)	p value #
Smoking status			
Non-smokers <sup>c</sup> (688, 57.0)	46 (6.7)	642 (93.3)	<0.01**
Ex-smokers <sup>d</sup> (167, 13.8)	32 (19.2)	135 (80.8)	
Current smokers <sup>e</sup> (352, 29.2)	80 (22.7)	272 (77.3)	
Second-hand smoke, exposed to ETS <sup>f</sup>			
Yes (222, 18.4)	63 (28.4)	159 (71.6)	<0.01**
No (985, 81.6)	95 (9.6)	890 (90.4)	
Occupational exposure to dust or gas			
Yes (242, 20.0)	119 (12.3)	846 (87.7)	>0.05
No (965, 80.0)	39 (16.1)	203 (83.9)	

<sup>a</sup> Cleaner fuels: electricity or electromagnetism

<sup>b</sup> Fuel mix: mix of coal and liquid petroleum gas or kerosene and cleaner fuels.

<sup>c</sup> Non-smokers: the respondent had never smoked for more than a six-month continuous period.

<sup>d</sup> Ex-smokers: the respondent had stopped smoking at least one year before the survey.

<sup>e</sup> Current smokers are defined as those who had smoked at least 100 cigarettes (five packs) in their lifetime and who smoked on a daily basis within the time of the survey.

<sup>f</sup> Secondhand smoke. Participants were asked the following question: "Have you at any point within the winter or summer month regularly spent time in the same room with smoker/s who was/were smoking cigarettes, for more than 15 minutes (or the time for about one cigarette), at least three times per week?" If they respond positively, they are categorized as passive smokers. Values are number (%).

# Chi-squared test,  $\alpha = 0.05$ ,

\*significant at  $p < 0.05$ ,

\*\*significant at  $p < 0.01$ .

Bivariate analysis showed significant associations between asthma and asthma-related symptoms and gender, age, asthma in childhood, familial history of asthma, stove used for cooking or heating, cooking oil fumes, smoking status, exposure to environmental tobacco smoke (ETS) and pet-keeping. Multiple logistic regression analysis indicated some factors to be significantly associated with asthma, namely age, asthma in childhood, familial history of asthma, coal used for cooking or heating, cooking oil fumes, smoking status, exposure to ETS, and pet-keeping (Table 2). Gender, BMI, education, and occupational exposure to dust or gas in the workplace were not entered in the final logistic model.

Table 2 also shows the estimated effects of coal used for cooking or heating, cooking oil fumes, smoking status,

Table 2. Prevalence of asthma and asthma-related symptoms and outcome of logistic regression analysis in Zunyi.

Variables	Asthma and asthma-related symptoms N (%)	Crude OR (95% CI)	p value	Adjusted OR (95% CI)	p value
Age (year)			<0.001***		<0.05*
18-39	41 (3.4)	1.00 (reference)		1.00 (reference)	
40-59	74 (6.1)	1.985 (1.325 to 2.974)		1.651 (1.022 to 2.667)	
≥60	43 (3.6)	2.549 (1.608 to 4.040)		2.387 (1.369 to 4.163)	
Asthma in childhood			<0.001***		<0.001***
Yes	92 (7.6)	6.914 (4.847 to 9.863)		5.801 (3.851 to 8.736)	
No	66 (5.5)	1.00 (reference)		1.00 (reference)	
Familial history of asthma			<0.001***		<0.001***
Yes	93 (7.7)	3.891 (2.756 to 5.495)		2.851 (1.902 to 4.276)	
No	65 (5.4)	1.00 (reference)		1.00 (reference)	
Stove used for cooking or heating			<0.001***		<0.05*
Cleaner fuel	36 (3.0)	1.00 (reference)		1.00 (reference)	
Fuel mix	45 (3.7)	2.523 (1.581 to 4.026)		1.517 (0.870 to 2.645)	
Coal	77 (6.4)	2.407 (1.584 to 3.658)		1.893 (1.157 to 3.097)	
Cooking oil fumes			<0.001***		<0.001***
Yes	82 (6.8)	2.620 (1.866 to 3.678)		2.218 (1.466 to 3.356)	
No	76 (6.3)	1.00 (reference)		1.00 (reference)	
Smoking status			<0.001***		<0.001***
Non-smokers	46 (3.8)	1.00 (reference)		1.00 (reference)	
Ex-smokers	32 (2.7)	3.308 (2.031 to 5.388)		2.414 (1.341 to 4.343)	
Current smokers	80 (6.6)	4.105 (2.781 to 6.059)		4.201 (2.647 to 6.667)	
Second-hand smoke, exposed to ETS			<0.001***		<0.001***
Yes	63 (5.2)	3.712 (2.589 to 5.323)		3.654 (2.355 to 5.668)	
No	95 (7.9)	1.00 (reference)		1.00 (reference)	
Keep pets			<0.001***		<0.001***
Yes	73 (6.0)	3.714 (2.620 to 5.266)		2.170 (1.424 to 3.308)	
No	85 (7.0)	1.00 (reference)		1.00 (reference)	

For variable definitions, see Table 1.

\*significant at  $p < 0.05$ , \*\*\*significant at  $p < 0.001$

exposure to ETS, and pets, and selected demographic and socioeconomic variables on the prevalence of asthma and asthma-related symptoms among the adult residents. After adjustment for host factors such as gender, age, education level, smoking status, and cooking fuels, we found that adult residents who had asthma in childhood to be closely significantly related to adulthood asthma and asthma-related symptoms (Table 2), with an odds ratio (OR) of 5.80 (95% confidence interval (CI), 3.851 to 8.736). Subjects who had familial history of asthma also have significantly higher asthma and asthma-related symptoms than those without a familial history of asthma (OR = 2.851; 95% CI, 1.902 to 4.276). Among home environmental factors, with

other variables controlled, coal used for cooking or heating has a statistically significant effect (OR = 1.893; 95% CI, 1.157-3.097) on the prevalence of adult asthma and asthma-related symptoms. Fuel mix used for cooking or heating does not seem to have any significant effect on the risk of adult asthma and asthma morbidity. Adult residents who were exposed to cooking oil fumes are at a considerably higher risk of suffering from asthma and asthma-related symptoms (OR = 2.218; 95% CI, 1.466-3.356) than those without such exposure.

The adjusted odds of suffering from asthma and asthma-related symptoms are almost four times higher among the subjects who are current smokers than among those

who have never smoked (OR = 4.201; 95% CI, 2.647-6.667). Subjects who have ever smoked regularly in the past also are at a considerably higher risk of suffering from asthma (OR = 2.414; 95% CI, 1.341-4.343). The odds of suffering from asthma and asthma-related symptoms are 3.65 (95% CI, 2.355-5.668) times higher among the adult residents who are exposed to secondhand smoke than among those without such exposure. Compared with subjects of the reference category, subjects who kept pets were 2.17 times more likely to develop asthma and asthma-related symptoms (OR = 2.170; 95% CI, 1.424-3.308).

## Discussion

The prevalence of asthma is poorly defined in developing countries. In order to describe the epidemiology of asthma and asthma-related symptoms in southwest China and to clarify the role of indoor environmental risk factors for asthma and asthma-related symptoms, we have completed a cross-sectional questionnaire survey of people aged  $\geq 18$  years in the inner-city areas of Zunyi city, Guizhou Province, China. There have been relatively few studies using a standardized questionnaire to determine the prevalence of asthma and asthma-related symptoms in the adult population in China. To the best of our knowledge, this is the first study to examine potential effect modifiers of indoor environmental exposure on adult asthma and asthma-related symptoms in an acid rain-plagued area in China.

This study found that the prevalence of asthma in the adult population of Zunyi city was 1.8% using data collected from a random sample of the registered population, which was lower than those reported by European (4.1%) and American (15.4%) studies [12, 13], and a study conducted in three Chinese cities in 1988 (3.6%) [14]. The rates were closer to the findings of two community-based studies (1.9% vs 2.0%) performed in rural Beijing in China [15, 16]. In general terms, higher prevalence rate have been found among adults from "westernized" countries than in developing countries. This difference may be real or may reflect study methodology. The low prevalence of adult asthma and asthma-like symptoms in the inner-city areas of Zunyi may be due to fewer respiratory infections in adults, poor knowledge of health or poor self-reported access to medical care because of high medical cost.

In this study it was verified that gender, age, asthma in childhood, familial history of asthma, stove used for cooking or heating, cooking oil fumes, smoking status, secondhand smoke, and pets were associated with asthma and asthma-related symptoms in adults. The results were in accordance with previous indoor environmental studies in China [17]. Adjusted for host characteristics and other factors, exposure to active tobacco, secondhand smoke, coal combustion smoke, cooking oil fumes, and pets were found to be independently strongly linked to adult asthma and asthma-related symptoms.

Stoves fueled by coal or other biological fuels, which are major sources of indoor combustion, release respiratory irritants such as particulate matter, sulfur dioxide, and other

organic toxins. According to some estimates, half of the world's population still uses coal or biomass fuels for heating and cooking, and most of them live in developing countries such as China. Bivariate and multivariate analyses showed a positive association between asthma and asthma-related symptoms and exposure to coal used for cooking or heating, but mixed fuel tends not to have any significant effect. Our findings of increased risks of asthma and asthma-related symptoms in association with exposure to coal used for cooking or heating corroborate those of a large number of studies of the effects on health-related exposure to cooking smoke (conducted in China) [18, 19] and elsewhere [20, 21]. Peabody and colleagues investigated the association between individual health status and domestic cooking as a source of indoor air pollution. Their findings suggested that the high levels of indoor air pollution from household coal use in Chinese households have also been linked to an increased incidence of asthma in rural residents in China [20].

Zunyi has a rich reservation of coal, in which many coal uses in Zunyi households are high-sulfur coal with a sulfur content of approximately 3% [22]. There is a large demand for coal for cooking, baking, and heating in households, particularly in the winter season. For many people, the risks to respiratory health may be greater due to exposure to excessively high indoor air pollutants from poorly ventilated household stoves. In this respect, we concur with the proposal that the Chinese government further its commitment to reduce its dependence on coal and improve residential environment conditions [23].

Exposure to a large amount of cooking oil fumes may present a health risk that is similar to that from tobacco smoke. As expected, we found exposure to cooking oil fumes to be a strong determinant of adult asthma and asthma-related symptoms, and this finding is in agreement with other studies [24, 25]. Smoking is a well-documented indoor risk factor that contributes substantially to asthma and asthma-related symptoms in adults [26]. As shown in our study, approximately 6.6% of subjects with asthma and asthma-related symptoms, including 16.2% of men and 6.5% of women with asthma and asthma-related symptoms, were current smokers; this is consistent with other sources of data [26, 27]. This study revealed a higher prevalence of adult asthma and asthma-related symptoms in current smokers compared with ex-smokers and non-smokers, and a higher relative OR for asthma and asthma-related symptoms in current smokers after adjusting for other variables. This can be explained by the fact that the majority of Chinese smokers with poor education in tobacco control and the harmfulness of smoking to health have not been determined to quit smoking unless afflicted with severe diseases or old age. In addition, a higher stress level and lack of open spaces may also be possible reasons for the high asthma prevalence in smokers living in inner-city areas.

ETS exposure also is common in Chinese homes and has been associated with increased risk of asthma morbidity in adults [28]. In addition to tobacco use, results from this study were suggestive of higher levels of exposure to others' cigarette smoking among inner-city residents in households.

After controlling for age, BMI, education, and other variables, we found association between exposure to ETS at home and asthma and asthma-related symptoms among adults in homes. Significant associations with asthma and asthma-related symptoms also were presented in the subset of non-smoking women (data not shown). Similar results also have been reported in other epidemiological surveys on ETS [18, 29]. Collectively, these findings suggest that those residing in inner-city areas are at high risk for tobacco-related morbidity due to both their own tobacco use and exposure to others' cigarette smoking, together with other probable facts that adult residents, especially among non-smoking women, have less knowledge about ETS and less negative attitudes about ETS, as well as smoke-free home rules are not available. The impact of tobacco on adult health requires urgent attention.

In addition to well-documented causative factors (e.g., ETS exposure, cooking fuels) for asthma, other factors may also have a role in the aetiology of the disease. Of these, genetic susceptibility has attracted general attention. In the present study, familial history of asthma was associated with an increased risk of asthma, suggesting that genetic factors play a central role in the development of asthma and asthma-related symptoms in adults, which is consistent with other studies [30, 31]. It is likely that asthma and asthma-related symptoms resulted from the effect of environmental stimuli in susceptible individuals. Furthermore, asthma in childhood was also found to be a major risk factor for adult asthma in this study; this finding is in accordance with several large longitudinal studies [32, 33], which were designed to follow children with asthma into adulthood have provided evidence that severe asthma in childhood significantly impacts lung function in early to middle adult life.

Several limitations of the present study need to be acknowledged. First, the sample size was relatively small. Second, the cross-sectional nature of the study did not allow the determination of causal relationships between asthma and asthma-related symptoms and risk factors. Third, most of the subjects' information was obtained from self-assessment questionnaires. The asthma and asthma-related symptoms and other individual information such as exposure to indoor risk factors and medical history were self-reported and subjected to recall bias, misclassification, and incomplete information, as with other cross-sectional studies. Other factors such as living in a different location, socioeconomic status, and outdoor air pollution could have biased our results. Despite these limitations, our study gives an overview of the relationship between indoor environmental risk factor exposure and the prevalence of asthma and asthma-related symptoms among adult residents of inner-city areas of China.

In conclusion, the studied Chinese adult population residing in an acid rain-plagued city recorded a lower prevalence rate of asthma than those of western countries, and was close to earlier reports of a rural sample of the Chinese population. Among a variety of risk factors, age, asthma in childhood, familial history of asthma, stove used for cooking or heating, cooking oil fumes, smoking status,

exposure to ETS, and pets were associated with increased risks of asthma and asthma-related symptoms. In China, the total population exposed to such indoor air pollution is large, and more attention should be paid to improve indoor air quality in inner-city communities. Interventional studies may be required for stronger evidence of this association and, more importantly, to determine the size of the health benefit achievable from feasible reductions in exposure.

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