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The relationship of air pollution to the prevalence of allergic diseases in Taichung and Chu-Shan in 2002

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This study was conducted in order to determine the relationship between air pollution and the varying prevalence of allergic diseases in the city of Taichung and the rural town of Chu-Shan. We used questionnaires to screen children aged from 7 to 15 years in Taichung and Chu-Shan and compared the results from these 2 areas with the factors related to air pollution. The study included 11,580 children in Taichung and 2621 children in Chu-Shan. In Taichung, the prevalence of asthma was 7.0%, of allergic rhinitis 27.6% and of atopic dermatitis 3.4%. In Chu-Shan, the prevalence of asthma was 5.6%, of allergic rhinitis 21.8% and of atopic dermatitis 3.3%. We also collected data on the concentration of air pollutants in the 2 areas over a 1-year period from January to December 2001 and compared the average annual concentrations of various pollutants. Compared with Chu-Shan, Taichung had higher air concentrations of nitric oxide (NO; 11.47 ± 4.75 vs 5.07 ± 2.81 ppb), carbon monoxide (CO; 0.78 ± 0.19 vs 0.59 ± 0.12 ppm), nitrogen dioxide (NO_2; 24.99 ± 6.8 vs 21.45 ± 7.87 ppb) and sulfur dioxide (SO_2; 2.58 ± 1.0 vs 2.44 ± 0.88 ppb). Student's *t* test results showed that CO and NO were related significantly to the prevalence of allergic disease ($p<0.005$). The prevalence of both asthma and allergic rhinitis is higher in Taichung than in Chu-Shan, a finding that could be related to higher levels of some air pollutants in the urban location.

Key words: Asthma, enviromental air pollutants, perennial allergic rhinitis, rural population, urban population

The prevalence of allergic disease has increased in school children over the past 30 years. In Taiwan, the prevalence of allergic disease is increasing simultaneously with urbanization. For example, the prevalence of asthma among children aged 7 to 15 years in Taipei city has increased from 1.3% in 1974 to 5.1% in 1985 [1]. The prevalence of asthma in school children in Taichung has also increased from 2.19% in 1987 to 3.54% in 1994 and 7.0% in 2002.

The prevalence of allergic diseases in rural and urban areas has been studied elsewhere and evidence for lower prevalence of asthma in rural areas has been found. For example, in West Germany the prevalence of asthma was higher than in East Germany (9.2% vs 7.2%) [2]. In Taiwan, in 1 study on the prevalence of asthma in urbanized area and rural areas, it has also been shown that there is a higher prevalence in highly urbanized areas (11.2%) compared to moderately urbanized areas (7.4%) and less urbanized areas (6.5%) [3]. In order to analyze the effect of air pollutants on the prevalence of allergic diseases, we carried out a study on the relationship between air pollution and allergic disease in Taichung city (an urban area) and Chu-Shan town (a rural area).

Materials and Methods

Two primary schools and 2 junior high schools were chosen at random in the north, middle and south area of Taichung. Similarly, 2 primary schools and 2 junior high schools were chosen at random in Chu-Shan. We used questionnaires to survey school children from 7 to 15 years old. In Taichung, returned questionnaires totaled 11,580 from 14,296 children and in Chu-Shan 2621 questionnaires were returned from 3962 children. In Taichung, the 11,580 children consisted of 5857 males and 5723 females and in Chu-Shan the 2621 children consisted of 1258 males and 1336 females.

The asthma screening instruments were modified from the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaires and the questions

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included information on the following: where the children lived, allergic symptoms, any family history of allergic disease, the parent's level of education, when any allergic diseases began, whether the symptoms had improved or still persisted, and when the symptoms had improved. Students responding affirmatively for any episode were classified as suffering from allergic disease and those who had suffered from asthmatic wheezing during the previous 12 months were also classified as presently being asthmatic. All others were classified as normal. The questionnaires used self-reporting by the children and their parents and questionnaires were not included if all answers were not completed or if the questionnaire was not returned by February 28, 2002. In order to check the accuracy of the answers, we chose 200 children in Taichung and 50 children in Chu-Shan at random and evaluated their symptoms, signs, and family history, and a skin test was also performed. The outcomes were examined by a physician specialized in immunology and the results correlated with the questionnaire results. A chi-squared test was used to test the difference between the 2 methods of diagnosis. In this study, we used the annual average air pollution concentration in each area as an indicator of air pollution and we collected air pollution data from January to December 2001 from the Environmental Protection Administration, Republic of China. We used a Student's *t* test to evaluate any comparison.

Results

In Taichung, the prevalence of asthma was 7.0% and the prevalence of asthma was higher in boys than in girls (8.2% vs 5.7%). The prevalence of allergic rhinitis was 27.6% and the prevalence of allergic rhinitis was also higher in boys than in girls (31.0% vs 24.1%). In Chu-Shan, the prevalence of asthma was 5.6% and was higher in boys than in girls (7.5% vs 3.7%). The prevalence of allergic rhinitis was 21.8% and was also higher in boys than girls (26.7% vs 17.1%). The overall prevalence of asthma and allergic rhinitis was thus higher in Taichung than in Chu-Shan but there was no difference in the prevalence of atopic dermatitis between Taichung and Chu-Shan. When current asthma was compared, there was also a significant difference between Taichung and Chu-Shan (5.25% vs 4.04%) [Table 1].

The annual concentrations of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) were higher in Taichung (2.58 ± 1.0 and 24.99 ± 6.8 ppb) than in Chu-Shan (2.44 ± 0.88 and 21.45 ± 7.87 ppb). In contrast, the annual concentration of ozone (O_3) and suspended particulates was higher in Chu-Shan (22.56 ± 4.11 ppb and 72.25 ± 24.60 μg/m^3) than Taichung (22.38 ± 4.47 ppb and 63.08 ± 17.73 μg/m^3); however, these differences were not statistically significant (p>0.05). Interestingly, carbon monoxide (CO) and nitric oxide (NO) in Taichung (0.78 ± 0.19 ppm and 11.47 ± 4.75 ppb) and in Chu-Shan (0.59 ± 0.12 ppm and 5.07 ± 2.81 ppb) did show a significant difference (p<0.005) [Table. 2].

Discussion

Studies have shown that as many as 78% of asthma patients have nasal symptoms and 38% of allergic rhinitis patients have asthma [4]. In our study, the proportion of asthma sufferers who also had nasal symptoms was 70% in Taichung and 68% in Chu-Shan, a non-significant difference. A previous study has shown that the prevalence of asthma by area has a strong association with the annual average level of CO [3]. Therefore, we analyzed annual

Table 1. Demographic and allergic disease data of study subjects from Taiching city and Chu-Shan town

Variable	Taichung city	Chu-Shan town	χ^2	p
Number of subjects	11580	2621		
Gender (male/female)	5857/5732	1285/1336	1.955	0.162
Current asthma (%)	5.25	4.04	6.512	0.011[a]
Prevalence of bronchial asthma (%)	7.0	5.6	6.460	0.011[a]
Male	8.2	7.5	0.656	0.418
Female	5.7	3.7	8.326	0.004[b]
Prevalence of allergic rhinitis (%)	27.6	21.8	36.470	<0.001[c]
Male	31.0	26.7	9.223	0.002[b]
Female	24.1	17.1	29.923	<0.001[c]
Prevalence of atopic dermatitis (%)	3.4	3.3	0.006	0.936

[a]p<0.05.
[b]p<0.01.
[c]p<0.001.

Table 2. Comparison of atmospheric pollutant levels (mean ± standard deviation) in Taiching city and Chu-Shan town

Pollutant	Taichung city	Chu-Shan town	*p*
Sulfur dioxide	2.58 ± 1.0 ppb	2.44 ± 0.88 ppb	0.437
Carbon monoxide	0.78 ± 0.19 ppm	0.59 ± 0.12 ppm	0.003
Ozone	22.38 ± 4.47 ppb	22.56 ± 4.11 ppb	0.907
Suspended particulates	63.08 ± 17.73 μg/m^3	72.25 ± 24.60 μg/m^3	0.217
Nitric oxide	11.47 ± 4.75 ppb	5.07 ± 2.81 ppb	<0.001
Nitrogen dioxide	24.99 ± 6.8 ppb	21.45 ± 7.87 ppb	0.179

average concentration of CO, NO, SO_2, O_3, NO_2 and suspended particulates as air pollution factors.

At present, many countries are experiencing an increasing prevalence of childhood asthma as well as a higher prevalence of childhood asthma in urbanized versus rural areas. In West Germany, the prevalence of asthma was higher than in East Germany (9.2% vs 7. 2%) [2]. In several African countries, childhood asthma is more prevalent in urbanized than in rural areas [5,6]. In Taiwan, a study has also shown that the prevalence of asthma is highest in highly urbanized areas (11.2%) followed by moderately urbanized areas (7.4%) and less urbanized and rural areas (6.5%) [3]. Our study also showed that the prevalence of asthma and/or current asthma and allergic rhinitis was higher in Taichung (an urbanized area) than Chu-Shan (a rural area).

In our study, air pollution included O_3, NO_2, SO_2, suspended particulates, CO and NO. In many studies, O_3, NO_2 and suspended particulates have been found to play a very important role in the increasing prevalence of asthma [7]. In Taiwan, a previous study found a relationship between the prevalence of asthma and CO [3]. Overall, in this study, we found that air pollution in Taichung was higher than in Chu-Shan.

O_3 is a strong oxidizing agent in the troposphere and undergoes a complex series of reactions involving the action of sunlight on NO_2 and hydrocarbons [8]. The data used in this study showed the concentration of O_3 in Chu-Shan to be slightly higher than in Taichung (22.56 ± 4.11 vs 22.38 ± 4.47 ppb) but not statistically significant. Therefore, O_3 would seem not to be an important factor affecting the prevalence of asthma and/or current asthma in Chu-Shan and Taichung.

The major source of anthropogenic emission of nitrogen oxides into the atmosphere is the combustion of fossil fuels from stationary sources (heating power generation) and motor vehicles [7]. NO_2 in Chu-Shan was slightly (non-significantly) lower than in Taichung (21.45 ± 7.87 vs 24.99 ± 6.8 ppb), and therefore unlikely to affect the relative prevalence of asthma and/or current asthma between Chu-Shan and Taichung.

Particulate air pollution is a mixture of solid, liquid or solid and liquid particles suspended in the air. The size of the suspended particles varies from a few nm to μm. The largest particles (the coarse fraction) are mechanically produced by attrition of larger particles. Small particles (<1 μm) are largely formed from gases, the smallest (<0.1 μm) are formed by nucleation resulting from condensation or chemical reactions that form new particles [7]. In this study, the particulate concentration in Chu-Shan was slightly higher than in Taichung (72.25 ± 24.60 vs 63.08 ± 17.73 μg/m^3) but not statistically significantly so, suggesting that particulate concentration is not an important factor in the prevalence of asthma. The physiological effects of CO on asthma are poorly understood. One study has shown that CO can inhibit human airway smooth muscle cell proliferation via the extracellular signal-regulated kinase 1 and 2 mitogen-activated protein kinase (ERK1/ERK2 MAPK) pathway that is independent of the guanylyl cyclase/cGMP independent pathway. CO might act as an important mediator in the remodeling of human airway during asthma [9].

In Taiwan, a study has shown that the prevalence of asthma by area is strongly associated with the annual average level of CO. The concentration of CO was divided into 3 levels; high (>1.0 ppm), intermediate (0.75–0.99 ppm) and low (<0.75 ppm) and higher rates of asthma were found in highly urbanized areas compared to moderately and less urbanized areas [3].

In our study, the concentration of CO in Chu-Shan was statistically significantly lower than in Taichung (0.59 ± 0.12 vs 0.78 ± 0.19 ppm, p=0.003). Thus, CO might be a factor affecting the prevalence of asthma.

SO_2 is a common irritant pollutant gas in the community. There is a clinically significant airway contraction and symptoms after only a few minutes of moderate exercise in SO_2 concentrations as low as 0.25 ppm [10]. The concentration of SO_2 in Chu Shan town was only slightly lower than in Taichung (2.44 ± 0.88 vs 2.58 ± 1.0 ppb) and thus unlikely to be implicated in the prevalence of asthma.

It is still controversial whether the effect of NO is proinflammatory or anti-inflammatory in asthma. Asthmatic patients have a significantly higher NO level in exhaled air than in normal non-smoking individuals [11]. A study has demonstrated an inhibitory effect of NO on cytokine production stimulated by CD23 receptor activation. CD23 receptor expression is enhanced on monocytes and alveolar macrophages during asthmatic exacerbation. Monocytes and macrophages are major sources of cytokines in the lung and important potential contributors to asthmatic airway inflammation [12]. This study found the annual average concentration of NO was significantly lower in Chu-Shan than in Taichung (5.07 ± 2.81 vs 1.47 ± 4.75 ppb), thus suggesting that NO might play an important role in the variation in asthma prevalence.

The prevalence of asthma and allergic rhinitis is higher in urbanized areas than rural areas and air pollution might be one of important factors affecting this. In this study, we found the prevalence of allergic disease in Chu-Shan was lower than in Taichung and that concentrations of SO_2, CO, NO and NO_2 were lower in Chu-Shan than in Taichung. It was noted that levels of CO and NO were significantly lower in Chu-Shan, indicating that these agents might play a more important role in the prevalence of allergic diseases than other pollutants. However, further studies are needed to explore the various factors identified here.

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