

## Effects of ambient air pollution on allergic rhinitis among preschool children in Changsha, China

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Prevalence of allergic rhinitis has rapidly increased among Chinese children, but the reasons are unclear. Recent findings have suggested that exposure to outdoor air pollutants may increase the risk of allergic rhinitis, but the results were inconsistent. This study further investigated the effect of outdoor air pollutants on allergic rhinitis among preschool children. A standardized questionnaire on health, home and environmental factors was conducted for 4988 children aged 1–8 in the city of Changsha, and the concentrations of PM<sub>10</sub> (particle diameter  $\leq 10 \mu\text{m}$ ), sulfur dioxide (SO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) during 2006–2011 were acquired from the official web of Changsha Environmental Protection Agency. Results showed that the prevalence of children's doctor diagnosed rhinitis was 8.4% (95% confidence interval [CI] 7.0%–10.0%). It was found that the prevalence of rhinitis was not associated with site-specific background concentrations of air pollutants, but significantly positively correlated with age-related accumulative personal exposure of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub>. We conclude that age-related accumulative personal exposure to ambient air pollution may play an important role in the development of rhinitis.

**air pollutants, diagnosed rhinitis, background concentration, logistic regression, personal exposure**

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The prevalence of allergic diseases including allergic rhinitis (AR) largely increased not only in developed countries [1,2] but also in developing countries [3,4] in the recent decades. China, as the largest developing country, has experienced a rapid increasing in the prevalence of AR. In Hong Kong, the prevalence of AR among children aged 6–7 years has been reported to increase from 1995 to 2001 [3]. The International Study of Asthma and Allergies in Childhood (ISAAC) estimated the prevalence in five cities of Mainland China (Beijing, Chongqing, Guangzhou, Shanghai and Urumqi) and Hong Kong was respectively as high as 5%–10% and 24% among children aged 13–14 in 1998 [4]. Most studies evaluated the prevalence of AR for older children and/or adults, only a few epidemiological studies on the prevalence of AR in younger children [5]. However, the knowledge

about the prevalence of the allergic diseases in the earlier stages of childhood is of greater significance for the following development of the diseases.

Exposure to ambient air pollutants has been suggested to increase the risk of AR in children, but the evidence was still weak and inconclusive [6–13]. Some studies have suggested that exposure to outdoor air pollutants, especially for traffic-related pollutant, may increase the risk of allergic rhinitis in children [6–8]. These studies mainly focused on the background air pollution. However, the impact of air pollutants on health is closely related to the extent of individual exposure, which includes not only exposure concentration but also exposure time [14]. Although numerous studies indicated that the airway health could be caused by short-term exposure to air pollutants at high concentration, long-term exposure to air pollutants at low concentrations may also induce an equivalent effect, which suggests an

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accumulative effect of air pollution exposure on health [15–19]. Therefore, the effect of the timing of exposure to air pollutants or the accumulative exposure to air pollutants on childhood allergic rhinitis needs to be further investigated.

China has witnessed worsening air quality during the past two decades, due to the rapid urbanization, economic growth, industrial development, and increasing amount of vehicles [20]. Although municipal government adopted a series of measures including reduction and control of factory pollution, the air quality is still serious in some cities [21]. For example, in Changsha, the capital city of Hunan province, the annual level of PM<sub>10</sub>, the major component of air pollution, continuously exceeded the National Ambient Air Quality Standard (NAAQS) (100 µg/m<sup>3</sup>) during the period from 2003 to 2007 (<http://www.csqx.com/>). The effect of high air pollution in China on the children's allergic diseases is lack.

In the present study, we assume that long-term exposure to high concentration of ambient air pollutants may increase the risk of children's AR. Based on above hypothesis, the objectives of this study are to assess the different prevalence of allergic rhinitis in children aged 3–6 in Changsha, and to investigate and compare the effect of site-specific average background and age-related personal accumulative exposure to PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> on children's diagnosed allergic rhinitis.

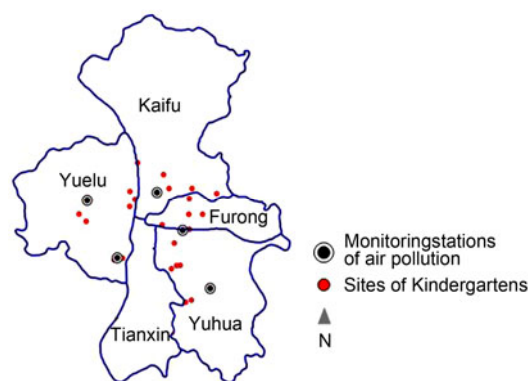
## 1 Methods

### 1.1 Questionnaire and study population

The questionnaire is basically the same as used in parallel studies in Sweden, Bulgaria and many other countries [22,23], with small changes taking into consideration of the specific Chinese housing and cultural characteristics. The questionnaire surveys the life style of residents, home environment and the health status of children and family members. The outcome of interest in the present study was childhood diagnosed allergic rhinitis, which was defined on the basis of the answers to the question: "Has a physician ever diagnosed your child as having allergic rhinitis?". Information on potential confounders was also obtained from the questionnaire. The personal covariates in the present analyses included age, gender, family atopy, environmental tobacco smoke (ETS), breast-feeding, cockroaches noted, flooding or water damage and visible mould. The definition in detail for each covariate was described in Table 1. Children aged 1–8 in 23 kindergartens located in 4 districts (Kaifu, Yuhua, Yuelu and Furong) of Changsha were investigated (Figure 1). The 4988 questionnaires were randomly distributed during the period from November 2011 to January 2012. The questionnaires were firstly distributed to the kindergartens with the permission of their principals, then the trained teachers working at each kindergarten handed out these questionnaires to the parents, and finally the completed questionnaires filled by the parents were returned back within one

**Table 1** Definition of covariates applied in the questionnaire

Determinant	Definition
Parental atopy	Farther or mother of the index child ever having diagnosed asthma, allergic rhinitis, or atopic eczema
ETS	Home environmental tobacco smoke, cigarette smoking by father, mother, grandparents or other people who live with the children
Breast-feeding	The duration of breast-feeding for the child: No breast-feeding, <1 month, 1–2 months, 3–6 months, and >6 months
Cockroaches	Notice cockroach always/frequently/sometimes in the house
Water damage	Flooding or other water damage in the house ever
Visible mould	Noticed any visible mildew or mould in the floor, 2 wall or ceiling of child's room



**Figure 1** (Color online) Distributions of kindergartens and air pollution monitoring stations in Changsha.

week. The data of the questionnaires were collected in a database, and the data for the children aged 3–6 were used in this study.

### 1.2 Exposure assessment

Routinely monitored data for PM<sub>10</sub> (particles with an aerodynamic diameter of 10 µm or less), sulphur dioxide (SO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) are available from Changsha Environmental Protection Agency. Daily concentrations of each pollutant were measured continuously and reported by the website of Changsha Common Meteorologic Information Service (<http://www.csqx.com/>).

In the present study, background concentrations of air pollutants at different monitoring sites were calculated by the annual average concentrations of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> during the period 2007–2011. The annual value from the closest local monitoring station was used to all children in that district. For age-related personal accumulative exposure, the values were calculated by the sum of previous annual concentrations of each pollutant and as an example, the personal accumulative exposure for children aged 3 was the sum of annual concentrations of air pollutants over the past three years (2009, 2010 and 2011) [24].

### 1.3 Statistical methods

The association between air pollutants and allergic rhinitis in children was analyzed by multivariate logistic regression models, adjusting for confounding factors. The odds ratio (OR) was used as a measure of the relation between exposure to air pollution and the prevalence of allergic rhinitis in childhood. The results were showed by adjusted odds ratios with 95% confidence interval (CI). A  $P$ -value $<0.05$  indicates statistical significance. Any covariates that were significant at the  $P<0.05$  level were included in all subsequent analyzed models as confounding factors. SPSS 16.0 was adopted to calculate the prevalence and to conduct multivariate regression models.

## 2 Results

### 2.1 Study population and prevalence

The survey recovered 2636 completed questionnaires with

59% the response rate. A number of 2159 responses for children aged 3–6 years with 1159 boys (54%) and 1000 girls (46%) were used in this study.

The characteristics of the study population and the prevalence of allergic rhinitis in childhood according to the covariates were shown in Table 2. The overall prevalence of children's diagnosed allergic rhinitis was 8.4% (95% CI: 7.0%–10.0%). Higher prevalence was observed in children aged 6 than those aged 3. The prevalence for boys 9.2% (95% CI: 8.0%–11.0%) was relatively higher than that for girls 7.5% (95% CI: 6.0%–9.0%). The prevalence of children's allergic rhinitis was significantly positively associated with older children, family atopy, cockroaches noted, and flooding ever or water damage at home. A negative association was found for the duration of breast-feeding. The prevalence was also related to the presence of environmental tobacco smoking (ETS) and visible mould, although not significantly. Therefore, the main confounding factors related with the development of allergic rhinitis in the present study were considered as age, parental atopy, breast-feeding,

**Table 2** Number of rhinitis cases, prevalence of diagnosed rhinitis, and odds ratios (ORs) of diagnosed rhinitis with 95% confidence interval (95% CI) by age, sex, parental atopy, environmental tobacco smoke, breast-feeding, cockroaches, flooding or water damage, and visible mould<sup>a)</sup>

Determinant	Number of children	Number with diagnosed rhinitis	Prevalence (%)	OR (95% CI)
Total	2159	182	8.4 (7.0–10.0)	
Age (years)				
3	556	34	6.1 (4.0–8.0)	<b>0.468 (0.250–0.877)</b>
4	772	70	9.1 (7.0–11.0)	0.717 (0.402–1.277)
5	700	62	8.9 (7.0–11.0)	0.698 (0.389–1.253)
6	131	16	12.2 (7.0–18.0)	1.000
Sex				
Male	1159	107	9.2 (8.0–11.0)	1.254 (0.922–1.707)
Female	1000	75	7.5 (6.0–9.0)	1.000
Parental atopy*				
No	1772	95	5.7 (5.0–7.0)	1.000
Yes	335	84	26.2 (21.0–31.0)	<b>5.907 (4.259–8.191)</b>
ETS*				
No	750	57	7.6 (6.0–10.0)	1.000
Yes	1383	125	9.0 (8.0–11.0)	1.208 (0.871–1.675)
Breast-feeding*				
No	188	23	12.2 (8.0–17.0)	1.000
<3 months	280	26	9.3 (6.0–13.0)	0.734 (0.405–1.330)
3–6 months	443	45	10.2 (7.0–13.0)	0.811 (0.475–1.384)
>6 months	1207	84	7.0 (6.0–8.0)	<b>0.537 (0.329–0.875)</b>
Cockroaches noted*				
No	802	54	6.7 (5.0–8.0)	1.000
Yes	1243	122	9.8 (8.0–11.0)	<b>1.508 (1.080–2.104)</b>
Water damage*				
No	1830	145	7.9 (7.0–9.0)	1.000
Yes	207	29	14.0 (9.0–19.0)	<b>1.893 (1.235–2.903)</b>
Visible mould*				
No	1908	153	8.0 (7.0–9.0)	1.000
Yes	140	15	10.7 (6.0–16.0)	1.376 (0.786–2.411)

a) \*Number of subjects can not add up to total  $N$  because of missing data. Values in bold are indicated as  $P<0.05$ .

cockroaches noted, and flooding or water damage.

## 2.2 Air pollution and allergic rhinitis

The distributions of annual average background and age-related personal accumulative exposure of air pollutants including PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> were presented in Table 3.

For the site-specific average background exposures, the average annual concentrations of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> were 91.71, 49.63 and 46.87 µg/m<sup>3</sup>, respectively. All the levels of three air pollutants were significantly different among dif-

ferent monitoring stations ( $P < 0.001$  in  $T$ -test). For the age-related personal accumulative exposures, the older children exposed to the higher levels.

Table 4 showed the associations between the prevalence of childhood rhinitis and average site-specific background levels of air pollutants and age-related personal accumulative exposure by using multivariate logistic regression models. Children's diagnosed allergic rhinitis was not statistically significantly associated with average background concentrations of the three pollutants, but significantly related with age-related personal accumulative exposure of

**Table 3** Mean and distribution of annual average and personal exposure of ambient air pollution for children with different ages in Changsha

	Mean (SD)	Minimum	25th percentile	Median	75th percentile	Maximum
Site-specific background air pollution during 2007–2011						
PM <sub>10</sub>	91.71 (4.21)	87.48	87.64	92.12	95.57	97.52
SO <sub>2</sub>	49.63 (10.32)	34.08	41.53	50.07	57.50	62.97
NO <sub>2</sub>	46.87 (7.81)	40.45	41.60	43.91	52.12	59.99
Age-related accumulative personal exposure of air pollution						
3 years						
PM <sub>10</sub>	257.01 (18.88)	237.55	239.37	254.74	275.78	282.36
SO <sub>2</sub>	122.35 (27.59)	86.36	95.42	125.73	147.59	156.08
NO <sub>2</sub>	140.59 (22.05)	128.77	129.19	131.42	156.58	179.91
4 years						
PM <sub>10</sub>	352.79 (23.54)	330.71	331.08	351.29	375.24	386.72
SO <sub>2</sub>	177.95 (37.06)	124.24	145.69	180.36	209.00	225.70
NO <sub>2</sub>	186.01 (30.07)	166.02	168.90	176.11	208.06	239.25
5 years						
PM <sub>10</sub>	458.53 (21.05)	437.42	438.18	460.59	477.86	487.62
SO <sub>2</sub>	248.14 (51.06)	170.40	207.66	250.33	287.52	314.83
NO <sub>2</sub>	231.35 (39.06)	202.23	208.02	219.53	260.60	299.95
6 years						
PM <sub>10</sub>	569.18 (15.12)	553.64	554.03	570.67	583.58	587.97
SO <sub>2</sub>	335.35 (85.10)	219.04	271.66	325.72	403.86	457.88
NO <sub>2</sub>	272.50 (47.33)	237.72	246.22	254.92	307.57	355.88

**Table 4** Adjusted odds ratios (ORs) and 95% confidence interval (CIs) of physician diagnosed rhinitis in single and two-pollutant models<sup>a)</sup>

	Single-pollutant model	Two-pollutant model 1 (PM <sub>10</sub> +SO <sub>2</sub> )	Two-pollutant model 2 (PM <sub>10</sub> +NO <sub>2</sub> )
Site-specific background air pollutants			
PM <sub>10</sub> (per 10 µg/m <sup>3</sup> )	1.074 (0.710–1.627)	1.343 (0.592–3.044)	0.891 (0.465–1.708)
SO <sub>2</sub> (per 10 µg/m <sup>3</sup> )	0.997 (0.843–1.179)	0.901 (0.650–1.249)	
NO <sub>2</sub> (per 10 µg/m <sup>3</sup> )	1.083 (0.875–1.340)		1.134 (0.808–1.594)
Age-related accumulative exposure of air pollutants			
PM <sub>10</sub> (per 10 µg/m <sup>3</sup> )	<b>1.021 (1.003–1.039)</b>	1.007 (0.969–1.047)	1.008 (0.972–1.046)
SO <sub>2</sub> (per 10 µg/m <sup>3</sup> )	<b>1.026 (1.005–1.048)</b>	1.018 (0.972–1.066)	
NO <sub>2</sub> (per 10 µg/m <sup>3</sup> )	<b>1.037 (1.006–1.069)</b>		1.025 (0.963–1.090)

a) Logistic regression models for site-specific background air pollutants adjusting for age, parental atopy, breast-feeding, cockroaches noted and flooding or water damage, while age was not adjusted for the models for age-related accumulative exposure of air pollutants. Values in bold are indicated as  $P < 0.05$ .

PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub>. In the one-pollutant model, age-related personal accumulative exposure of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> were significantly positively associated with allergic rhinitis. An increase of 10 µg/m<sup>3</sup> in age-related personal accumulative exposure to PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> may lead to an increase in the prevalence of children's rhinitis by 2.1% (95% CI, 0.3%–3.9%), 2.6% (95% CI, 0.5%–4.8%) and 3.7% (95% CI, 0.6%–6.9%), respectively. Among these three pollutants, NO<sub>2</sub> indicated a higher risk in rhinitis than PM<sub>10</sub> and SO<sub>2</sub>. In the two-pollutant model, no significant estimate effect was observed when added to either of two air pollutants. Therefore, the risk of children's rhinitis was significantly associated with age-related personal accumulative exposure of single air pollutant.

To further explore whether the main covariates mentioned in Table 2 aggravate the effect of air pollutant on the rhinitis prevalence, stratified analyses were systematically conducted for age-related personal accumulative exposure of air pollutants by different categories of gender, parental atopy, duration of breast-feeding, cockroaches noted and water damage. The results indicated that exposure to air pollution has significantly higher risk for males, children having breast-feeding less than 3 months, and those living in the home with water damage (Table 5).

### 3 Discussion

#### 3.1 Effects of household and personal characteristics

We found that certain residential, demographic, and housing

characteristics were associated with the prevalence of rhinitis in children aged 3–6 in Changsha. Main risk factors included parental atopy, the shortage of breast-feeding, cockroaches, and water damage in the home. Most of these risk factors identified in the present study have been found in previous questionnaire assessments of children living in different climates and exposure to different air pollution. In a cross-sectional study in Taiwan, China, a significantly increased risk of rhinitis was found to be related to parental atopy [8]. The study by Åberg et al. [25] also showed that the family history of the diseases was the strongest background factor for the development of children's asthma and allergic diseases. In addition, the study by Hwang et al. [8] showed a significant effect of home dampness (or more specifically, water damage, and mold or mildew-derived allergens) on children's diagnosed rhinitis. Similar effects of dampness on both diagnosed rhinitis and ever related symptoms in middle-school children were observed in Taiwan, China [7]. In our study, shortage of breast-feeding and cockroaches in the home also showed a significant effect on the preschool children's rhinitis.

The overall consistency between our results and previous findings suggests that most or all of the known personal and household risk factors operate over a considerable range of population and environmental characteristics [26]. On the basis of this evidence, broad-based campaign to abate air-borne hazards inside homes, including specific allergens from cockroaches and dampness-dependent organisms, would be an effective intervention on behalf of children's respiratory health.

**Table 5** Adjusted odds ratios (ORs) along with 95% confidence interval (CIs) of diagnosed rhinitis stratified by different levels of covariates in the relation between diagnosed rhinitis and age-related personal accumulative exposure of air pollutants per 10 µg/m<sup>3</sup> increase

	Gender	OR (95% CI) <sup>a</sup>	Parental atopy	OR (95% CI) <sup>a</sup>	Breast feeding	OR (95% CI) <sup>a</sup>	Cockroaches noted	OR (95% CI) <sup>a</sup>	Water damage	OR (95% CI) <sup>a</sup>
PM <sub>10</sub>	Male	<b>1.025</b> ( <b>1.002–1.049</b> )	Yes	1.023 (0.992–1.055)	No	1.015 (0.965–1.067)	Yes	1.020 (0.998–1.043)	Yes	<b>1.059</b> ( <b>1.008–1.112</b> )
	Female	1.011 (0.982–1.041)	No	1.020 (0.997–1.043)	<3 months	<b>1.047</b> ( <b>1.001–1.095</b> )	No	1.023 (0.991–1.056)	No	1.015 (0.995–1.035)
					3–6 months	1.035 (0.997–1.074)				
					>6 months	1.008 (0.981–1.036)				
	Male	<b>1.035</b> ( <b>1.009–1.062</b> )	Yes	1.033 (0.995–1.072)	No	1.027 (0.971–1.087)	Yes	1.024 (0.997–1.051)	Yes	<b>1.056</b> ( <b>1.000–1.114</b> )
	Female	1.006 (0.970–1.044)	No	1.022 (0.996–1.049)	<3 months	<b>1.062</b> ( <b>1.012–1.115</b> )	No	1.029 (0.991–1.068)	No	1.021 (0.997–1.045)
3–6 months					1.026 (0.981–1.074)					
>6 months					1.013 (0.980–1.046)					
NO <sub>2</sub>	Male	<b>1.050</b> ( <b>1.010–1.091</b> )	Yes	1.043 (0.990–1.098)	No	1.063 (0.977–1.157)	Yes	1.032 (0.994–1.070)	Yes	<b>1.103</b> ( <b>1.018–1.196</b> )
	Female	1.012 (0.963–1.064)	No	1.035 (0.996–1.074)	<3 months	<b>1.081</b> ( <b>1.008–1.159</b> )	No	1.050 (0.993–1.109)	No	1.028 (0.994–1.063)
					3–6 months	1.042 (0.978–1.110)				
					>6 months	1.016 (0.969–1.064)				

a) Logistic regression adjusting for other covariates. Values in bold are indicated as  $P < 0.05$ .

### 3.2 Effects of ambient air pollution

In the present study, the prevalence of allergic rhinitis in children aged 3–6 years was significantly positively associated with age-related personal accumulative exposure levels of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub>, but not with site-specific average background exposures (Table 4). And the results provided evidence that males, breast-feeding less than 3 months, and water damage in the home could aggravate the effect of age-related personal accumulative exposure to air pollutants on allergic rhinitis in children (Table 5).

For site-specific average background exposure, our results were consistent with some previous studies. In French ISAAC study, no association was observed between prevalence of allergic rhinitis and mean concentrations of both SO<sub>2</sub> and NO<sub>2</sub> [10]. Guo et al. [27] and Lee et al. [7] found no significant association between prevalence of lifetime allergic rhinitis and fossil fuel combustion related air pollutants (namely SO<sub>2</sub> and PM<sub>10</sub>). A prospective birth cohort study [11] assessed the relationship between individual-based exposure to traffic-related air pollutants and allergic diseases outcomes during the first 6 years of life, and they also found no association between NO<sub>2</sub> exposure and allergic sensitization. One possible reason for the lack of association may be due to the low concentration of air pollutants, the average values of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> in these studies ranging from 34.9–69.2, 17.3–57.4 and 20.3–51.3 μg/m<sup>3</sup>, respectively. However, no significant effect was also obtained in the present study, although the background exposure levels of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> were high up to 91.71, 49.63 and 46.87 μg/m<sup>3</sup>, respectively. These results suggested that the concentration may not be the only factor which affects AR. On the other hand, some recent studies have found that traffic-related pollutants were closely associated with AR. The references [29,30] reported positive correlation between traffic density and the prevalence of AR. Weiland et al. [30] also suggested a possible role of factors associated with automobile exhausts in children's AR. Hwang et al. [8] investigated the relationship between traffic-related air pollutants and allergic rhinitis in middle-school students in Taiwan, China, and found significant associations for traffic-related air pollutants (e.g. CO, NO<sub>x</sub> and O<sub>3</sub>) in both sexes but none for SO<sub>2</sub> and PM<sub>10</sub>. These results indicated that both concentration and source type of the air pollution may contribute to the development of AR.

However, all above studies addressed the same average background concentration on all the children with different ages. In the present study, we not only investigated the site-specific average background air pollution, but also considered the age-related personal accumulative exposure. Based on our data, the site-specific background exposures of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> were not associated with AR, but significant effects were observed for age-related personal accumulative exposure to each of these air pollutants. Our result indicates that the timing for exposure to air pollution

is important to the development of childhood's AR. For example, a significantly higher prevalence of rhinitis was found in the children aged 6 years 12.2% (95% CI, 7.0%–18.0%) than those aged 3 years 6.1% (95% CI 4.0%–8.0%) (Table 2).

### 3.3 Limitation

In the present study, the exposure to the air pollution for each kindergarten was determined by the data from the nearest monitoring station. Due to the similar sources and strength of air pollution, we assumed that the individual exposure could be characterized by the adjacent exposure in the same community. Actually, it is not the exact personal exposures, which may lead to some errors in the results. In addition, children are actually exposed to both kindergarten and home environments, but the present study only considered the exposures at kindergartens. Although previous study suggested that exposure at locations other than home, especially at school or kindergarten where children spent a large proportion of waking hours and engaging in physical activity may have strong influences on occurrence of respiratory diseases [31], the effect of exposure at home environment may not be ignored. Therefore, the mixed effects of exposure to air pollutants both at kindergarten and home environments on children's AR or other allergies need to be further investigated.

## 4 Conclusions

The present study assessed the prevalence of diagnosed allergic rhinitis in children aged 3–6 years in Changsha, and investigated the relationship between allergic rhinitis and both site-specific average background and age-related personal accumulative exposures to ambient air pollutants including PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub>. The main conclusions of this study are as follows:

(1) The prevalence of allergic rhinitis in children aged 3–6 in Changsha were 8.4% (95% CI, 7.0%–10.0%). Boys had a higher morbidity with 9.2% (95% CI: 8.0%–11.0%) than that for girls with the value of 7.5% (95% CI: 6.0%–9.0%).

(2) Age-related personal accumulative exposure of PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>2</sub> may play an important role in the development of preschool children's allergic rhinitis, and traffic-related pollutant NO<sub>2</sub> has a relatively higher risk than PM<sub>10</sub> and SO<sub>2</sub>. However, no effect was found for site-specific average background exposures.

(3) Long-term exposure to high concentration level of ambient air pollution may be more likely to develop preschool children's allergic rhinitis.

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