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Original Research

Prevalence of Asthma and Asthma-Related Symptoms Among Adults Exposed to Indoor Environmental Risk Factors: a Comparison between Winter and Summer in Zunyi, China

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Abstract

Weather and climate are known to influence human health. Seasonal changes of temperature promote alterations in respiratory morbidity and in total and cause-specific mortality. Data on the prevalence of asthma and asthma-related symptoms and its disparities between winter and summer in the acid rain-plagued city of Zunyi in southwestern China have not been widely available.

In order to describe the epidemiology of asthma and asthma-related symptoms and its prevalence changes between winter and summer, we have completed two cross-sectional surveys of people aged ≥18 years in winter and summer in the inner-city areas of Zunyi city, Guizhou Province, China.

The subjects were selected using a simple random sampling method. Data on asthma and asthma-related symptoms and selected home environmental factors were assessed by questionnaire.

The studied Chinese adult population residing in Zunyi recorded a lower prevalence rate of asthma than those of Western countries. There was significant difference in asthma prevalence among adult respondents between winter (1.8%) and summer (0.8%) in inner-city Zunyi. Asthma and asthma-related symptoms occurred more frequently in winter than summer, and that difference mainly correlated with environmental risk exposures, including coal combustion, frequency of stove cooking, fan or range hood usage, mattress material, pet possession, must and mould in the bedroom, etc.

The prevalence of adult asthma and asthma-related symptoms was higher in winter compared to the summer in Zunyi, China. Our study suggests that asthma may be an important component of the public health burden of indoor air pollution, especially in winter.

Keywords: asthma, asthma-related symptoms, adult, inner-city area, winter, summer

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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 [1, 2]. It is estimated that there are approximately 300 million asthma patients worldwide and that 15 million disability-adjusted life years are lost annually because of asthma [3].

Illness, hospitalization, and death from asthma occur with a seasonal periodicity. Some of the potential factors that may contribute to the seasonal pattern in asthma morbidity include changes in temperature; seasonal patterns of viral infections; variations in tree, grass, and weed pollen counts; and fluctuations in the amount of indoor aerocontaminants such as fungal spores and house dust mites [4]. Various authors have demonstrated a variation in the rate of emergency room visits, hospitalizations, and mortality during certain periods of the year [5]. The influence of weather conditions and air pollution on health is a major focus of research. Identifying seasonal periodicity for asthma morbidity can provide elements for researching environmental factors and altered organic responses that provide guidance for the institution of preventive measures.

Zunyi District possesses abundant coal reserves and is known as one of the cities most seriously polluted by high levels of particulate matter (PM) air pollution in China. In Zunyi, coal is still a major source of fuel for cooking and warming throughout the year, particularly in the winter. The use of coal for cooking and warming is considered an important factor associated with the prevalence of asthma and asthma-related symptoms [6, 7].

Both upper and lower respiratory symptoms were more prevalent during the winter followed by the spring, which corresponds with the concentration of PM or other aerocontaminants, which was highest during the winter and lowest during the summer in Zunyi [8]. During the winter months, the burning of coal in household stoves has been implicated in increasing indoor particulate matter levels in Zunyi to three-fold greater than is desirable [8]. There are fewer obvious indoor sources of air pollution during the summer in Zunyi. It would be interesting to know whether urban adults experience deterioration in pulmonary function during the winter months compared to summer months, when they are likely have greater exposure to indoor air pollution from human activities (e.g., coal burning and pet possession). Furthermore, it would be vital to clarify whether a seasonal difference plays a role in the levels of indoor air pollution and the prevalence of asthma and asthma-related symptoms in adults in a developing country.

Methods

Study Design

Two population-based cross-sectional epidemiological surveys of asthma and asthma-related symptoms were conducted in the city of Zunyi, Guizhou Province, China. The two surveys of 610 people aged ≥18 years were conducted once in winter (December 2011 to March 2012) and once in summer (June 2012 to September 2012). Data from two cross-sectional investigations enabled us to estimate seasonal exposure variability among adults in Zunyi.

Study Location

Zunyi is the largest city in northern Guizhou. Both urban districts of the city, Huichuan and Honghuagang, were selected. Honghuagang district comprises eight 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 three inner-city areas, namely Shanghai (SH) Road, Xima (XM) Road, and Dalian (DL) Road. Therefore, the inner-city area of Zunyi is comprised of 11 areas covering a wide range of geographic areas in the city (105 km^2) and a total population of more than 900,000.

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 12 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. 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 subjects were taken to confirm his/her chronic bronchitis or emphysema disease [9].

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 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 during the previous winter. The presence of these symptoms was coded positive for having asthma-related symptoms. (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 [10].)

Questionnaire

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 language. 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 have been validated in epidemiologic studies in Norway, Japan, and Sweden [7].

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 questionnaire is to gather a subject's personal and socio-demographic data. The second part of the questionnaire elicits the information on subjects' experiences of asthma and asthma-related symptoms in the last winter. The third part of the questionnaire is the major part of this study. The goal is to gather information regarding the risk factors of asthma and asthma-related symptoms in the residential environment.

Assignment of Potential Exposure Sources of Indoor air Pollutants

Kitchen Characteristics

Median score of kitchen characteristics: the numerical value separating the higher half of a score of kitchen characteristics from the lower half.

Sleeping Area Characteristics

Median score of sleeping area characteristics: the numerical value separating the higher half of a score of sleeping area characteristics from the lower half.

In winter the authors identified 20 (19 in summer) potential exposure sources of indoor air pollutants in relation to kitchen and sleeping area characteristics. We assigned an exposure value for each source. For summer exposure, the sum of maximum exposure value for kitchen risk factors was 22, and the sum of minimum exposure value for kitchen risk factors was 0. Similarly, the sum of maximum exposure value for sleeping area risk factors was 19, and the sum of minimum exposure value was 0. While for winter exposure the sum of maximum exposure value for kitchen risk factors was 27, and the sum of minimum exposure value for kitchen risk factors was 0; similarly, the sum of maximum exposure value for sleeping area risk factors was 23, and the sum of minimum exposure value was 0.

Data Analysis

Data analysis was carried out using Statistical Package for Social Sciences (SPSS) Version 20.0. Pearson's chi-square (x^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. McNemar chi-square test was used to evaluate the difference in the prevalence of asthma and asthma-related symptoms between summer and winter. A p-value of less than 0.05 is considered the level of statistical significance.

Results

Characteristics of 610 Adult Residents who Participated in the Study in Both Winter and Summer Seasons

A total of 610 study members (in 213 households) participated in the study in both winter and summer seasons. These 610 adults completed the winter and summer questionnaire. The basic information of the study population is shown in Table 1.

Table 1. Socio-demographic characteristics of the 610 respondents wh who participated in both winter and summer seasons.

Socio-demographic characteristics	Subjects	
	Number (n = 610)	Percentage (%)
Gender		
Male	278	45.6
Female	332	54.4
Age distribution (years)		
18-39	256	42.0
40-59	239	39.2
≥60	115	18.8
Ethnic group		
Han	585	95.9
Ethnic of minority	25	4.1
Marital status		
Not-married	111	18.2
Married	499	81.8
Education		
Senior high school and above	380	62.3
Below senior high school	230	37.7
BMI (kg/m^2)		
Underweight (BMI<18.5 kg/m^2)	107	17.5
Normal weight (18.5≤BMI<23 kg/m^2)	394	64.6
Overweight (BMI≥23 kg/m^2)	109	17.9
Asthma and asthma-related symptom in childhood		
Yes	132	21.6
No	478	78.4
Familial history of asthma and asthma-related symptom		
Yes	181	29.7
No	429	70.3
Monthly household income		
Low household income	124	20.3
High household income	486	79.7
Occupational exposure to dust or gas		
Yes	123	20.2
No	487	79.8

The mean±SD (standard deviation) age of the study population was 44.9±16.2 years. Both sexes were almost equally participating in the survey (45.6% male vs. 54.4% female). Chinese ethnic groups (Han) comprised a higher proportion (95.9%), and higher proportions of the adult residents were married (81.8%). The majority of the adult residents had at least a high school education (62.3%). More than half of the participants (64.6%) had normal weight. Around 22.0% of subjects had childhood asthma and asthma-related symptoms, and 30.0% had a familial history of asthma and asthma-related symptoms. Most subjects had a total monthly family income of at least 1,753 Chinese yuan (79.7%). Subjects who were exposed regularly to dust or gas at work accounted for 20.2% (Table 1).

Prevalence of Adult Asthma and Asthma-Related Symptoms

Of the 610 adult subjects in winter, only nine (1.5%) met the case definition of asthma. Fifty adults who had no definite asthma, but noted asthma-related symptoms on the questionnaire, were grouped as having asthma-related symptoms during the past winter season. We excluded subjects using items in the same questionnaire for patient history and symptoms of chronic bronchitis and emphysema. A total of 59 (9.7%) subjects either had a diagnosis of asthma by physicians or reported suffering from asthma-related symptoms on the questionnaire. Nine of the 59 subjects had asthma attacks in the past winter. Therefore, the prevalence of asthma was 1.5% among the 610 adult subjects during the past winter.

Of the 610 participants in summer, five adult participants (0.8%) were identified with asthma diagnosed by physicians, and 41 (6.7%) met the case definition of asthma-related symptoms during the previous summer. A total of 46 (7.5%) subjects either had a diagnosis of asthma by physicians or reported suffering from asthma-related symptoms on the questionnaire. Five of the 46 subjects had a prevalence of asthma in the past three months. Therefore, the prevalence of asthma was 0.8% during the past summer season.

Comparison of Prevalence of Asthma and Asthma-Related Symptoms

Among the same 610 study subjects who participated in winter and summer surveys, asthma and asthma-related symptoms were more prevalent in winter (9.7%) than in summer (7.5%). McNemar tests were performed to compare the statistical differences in the prevalence of asthma and asthma-related symptoms between summer and winter. In total, we have 610 pairs of participants. The prevalence of asthma and asthma-related symptoms were significantly higher in winter (3.9%) compared to the summer (1.8%) ($p = 0.041$) (Table 2).

The risks of asthma and asthma-related symptoms were significantly greater among adults in families using a coal stove (18.4% vs. 14.2%) and fuel-mix stove (13.2% vs. 9.8%) in summer compared to the winter. An opposite pattern was observed for adults using a clean-fuel stove (5.0% vs. 3.2%, $p<0.001$). The prevalence of asthma

Table 2. Comparison in the prevalence of asthma and asthma-related symptoms between summer and winter.

			Summer			
			Asthma and asthma-related symptoms (n, percentage)		Total	p value[#]
			Yes	No		
Winter	Asthma and asthma-related symptoms (n, percentage)	Yes	35 (5.7)	24 (3.9)	59	0.041*
		No	11 (1.8)	540 (88.5)	551	
	Total		46	564	610	

[#] McNemar test, α = 0.05, *significant at p<0.05.

and asthma-related symptoms in adults who used stoves for cooking daily (10.7% vs. 0), most of the time (9.1% vs. 0), occasionally (6.2% vs. 6.1%), and who did no cooking (14.3% vs. 14.1%) were significantly higher in winter than in summer (p<0.001). Asthma and asthma-related symptoms were more prevalent among subjects who used their fans or range hoods all of the time (9.9% vs. 9.3%), some of the time (7.3% vs. 7.1%), and none of the time (15.4% vs. 14.3%) in winter vs. summer, but asthma and asthma-related symptoms were more significantly prevalent among subjects who used their fans or range hoods for little time (18.5% vs. 6.3%) in summer than in winter (p = 0.001). No other differences in the prevalence of asthma and asthma-related symptoms among adult residents who were exposed to other kitchen risk factors attained significance (Table 3).

The prevalence of asthma and asthma-related symptoms in adults who used feather or hairpiece mattresses (17.4% vs. 12.5%), foam or grass/grain husk mattresses (6.8% vs. 5.6%), and cloth mattresses or no mattress (9.0% vs. 7.5%) were higher in winter than in summer (p = 0.049). There was a significantly higher prevalence of asthma and asthma-related symptoms among adults who kept pets in winter (21.0%) than in summer (8.9%) (p = 0.008). Adults who reported the presence of musty air in their bedrooms had a significantly higher prevalence of asthma and asthma-related symptoms in summer (45.8%) than in winter (5.4%) (p = 0.005). Adults who stated the presence of mould in their bedrooms had a similar significantly higher prevalence of asthma and asthma-related symptoms in summer (52.9%) than in winter (5.4%), as did the adults who reported on the presence of musty air in their bedrooms (p = 0.007). There were no significant difference in the prevalence of asthma and asthma-related symptoms among adult residents who were exposed to other sleeping area risk factors (Table 4).

Comparison of Effects of Indoor Environmental Risk Factors on the Prevalence of Asthma and Asthma-Related Symptoms between Two Seasons

With regard to the score for kitchen characteristics, although the median scores for kitchen characteristics in adult subjects with asthma and asthma-related symptoms (5.0 (3.0-7.0) vs. 3.5 (2.0-7.0)) were higher in winter than in summer, no significant difference in the score for kitchen characteristics among adult subjects with asthma and asthma-related symptoms was discovered between winter and summer (Mann-Whitney U test, p = 0.173).

Table 3. Respondents with asthma and asthma-related symptoms by summer/winter and selected kitchen characteristics (n = 610).

Variables	Winter				Summer				$\chi^{2\#}$	p value
	Asthma and asthma-related symptoms				Asthma and asthma-related symptoms					
	Yes (n = 59)		No (n = 551)		Yes (n = 46)		No (n = 564)			
	Number (n)	Percentage (%)	Number (n)	Percentage (%)	Number (n)	Percentage (%)	Number (n)	Percentage (%)		
Kitchen location									0.099	0.753
Separated from other rooms	56 (9.5)		531 (90.5)		43 (7.3)		544 (92.7)			
In the living room or bedroom	3 (13.0)		20 (87.0)		3 (13.0)		20 (87.0)			
Kitchen size									0.733	0.392
≥4 m²	50 (9.5)		476 (91.5)		36 (6.8)		490 (93.2)			
<4 m²	9 (10.7)		75 (89.3)		10 (11.9)		74 (88.1)			

Continued

Frequency of opening kitchen windows					3.969	0.265
Occasionally or never	3 (18.8)	13 (81.2)	0	0		
Sometimes	4 (5.8)	65 (94.2)	3 (15.0)	17 (85.0)		
Most of the time	9 (12.3)	64 (87.7)	12 (15.4)	66 (84.6)		
Always	43 (9.5)	409 (90.59)	31 (6.1)	481 (93.9)		
Stove used for cooking					18.607	<0.001***
Clean fuel stove	12 (5.0)	229 (95.0)	12 (3.2)	359 (96.8)		
Fuel mix stove	12 (9.8)	110 (90.2)	25 (13.2)	165 (86.8)		
Coal stove	35 (14.2)	212 (85.8)	9 (18.4)	40 (81.6)		
Frequency of stove cooking					21.611	<0.001***
No cooking	24 (14.3)	144 (85.7)	30 (14.1)	231 (85.9)		
Occasionally	7 (6.2)	106 (93.8)	11 (6.1)	203 (93.9)		
Sometimes	7 (5.9)	111 (94.1)	5 (7.6)	123 (92.4)		
Most of the time	9 (9.1)	90 (90.9)	0 (0)	5 (91.9)		
Daily	12 (10.7)	100 (89.3)	0 (0)	2 (89.8)		
Duration of cooking per day					0.692	0.708
< 30 minutes	34 (9.5)	324 (90.5)	24 (6.3)	360 (93.8)		
30-60 minutes	18 (9.3)	175 (90.7)	14 (10.3)	122 (89.7)		
> 60 minutes	7 (11.9)	52 (88.1)	8 (8.9)	82 (91.1)		
Cooking oil fumes					3.538	0.060
Never or seldom	34 (7.8)	401 (92.2)	18 (4.2)	409 (95.8)		
Frequently or sometimes	25 (14.3)	150 (85.7)	28 (15.3)	155 (84.7)		
Fan or range hood usage					15.589	0.001**
None of the time	4 (15.4)	22 (84.6)	1 (14.3)	21 (85.7)		
Few of the time	1 (6.3)	15 (93.8)	11 (18.5)	96 (81.5)		
Some of the time	6 (7.3)	76 (92.7)	8 (7.1)	89 (92.9)		
All of the time	48 (9.9)	438 (90.1)	26 (9.3)	358 (90.7)		
Kitchen haunted with pest					3.484	0.175
None of the time	50 (9.1)	502 (90.9)	32 (5.8)	521 (94.2)		
Few of the time	7 (13.5)	45 (86.5)	11 (25.6)	32 (74.4)		
Some of the time	2 (33.3)	4 (66.7)	3 (21.4)	11 (78.6)		

Values are number (%). #chi-squared test, α = 0.05; *significant at p<0.05; **significant at p<0.01; *** significant at p<0.001.

Table 4. Respondents with asthma and asthma-related symptoms by summer/winter and selected sleeping area characteristics (n = 610).

Variables	Winter				Summer				$\chi^{2\#}$	p value
	Asthma and asthma-related symptoms				Asthma and asthma-related symptoms					
	Yes (n = 59)		No (n = 551)		Yes (n = 46)		No (n = 564)			
	Number (n)	Percentage (%)	Number (n)	Percentage (%)	Number (n)	Percentage (%)	Number (n)	Percentage (%)		
Person(s) shared in one bedroom									0.004	0.950
≥3 persons	17 (14.5)		100 (85.5)		13 (11.5)		100 (85.5)			
<3 persons	42 (8.5)		451 (91.5)		33 (6.6)		464 (93.4)			
Carpet									0.707	0.400
No	54 (9.3)		525 (90.7)		44 (7.6)		535 (92.4)			
Yes	5 (16.1)		26 (83.9)		2 (6.5)		29 (93.5)			
Carpet use history									0.166	0.920
≤1 year	56 (9.6)		526 (90.4)		44 (7.5)		540 (92.5)			
1-5 years	1 (4.8)		20 (95.2)		1 (5.6)		17 (94.4)			
>5 years	2 (28.6)		5 (71.4)		1 (12.5)		7 (87.5)			
Mattress material									6.050	0.049*
Cloth or no mattress	35 (9.0)		356 (91.0)		37 (7.5)		466 (92.5)			
Foam or grass/grain husks	9 (6.8)		124 (93.2)		5 (5.6)		90 (94.4)			
Feather or hair piece	15 (17.4)		71 (82.6)		4 (12.5)		8 (87.5)			
Mattress use history									5.620	0.060
≤1 year	24 (9.7)		223 (90.3)		28 (10.0)		251 (90.0)			
1-5 years	26 (8.6)		278 (91.4)		16 (5.8)		258 (94.2)			
>5 years	9 (15.3)		50 (84.7)		2 (3.5)		55 (96.5)			
Blanket material									2.268	0.132
Cotton or no blanket	46 (9.2)		453 (90.8)		41 (7.3)		523 (92.7)			
Feathers or wool	13 (11.7)		98 (88.3)		5 (10.9)		41 (89.1)			
Fluffy blanket									0.779	0.377
No	46 (8.5)		496 (91.5)		39 (6.8)		533 (93.2)			
Yes	13 (19.1)		55 (80.9)		7 (18.4)		31 (81.6)			
Pillow material stuffed									3.489	0.175
Cloth or no pillow	44 (9.0)		446 (91.0)		40 (7.5)		495 (92.5)			
Grass or foam	6 (10.0)		54 (90.0)		4 (6.2)		61 (93.8)			
Feather	9 (15.0)		51 (85.0)		2 (20.0)		8 (80.0)			
Keep pets									6.982	0.008**
No	30 (6.4)		442 (93.6)		35 (7.2)		452 (92.8)			
Yes	29 (21.0)		109 (79.0)		11 (8.9)		112 (91.1)			

Continued

Pet allowed in bedroom					1.167	0.280
No	53 (9.2)	520 (90.8)	38 (6.7)	530 (93.3)		
Yes	6 (16.2)	31 (83.8)	8 (19.0)	34 (81.0)		
Water damages					0.894	0.169
No	54 (9.7)	501 (90.3)	38 (6.6)	537 (93.4)		
Yes	5 (9.1)	50 (90.9)	8 (22.9)	27 (77.1)		
Musty air in bedroom					7.930	0.005**
No	56 (10.1)	498 (89.9)	35 (6.0)	551 (94.0)		
Yes	3 (5.4)	53 (94.6)	11 (45.8)	13 (54.2)		
Mould in bedroom					7.211	0.007**
No	57 (9.9)	516 (90.1)	37 (6.2)	556 (93.8)		
Yes	2 (5.4)	35 (94.6)	9 (52.9)	8 (47.1)		
New furniture					0.140	0.708
No	54 (9.6)	510 (90.4)	43 (7.3)	550 (92.7)		
Yes	5 (10.9)	41 (89.1)	3 (17.6)	14 (82.4)		
Decoration and fitment					0.140	0.708
No	54 (9.4)	521 (90.6)	43 (7.2)	556 (92.8)		
Yes	5 (14.3)	30 (85.7)	3 (27.3)	8 (72.7)		

Values are number (%). [#]chi-squared test, α= 0.05; *significant at p<0.05; **significant at p<0.01; *** significant at p<0.001.

The median scores for kitchen characteristics in adult subjects without asthma and asthma-related symptoms (5.0 (3.0-6.0) vs. 2.0 (1.0-5.0)) were also higher in winter than in summer. However, there was significant difference in the score for kitchen characteristics among adult subjects without asthma and asthma-related symptoms between the two seasons (Mann-Whitney U test, p = 0.025) (Fig. 1).

The median score for sleeping area characteristics in adult subjects with asthma and asthma-related symptoms (3.0 (2.0-6.0) vs. 2.0 (0.8-4.0)) were higher in winter than in summer. A significant difference in score for sleeping area characteristics was found between the two seasons (Mann-Whitney U test, p<0.001). Although similar median

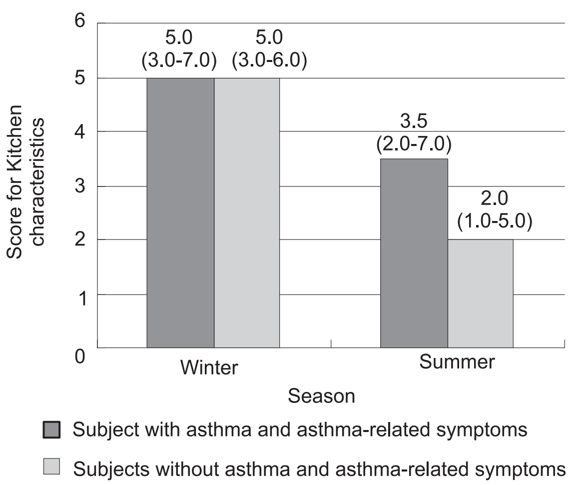

Fig. 1. Median score of kitchen characteristics in adults with and without asthma and asthma morbidity between two seasons.

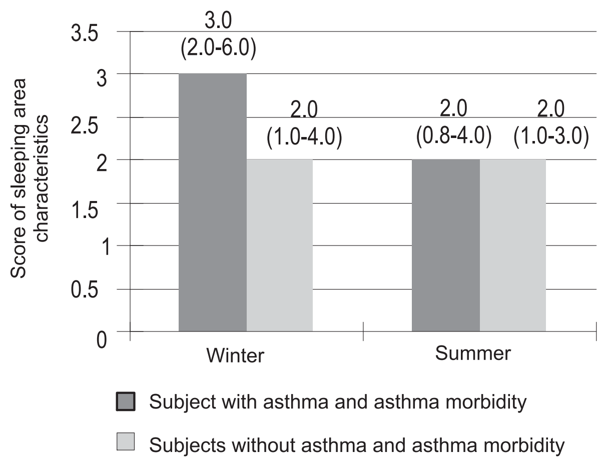

Fig. 2. Median score of sleeping area characteristics in adults with and without asthma and asthma morbidity between two seasons.

score values for sleeping area characteristics in adult subjects without asthma and asthma-related symptoms (2.0 (1.0-4.0) vs. 2.0 (1.0-3.0)) were observed between winter and summer, a significant difference in the score for sleeping area characteristics among adult subjects without asthma and asthma-related symptoms was noted between the two seasons (Mann-Whitney U test, $p<0.001$) (Fig. 2).

The asthma and asthma-related symptoms among current smokers were more prevalent in winter (17.3%) than in summer (11.2%), though no significant difference in the prevalence of asthma and asthma-related symptoms was found ($p = 0.144$) (Fig. 3).

The risk of asthma and asthma-related symptoms among subjects who were exposed to secondhand smoke was greater in winter (23.2%) than in summer (21.7%), with no significant difference between the two seasons (Fig. 4).

Discussion

Weather and climate are known to influence human health. Seasonal changes of temperature promote

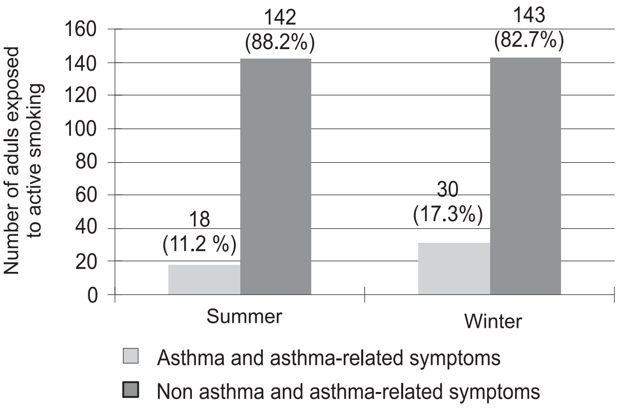

Fig. 3. Comparison of the prevalence of asthma and asthma-related symptoms in adults exposed to active smoking.

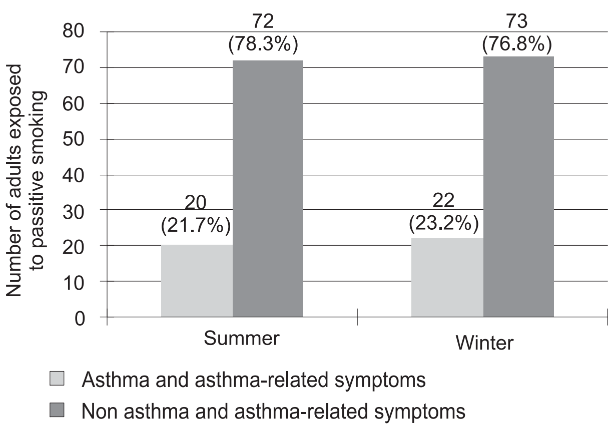

Fig. 4. Comparison of the prevalence of asthma and asthma-related symptoms in adults exposed to passive smoking.

alterations in respiratory morbidity and in total and cause-specific mortality. Data on the prevalence of asthma and asthma-related symptoms and its disparities between winter and summer in the acid rain-plagued city of Zunyi in have not been widely available. In order to describe the epidemiology of asthma and asthma-related symptoms and its prevalence changes between winter and summer, we have completed two cross-sectional surveys of people aged ≥18 years in winter and summer seasons in the inner-city areas of Zunyi. To the best of our knowledge, this is the first study to examine the prevalence of asthma and asthma-related symptom among adults and its difference in the prevalence in summer and winter seasons in an acid rain-plagued area in China.

Difference in the Prevalence of Adult Asthma and Asthma-Related Symptoms between Two Seasons

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. The prevalence of asthma is poorly defined in developing countries. Asthma is a serious problem among people in China. According to a report, almost 15-20 million people suffer from asthma in China [11]. This study found that the prevalence of asthma in winter and in summer in the adult population of Zunyi were 1.8% and 0.8%, respectively, using data collected from a random sample of the registered population, which was lower than those reported by Western European (4.1%), Eastern European (5.4%) and American (15.4%) studies [12-14], plus a study conducted in three Chinese cities in 1988 (3.6%) [15]. The rates were closer to the findings of two community-based studies (1.9% vs. 2.0%) performed in rural Beijing in China [16-17]. In general terms, higher prevalence rates have been found among adults from Western 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, the prevalence of asthma and asthma-related symptoms in the same adult population was 9.7% in winter and 7.5% in summer, suggesting significant seasonal variation. Few studies have investigated the differences in effects of indoor environmental factors on the prevalence of asthma morbidity in various seasons. Weather and climate are known to influence human health. Seasonal changes of temperature promote alterations in respiratory morbidity and in total and cause-specific mortality. Our previous study found that seasonal changes in Zunyi were associated with residents' respiratory [5, 9] and cardiovascular morbidity [18], including asthma and asthma-related symptoms. Moreover, our exploratory study has revealed a linear relationship between respiratory outcomes and daily mean air temperature.

For a 1ºC increase in daily average temperature below a threshold (10ºC), the number of hospital outpatient visits for respiratory morbidity increased by 1.05-fold [13].

The higher prevalence of asthma and asthma-related symptoms in winter than in summer found in our study might be due to: different climatic exposure in summer (e.g., sunny, hot weather; fuel for cooking such as coal and gas; frequently open doors or windows; low PM concentration and good ventilation), and winter season (e.g., cloudy, cold weather; fuel for warming and cooking such as coal; doors and windows closed tightly; people staying indoors and high PM concentration) might affect susceptible adult hosts, resulting in airway inflammation and obstruction that induce the disparity in the prevalence of asthma and asthma-related symptoms in the inner-city area. Potentially influencing each step of this process are underlying susceptibility factors (e.g., inner-city area, socio-demographic characteristics, ETS exposure, home environment, biological contaminant exposure such as allergen and mold, outdoor air pollution, etc) that are specific to the city and serve to cause discrepancies in asthma and asthma-related symptoms in these two seasons. Furthermore, factors like specific genetic background of the person exposed influences host susceptibility to environmental stimuli (Fig. 5).

The Impact of Seasonal Variation on Asthma Morbidity

Ambient air temperature is a significant cause of respiratory morbidity and mortality worldwide. Temperature may have direct effects on inflammation pathways or airway hyper-responsiveness, causing asthma morbidity. Furthermore, temperature may have indirect effects on asthma that operate through other asthma triggers (e.g., viral infections, pollen, mold, house dust mites, and cockroaches) [19]. This study showed a higher prevalence of asthma and asthma-related symptoms in winter than in summer. Many of the studies reported in the literature considered low temperature as a risk factor to trigger asthma morbidity. Our previous finding [5] in Zunyi, which showed a negative linear relationship between daily mean air temperature and the number of hospital outpatient visits for asthma morbidity, is in agreement with two investigations performed in Auckland, New Zealand, where increases in respiratory admissions (mainly of asthma) were strongly linked to minimum temperatures during winter over the 1994 to 2004 period [20], and in North Carolina, United States, in 2007 through 2008. Buckley et al. [19] deemed that significant variation in temperature-asthma associations was observed by season

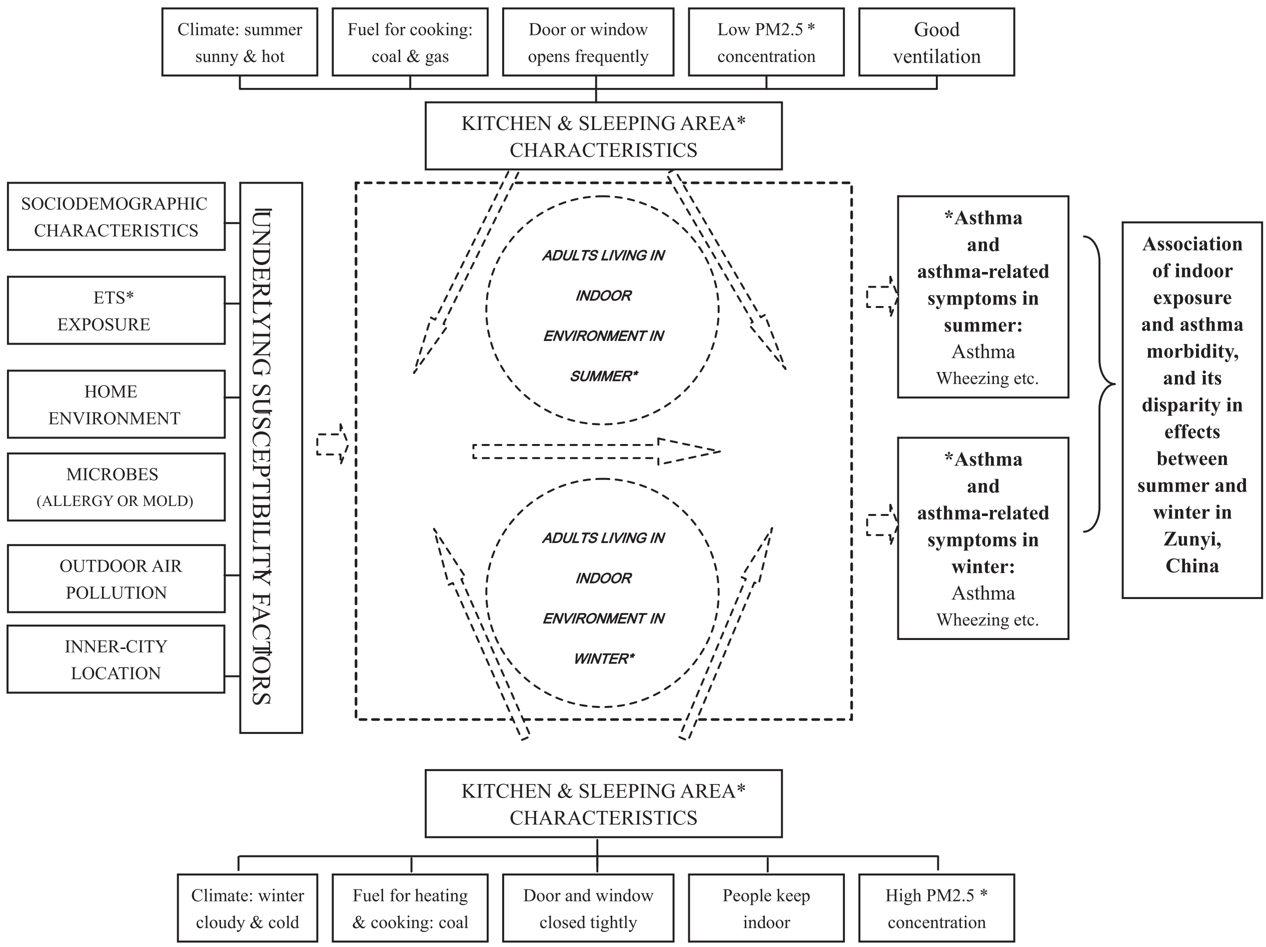

Fig. 5. A diagram of human exposure pathways and potential factors that affect adult asthma susceptibility between winter and summer (PM: particulate matter). * The variables under study.

and by month of the year. ORs per 5 degrees Celsius increased in February (OR = 1.06), July (OR = 1.16), and December (OR = 1.04), and decreased in September (OR = 0.92). The variation pattern in our study was consistent with asthma morbidity seasonal variation; the changeable pattern may be associated with seasonal variation in Zunyi and seasonal variation pattern of temperature and infection among the population. Generally, Zunyi has a subtropical climate. The relative humidity is above 80% all year. Unseasonably warm or cold spells are common, though temperatures rarely reach extremes. Rain falls throughout the year, especially in summer. Chinese western regions have been most affected by acidic deposition in the past three decades. Meteorological and environmental conditions may contribute to our season-specific observation in Zunyi.

The influence of weather conditions and air pollution on health is a major focus of research. An estimated 1.5 million deaths occur annually as a result of household air pollution from solid fuel use – mainly for cooking as well as winter season heating [21]. There have been numerous reported acute poisonings, including fatal cases, especially during heating seasons, resulting from indoor coal combustion under poor ventilation conditions. Under normal combustion and ventilation conditions, Zhang et al. [22] measured elevated blood levels of CO-hemoglobin adduct (COHb) in residents of households using coal and reported that the contribution to COHb from indoor coal combustion was larger than that from cigarette smoking. Moreover, patterns of human activity also change from season to season, so that a particular air pollution concentration in one season may lead to different exposure in another season.

Winter is a prime time for asthma attacks. The combination of cold weather, irritants from indoor air factors, and the risk of respiratory tract infections (such as the common cold and influenza), can be especially hazardous for people with asthma and asthma-related symptoms. Nastos et al. [23] assumed that the inter annual variation of bronchial asthma admissions reveals peaks within the transitional seasons of the year (spring and autumn), while the minimum is apparent during the summer – especially in August in Greece. In addition, Yeh et al. [24] suggested that winter was the most frequent asthma admission season in the adult group. Asthma, like other conditions such as influenza, myocardial infarction, and cerebrovascular accidents, shows a seasonal pattern. Consistent with previous population-based studies, in our study the studied Chinese adult respondents residing in Zunyi recorded lower prevalence rates of asthma in summer (0.8%) than in winter (1.8%). A significantly higher prevalence of asthma and asthma-related symptoms was found in winter (13.1%) than in summer (7.5%) ($p<0.05$).

Difference in the Prevalence of Adult Asthma and Asthma-Related Symptoms Among Adults Exposed to Indoor Environmental Risk Factors and in Winter and Summer

Indoor Exposure to Coal Smoke

Stoves fueled by coal or other biological fuels that 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, most of them lived in developing countries such as China [25]. Bivariate analyses showed a significant difference in the prevalence of asthma and asthma-related symptoms among adult residents, mainly from coal-using families between summer and winter. The weather is usually cold and cloudy in winter in Zunyi. The high rate of coal stove use is attributable to the fact that coal is one of most accessible sources of energy available to local residents. Zunyi has rich reserves of coal, and Zunyi households use high-sulfur coal with a sulfur content of approximately 3% [26]. There is a large demand for coal for cooking, baking, and warming in households in both winter and summer. 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 environmental conditions [27].

Indoor Exposure to Pets

Numerous studies have shown that biological contaminants can be present in the environment. Allergies to dust mites, dogs, and cats are more often reported by residents in metropolitan centers. Homes with pets contain much higher levels of allergens than homes without pets [28, 29]. Cats, dogs, and birds are the most popular pets in most cities of China, like Zunyi, but keeping these animals at home is associated with a high prevalence of allergic sensitization. A recent Swedish study examined if exposure to indoor allergens was associated with allergic sensitization prevalence. The study identified a positive association between asthma symptoms and cat allergen levels (OR, 1.53; 95% CI, 1.04-2.24), whereas levels of viable molds were significantly associated with increased bronchial responsiveness. The lower prevalence of allergic sensitization in Reykjavık may be partly related to lower indoor allergen exposure [30]. Our results showed that the prevalence of asthma and asthma-related symptoms among adult residents who kept pets in their houses was higher in winter than in summer, which was consistent with other studies from Ireland [29] and Italy [31]. Although previous studies suggest that exposure to aeroallergens in homes may significantly affect pulmonary health, the underlying mechanisms responsible for the observed health effects are not well understood [32, 33].

Several limitations of the present study need to be acknowledged. First, when interpreting the results of this study, the cross-sectional design needs to be acknowledged to limit causal inference. Thus, past exposure to indoor environmental risk factors and recent changes in indoor environment exposure were not assessed. Second, 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 is typical of other cross-sectional studies). Third, the limitation in this study was the inability to assess impact on long-term health outcomes. Only short-term (acute) effects could be measured. Furthermore, 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 prevalence of asthma and asthma-related symptoms among adults in summer and winter seasons, and its disparity in the prevalence between the two seasons in inner-city areas of southwest China.

Conclusion

The studied Chinese adult population residing in Zunyi recorded a lower prevalence rate of asthma than those of Western countries. There was significant difference in asthma prevalence among adult respondents between winter (1.8%) and summer (0.8%). A significantly higher prevalence of asthma and asthma-related symptoms was revealed among adult respondents in winter (13.1%) than in summer (7.5%) in inner-city Zunyi. Our study suggests that asthma disease may be an important component of the public health burden of indoor air pollution, especially in winter.

Acknowledgements

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