

The association of seasonal variations of asthma hospitalization with air pollution among children in Taiwan

Kuo-Wei Yeh¹, Chee-Jen Chang² and Jing-Long Huang¹

Summary

Background: The impact of air pollution on asthma in children in different age group has not been well defined.

Objective: This study aimed to evaluate the association between seasonal variations in air pollution and asthma hospitalization of children within a two-year period.

Methods: Using the National Health Insurance database, seasonal variations in hospitalization trends in children with a primary diagnosis of asthma (International Classification of Disease 9th revision, code 493) for patients aged < 18 years from 2001 to 2002 were investigated. Data on the average concentration of nitrogen dioxide (NO₂), carbon monoxide (CO), ozone (O₃), sulphur dioxide (SO₂), and particles with aerodynamic diameter < 10 µm (PM₁₀) for each month were obtained from the Environmental Protection Department through 71 stations of air quality monitor distributed nationwide. PSI value (pollutants standard index) > 100 was considered poor air quality. Seasonal variations in asthma admissions were compared to the air pollution quality data using Spearman's rank correlation.

Results: Asthma hospitalization was not related to the number of days when the PSI was > 100 during the 24-months period ($r = -0.361$; $p = 0.083$). However, it was significantly associated with seasonal changes in the

concentration of each pollutant. The most strongly related air pollutant variable was PM₁₀ (standardized coefficients 0.384), followed by O₃ (standardized coefficients 0.255) and SO₂ (standardized coefficients 0.162) concentrations. The association of seasonal changes in asthma hospitalization with these pollutants was greater in pre-school and school age children. Temperature and rainfall in all seasons were not related to asthma hospitalization. None of the pollutants were associated with seasonal variations in admission rate for adolescents.

Conclusion: Seasonal variations of asthma hospitalization among preschool children are associated with concentration of air pollutants. (*Asian Pac J Allergy Immunol 2011;29:34-41*)

Key words: asthma, preschool, air pollution, hospitalization

Introduction

Asthma is a chronic and heterogeneous airway disease with significant global impact. It is considered to be a disease influenced by genetic and environmental factors. Despite its increasing global prevalence, asthma admission patterns vary between different countries.^{1,2} However, asthma admissions among children are still increasing as compared to the adult group. One of the possible reason is the increase in industrialized lifestyles which has resulted into declining air quality. Furthermore, for children aged <18 years, the asthma admission rate shows a seasonal pattern, with autumn being the most common season, followed by winter and early spring, and summer, which has the lowest admission rate. However, this is not the case in the adult group.³

Air pollutants, such as SO₂, CO, and particulate matter, are either emitted into the atmosphere or formed in the air secondary to chemical reactions. There is an association between ambient ozone levels below the limits set by the Environmental Protection Agency and asthma symptoms in asthmatic children living in

From the ¹Division of Allergy, Asthma and Rheumatology, Department of Pediatrics, Chang Gung Memorial Hospital at Linkuo and Chang Gung University, Taoyuan, Taiwan

²Biostatistical Center for Clinical Research, Chang Gung Memorial Hospital at Linkuo, Taoyuan, Taiwan

Corresponding author: Jing-Long Huang

Email: long@adm.cgmh.org.tw

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New England.⁴ Many studies have investigated the effects of automobile-related pollutants on heavily traveled highways as a cause of asthma symptoms in allergic children. High vehicle traffic is associated with asthma symptoms in children with known allergen sensitization,^{5,6} which is not noted in adults.⁷

Moreover, odoriferous chemical vapor is a major risk factor for respiratory illness in the residential environment of schoolchildren in Taipei.⁸ It has been noted that CO and NO_x are associated with asthma prevalence. In a cross sectional study, both SO₂ and O₃ were also associated with emergency room visits due to asthma attack.⁹

Air pollution is considered to be related to human health and respiratory diseases. From a clinical point of view, air pollutants cause airway inflammation and impair lung function and development.^{10,11} The entire environment contains various kinds of pollutants rather than a single compound. The ozone interacts with aeroallergens in subjects with bronchial hyperactivity under natural conditions.¹⁰ It can decrease lung function¹² and trigger asthma emergency visits in childhood.¹³ However, NO₂ and SO₂, but not O₃, were associated with daily admission rates for asthma in a study in London.¹⁴ In a European study, NO₂ was associated with emergency visits for asthma during the cold season,¹⁵ while particulate matter was associated with emergency room visits in Seattle.¹⁶

It is common to use broadly defined age groups in children. However, there are important differences between infants, schoolchildren, and even adolescents in terms of lung development, disease presentation, and immune systems. The effects of air pollution on children's health varies, depending on different age groups.¹⁷

It is valuable to identify exposure to air pollution in order to understand the risk of asthma. This study aimed to investigate the association of seasonal variations in childhood asthma hospitalization and air pollutants in different age groups in Taiwan.

Methods

Asthma hospitalization

Hospitalization health care records were collected from NHI (National Health Insurance) databases from 2001 to 2002. These databases contained health care data from >95% of all

hospitals in Taiwan and from >96% of the population receiving health care.¹⁸ From this database, hospitalized patients were selected on the basis of the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code for asthma (493.xx) listed as the major diagnosis. Patterns of asthma hospitalization for those aged <18 years in each month between 2001 and 2002 were analyzed. The study group was further divided into 3 different age groups: pre-school (2-5 years), school age (6-12 years), and young adolescent (13-18 years).

Air pollutants data

There are 71 stations measuring air quality, 28 in northern, 16 in central, 24 in southern and 4 in eastern Taiwan. Data on the average concentrations of nitrogen dioxide (NO₂, ppb), carbon monoxide (CO, ppm), ozone (O₃, ppb), sulphur dioxide (SO₂, ppb), and particles with aerodynamic diameter <10µm (PM₁₀, µg/m³) in each month were obtained from the Environmental Protection Department. The Pollutants Standard Index value (PSI) >100, as a reflection of poor air quality¹⁹, was calculated as follows: First, each of the air pollutants monitored in the air by one of the monitoring stations scattered in Taiwan Area was converted to the PSI sub-index value. Second, the largest from the 5 PSI sub-index values calculated by the station for a day was chosen to serve as the PSI for the station on that specific day. The PSI scale, ranging from 0 to 500, was based on a scale devised by United States Environmental Protection Agency. Generally, it indicates conditions likely to cause ill healthy in population if the scale above 100.

Statistical analysis

The association of seasonal variations of asthma admission and air pollution quality was compared using Spearman's rank correlation coefficient for the 24-month study period. Simple linear regression followed by multiple regression model and calculation of standardized coefficients was used to analyze the impact of air pollutants on asthma admissions. Standardized coefficients can determine whether a 1 standard deviation change in one air pollutant produces more of a change in relative position than a 1 standard deviation change in another pollutant. All statistical analysis



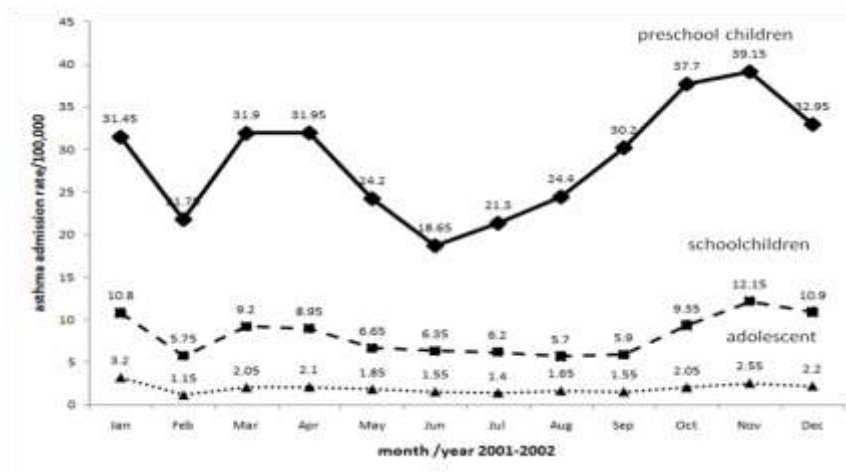


Figure 1. Seasonal variations in asthma hospitalization rates in different pediatric age groups during 2001-2002

was done using SPSS 15.0 (SPSS Incorporated, Chicago, USA).

Results

Hospitalization of different age groups

In a survey of asthma hospitalization in children below age of 18 in Taiwan from 2001 to 2002, the admission rates were 120.9/100,000 and 120.3/100,000 respectively. There appeared to be significant seasonal variations in asthma hospitalization in children. There were two peak seasons for pediatric asthma admissions per year in Taiwan i.e. the first was in autumn into winter (14.1/100,000) and the other was during early spring (11.4/100,000). Furthermore, when divided into pre-school, school age, and young adult groups, the highest admission rate was among pre-school children (278.3/100,000) followed by

the school age group (90.2/100,000) and the young adolescent group (21.3/100,000). All three sub-groups presented with similar seasonal patterns of asthma admission. However, the trends were most prominent in the pre-school age group use. (Figure 1)

Association of poor air quality and asthma admission in children

There were 829 and 718 day-stations with PSI value >100 in 2001 and 2002, respectively, with an average of 2.9 days of poor air quality in a month. The months with the most frequent PSI >100 were February 2001 and November 2002. The period of the year with the lowest pollution was the summer season (from June to August). However, there was no seasonal variation during the continuous 24-month recordings. The prevalence of asthma hospitalization did not

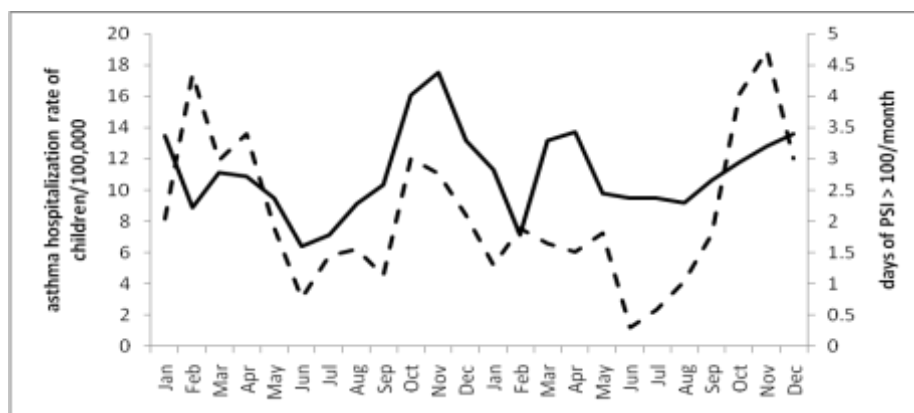


Figure 2. Change in PSI (air pollution index) was not associated with asthma hospitalization rates within a 24-month period. The solid line represented asthma hospitalization rate; the dotted line represented days with poor air qualities.



correlate to days with PSI >100 in each month ($r = -0.361$, $p = 0.083$). There was also no correlation between the days of poor air quality per month and the admission rate of pre-school children ($r = 0.381$, $p = 0.067$), school age children ($r = 0.321$, $p = 0.127$), and young adolescents ($r = -0.006$, $p = 0.979$). (Figure 2)

Correlation of concentration of different air pollutants with asthma admissions in different age group

The average concentration of SO₂ was 3.83 ± 0.72 ppb within this period. The average concentration of CO, NO₂, O₃, and PM₁₀ were 0.64 ± 0.08 ppm, 20.48 ± 4.29 ppb, 26.08 ± 4.21 ppb, and 57.19 ± 15.41 µg/m³, respectively. Seasonal changes in concentrations of air pollutants were positively associated with asthma admission rates in children below age of 18 within this period. The air pollutant most strongly correlated was PM₁₀ (standardized coefficients 0.384), followed by O₃ (standardized coefficients 0.255). When the study group was divided into 3 different age groups, the association was more prominent among pre-school and school age children (Figure 3-1). However, none of the pollutants were associated with the seasonal variation of admission rate in the adolescent group (Table 1).

Humidity and rainfall and asthma admission

Generally, Taiwan has a subtropical climate. The relative humidity is above 80% all year around, including summer, and there is no

seasonal variation. The change in humidity is also independent to all the air pollutants. There was no association between humidity and asthma admission pattern of children in general ($r = -0.37$, $p = 0.08$). However there was a negative association among school age children ($r = -0.46$, $p = 0.023$), but not in the pre-school and adolescent groups ($r = -0.33$, $p = 0.12$ and $r = -0.36$, $p = 0.08$, respectively).

The average rainfall was 131.2 mm per month in 2001 and 2002. In contrast, there was a prominent negative association of asthma admission and rainfall in children ($r = -0.56$, $p = 0.006$), with a similar trend among all three sub-groups (preschool: $r = -0.56$, $p = 0.007$, school age: $r = -0.65$, $p = 0.001$; and adolescents: $r = -0.43$, $p = 0.038$) (Figure 3-2).

Prediction of asthma admission trend

Only rising levels of ozone were significantly associated with asthma hospitalization with a lag of 1 month, where an increase in one ppb of ozone would increase the asthma hospitalization rate by 0.3% ($p = 0.023$, CI, 0.15-0.62). However, all of the air pollutants started to decrease as early as four months before the decreasing trend of hospitalization of asthma. Table 2 represented the effects of each pollutant.

Discussion

The prevalence of asthma in children has not reached a plateau in western countries and has continued to increase in developing countries.^{20,21}

Table 1. Correlation between various air pollutants and asthma admissions in different pediatric age groups

	Preschool			School		Adolescent		All Children			
	Mean	r	P	r	P	r	P	r	P		
Average admission rate per 100,000	278.3			90.2				21.3			132.9
		Seasonal correlation		Seasonal correlation		Seasonal correlation		Seasonal correlation		Seasonal correlation	
SO ₂ (ppb)	3.83	0.49	0.014	0.63	0.001	0.37	0.079	0.55	0.005		
CO (ppm)	0.64	0.36	0.084	0.51	0.011	0.19	0.375	0.45	0.029		
NO ₂ (ppb)	20.5	0.45	0.029	0.57	0.004	0.23	0.286	0.50	0.014		
O ₃ (ppb)	26.1	0.56	0.005	0.21	0.336	0.09	0.682	0.41	0.045		
PM ₁₀ (µg/m ³)	57.2	0.51	0.011	0.55	0.006	0.25	0.241	0.50	0.013		

Figure 3-1.

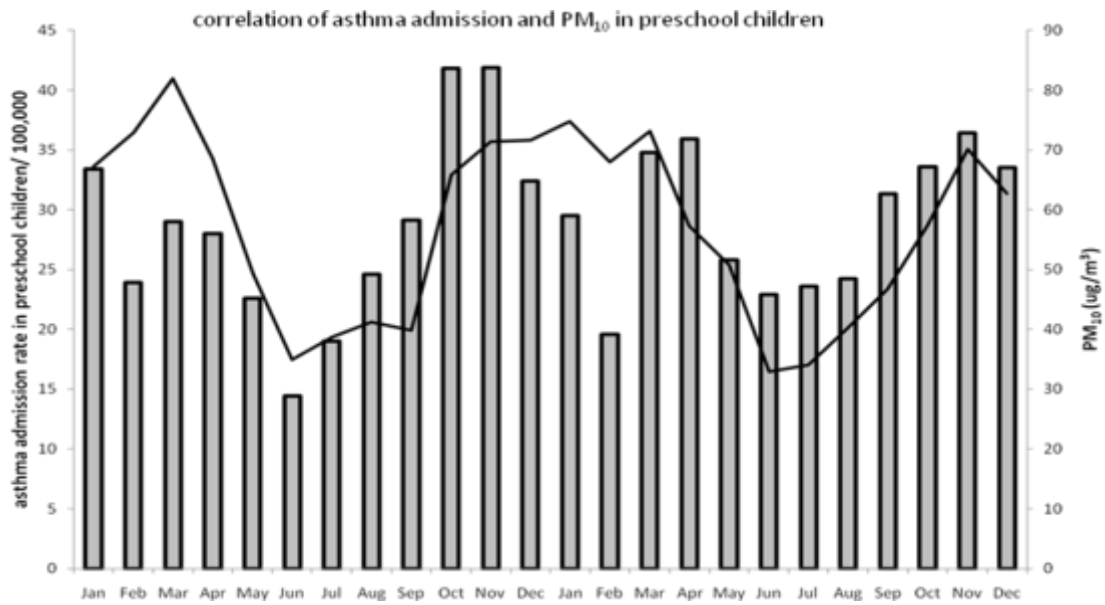


Figure 3-2.

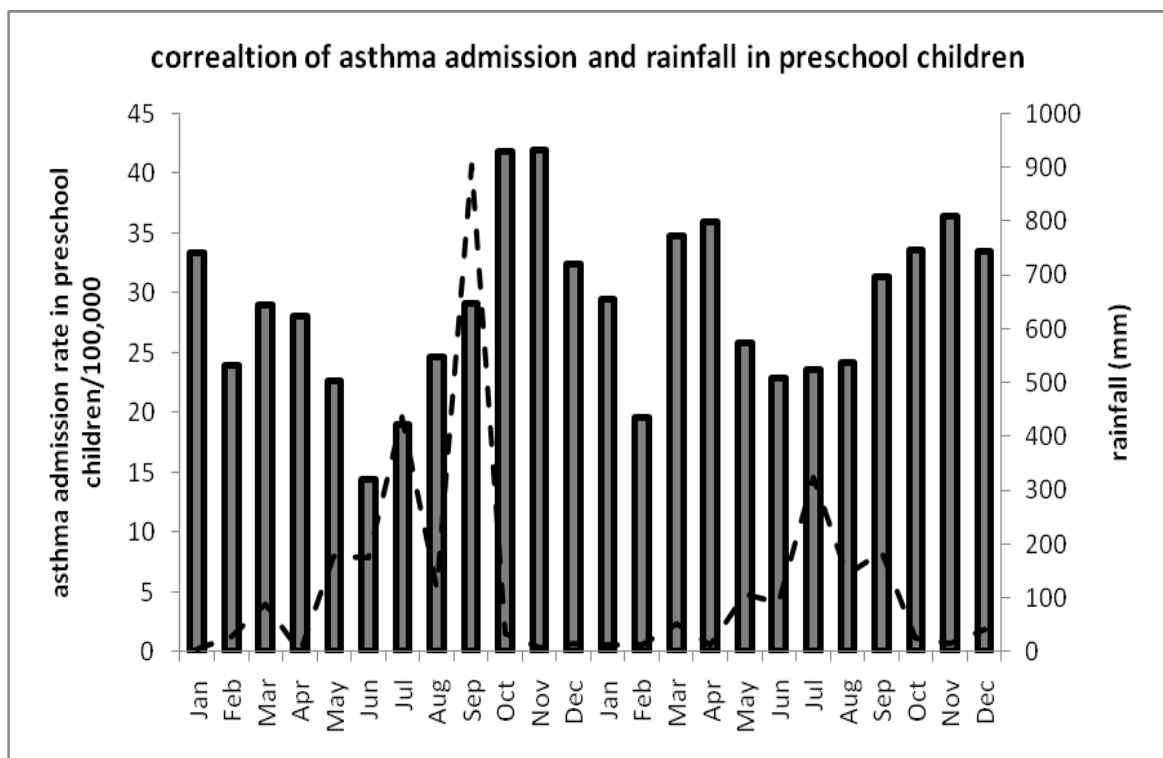


Figure 3-1. and 3-2. Correlations with seasonal changes in PM₁₀, rainfall, and asthma admissions in preschool children within a 24-month period. The bar represented hospitalization rate per 100,000 of population; the line represented PM₁₀ concentration (µg/m³); the dotted line represented the average rainfall (mm) per month



Table 2. Lag time in predicting increasing or decreasing asthma admissions

	Lag month	Admission rate/every 1 level decreasing each pollutants	Confidence interval		P value	t score
		Estimate	2.50%	97.50%		
Increase						
SO ₂	0	1.81	0.32	3.30	0.020	2.52
CO	0	12.65	-0.72	26.02	0.063	1.96
NO ₂	0	0.32	0.08	0.57	0.013	2.72
O ₃	1	0.30	0.15	0.62	0.023	3.36
PM ₁₀	0	0.05	-0.03	0.12	0.227	1.25
Decrease						
SO ₂	4	-2.20	-3.79	-0.61	0.009	-2.91
CO	4	-20.34	-33.38	-7.31	0.004	-3.28
NO ₂	4	-0.42	-0.67	-0.17	0.002	-3.52
O ₃	4	-0.45	-0.73	-0.73	0.004	-3.32
PM ₁₀	4	-0.12	-0.18	-0.18	0.002	-3.68

Long-term exposure to traffic-related pollutants such as NO₂, O₃, and CO is one of the reasons cited for the increasing prevalence of asthma in school children.²² In a previous survey of asthma prevalence, there was a higher rate of asthma in polluted areas around factories compared to less polluted areas.²³ The asthma admission rate is still increasing in children with significant seasonal variations that are more marked in autumn and early spring.^{3,24} In a survey of the adult population, the asthma admission rate was high in spring, and its seasonal variations were correlated positively with air pollutants.²⁵ In this study, air pollutants have similar trends to seasonal changes and are considered to be related the seasonal variation of asthma admission in children.

Early asthma symptoms usually begin to develop at the age of 3 or 4 years. Although it is hard to have a consensus on diagnosis of asthma in pre-school children, it is obvious that this group has a higher asthma admission rate based on ICD-9-CM code, from the large database survey. To minimize the inclusion of other asthma-like symptoms or diagnoses, only individuals with a first diagnosis code of asthma have been included in this study. Air pollutants can reportedly influence respiratory symptoms in pre-schoolers in a cross-sectional study.²⁶ An increase of ambient NO₂ and CO levels during summer is associated with asthma emergency visits among

children 2-4 years of age.²⁷ In the findings here, air pollutants are related to asthma admission especially in pre-school children. Increasing indoor particulate matter levels have been associated with asthma symptoms and even use of rescue medication in pre-school children who spend most of their time at home.²⁸ However, outdoor air pollution can penetrate the indoor environment and increase the indoor pollutants, thereby causing asthma morbidity.

There was no significant relationship between asthma hospitalization and air pollutants in the adolescent group in our survey. However, environmental exposure in early life and its long-lasting effects should be greatly emphasized. Because of increased airway caliber when growing up, or implantation of asthma control programs after diagnosis, the impact of air pollution is less prominent in the adolescent group. In a study of adults, air pollutants still induced a reduction in lung function despite the patient remaining clinically asymptomatic.²⁹

The ambient pollutant most strongly associated with asthma morbidity is the ozone, which can enhance airway inflammation. A strong association between ozone and asthma emergency visits has been established in schoolchildren.²⁷ In this study, although there was an association between ozone and asthma hospitalization in children, this association is only observed among



pre-school children. It is not statically significant in school age and young adolescent children.

In Australia and New Zealand, asthma hospitalization in school children increased in relation to the elevation of NO₂.³⁰ In an analysis of eight cities in North America, NO₂ and CO but not O₃ were associated with asthma exacerbations.³¹ However, SO₂ and O₃ were associated with asthma emergency room visits in Poland.⁹ In Oslo, Norway, the higher admission rates were located along the main motor roads.³² Except ozone, all pollutants are associated with the seasonal change of asthma admissions among schoolchildren. Although particulate air pollution mainly affects pre-school and school age children, the pattern of seasonal variation cannot be ascribed to traffic load in this study. The complex mixture of air pollutants in different regions may produce equivocal findings.

Dust mite is the most common indoor aeroallergen in allergic diseases, with 60-85% sensitivity among asthmatic children.³³ The mean number of mites is greater in August through November and lowest in July in Taiwan.³⁴ The distribution pattern is not similar to hospitalization patterns of asthma. Pollen is not a major allergen and has no seasonal change even in spring or summer in Taiwan. There is no pollen or spore distribution data from the Environment Protection Department because there is less spread of pollen even in the blooming season. Neither allergen has contributed to our findings.

Coal emission is one of the causes of air pollution. However, the change of cooking style from coal to electricity or gas has evolved in the last three decades. It is not one of the reasons for the seasonal variation of asthma admission in Taiwan. Moreover, because of the sub-tropical climate with high humidity and general warmth in Taiwan, it is very unusual to find living rooms equipped with heaters or fireplaces.

In this study, the total days of air pollution exposure in a month were not related to hospitalization of asthma in childhood. Days of increased air pollution index were identified during the study period, with approximately only 2 days of poor air quality recorded in each station per month nationwide and without any seasonal variations. The trend in air pollution concentrations has significant seasonal changes which are associated with admission patterns.

High humidity can change airway permeability and lead to an asthma attack. Fluctuations in environmental humidity appear to influence emergency visit for asthma in children.³⁵ Controlling indoor humidity to 50-60% has been suggested as part of asthma treatment. In the findings here, the relative humidity level had no significant variation in the different seasons during the 24-month study period. Although heavy rainfall can elevate ambient humidity, in this study, it is not humidity per se that is associated with asthma admission in all sub-groups. Rain has a 'washout' effect on air pollution.³⁶ In addition, higher rainfall correlates to lower asthma admission rate in children in different age groups.

Increasing levels of SO₂, NO₂ and O₃ can predict an elevation in hospitalization rates within 1 month. However, it takes four months to reflect a decreasing trend in admissions after the levels of all pollutants start to decrease. This also shows that air pollutants have immediate and continuous effects on asthma hospitalization. Increases in the inter-quartile range of the 5-day average of NO₂ and CO are associated with the risk of emergency visit for asthma.²⁷ Furthermore, long-term exposure to air pollutants, even at low levels, is associated with respiratory symptoms.³⁷

This study has some limitations. Although the air stations are distributed around whole country and the data can be obtained from each station in different regions, the original hospitalization data obtained from the national health insurance database are not divided into different locations. As such, it was not possible to compare the differences and correlations between urban and rural areas. There was also no indoor air quality data available to indicate its impact on asthma admissions.

Environmental protection is a global health issue. It is important that pre-school children have high admission rates of asthma and that air pollution is prominently related to this phenomenon. From the clinical viewpoint, there should be more emphasis on asthma prevention and treatment aside from pollution control, especially on pre-school children who usually present with early subtle symptoms.

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