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SHORT COMMUNICATION

Association between $PM_{2.5}$ and primary care visits due to asthma attack in Japan: relation to Beijing's air pollution episode in January 2013

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Abstract

Aim In January 2013, extremely high concentrations of fine particles ($PM_{2.5}$) were observed around Beijing, China. In Japan, the health effects of transboundary air pollution have been a matter of concern. We examined the association between the levels of outdoor $PM_{2.5}$ and other air pollutants with primary care visits (PCVs) at night due to asthma attack in Himeji City, western Japan.

Methods A case–crossover study was conducted in a primary care clinic in Himeji City, Japan, involving 112 subjects aged 0–80 years who visited the clinic due to an asthma attack between 9 p.m. and 6 a.m. during the period January–March, 2013. Daily concentrations of particulate matter, ozone, nitrogen dioxide, and some meteorological elements were measured, and a conditional logistic regression model was used to estimate the odds ratios (OR) of PCVs per unit increment in air pollutants or meteorological elements.

Results Of the 112 subjects, 76 (68 %) were aged <15 years. We did not note any association between daily $PM_{2.5}$ levels and PCVs due to asthma attack at night. A positive relation between ozone and PCVs due to asthma attack was detected. The OR per 10 ppb increment in daily mean ozone the day before the visit was 2.31 (95 % confidence interval 1.16–4.61).

Conclusion These findings do not support an association between daily mean concentration of $PM_{2.5}$ and PCVs at night. However, we did find evidence suggesting that ozone is associated with PCVs.

Keywords Air pollution · Asthma · Ozone · Particulate matter · $PM_{2.5}$

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Introduction

In January 2013, extremely high concentration levels of air pollution, including particulate matter (PM) with an aerodynamic diameter of $\leq$2.5 μm ($PM_{2.5}$), were observed around Beijing, China [1]. During this same period, the concentration of $PM_{2.5}$ was reported to be transiently elevated in the western part of Japan due to transboundary air pollution, exacerbating concerns about the health effects of $PM_{2.5}$.

Here, we examined the association between the concentrations of outdoor $PM_{2.5}$ and other air pollutants with primary care visits (PCVs) at night due to asthma attack in Himeji City, in western Japan.

Methods

Subjects

The setting of this study was the Himeji City Emergency Clinic, Himeji, Japan, which was established for the purpose of treating emergency cases between 9 p.m. and 6 a.m. on weekdays [2]. Himeji City is located in western Japan, within 100 km of central Osaka and facing the Setonaikai Sea. Subjects were city residents with a history of asthma attack who visited the clinic for asthma attack between 9 p.m. and 6 a.m. from January to March, 2013, and who had received a prescription for bronchodilators from their primary care physician. In Himeji City, primary care at night is generally only available at this emergency clinic, and almost all patients who have an asthma attack at night visit the clinic. Patients who visited the clinic on national holidays were excluded (see Statistics section). The medical records of all patients were provided retrospectively, and patient age, sex, diagnosis, and date of visit were recorded. The study protocol was approved by the Ethics Committee of Hyogo College of Medicine.

Air pollutants and meteorological elements

Concentrations of $PM_{2.5}$, PM with an aerodynamic diameter ≤10 μm (PM_{10}), and optical black carbon (OBC) were measured hourly at a point near the monitoring station using a SPM-613D dichotomous beta gauge monitor (Kimoto Electric Co. Inc, Osaka, Japan) from October 2012 through March 2013. Data on daily concentrations of ozone and nitrogen dioxide (NO_2) from January through March 2013 were obtained from the Himeji local government. All subjects resided within 10 km of the monitoring station, which was located in a residential street in the city. Data for meteorological elements, such as daily mean values for atmospheric pressure, relative humidity, temperature, and wind speed, as well as the number of total hours of daylight, were obtained from the Japan Meteorological Agency and also assessed.

Statistical methods

The study was conducted under a time-stratified case–crossover design, which is used to assess brief changes in risk associated with transient exposures [3, 4]. Case–crossover analyses require exposure data for cases only. They can be regarded as a special type of case–control study in which each case serves as its own control, providing inherent control of potential confounding by fixed individual characteristics, such as sex, race, diet, and age. "Time-stratified" indicates the method by which the control periods were chosen. Specifically, we stratified time into months to select days for control periods that fell on the same day of the week within the same month as the date of the PCV (day of the index period), thereby also controlling for long-term trends, seasonality, and day of the week.

We excluded patients who visited the clinic on national holidays because of bias in control selection. That is, if patients whose visits occurred on holidays were included as subjects, the estimated relative risks were lower than expected because the concentration of air pollutants on holidays (days included in index periods) was usually/systematically lower than that on non-holidays (days included in control periods) [5].

We examined associations of daily mean concentrations (same day of PCV and day before PCV) and 3-day mean concentrations of each air pollutant before the PCV with the risk of a PCV at night due to asthma attack. We estimated the odds ratios (ORs) of PCVs at night due to asthma attack per 10 μg/m^3 difference in $PM_{2.5}$ in a single-pollutant model adjusted for 1-day mean atmospheric pressure (hPa), relative humidity (%), temperature (°C), wind speed (m/s), and hours of daylight (h). Similarly, we also estimated the ORs of the PCVs per 10-ppb difference in NO_2 and in ozone. In addition, we estimated the ORs of PCVs at night due to asthma attack per 10 μg/m^3 difference in $PM_{2.5}$, per 10 ppb difference in NO_2, and per 10 ppb difference in ozone in a multi-pollutant model adjusted for the same variables as the single pollutant model.

Conditional logistic regression was performed using the PHREG procedures of SAS release 9.2 (SAS Institute, Inc, Cary, NC). All tests were two-tailed, and alpha was set at 0.05. We computed ORs and their 95 % confidence intervals (CIs).

Results

Subject characteristics are shown in Table 1. The number of cases in January, February, and March 2013 were 46, 33, and 33, respectively. Daily mean concentrations of air pollutants and other meteorological data are shown in Table 2. The mean monthly concentrations of $PM_{2.5}$ from January through March 2013 were slightly higher than those in the corresponding months in 2011 or 2012. Figure 1 shows the daily concentrations of $PM_{2.5}$ from October 2012 through to March 2013.

Table 3 shows the associations between air pollutants and PCVs at night using the single-pollutant model. We

Table 1 Age and sex of subjects

Age group (years)	Sex		Total
	Male	Female	
0–1	7	3	10
2–5	21	10	31
6–14	18	17	35
15–19	4	3	7
20–39	5	9	14
40–64	7	5	12
≥65	1	2	3
Total	63	49	112

Table 2 Summary statistics of daily concentrations of air pollutants and meteorological indices

Air pollutants and meteorological indices	2011			2012			2013		
	January	February	March	January	February	March	January	February	March
$PM_{2.5}$ (μg/m^3)	13.9	26.9	20.9	19.9	24.2	26.7	24.1	25.3	37.2
PM_{10} (μg/m^3)	19.6	39.1	33.0	26.0	30.8	36.5	31.8	33.7	59.9
OBC (μg/m^3)	0.4	0.7	0.4	0.4	0.4	0.4	0.5	0.4	0.8
NO_2 (ppb)	15.9	13.4	11.8	11.3	12.0	14.2	12.6	12.1	14.5
Ozone (ppb)	20.7	26.4	32.5	19.9	23.0	26.8	23.6	27.7	30.6
Atmospheric pressure (hPa)	1,014.5	1,014.8	1,013.7	1,015.6	1,014.7	1,012.6	1,016.8	1,016.5	1,011.7
Relative humidity (%)	64	68	65	67	67	68	68	69	67
Temperature (°C)	2.4	5.8	6.5	4.1	3.7	7.8	3.5	4.6	9.0
Wind speed (m/s)	2.8	2.3	2.5	2.5	2.7	2.8	2.5	2.4	2.7
Daylight (h)	6.3	5.5	6.0	4.6	4.6	4.4	5.4	4.7	5.7

NO_2 nitrogen dioxide, *OBC* optical black carbon, *PM* particulate matter

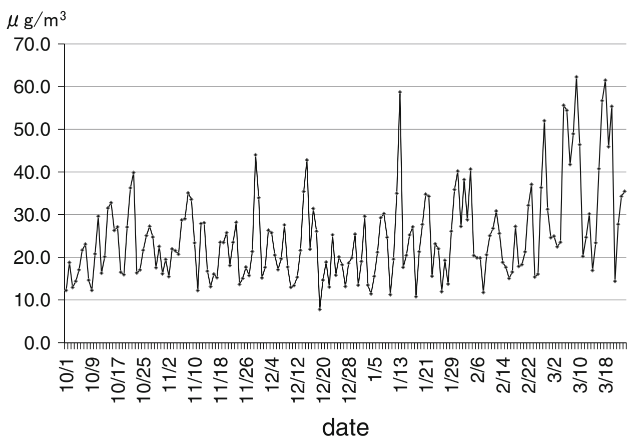

Fig. 1 Daily concentrations of particulate matter an aerodynamic diameter of ≤2.5 μm ($PM_{2.5}$) from October 2012 through March 2013. The Japanese environmental quality standard for daily concentration of ambient $PM_{2.5}$ is set at ≤35 μg/m^3

noted no association between $PM_{2.5}$ and PCVs, but there was a positive relation between ozone on the day before the PCV and PCV due to asthma attack, and between the 3-day mean ozone before the PCV and the PCV due to asthma attack. Table 4 shows the results for the multi-pollutant model. We noted statistical significance in the relation between ozone levels and PCVs. The OR per 10 ppb increment in daily mean ozone level (the day before the PCV) was 2.31 (95 % CI 1.16–4.61). No statistically significant associations were noted between PCVs due to asthma attack and the concentrations of $PM_{2.5}$.

Discussion

In this study, to better understand the association between ambient $PM_{2.5}$ and PCVs due to asthma, we evaluated this association in Himeji City, western Japan, during a period when the concentration of $PM_{2.5}$ around Beijing, China were extremely high. $PM_{2.5}$ concentrations in Himeji City from January through to March 2013 were slightly elevated. We found no association between 1- or 3-day $PM_{2.5}$ levels and PCVs due to asthma attack at night. However, we did find evidence that ozone may be associated with PCVs due to asthma attack. Our previous study ($n = 174$) also found no association between $PM_{2.5}$ and PCVs among children in the 2010/2011 or 2011/2012 winters in the same setting [2]. Our present sample size ($n = 112$) was smaller than that in our previous study, and insufficient statistical power might accordingly be a limitation.

Our finding of a potential association between ozone and physician visits due to asthma attack is consistent with the results of previous studies. A recent U.S. Environmental Protection Agency analysis of ambient ozone health effects concluded that children with asthma suffer acute adverse health consequences at current ambient levels of ozone [6]. Babin et al. [7] and Moore et al. [8] also observed an association between pediatric emergency room visits for asthma exacerbation and outdoor ozone levels. In a Japanese study, Yamazaki et al. [9] found an association between ozone and PCVs due to asthma attack in the summer but not during the winter. In contrast, Yamazaki et al. [2] found no stable association between ozone and PCVs in another study. We could not explain the reason of the uncertainty of the association.

Limitations

In addition to its low statistical power, several other limitations of our study warrant mention. First, the significance of the association between air pollution and PCVs at night due to asthma attack is diminished because PCVs due to asthma attack are a surrogate measure of asthma

Table 3 Association between air pollutants and primary care visits at night due to asthma attack (single pollutant model)

Air pollutants	Unit increment	Concentration on the day of the PCV			Concentration on the day before the PCV			3-Day mean concentration before the PCV		
		OR	95 % CI		OR	95 % CI		OR	95 % CI	
$PM_{2.5}$	10 μg/m^3	1.241	0.938	1.643	0.972	0.725	1.303	1.219	0.744	1.998
PM_{10}	10 μg/m^3	1.120	0.953	1.315	1.067	0.881	1.292	1.220	0.915	1.625
OBC	0.1 μg/m^3	1.062	0.977	1.153	0.978	0.905	1.057	1.028	0.904	1.168
NO_2	10 ppb	2.083	1.092	3.976	0.829	0.469	1.464	1.267	0.514	3.118
Ozone	10 ppb	0.838	0.512	1.370	1.615*	1.037	2.514	2.603*	1.068	6.344

Associations are shown as the odds ratio (OR) and their 95 % confidence interval (CI) per unit increment of each pollutant. Values have been adjusted for daily mean atmospheric pressure, relative humidity, temperature, wind speed, and hours of daylight

PVC primary care visit

* $p < 0.05$

Table 4 Associations between air pollutants and primary care visits at night due to asthma attack (multiple pollutant model)

Air pollutants	Unit increment	Concentration on the day of the PCV			Concentration on the day before the PCV			3-day mean concentration before the PCV		
		OR	95 % CI		OR	95 % CI		OR	95 % CI	
$PM_{2.5}$	10 μg/m^3	0.994	0.681	1.450	0.969	0.680	1.383	0.864	0.461	1.620
NO_2	10 ppb	2.865	0.829	9.902	1.912	0.677	5.398	2.271	0.626	8.242
Ozone	10 ppb	1.359	0.641	2.879	2.314*	1.163	4.606	3.977*	1.277	12.383
Atmospheric pressure	1 hPa	0.978	0.921	1.038	1.012	0.956	1.071	1.017	0.942	1.098
Temperature	1 °C	0.886	0.775	1.013	0.928	0.786	1.096	1.013	0.808	1.270
Relative humidity	10 %	0.902	0.508	1.601	1.252	0.787	1.992	1.054	0.460	2.411
Wind speed	1 m/s	1.017	0.610	1.695	0.931	0.577	1.502	0.805	0.357	1.812
Daylight	1 h	0.893	0.790	1.010	1.036	0.929	1.156	0.914	0.761	1.097

Associations are shown as the OR and 95 % CI per unit increment of each index

NO_2 nitrogen dioxide, *PM* particulate matter

* $p < 0.05$

exacerbation. Second, the selection of subjects for this study may have been subject to issues with external validity, as we restricted our population to nighttime patients. Third, the estimated ORs in this study may suffer from non-differential misclassification, causing our results to be biased towards null because single air pollution concentrations or meteorological data were assigned to all individuals living in certain areas. In addition, the study may suffer from differential misclassification causing our results to be biased towards negative because news of air pollution in Beijing was broadcast during the study period, which may have resulted in subjects with asthma remaining indoors when $PM_{2.5}$ concentrations were high. If the association between $PM_{2.5}$ and PCVs were true, the measured concentrations in the case periods were lower than the expected concentrations. Fourth, our use of a number of statistical test procedures led to issues with multiple comparison. We did not devise any countermeasures for these issues, however, as we believe that the elevated risk of air pollutants in this study should be demonstrated by the precautionary principle. Finally, we were unable to distinguish between $PM_{2.5}$ arising locally in Himeji City versus that which was derived from Beijing.

Conclusion

The findings of this study do not support an association between daily mean concentration of $PM_{2.5}$ and PCVs at night due to asthma. However, we did find evidence indicating that ozone levels may be associated with PCVs.

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Conflict of interest All authors declare that they have no competing financial interests.

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