

Temporal relationship between air pollution and hospital admissions for asthmatic children in Hong Kong

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Summary

Background Many epidemiological studies have shown positive association between respiratory health and current levels of outdoor air pollution in Europe and America.

Objective The aim of this study was to investigate the association between air pollution and the number of childhood admissions for asthma in Hong Kong.

Methods Daily counts of childhood admission for asthma to a large teaching Hospital were obtained from the computerized database for the period 1993–1994. A Poisson regression allowing for seasonal patterns and meteorological conditions was used to assess the associations between the number of Hospital admissions and the three pollutants: nitrogen dioxide, sulphur dioxide and inhalable particles (measured as PM₁₀, particles < 10 µm in aerodynamic diameter).

Results A total of 1217 children under 15 years of age were admitted for asthma during the study period. The calculated annual hospitalization rates were 283 and 178 per 100 000 for boys and girls, respectively. The mean PM₁₀, NO₂ and SO₂ levels were 44.1 µg/m³, 43.3 µg/m³, and 12.2 µg/m³, respectively. Daily admission for asthma increased significantly with increasing ambient level of nitrogen dioxide (relative risk (RR) = 1.08 per 10 µg/m³ increase), sulphur dioxide (RR = 1.06) and inhalable particles (RR = 1.03). No association was found between hospital admission and humidity, temperature or atmospheric pressure.

Conclusion This is the first daily time series study of childhood admissions for asthma and air pollution in Hong Kong. The results support that current levels of air pollution contribute to the respiratory morbidity in asthmatic children in Hong Kong.

Keywords: asthma, air pollution, children, hospital admission

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Introduction

Many epidemiological studies have demonstrated the association of environmental air pollution and deterioration of respiratory health. Individuals with chronic respiratory diseases such as asthma and chronic obstructive airway disease are particularly susceptible to the adverse effects of air pollution. Experimental studies in humans have also shown that air pollutants including ozone (O₃), sulphur

dioxide (SO₂), inhalable particles < 10 µm in aerodynamic diameter (PM₁₀), and nitrogen dioxide (NO₂) all can aggravate airway pathology by inducing or enhancing airway inflammation [1–4]. Many studies have shown that levels of air pollution are associated with reduced pulmonary function, increased respiratory symptoms and even increased mortality [5–10]. In both adults and children, air pollution has also been found to be associated with increased visits to emergency and admissions to Hospitals due to respiratory complaints or asthma exacerbation [11–15]. In contrast, there was also a study which failed to demonstrate any relationship between the levels of

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airborne particles and exacerbation of respiratory disease in children [9].

Analyses of daily time series of Hospital admissions for asthma provide a valid method of investigating the effect of pollution on the asthmatic population at large. In Hong Kong, chronic respiratory diseases are prevalent conditions. Epidemiological surveys have shown that 12% of children and 7% of young adults suffer from asthma [16,17]. Among the Chinese population living in various parts of the world, the prevalence of asthma among schoolchildren has been found to be highest in Hong Kong [18]. To clarify the possible role of air pollution on respiratory health of asthmatic children, this study was performed to investigate the temporal relationship between the ambient levels of each of the air pollutants — PM₁₀, NO₂, and SO₂ — on Hospital admissions due to asthma in children living in Hong Kong.

Methods

Admission and pollution monitoring

The computerized daily number of admissions for asthma in children was collected from a large teaching Hospital, the Prince of Wales Hospital. The Hospital was the only one with paediatric beds serving the North-east region of Hong Kong with a catchment population of approximately 1.2 million. Of these, 240 000 were children under 15 years of age. Daily counts of paediatric patients with asthma admissions — i.e. any admission with the ICD-9 code 493 — were obtained. It is the Hospital policy that all patients under 15 years of age are admitted to the paediatric wards. During the study period between January 1993 and December 1994, there was no major change in the population structure in the catchment population.

There are a total of nine monitoring stations throughout Hong Kong. The following air pollutants were measured: nitrogen dioxide (NO₂), sulphur dioxide (SO₂), and inhalable particles (measured as PM₁₀). All stations monitored hourly SO₂ by the acidimetric bubbler system, NO₂ using chemiluminescence method, and hourly PM₁₀ mass using tapered element oscillating microbalance (TEOM) instruments [19]. Daily averages were then calculated for all four pollutants for further analyses. Meteorological variables including 24 h mean temperature, humidity and atmospheric pressure were also obtained from the Royal Observatory of Hong Kong. Since the catchment population was from the North-east region of Hong Kong, the average of the meteorological and pollutant levels in the two monitoring stations, namely Shatin and Taipo stations located in the North-east region of Hong Kong, were used for correlating with the number of daily Hospital admissions.

Statistical analysis

The statistical analysis was based upon the methods developed by the 'Air Pollution and Health: a European Approach' (APHEA) project [20]. Spectral analysis was used to determine the periodicity of the seasonal patterns and appropriate trigonometric variables constructed to account for them in a statistical model. The suitability of the statistical model was assessed using the overdispersion parameter, model deviance and plots of Pearson residuals, and any remaining serial correlation was assessed using the partial autocorrelation function. Any remaining association between the observed counts and temperature and humidity was determined using plots of the model residuals against various meteorological measures. Poisson regression allowing for overdispersion and autocorrelation was used to determine the percentage change in the mean number of asthma admissions associated with an increase in the pollutant levels. The possibility of a lag effect of each pollutant was explored by significance test and plotting residuals against each variable lagged by 1, 2, 3, 4, or 5 days, as well as cumulative lags, calculated as the mean of lags 0 and 1, lags 0–2 and lags 0–3. For each pollutant, the most significant single-day lag or cumulative lag was selected for reporting purposes. The results are presented as relative risk (RR) values associated with a 10-unit increase in the pollutant level. A relative risk of 1.01 corresponds to a 1% increase of asthma admission.

Results

A total of 1217 children under 15 years of age were admitted for asthma during the study period. There were 770 boys and 447 girls, giving a male to female ratio of 1.7:1. The calculated annual Hospitalization rates were 283 and 178 per 100 000 for boys and girls, respectively. The mean PM₁₀, NO₂ and SO₂ levels were 44.1 µg/m³ (range 10–195 µg/m³), 43.3 µg/m³ (9–106 µg/m³), and 12.2 µg/m³ (0–98 µg/m³), respectively. The levels of pollutants and admissions in four different seasons are summarized in Table 1. The PM₁₀ levels were found to be highest in autumn and winter while SO₂ was highest during the summer. Figure 1 shows the distribution of daily number of Hospital admissions for childhood asthma during the study period. The mean ± S.D. daily number of admissions was 2.7 ± 1.9. Table 2 shows the distribution of variables used in the analysis.

There were consistent and statistically significant associations between asthma admission and increase in daily levels of SO₂, NO₂ and PM₁₀. Table 3 summarizes these results and the RR values in different seasons. Particularly strong associations and high relative risk were related to SO₂ and NO₂. Other non-significant associations

Table 1. Seasonal variations in admissions and levels of air pollutants

Season	Admissions	PM ₁₀ mean $\pm$ S.D. ($\mu\text{g}/\text{m}^3$)	NO ₂ mean $\pm$ S.D. ($\mu\text{g}/\text{m}^3$)	SO ₂ mean $\pm$ S.D. ($\mu\text{g}/\text{m}^3$)
Autumn (September–November)	395	51.2 $\pm$ 29.8	51.7 $\pm$ 17.6	10.6 $\pm$ 9.6
Winter (December–February)	304	57.0 $\pm$ 29.7	46.6 $\pm$ 15.5	10.0 $\pm$ 7.5
Spring (March–May)	294	41.7 $\pm$ 21.4	40.7 $\pm$ 11.8	9.6 $\pm$ 8.8
Summer (June–August)	224	29.5 $\pm$ 18.1	32.6 $\pm$ 13.7	18.5 $\pm$ 19.5

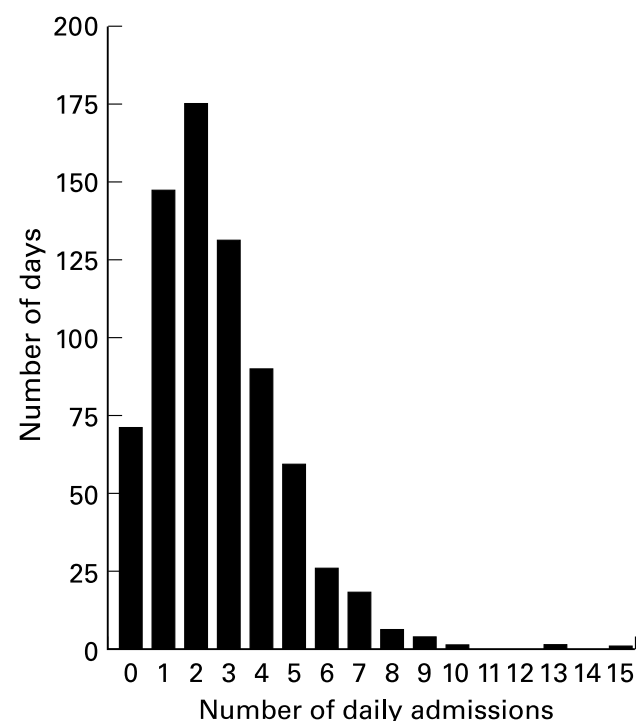
were not shown. Throughout the study period, daily admissions increased significantly with increasing ambient levels of PM₁₀ (lag 5, $P = 0.017$), NO₂ (lag 0, $P = 0.001$), and SO₂ (lag 3, $P = 0.004$). Further analyses according to season were performed and no associations were noted in the spring or winter. No significant association was found between Hospital admissions and the day of the week, humidity, temperature or atmospheric pressure.

Discussion

Most published studies of health effects of air pollution on respiratory morbidity have been performed in America and Europe. Among the Chinese population in different parts of the world, the prevalence rate of childhood asthma has been

found to be highest in Hong Kong, as demonstrated by standardized questionnaire survey [18]. Our research group has also documented an increasing trend of childhood asthma prevalence in Hong Kong [17]. The role of air pollution and respiratory morbidity can be investigated by assessing the pulmonary function of patients, respiratory symptom diary in healthy or asthmatic patients, as well as Hospital admissions or emergency visits. The current study is the first to investigate the relationship between daily Hospital admissions of children due to asthma and the three common air pollutants in our locality. All three pollutants were found to be associated with Hospital admission for asthma in children.

Several recent studies have confirmed the significant associations of the levels of air pollutants and visits to

**Fig. 1.** Histogram of daily number of Hospital admissions for asthma of children under 15 years of age.**Table 2.** Distribution of levels of air pollutants, meteorological variables and admissions

Variable	Mean	Minimum	Maximum	S.D.
Daily admission	2.7	0	15	1.9
PM ₁₀ ($\mu\text{g}/\text{m}^3$)	44.1	10	195	24.0
NO ₂ ($\mu\text{g}/\text{m}^3$)	43.3	9	106	16.6
SO ₂ ($\mu\text{g}/\text{m}^3$)	12.2	0	98	12.9
Temperature ($^{\circ}\text{C}$)	22	5	32	6
Humidity (%)	82	38	99	11

Table 3. Relative risk of admissions and asthma admission for a 10- $\mu\text{g}/\text{m}^3$ increase in air pollutants

Season	Pollutant	Lag time (days)	Relative risk	<i>P</i>
Whole year	NO ₂	0	1.08	0.001
	SO ₂	3	1.06	0.004
	PM ₁₀	5	1.03	0.017
Summer	PM ₁₀	5	1.06	0.025
Autumn	NO ₂	0	1.08	0.017
	PM ₁₀	5	1.07	0.003

Emergency Departments due to asthmatic attack in children [13,15,21]. Unlike Hospital admissions, visits to Emergency Departments are not limited by bed availability. Furthermore, visits to Emergency include both mild and severe cases of asthma while Hospital admissions usually include the more severely affected cases. In our study, the statistics were not affected by bed availability because it was the Hospital policy to add extra beds in the paediatric wards when the wards were 'full'. No asthmatic patient requiring Hospitalization was refused admission during the study period. Furthermore, the Environmental Protection Department has not yet started releasing the pollution levels to the public during the study period. In our study, the decision on Hospital admission was primarily dependent on the clinical condition of the patients. One recent study in London revealed significant associations between the levels of air pollutants including NO₂, SO₂, and PM₁₀ and emergency visits in both children and adults. The strongest association was found in children with a lag time of 1 day [21]. A comparative study of four European cities, Barcelona, Helsinki, Paris and London, also confirmed the association of ambient levels of NO₂ and SO₂ and emergency visits. For children < 15 years old, the relative risk of emergency visits was 1.075 for 50 µg/m³ increase in SO₂ on the same day. For the same increase in NO₂, the relative risk was 1.037 with a lag period of 1 day. Furthermore, a recent study from Israel also demonstrated a significant association of emergency visits by asthmatic children and the levels of NO₂, SO₂ and high atmospheric pressure [15]. Statistical analysis showed that 69% of the variance in emergency visits could be explained by the combination of air pollutants and weather parameters. Although meteorological factors such as temperature have been documented to affect asthma exacerbation [22], our study did not demonstrate any association between asthma admission and temperature or humidity. Hong Kong has a subtropical climate such that the magnitude of variations in meteorological measurements such as temperature is relatively small when compared with other cities in the temperate zone. Therefore, the effect of these factors on asthma admission may be small.

Many studies of the associations of daily Hospital admissions for asthma and air pollution have been performed [12,14,23–25]. A recent comprehensive study from London showed that SO₂, NO₂, O₃ and black smoke were all associated with daily asthma admissions [14]. For both SO₂ and NO₂, there was a tendency for cumulative lags by 1–2 days to have a stronger effect. In addition, variations in the level of pollen were not found to be significant in altering such associations. The phenomenon of a lagged response was also observed in studies of the effect of ambient air pollution on pulmonary function on children [7]. Boezen *et al.* reported a study of the effect of

environmental pollutants on the respiratory symptoms and peak expiratory flow in 459 children. Those children with high serum IgE levels and bronchial hyperreactivity as documented by methacholine challenge were found to have more respiratory symptoms and decreased peak expiratory flow when there was an increase in black smoke, SO₂ or NO₂. Normal children without bronchial hyperreactivity or raised serum IgE levels, however, were not affected. In contrast, the recent PEACE study, which investigated the association of airborne particles and exacerbation of respiratory disease in children, did not show any consistent relation between these variables in 14 centres involving 2010 children across Europe [9]. A similar community study has also been performed recently in California, USA [6]. In this study, a total of 3293 children from grades 4, 7 and 10 were recruited to study the effects of ambient pollutants on respiratory symptoms and function. Both PM₁₀ and NO₂ were significantly associated with lower FVC, FEV₁ and maximal mid-expiratory flow.

Although there are inconsistencies in the studies of the effect of ambient air pollution and respiratory morbidity, many possible factors may contribute to such inconsistencies. Difference in the methodology in obtaining the environmental data can certainly influence the analysis. In large regions with varying levels of pollutants, personal exposure may not be adequately or accurately reflected by the data collected by the monitoring stations [26]. This is particularly true for NO₂, because indoor NO₂ exposure could be very high for individuals who live in a house with gas appliances. The outdoor NO₂ levels often reflect the degree of traffic pollution so that other covarying pollutants rather than NO₂ may be responsible for respiratory morbidity. Nevertheless, our study does have an advantage because of the small geographic size and homogeneous environment within the study area. The background prevalence and severity of asthma, differences in admission policy, concurrent viral epidemics as well as use of prophylactic medication in an asthmatic population can all be potential confounders. Given that the majority of studies have demonstrated a positive association, ambient air pollutants probably have a contributory role to respiratory morbidity, especially in subjects with pre-existing pulmonary problems. The magnitude of influence may vary across different regions of the world.

In conclusion, our study is the first daily time series study of childhood admissions for asthma and air pollution in Hong Kong showing that SO₂, NO₂ and PM₁₀ are associated with asthma admission in children. In agreement with reports from Europe and America, the results of our study support that current levels of air pollution contribute to respiratory morbidity in asthmatic children in Hong Kong.

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