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RESEARCH ARTICLE

# The effect of Asian dust on asthma by socioeconomic status using national health insurance claims data in Korea

Yoon-Sung Park<sup>1,2</sup>, Jeong-Hee Kim<sup>1,3</sup>, Hae-Ji Jang<sup>1</sup>, Yoon-Hee Tae<sup>4</sup>, and Dae Hyun Lim<sup>1,3</sup>

<sup>1</sup>Environmental Health Center for Allergic Disease, INHA University Hospital, Incheon, Korea, <sup>2</sup>Department of Biostatistics, Korea University, Seoul, Korea, <sup>3</sup>Department of Pediatrics, College of Medicine, INHA University, Incheon, Korea, and <sup>4</sup>National Health Insurance Service, Seoul, Korea

## Abstract

**Context:** Asian dust events are associated with increased asthma incidence, asthma exacerbation, decreased lung function and increased risk for hospitalization.

**Objective:** The purpose of this study was to evaluate the effect of Asian dust events on asthma exacerbation by socioeconomic status using national health insurance claims data.

**Materials and methods:** A case-crossover design was used to analyze asthma-related national health insurance claims, air pollutant and climate data from 2007 to 2013 in Seoul and Incheon, Korea. We stratified our analysis by socioeconomic status (health insurance versus medical aid subscribers) and calculated the maximum air pollutant levels and average climate values per day. The number of asthma-related visits to medical institutions per day was compared between “event” and “control” days.

**Results:** Compared with “control days”, the average number of asthma-related visits to medical institutions decreased on “event” days and increased 1–5 d thereafter. The number of visits by health insurance subscribers also decreased on “event” days and increased 1–5 d thereafter, while the number of visits by medical aid subscribers did not change on “event” days but increased 1–4 d thereafter.

**Discussion and conclusion:** Our study confirms that Asian dust events result in an increased number of asthma-related visits to medical institutions. This effect differed by socioeconomic status.

## Keywords

Asian dust, asthma, health insurance claim

## History

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## Introduction

Asian dust refers to a phenomenon that occurs mostly during the spring when sand and dust from the deserts of Mongolia and China rise and blow over the Westerlies before settling.

Currently, there are 300 million asthma patients worldwide, with a mortality rate of 250 000 persons/year (GINA, 2015; WHO, 2013). In 2008, 4.7% of the population in Korea were treated for asthma; this percentage has been increasing, and mainly children and the elderly are affected (Lee et al., 2011; Park et al., 2009). Several studies have reported differences in asthma prevalence, incidence, mortality and asthma-related healthcare utilization rates by sex, age and socioeconomic status (Carr et al., 1992; Chae, 2005; Park et al., 2009; Son et al., 2006; Volmer, 2001).

Asian dust events have been shown to be associated with increased rates of hospitalization owing to asthma (Kanatani et al., 2010), exacerbated respiratory symptoms and decreased lung function caused by an increase in fine dust (Watanabe et al., 2011; Yoo et al., 2008). In particular, an increased risk for hospitalization for asthma after Asian dust events has been

reported by several studies (Kim et al., 2005; Park et al., 2003; Ueda et al., 2010; Wang et al., 2014). However, other studies did not show statistically significant effects (Kwon, 2012; Yang et al., 2005).

It is crucial to understand the timing of asthma exacerbation after Asian dust events and to determine if differences in socioeconomic status affect the severity of asthma exacerbation and prevent acute exacerbation of asthma as a result of Asian dust events. Thus, the present study investigated the impact of Asian dust events on asthma-related visits to medical institutions and if there was any difference in the effects with respect to patients' socioeconomic status.

## Methods

### Data sources

We used asthma-related national health insurance claims data (restricted to claims using the primary asthma disease codes ICD-10 J45 and J46) as well as data on climate and air pollutant emissions from the Seoul and Incheon regions of Korea from 2007 to 2013. National health insurance eligibility data were used to determine the asthma patients' socioeconomic status. By law, all Koreans are included in the national health insurance program. The national health insurance in Korea is classified as follows: health insurance

Address for correspondence: Dae Hyun Lim, Department of Pediatrics, College of Medicine, INHA University, 7-206 Shinheung-dong, 3-ga, Jung-gu, Incheon 400-711, Korea. Tel: 032-890-3658. Fax: 032-890-2629. E-mail: dhyunlim@inha.ac.kr

and medical aid. On attaining adulthood and getting a job, Korean individuals are included into the “health insurance” scheme with their families. However, individuals who are a part of the livelihood program, individuals with low incomes or individuals of national merit are included in the “medical aid” scheme along with their families. The government pays the medical expenses of individuals who receive medical aid.

Climate data were provided by the Korea Meteorological Administration and included the absence or presence of Asian dust, its visibility range (km), temperature (°C), humidity (%), wind speed (m/s) and air pressure (hPa). Air pollution data were provided by the National Institution of Environmental Research and included CO (ppb), NO<sub>2</sub> (ppb), O<sub>3</sub> (ppb), SO<sub>2</sub> (ppb) and particulate matter (PM<sub>10</sub>, µg/m<sup>3</sup>) levels.

## Measures

Using national health insurance claims data, the number of asthma-related visits of the patients to medical institutions per day was calculated. The variables used in this study included a geographical region (Seoul and Incheon, South Korea), age in decades, the number of in- and outpatient visits to medical institutions and the patients’ insurance type (health insurance versus medical aid subscribers). We calculated the daily measured averages for all climate data and the daily measured maximum levels for all air pollutants.

## Study design and selection of “event” and “control” days

We employed a case-crossover study design in the present study.

Event days were selected as detailed below. We believe that the effects of Asian dust disappear after 7 d. All dates on which Asian dust events had occurred since the past 7 years were selected. Event days were only included if there was yellow dust in both Seoul and Incheon on that day. We excluded all holidays and weekends on which outpatient clinics were closed from these dates. Furthermore, if another Asian dust event had occurred before or after 14 d of a recorded Asian dust event, then that particular event date was excluded. The last event day was selected if an Asian dust event lasted for more than 1 d. For the “control” days, 2 d were selected – 1–7 d before and another 7 d after the selected “event” day. Changes in the number of asthma-related visits to medical institutions per day were observed for the 7 d after the “event” day.

## Statistical analysis

*T*-tests were performed to determine the differences in climate, air pollutant emissions and the number of asthma-related visits to medical institutions between “event” and “control” days. A log Poisson regression model was used to investigate the changes in the number of asthma-related visits to medical institutions visits on “event” compared to “control” days. Climate, sex, age and region were controlled for. SAS Enterprise Guide 6.1 (SAS Institute Inc., Cary, NC) was used for statistical analysis, and the level of statistical significance was set to  $p < 0.05$ .

## Ethics statement

This study was approved by the Institutional Review Boards of the INHA University Hospital (approval no.: IUH-IRB 15-0532).

## Results

Asian dust events occurred on 62 d in the Seoul and Incheon regions from 2007 to 2013 (Supplementary Table 1). Of these days, we selected the following 7 d as the “event days” based on the eligibility criteria: 03/06/2007 (Tuesday), 02/12/2008 (Tuesday), 02/20/2009 (Friday), 09/22/2009 (Tuesday), 01/25/2010 (Monday), 04/02/2010 (Friday) and 11/28/2012 (Wednesday).

First, we conducted a univariate analysis to reveal the differences in the number of asthma-related patient visits to medical institutions between “event” and “control” days (Table 1). We found that the number of asthma-related visits to medical institutions was higher on “event” days than that on “control” days, but this difference was not statistically significant. We also observed a higher number of visits by patients in the age groups 11–20, 51–70 and >90 years on “event” days than that on “control” days; however, this difference was not statistically significant. For insurance type, the numbers of asthma-related visits to medical institutions by both health insurance and medical aid subscribers were higher on “event” than on “control” days. Lastly, the number of visits of patients from the Seoul region was higher on “event” days than that on “control” days. However, the differences in insurance type and region were not statistically significant (Table 1).

We then conducted a Poisson regression analysis in which climate, age, sex and region were controlled for. The ratio of an average number of asthma-related visits to medical institutions per day decreased on day 0 (ratio, 0.96, 95% confidence intervals, 0.95–0.98) and increased between days 1 and 5 after the “event” day (Table 2). When we stratified by insurance type, the number of asthma-related visits to medical institutions by health insurance subscribers also decreased on day 0 (ratio, 0.96, 95% confidence intervals, 0.95–0.97) and increased between days 1 and 5 after the “event” day, whereas the number of visits by medical aid subscribers did not change on day 0 (ratio, 1.00, 95% confidence intervals, 0.94–1.07) but increased between 1 and 4 d after the “event” day (Figure 1). When the analysis was stratified by type of visit (inpatient versus outpatient), the number of visits by outpatients decreased on day 0 (ratio, 0.97, 95% confidence intervals, 0.95–0.98) and increased between days 1 and 5 after the “event” day, whereas the number of visits by inpatients did not change on day 0 (ratio, 0.97, 95% confidence intervals, 0.78–1.21) include other days (Table 2, Figure 2).

## Discussion

This study revealed differences in the average number of asthma-related visits to medical institution visits per day with respect to time after Asian dust events. In particular, the average number of visits was lower on “event” (day 0) than on “control” days. The Korea Meteorological Administration and Korea Environment Corporation publishes Asian dust

Table 1. Comparison of air pollutant levels, environmental factors and the number of asthma-related visits to medical institutions between “event” and “control” days and by region.

|                                                                   | Parameters                            | Region          |           |        |             |           |       |             |           |       |
|-------------------------------------------------------------------|---------------------------------------|-----------------|-----------|--------|-------------|-----------|-------|-------------|-----------|-------|
|                                                                   |                                       | Seoul + Incheon |           |        | Seoul       |           |       | Incheon     |           |       |
|                                                                   |                                       | Control day     | Event day | p      | Control day | Event day | p     | Control day | Event day | p     |
| Air pollutant<br>(MAX/day)*                                       | CO (ppb)                              | 2.5857          | 1.8000    | 0.031  | 2.2571      | 1.6571    | 0.028 | 2.3429      | 1.5571    | 0.055 |
|                                                                   | NO <sub>2</sub> (ppb)                 | 0.1125          | 0.0844    | 0.019  | 0.1097      | 0.0827    | 0.028 | 0.0942      | 0.0661    | 0.024 |
|                                                                   | O <sub>3</sub> (ppb)                  | 0.0584          | 0.0546    | 0.589  | 0.0501      | 0.0466    | 0.592 | 0.0572      | 0.0544    | 0.688 |
|                                                                   | SO <sub>2</sub> (ppb)                 | 0.0284          | 0.0206    | 0.036  | 0.0180      | 0.0160    | 0.520 | 0.0282      | 0.0201    | 0.030 |
|                                                                   | PM <sub>10</sub> (μg/m <sup>3</sup> ) | 163.1           | 448.6     | 0.041  | 134.0       | 378.0     | 0.029 | 156.1       | 448.6     | 0.038 |
| Climate<br>(AVG/day)†                                             | Visibility (km)                       | 11.2228         | 11.7907   | 0.750  | 11.2966     | 11.2344   | 0.972 | 11.1491     | 12.3469   | 0.525 |
|                                                                   | Temperature (°C)                      | 5.7618          | 2.4732    | 0.389  | 5.6720      | 2.1036    | 0.362 | 5.8515      | 2.8429    | 0.419 |
|                                                                   | Humidity (%)                          | 63.8958         | 52.2530   | 0.086  | 60.1369     | 48.5536   | 0.089 | 67.6548     | 55.9524   | 0.095 |
|                                                                   | Wind speed (m/s)                      | 2.6699          | 4.0292    | 0.029  | 2.4125      | 3.3149    | 0.058 | 2.9274      | 4.7435    | 0.020 |
|                                                                   | Air pressure (hPa)                    | 1020.4          | 1020.0    | 0.891  | 1020.4      | 1019.9    | 0.876 | 1020.5      | 1020.1    | 0.905 |
| Asthma-related visits to<br>medical institutions<br>(person/day)‡ | Total                                 | 5958.9          | 5989.0    | 0.971  | 4472.9      | 4504.6    | 0.959 | 1486.1      | 1484.4    | 0.994 |
|                                                                   | Sex                                   |                 |           |        |             |           |       |             |           |       |
|                                                                   | Male                                  | 2832.4          | 2854.7    | 0.954  | 2108.6      | 2141.6    | 0.910 | 723.8       | 713.1     | 0.915 |
|                                                                   | Female                                | 3126.6          | 3134.3    | 0.986  | 2364.3      | 2363.0    | 0.997 | 762.3       | 771.3     | 0.936 |
|                                                                   | Age (years)                           |                 |           |        |             |           |       |             |           |       |
|                                                                   | 0–9                                   | 2544.1          | 2510.4    | 0.9360 | 1820.6      | 1806.0    | 0.962 | 723.5       | 704.4     | 0.872 |
|                                                                   | 10–19                                 | 393.1           | 407.4     | 0.880  | 292.8       | 304.6     | 0.868 | 100.4       | 102.9     | 0.918 |
|                                                                   | 20–29                                 | 194.6           | 201.3     | 0.782  | 155.4       | 164.7     | 0.644 | 39.1        | 36.6      | 0.646 |
|                                                                   | 30–39                                 | 377.6           | 376.1     | 0.978  | 295.6       | 298.0     | 0.955 | 82.1        | 78.1      | 0.763 |
|                                                                   | 40–49                                 | 427.4           | 419.1     | 0.884  | 330.4       | 321.3     | 0.835 | 97.1        | 97.9      | 0.953 |
|                                                                   | 50–59                                 | 573.0           | 601.6     | 0.720  | 443.1       | 462.4     | 0.750 | 129.9       | 139.1     | 0.644 |
|                                                                   | 60–69                                 | 675.8           | 697.3     | 0.800  | 531.6       | 551.6     | 0.770 | 144.1       | 145.7     | 0.932 |
|                                                                   | 70–79                                 | 577.3           | 580.0     | 0.971  | 450.0       | 451.3     | 0.982 | 127.3       | 128.7     | 0.935 |
|                                                                   | 80–89                                 | 178.8           | 177.7     | 0.960  | 139.2       | 131.4     | 0.661 | 39.6        | 46.3      | 0.216 |
|                                                                   | ≥90                                   | 17.1            | 18.0      | 0.813  | 14.1        | 13.3      | 0.772 | 3.0         | 4.7       | 0.104 |
|                                                                   | Hospitalization                       |                 |           |        |             |           |       |             |           |       |
|                                                                   | Inpatients                            | 32.2            | 24.0      | 0.242  | 21.9        | 17.9      | 0.346 | 10.4        | 6.1       | 0.041 |
|                                                                   | Outpatients                           | 5929.1          | 5965.9    | 0.965  | 4452.6      | 4487.4    | 0.855 | 1476.5      | 1478.4    | 0.993 |
|                                                                   | Health insurance                      | 5675.6          | 5685.9    | 0.990  | 4267.4      | 4285.0    | 0.977 | 1408.1      | 1400.9    | 0.971 |
| Medical aid                                                       | 283.4                                 | 303.1           | 0.605     | 205.4  | 219.6       | 0.616     | 77.9  | 83.6        | 0.595     |       |

\*Maximum levels of air pollutant per day.  
†Average climate values per day.  
‡Number of asthma-related visits to medical institutions per day.  
AVG, average; MAX, maximum.

Table 2. The ratio of the average number of asthma-related visits to medical institutions per day on “event” and “control” days according to insurance type and visit type (inpatient versus outpatient).

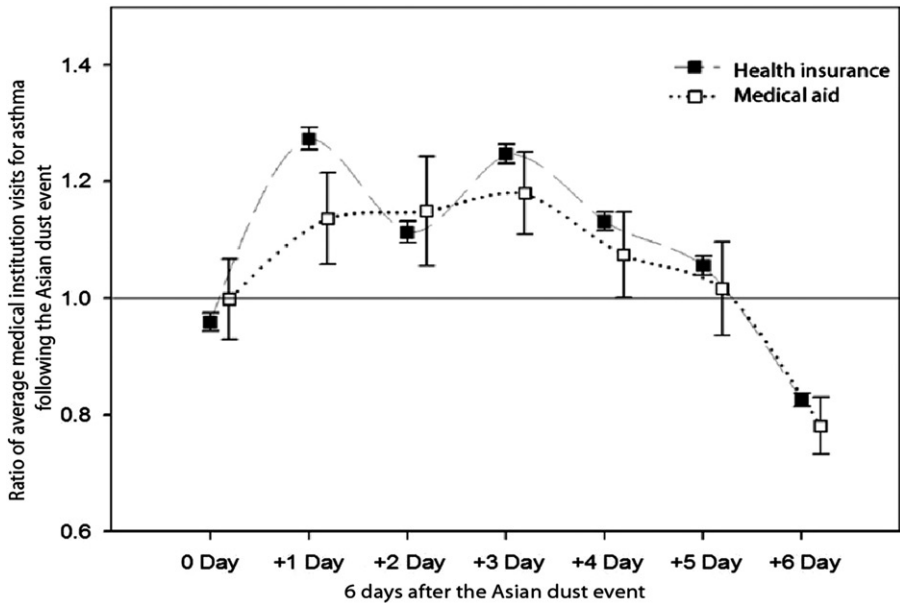
| Insurance type   |         | Event day   | Day +1      | Day +2      | Day +3      | Day +4      | Day +5      | Day +6      |
|------------------|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Total            | exp(β)* | 0.96        | 1.27        | 1.12        | 1.25        | 1.13        | 1.06        | 0.82        |
|                  | 95% CI† | (0.95–0.98) | (1.25–1.29) | (1.10–1.14) | (1.23–1.26) | (1.12–1.15) | (1.04–1.07) | (0.81–0.81) |
| Inpatient        | exp(β)  | 0.97        | 1.03        | 0.88        | 1.15        | 1.02        | 0.98        | 0.89        |
|                  | 95% CI  | (0.78–1.21) | (0.82–1.29) | (0.71–1.10) | (0.97–1.37) | (0.83–1.25) | (0.80–1.20) | (0.75–1.06) |
| Outpatient       | exp(β)  | 0.97        | 1.27        | 1.12        | 1.25        | 1.13        | 1.06        | 0.83        |
|                  | 95% CI  | (0.95–0.98) | (1.25–1.29) | (1.10–1.14) | (1.23–1.26) | (1.12–1.15) | (1.04–1.07) | (0.81–0.84) |
| Health insurance | exp(β)  | 0.96        | 1.27        | 1.11        | 1.25        | 1.13        | 1.06        | 0.83        |
|                  | 95% CI  | (0.95–0.97) | (1.26–1.29) | (1.09–1.13) | (1.23–1.26) | (1.11–1.15) | (1.04–1.07) | (0.81–0.84) |
| Inpatient        | exp(β)  | 0.97        | 1.05        | 0.92        | 1.14        | 1.01        | 1.00        | 0.90        |
|                  | 95% CI  | (0.77–1.23) | (0.83–1.34) | (0.74–1.15) | (0.95–1.37) | (0.82–1.25) | (0.81–1.23) | (0.74–1.08) |
| Outpatient       | exp(β)  | 0.96        | 1.27        | 1.11        | 1.25        | 1.13        | 1.06        | 0.83        |
|                  | 95% CI  | (0.95–0.97) | (1.26–1.29) | (1.09–1.13) | (1.23–1.26) | (1.12–1.15) | (1.04–1.07) | (0.82–0.84) |
| Medical aid      | exp(β)  | 1.00        | 1.14        | 1.15        | 1.18        | 1.08        | 1.02        | 0.78        |
|                  | 95% CI  | (0.94–1.07) | (1.06–1.22) | (1.06–1.25) | (1.11–1.25) | (1.01–1.15) | (0.94–1.10) | (0.74–0.83) |
| Inpatient        | exp(β)  | 0.76        | 1.05        | 0.90        | 0.94        | 0.96        | 0.85        | 0.85        |
|                  | 95% CI  | (0.34–1.69) | (0.43–2.60) | (0.37–2.17) | (0.52–1.72) | (0.44–2.08) | (0.40–1.83) | (0.46–1.56) |
| Outpatient       | exp(β)  | 1.02        | 1.14        | 1.16        | 1.16        | 1.07        | 1.04        | 0.78        |
|                  | 95% CI  | (0.95–1.09) | (1.07–1.22) | (1.07–1.25) | (1.10–1.23) | (1.00–1.15) | (0.96–1.12) | (0.73–0.83) |

\*exp(β) ratio of the average number of asthma-related visits to medical institutions per day:

$$\frac{\text{average number of asthma-related visits to medical institutions on “event” days}}{\text{average number of asthma-related visits to medical institutions on “control” days}}$$

†CI, confidence interval.

Figure 1. Ratio of the average number of asthma-related visits to medical institutions per day that occurred on the “event” and “control” days by insurance type.

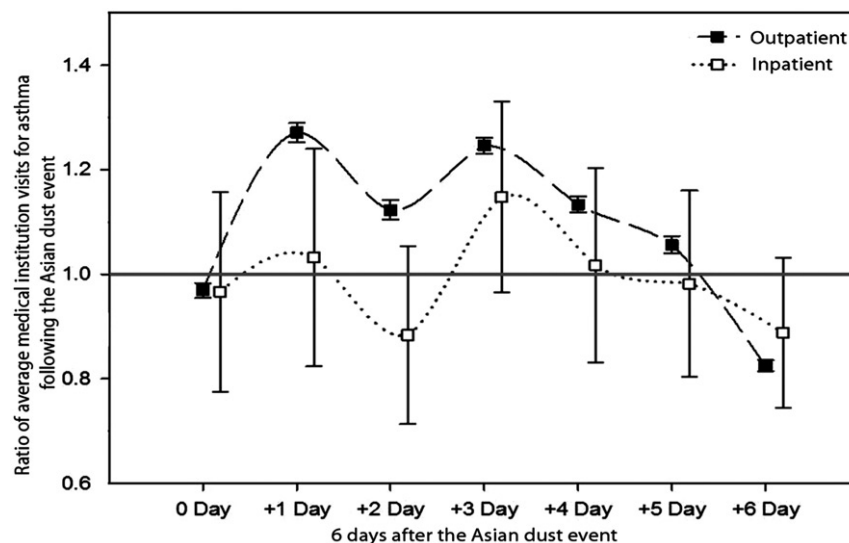


forecasts and hourly air pollutant levels, and the Korea Centers for Disease Control and Prevention publishes “health precautions against Asian dust” that include a recommendation on avoiding going outdoors during Asian dust events or wearing masks to protect against Asian dust. Since medical institutions are also educating asthma patients regarding precautions against Asian dust, one of the reasons why the average number of asthma-related visits to medical institutions was lower on Asian dust “event” compared to “control” days might be that asthma patients avoided going outdoors on these days.

The average number of asthma-related visits to medical institutions per day did not increase on the day of Asian dust events in this study. This is in contrast to a Japanese study that used logistic regression to analyze the admission rates of

asthma patients that were recorded by medical institutions for 7 d after an Asian dust event and reported a higher odds ratio for asthma-related admission on the day of the event (Kanatani et al., 2010). Yang et al. (2005) employed a Poisson regression analysis using national health insurance data in Taiwan and showed that there were no differences in the relative risk of hospitalization of asthma patients visiting the emergency department over a period of 4 d after an Asian dust event. A Taiwanese study that performed a time-series analysis using national health insurance data revealed that the number of asthma-related visits to medical institution per day exhibited an increase 1–3 d after an Asian dust event (Wang et al., 2014). Interestingly, the onset of asthma exacerbation following an Asian dust event was different depending on the type of data used in these studies. Observational studies

Figure 2. Ratio of the average number of asthma-related visits to medical institutions per day that occurred on the “event” and “control” days by type of visit (inpatient versus outpatient).



showed that the risk of hospitalization for asthma patients was highest on the day of the Asian dust event (Kanatani et al., 2010). On the other hand, studies using national health insurance claims data showed that the risks of hospital visits by asthma patients were highest after Asian dust events (Wang et al., 2014). In conclusion, the probability of hospitalization within 24 h after Asian dust events is likely high for patients with severe asthma. However, in this insurance claims-based study, there was no increase in the number of asthma-related visits per day on Asian dust “event” days. We hypothesize that this was because Korean patients with asthma would already be aware of the health precautions for Asian dust, and monitor the Asian dust forecasts. The pattern of the increase and decrease in the average number of asthma-related visits to medical institutions per day after Asian dust “event” days varied according to insurance type when compared to “control” days. The number of visits by health insurance subscribers was highest 1 d after an Asian dust event, whereas the number of visits by medical aid subscribers was highest 3 d after the event. In Korea, the government pays the medical expenses of individuals who receive medical aid. Therefore, the medical aid group has better access to medical institutions than the health insurance group. However, in this study, compared with the control days, there was no increase in the number of inpatients after the Asian dust events. This indicates that the time to an asthma-related visitation of a medical institution after Asian dust “event” days was longer in medical aid subscribers. However, we could not provide statistical results because the number of asthma-related visits by individuals who received medical aid on Asian event days was too small. This is likely because the level of asthma exacerbation among health insurance and medical aid subscribers differs according to the SES level due to differences in their exposure to pollution and other environmental hazards, health behaviors, access to health services, occupation, income and educational level (Son et al., 2006). When we stratified our analysis by the type of visit (inpatient versus outpatient), the number of outpatient visits increased after Asian dust events, whereas the number of inpatient visits did not. We hypothesize that Asian dust events likely did not exacerbate asthmatic

enough to warrant hospitalization. Moreover, the Asian dust forecasts and patient education are likely factors affecting this outcome.

We used a case-crossover study design in this study and selected “event” days spanning various seasons but excluding summer; hence, the data of the present study have temporal characteristics. Studies assessing the acute effects of air pollution on asthma have used a time-series analytical method. However, the case-crossover study design that has been used in epidemiological studies on air pollution in the US and Korea has provided case and control information from theoretically equivalent individuals (Lee & Schwartz, 1999; Maclure, 1992; Neas et al., 1999). Thus, when individual characteristics show a temporal change pattern that is either small or non-existent, case-crossover study is regulated by the same effects as pair-matched case-control studies, which is therefore superior to the time-series analytical method (Pope, 1999). Furthermore, since case-crossover studies can directly calculate risks for mortality, incidence and hospitalization rates, this study design is viewed as being superior to time-series analysis studies in terms of its ability to control for some of the confounding variables (Lee, 2003).

We used the same selection method for “control” days as previous studies on Asian dust-related asthma or allergic rhinitis that were conducted in Taiwan between 2005 and 2006 (Chang et al., 2006; Yang et al., 2005). In contrast, the authors of a Japanese study selected 4 d (28 and 14 d before as well as 14 and 28 d after the Asian dust event) as “control” days. Among the three studies mentioned above, only the data of the Japanese study had statistical significance; however, this was not due to differences in selecting “control” days but rather due to insufficient sample sizes in the Taiwanese studies. The present study, which used the same method to select “control” days as the Taiwanese studies, was able to obtain statistically significant results.

This study has several limitations. First, we used daily national health insurance claims data and not direct observational data to determine changes in asthma exacerbation over time. Since we were only able to compare the average number of asthma-related visits to medical institutions per day, the actual time individual patients spent until seeking treatment

for asthma was not known. Moreover, since asthma severity and the results of diagnostic testing are not included in the national health insurance claims data, factors related to these variables were not controlled for. We used national health insurance claims data since all citizens of South Korea are mandated to be enrolled in national health insurance under the National Health Insurance Law; hence, national health insurance claim data can be assumed to cover the entire Korean patient population (Hong et al., 2012). Second, we only analyzed the capital areas of Korea and not the entire country. The Korean population, medical institutions and air pollution stations are concentrated in the capital areas; hence, these were selected to minimize errors on the statistical estimates of our analyses. Third, the level of exposure to Asian dust among individual asthma patients could not be measured. Fourth, the differences in the asthma-related visits by asthma patients relative to Asian dust events were not directly compared between the two groups with different insurance type. On Asian dust “event” days, the majority of asthma-related visits to medical institutions were by national health insurance subscribers. The algorithm had not been converged for the Poisson regression model; thus, the corresponding estimated coefficient (for the average asthma-related visits per day) could not be estimated.

## Conclusion

This study confirmed that Asian dust resulted in an increase in the number of asthma-related visits to medical institutions and that this effect differs by the patients’ socioeconomic status. Thus, to evaluate the association between Asian dust and asthma exacerbation, patients’ insurance type should be considered. When national health insurance claims data are used for research purposes, the number of asthma-related visits to medical institutions should be monitored not just on the day of the event but also for a few days thereafter (preferably 1 week). A future study should assess the effect of Asian dust on asthma exacerbation by distinguishing between patients who have been diagnosed with asthma and patients with other respiratory disorders who show symptoms of asthma from the national health insurance claim data to minimize the range of error in the data and to enhance the study’s reliability.

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## Declaration of interest

This paper was written with support from the Ministry of Environment. The authors have no other conflicts of interest to declare.

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Supplementary Table 1. The seven selected Asian dust event days during 2007–2013

|                                 | 2007   |          | 2008   |          | 2009   |          | Year<br>2010 |          | 2011   |        | 2012   |          | 2013   |        | Total |
|---------------------------------|--------|----------|--------|----------|--------|----------|--------------|----------|--------|--------|--------|----------|--------|--------|-------|
|                                 | Date   | Status   | Date   | Status   | Date   | Status   | Date         | Status   | Date   | Status | Date   | Status   | Date   | Status |       |
|                                 | 06-Mar | Included | 12-Feb | Included | 20-Feb | Included | 25-Jan       | Included | 19-Mar | † §    | 31-Mar | * †      | 01-Mar | † ‡    |       |
|                                 | 27-Mar | §        | 02-Mar | † §      | 14-Mar | * †      | 13-Mar       | † §      | 20-Mar | † §    | 28-Nov | Included | 09-Mar | † ‡ §  |       |
|                                 | 28-Mar | ‡        | 03-Mar | ‡        | 16-Mar | §        | 15-Mar       | ‡        | 21-Mar | *      |        |          | 10-Mar | ‡      |       |
|                                 | 31-Mar | † ‡ §    | 16-Mar | † ‡      | 17-Mar | ‡        | 16-Mar       | §        | 01-May | † §    |        |          |        |        |       |
|                                 | 01-Apr | † ‡ §    | 03-Apr | §        | 22-Sep | Included | 02-Apr       | Included | 02-May | §      |        |          |        |        |       |
|                                 | 02-Apr | ‡ §      | 04-Apr | *        | 19-Oct | *        | 10-May       | §        | 03-May | † ‡    |        |          |        |        |       |
|                                 | 08-May | † §      | 30-May | §        | 20-Oct | *        | 11-May       | *        | 12-May | † ‡ §  |        |          |        |        |       |
|                                 | 09-May | ‡        | 31-May | †        | 25-Dec | † §      | 11-Nov       | §        | 13-May | ‡ §    |        |          |        |        |       |
|                                 | 25-May | † §      | 02-Dec | ‡        | 26-Dec | † ‡      | 12-Nov       | ‡        | 14-May | * †    |        |          |        |        |       |
|                                 | 26-May | †        | 09-Dec | ‡ §      | 30-Dec | ‡        | 27-Nov       | † ‡      |        |        |        |          |        |        |       |
|                                 | 26-Nov | *        | 10-Dec | * ‡      |        |          | 02-Dec       | ‡ §      |        |        |        |          |        |        |       |
|                                 | 29-Dec | † §      |        |          |        |          | 03-Dec       | ‡        |        |        |        |          |        |        |       |
|                                 | 30-Dec | * †      |        |          |        |          | 10-Dec       | ‡ §      |        |        |        |          |        |        |       |
|                                 |        |          |        |          |        |          | 11-Dec       | † ‡      |        |        |        |          |        |        |       |
| Total number of Asian dust days | 13     |          | 11     |          | 10     |          | 14           |          | 9      |        | 2      |          | 3      |        | 62    |
| Selected event days             |        | 1        |        | 1        |        | 2        |              | 2        |        | 0      |        | 1        |        | 0      | 7     |

Many dust days were excluded based on our inclusion criteria and the anticipated effect duration for these days. The reasons for their exclusion are indicated below:

\* The Asian dust only occurred in only one region (Incheon or Seoul), † The Asian dust occurred on a holiday or weekend (outpatient clinics closed),

‡ Another Asian dust event occurred within 14 days, § The Asian dust event lasted for >1 day