

Asthma and ambient air pollution in Helsinki

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Abstract

Objective - To study whether ambient air levels of sulphur dioxide (SO₂), nitrogen dioxide (NO₂), total suspended particulates (TSP), and ozone (O₃) affect the number of hospital admissions for asthma.

Design - The associations between the daily number of admissions and air pollutants were analysed with Poisson regression, taking into account potential confounding factors by using the standardised protocol of the APHEA project.

Setting - Helsinki, Finland, 1987-89.

Patients and measurements - Patients admitted to hospitals through emergency rooms because of asthma (n=2421). The daily mean concentration was 13-25 µg/m³ for SO₂, 33-41 µg/m³ for NO₂, 19-41 µg/m³ for O₃, and 58-109 µg/m³ for TSP during the different seasons. Values are means for various stations. The daily mean temperature during the three year period was +5.4°C (range -37-27°C).

Main results - Positive associations with admissions were observed for O₃ levels in all children under 14 years, and for SO₂ levels in 15-64 year olds and among those older than 64. Significant associations were also seen between admissions for digestive tract diseases (the control) and O₃ levels. This suggests that the modelling, which proved to be problematic, was unsatisfactory, or it may be a statistical coincidence. A rise in temperature was associated with a low number of admissions for asthma among 0-14 year olds and among 15-64 year olds, whereas humidity did not have a significant effect on the number of admissions.

Conclusions - It is possible than even low level pollution may increase hospital admissions for asthma. However, definitive conclusions will be justified only after meta-analysis comprising several studies. The methodology was seen to have a strong effect on the results and standardised methods, possibly differing from those for the study concerning mortality, are needed to investigate the association between morbidity and ambient air pollutants.

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increase the frequency of asthma attacks are not known with certainty. Nor is there adequate information on the synergistic effects between various pollutants and other factors such as cold, the relative importance of the different causative factors, or the differences in sensitivity between the different age groups. The results of many studies have been impaired by small size of samples, confounding socio-economic factors, insufficiently documented levels of pollutants, and the biases in collecting information about illness.

During recent years longitudinal studies have been used in these investigations because the populations studied serve as their own controls, eliminating a potential source of bias in cross sectional studies.^{5-8 11-14} Our study investigated in daily time series the relationship of daily hospital admissions to ambient air SO₂, NO₂, O₃, and TSP concentrations, temperature, and relative humidity in Helsinki as part of a European multicentre project. In particular, we investigated whether the numbers of hospital admissions for asthma in different age groups increase on days with high levels of pollutants. The methodology used was uniform for all A centres participating in the EEC APHEA project.¹⁴

Methods

AIR POLLUTANTS AND METEOROLOGICAL VARIABLES

The pollution parameters used were 24 hour means for SO₂, NO₂, and TSP, an 8 hour mean for O₃ and 1 hour maximum values for SO₂, NO₂, and O₃. The means of different stations were used for all variables except O₃, which was measured at one station only.

The city of Helsinki covers a relatively small area, 185 km². The main sources of air pollutants are energy production by coal fired and oil fired power plants, road traffic and, to a small extent, industrialisation. Air pollution measurements are conducted in Helsinki by district municipal authorities. During the study period 1987-89, SO₂ was measured hourly by coulometric instruments at four automatic monitoring stations, NO₂ by chemiluminescence at two stations, and O₃ by ultraviolet absorption at one station. The instruments are calibrated on a monthly basis for SO₂ and NO₂, and bimonthly for O₃, and as the results are followed continuously, any disturbance in their functioning is noticed immediately. Total suspended particulates are collected by high volume samplers at six stations, at four of them every second day and at two every third day. At one weather station, measurements of temperature and relative humidity are recorded hourly. The total number of stations is eight;

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Several studies have shown an association between ambient air pollutants and hospital admissions or emergency room visits of patients with chronic obstructive pulmonary diseases including asthma, or asthma alone.¹⁻¹¹ The concentrations at which ambient air pollutants

four of them are situated in the centre of the town and four in the suburbs, at heights of 2–10 m. The sites of these stations have been selected to represent the actual exposure of the population to ambient air pollutants.

THE MORBIDITY DATA

The data on morbidity comprise details on all patients admitted to hospitals for asthma via emergency wards in Helsinki in 1987–89. The age groups 0–14 years, 15–65 years, and >64 years were analysed separately. The diagnosis of asthma is based on the *Ninth International Classification of Diseases* (ICD-9 code 493) issued by the World Health Organization. The number of admissions for diseases of the digestive system (ICD 9 codes 520–579) was studied similarly and used as a control. The data concerning hospital admissions for exacerbations of asthma were obtained from the register kept of all episodes of illnesses requiring admission to hospital. The register contains information on the dates of hospital stay, and on the diagnoses and ages of the patients. The register, its comprehensive coverage, diagnostic criteria, and quality assessment have been described in detail earlier.^{9,15} The population of Helsinki was 488 604 in 1987, 491 148 in 1988, and 491 777 in 1989.

MISSING VALUES

The study period comprised 1096 days. Information on the concentration of TSP was lacking for 375 days because of the sampling strategy, and so were values for NO₂ and SO₂ for 13 and four days, respectively. However, the frequencies of admissions during the days with missing observations were similar to those on the other days. Thus, the effect of the missing observations is probably small. The missing values were imputed from regression analysis.

MODELLING

The variables were included in the regression analysis in the following order: (1) long term trend, (2) season, (3) epidemics, (4) day of week, (5) holidays, and (6) temperature and relative humidity. The final analysis investigating the association between average levels of pollutants measured at different stations and admission for asthma was made by Poisson regression analysis.

Long term trends have been controlled both separately and jointly for each year. In addition, yearly “dummies” have been used. Separate terms were tested for each year. Sinusoidal terms were introduced into the model up to the 6th order. The combination with the best adjusted R² was selected, including both sine and cosine terms. In addition, different terms for each year were tested, but found not to be significant. Six dummy variables were formed for the days of the week and one for holidays. For each Christmas, a separate exponentially decaying term – that is, exp – [days from Christmas] – was used.

Many attempts were made to reduce the number of uninterpretable results. Firstly, uniform selection criteria for transformations were selected for different age groups, and the effects of the sinusoidals and differences between years were studied. The time plots showed that the seasonal patterns changed from year to year. Also, it seemed clear from both the plots and the exploratory STL (Seasonal and trend decomposition using Loess)¹⁶ that the weekly patterns change with time. These patterns were modelled in many different ways, but no clear answer was found.

The number of sinusoidal terms was originally restricted to six, but up to 19 were tried. Different sinusoidal terms for each year were also tried, without success. Better adjustments were found by using different trends and especially different weekly dummies for each year. Although the STL decomposition suggested that the trend would differ between the days, this was found difficult to model using standard regression methodology. On including more sinusoidal terms, the results became more reasonable, and the opposite was also true. This could mean that there were some exceptional periods (heatwaves, etc) that the model was not able to take into account. However, the task of finding such periods proved impossible.

Another set of difficulties was encountered when determining the proper transformations for the pollutants. The data were rather kurtotic – that is, most of the values did not differ much from the mean, whereas there were some very extreme values. These extremes tended to dominate the fit if no transformations were used. In addition, the time plots seemed rather non-stationary. Logarithmic transformation was therefore used. In future, generalised additive models¹⁷ in addition to the STL seem to be an attractive way of avoiding such problems.

Lags of 0, 1, and 2 days and cumulative lags of up to 3 days were tried for the effects of all pollutants. For those of O₃, cumulative lags up to 5 days were tried. The lags for untransformed values of temperature and humidity were chosen from lags of 0, 1, and 2 days, and from the averages of lag 0 and 1, and of lag 0, 1, and 2 days. The lags for influenza epidemics were chosen from lag 0 to 15 days.

Results

NUMBER OF ADMISSIONS

There were altogether 2421 admissions to hospital for asthma during the three year period – that is, an average of 2.21 admissions daily (table 1).

Table 1 Number of emergency hospital admissions for asthma in Helsinki, 1987–89

Diagnosis and age group	No	Admissions per day	
		No	(SD)
Asthma, all ages	2421	2.21	(1.91)
Asthma, 0–14 y	961	0.88	(1.26)
Asthma, 15–64 y	813	0.74	(1.08)
Asthma, >64 y	647	0.59	(0.82)
Control*	9017	8.23	(3.63)

* Emergency admissions for digestive system diseases.

Table 2 Mean values of pollutants, temperature, and relative humidity by season in Helsinki, 1987–89

	December–February	March–May	June–August	September–November
SO ₂ (µg/m ³)	26	22	13	15
NO ₂ (µg/m ³)	38	44	39	34
O ₃ (µg/m ³)	20	30	23	15
TSP (µg/m ³)	64	116	62	64
Temperature (°C)	-4.3	+4.0	+15.8	+5.8
Relative humidity (%)	89	79	75	86

Table 3 Association between the number of admissions and levels of pollutants with various lags in the Poisson regression analysis

Disease and age group	Pollutant	Lag (d)	Parameter estimate	(SE)	p
Asthma 0- to 14-y	O ₃ , 8 h*	0	0.1600	(0.0778)	0.040
Asthma 15- to 64-y	SO ₂ , 24 h	2	0.2176	(0.1081)	0.44
Asthma 15- to 64-y	SO ₂ , 24 h	0–3	0.3086	(0.1545)	0.046
Asthma >64 y	SO ₂ , 24 h	2	0.2412	(0.0956)	0.012
Digestive tract diseases	O ₃ , 8 h*	0	0.0641	(0.0282)	0.023
Digestive tract diseases	O ₃ , 8 h*	0–4	0.1152	(0.0417)	0.006

* One station only

POLLUTANTS AND METEOROLOGICAL VARIABLES

Concentrations of most pollutants in the ambient air were relatively low. The mean concentrations of SO₂, NO₂, and O₃ during the three year period, presented as arithmetic means of the values measured at the respective stations, were 19 µg/m³, 39 µg/m³, and 22 µg/m³. The mean concentration of TSP was 76 µg/m³, a high value that resulted from the meteorological conditions and the erosions of street surfaces caused by the use of studded tyres during the winter, as well as the use of sand on the streets to treat icy surfaces. Mean values of pollutants by season are given in table 2.

RELATION OF CONFOUNDERS AND COFACTORS TO ADMISSIONS

The time plots of residuals of the regression analyses were checked after inclusion of intercept, trend, season, sinusoidal terms, influenza epidemics, day of week, holidays, and temperature and relative humidity.

In the final Poisson models, short term cycles and the effect of weekdays were seen in all the groups studied: among emergency admissions for asthma in the various age groups and among emergency admissions for digestive system disorders.

A rise in temperature was associated with a low number of admissions due to asthma among those aged 0–14 years and among 15–64 year olds, whereas humidity did not have a significant effect on the number of admissions.

AUTOCORRELATION AND DESCRIPTIVE STATISTICS

The control of autocorrelation was checked by using the residual diagnostic plots of the Poisson regressions and with the periodograms. The autocorrelation and partial autocorrelation functions of the series included approximate 95% confidence intervals defined as $\pm 2/\sqrt{n} - \text{lag} = \pm 0.06$.

RELATION OF AIR POLLUTANTS TO ADMISSIONS

A summary of the significant associations is presented in table 3. Admissions for asthma among 0–14 year olds were related to the 8 h O₃ levels, and those among 15–64 year olds and >64 year olds to the 24 h SO₂ levels.

Admissions for digestive tract disorders, which were used as a control, were significantly associated with 8 h O₃ levels, but not with other pollutants, temperature, or humidity.

Discussion

The modelling was problematic. In the first attempts, over correction for cyclicity and under correction for autocorrelation were made. Therefore, the number of sinusoidal terms was restricted from nine to six (but up to 19 were tried). Various transformations of pollution variables were tried; and finally logarithmic values were used.

The difficulties of the analysis suggest that the method of analysis may be unsatisfactory. The model was first used for analysing associations between air pollution and mortality.¹⁴ It is possible that the patterns of cyclical variation found in data for mortality and hospital admission may be different, a phenomenon that might be explained by the epidemiology associated with these outcome variables.

The results obtained here differ from those of an earlier analysis of the same data with a different methodology.⁹ In the earlier analysis, linear regression was used and the effect of cold was controlled with a less sophisticated method. With these methods, significant associations were observed between hospital admissions for asthma and the levels of SO₂, NO₂, O₃ and TSP.⁹

In the present study, not only average values of pollutants measured at different stations, but also the measurements at the station with the highest values were used first in the analysis. The results of these analyses were in part illogical, showing that these measurements do not sufficiently reflect the exposure of the population to pollutants.

Hospital admissions for digestive tract disorders were significantly associated with the 8 h O₃ levels at the only station. There are two possible explanations for this illogical finding. Firstly, the modelling may be defective; if so, the association between O₃ levels and admissions due to asthma among 0–14 year olds should also to be interpreted with caution. Alternatively, the apparent correlation may be a statistical coincidence.

The mean daily SO₂ values measured in Helsinki were lower than the maximum value recommended by the World Health Organization – 125 µg/m³.¹⁸ The daily guideline was not exceeded. However, a significant association was seen between daily SO₂ concentrations and the daily counts of emergency room admissions among the 15–64 year old patients and among those over 64 years old. However, this association was not observed among children. The inconsistency of the findings may suggest that there is no real effect. The other possibility is that there is a relation

between the number of patients admitted for asthma and the presence of SO₂ at lower concentrations than previously believed harmful or than are listed in the guidelines given in many countries and by the World Health Organization. The previous study from Helsinki suggested the same among patients with chronic bronchitis.¹⁵

Although our results, using the uniform methodology of the APHEA project, suggest that even low level pollution may increase hospital admissions for asthma, no definitive conclusion can be drawn from the results without meta-analysis. The effect of methodology was seen to have a strong effect on the results and new standardised methods, possibly different from those for the study on mortality, should be developed to investigate the associations between ambient air pollutants and morbidity.

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