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Influence of Asian Desert Dust on Lower Respiratory Tract Symptoms in Patients with Asthma over 4 Years

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The Asian Dust Storm (ADS) aggravates symptoms and pulmonary dysfunction in adult asthma patients. Our objective was to investigate the association of air pollutants and metals in desert dust with worsening of asthma symptoms during the ADS. A telephone survey was performed to investigate the upper and lower respiratory tract symptoms, ocular symptoms and skin symptoms of asthma patients during the ADS in March between 2007 and 2010. Four surveys were conducted in 46 patients. Two patients noted worsening of lower respiratory tract symptoms in all four surveys, as well as 2 patients in three surveys, 7 patients in two surveys, and 9 patients in one survey. There was no worsening of lower respiratory tract symptoms in 26 patients. In each patient, the influence of the ADS on lower respiratory tract symptoms varied between surveys. In 2010, the level of suspended particulate matter was highest in all four years, but the smallest number of patients noted worsening of lower respiratory tract symptoms. Among pollutants, only the maximum concentration of nitrogen dioxide during the ADS was significantly associated with the worsening of lower respiratory tract symptoms. The influence of the ADS on lower respiratory tract symptoms of adult asthma patients is variable.

Key words: air pollution; Asian Dust Storm; asthma; lower respiratory tract symptom; telephone survey

Dust storms originating in the deserts of Mongolia, northern China and Kazakhstan are collectively known as the Asian Dust Storm (ADS). It is a seasonal phenomenon that affects much of East Asia, and the ADS occasionally even reaches the east coast of the United States (Duce et al., 1980; Taylor, 2002). Recently, many studies have identified health problems related to the ADS, along with an increase in the frequency and duration of these storms (Han et al., 2004). In patients with asthma, some studies have found that exposure to the ADS increases hospitalization and emergency room visits, exacerbates symptoms, and impairs respiratory function (Kwon et al., 2002; Yoo et al., 2008; Kanatani et al., 2010). Our previous studies have also revealed that the ADS is associated with deterioration of symptoms and respiratory function in adults with asthma

Abbreviations: ADS, Asian Dust Storm; PEF, peak expiratory flow; PEFR, PEF rate; PM, particulate matter; SPM, suspended PM.

(Watanabe et al., 2011a, 2011b).

Dust from deserts in Mongolia and northern China has been reported to cause pulmonary and bronchial inflammation in animals (Lei et al., 2004; Hiyoshi et al., 2005; Ichinose et al., 2006), but the mechanism through which the ADS causes exacerbation of asthma has not been fully clarified. In addition, the optimum methods for prevention and treatment of asthma attacks during ADS are not well understood. Aggravation of asthma symptoms during ADS may not be due to dust alone, because Asian desert dust contains natural and man-made metal components, fungi and lipopolysaccharide, and because the levels of various air pollutants such as SO and NO_2 increase during ADS (Choi et al., 2001; Mori et al., 2003; Hong et al., 2010; Watanabe et al., 2011, in press). According to Hong et al. (2010), the concentrations of most of the metals bound to dust were significantly associated with a decrease of the peak expiratory flow rate (PEFR) in nonasthmatic school children, while the concentrations of particulate matter (PM) ≤ 2.5 μm and ≤ 10 μm in diameter were not significantly associated with the PEFR. We previously reported that pollen combined with the ADS led to augmentation of symptoms and pulmonary dysfunction in patients with asthma (Watanabe et al., in press).

Between 2007 and 2011, we investigated whether patients with asthma experienced worsening of symptoms and pulmonary dysfunction during ADS. The present study was performed to assess the relations between asthma symptoms during ADS, and air pollutants and metals found in desert dust based on the results of our 4-year survey.

Materials and Methods

Patients

In each year between 2007 and 2010, we performed a telephone survey 3 days after the 1st ADS event and inquired whether asthma patients had experienced exacerbation of upper and lower respiratory tract symptoms, ocular symptoms or skin symptoms (Watanabe et al., 2011a, 2011b). The present study focused on 46 asthma patients who participated in the telephone survey every March between 2007 and 2010. Asthma was diagnosed according to the criteria in the Global Initiative for Asthma guidelines (GINA, 1995). All patients had a history of intermittent wheezing and airway hyperresponsiveness to methacholine or > 20% diurnal fluctuation of peak expiratory flow (PEF). They satisfied the definition of moderate asthma according to National Institute of Child Health and Human Development and the National Heart, Lung, and Blood Institute when assessed during February in every year of the survey (Schatz et al., 2003). Their inhaled corticosteroid dosages were classified as low, medium, or high according to the Japanese Guidelines for Allergic Diseases (Japanese Society of Allergology, 2011). All patients gave written informed consent.

Definition of the ADS and measurement of air pollutants, airborne pollen and metals

In Japan, ADS days are defined as days when visibility is less than 10 km due to dust arising from the deserts of East Asia. In the present study, the ADS events were defined according to information provided by the Japan Meteorological Agency and the Ministry of the Environment. Suspended PM (SPM) and the levels of SO_2, NO and NO_2 were measured by Tottori Prefectural Institute of Public Health and Environmental Science. Natural and anthropogenic metal components such as Fe, Al, Ca, Cd, Mn, Ni, Cu, Pb and Cr, were also measured.

Airborne pollen was measured with a Durham sampler placed on the roof of a building (10 m above ground level) at a location with free air movement on all sides. Slides covered with glycerine jelly containing fuchin were exposed for 24 h. Then the pollen grains in an 18 × 18 mm area on each slide were counted after staining with Calbela's solution. The total daily pollen count was expressed as the number of pollen particles/cm^2.

Telephone survey

As in our previous surveys (Watanabe et al., 2011a, 2011b), we asked about the following symptoms during ADS days compared with a week before the

ADS: i) worsening cough, sputum, wheezing, dyspnea and use of short-acting β_2-agonists and hospital attendance for lower respiratory tract symptoms; ii) tearing, itching, mucus and pain as ocular symptoms; iii) stuffiness, sneezing, pharyngalgia and itching as upper respiratory tract symptoms and iv) itching, redness and pain as skin symptoms. We defined exacerbation of symptoms as worsening of at least one symptom, but excluded patients who had confirmed or suspected respiratory tract infection. We defined respiratory tract infection as existing in any of the following patient groups: i) patients with pyrexia, trachyphonia, or sore throat; ii) patients who concluded that they had respiratory tract infection based on their own interpretation of symptoms and iii) patients whose family members and/or colleagues also had cold-related symptoms.

Data analysis

Results are shown as the mean ± SD. SPSS software (Japanese version 16.0 for windows; IBM Japan, Tokyo, Japan) was used for statistical analysis. The χ_2 test was employed to estimate differences between the surveys with respect to maintenance treatment, as well as differences in the frequency of patients with exacerbation of upper and lower respiratory tract symptoms, ocular symptoms, skin symptoms, and multiple classes of symptoms. Multivariate logistic regression analysis was performed to compare the effects of weather conditions, air pollutants, and maintenance treatment on deterioration of lower respiratory tract symptoms during ADS. Significance was accepted at $P < 0.05$ for all analyses. The present study was approved by the Ethics Committee of Tottori University (permission number: 771 and 1082). All procedures were performed in accordance with the principles defined in the Declaration of Helsinki.

Table 1. Patient characteristics in 2007

Number	46
Age (yr)	63.4 ± 15.2
Gender (male/female)	23/23
Disease duration (mo)	109.3 ± 102.4
Presence of other allergic diseases	
Allergic rhinitis	22
Cedar pollen and/or cypress pollen allergy	8
Perennial allergic rhinitis	14
Allergic conjunctivitis	2
Atopic dermatitis	3
Non-allergic rhinitis	3

Data are presented as the mean ± SD.

Results

Patient characteristics

Table 1 shows the characteristics of the patients in February in 2007. Forty-six patients (23 male and 23 female) participated in the study. There were 22 patients with allergic rhinitis, 3 with non-allergic rhinitis, 2 with allergic conjunctivitis and 3 with atopic dermatitis. In all of the telephone surveys, none of the patients complained of other allergic diseases. Table 2 shows the maintenance treatment for asthma during March of each year. Use of intranasal corticosteroids increased every year of the survey from no patients (0%) in 2007 to 1 patient (2.2%) in 2008, 6 patients (13.0%) in 2009 and 10 patients (21.7%) in 2010. There were significant differences between the surveys according to the χ_2 test. Apart from the use of intranasal

Table 2. Comparison of maintenance treatment during March in each year

	2007 survey	2008 survey	2009 survey	2010 survey
Inhaled corticosteroid	47 (100)	47 (100)	47 (100)	47 (100)
Low dose	11 (23.9)	8 (17.4)	7 (15.2)	7 (15.2)
Medium dose	18 (39.1)	18 (39.1)	14 (30.4)	15 (32.6)
High dose	17 (37.0)	20 (43.5)	25 (54.3)	24 (52.2)
Long-acting β_2-agonists	19 (41.3)	21 (45.7)	25 (54.3)	26 (56.5)
Leukotriene receptor antagonist	18 (39.1)	18 (39.1)	22 (47.8)	20 (43.5)
Teophylline	10 (21.7)	9 (19.6)	9 (19.6)	8 (17.4)
Antihistamine	5 (10.9)	6 (13.0)	8 (17.4)	8 (17.4)
Nasal corticosteroid*	0 (0)	1 (2.2)	6 (13.0)	10 (21.7)

( ), %.
* $P < 0.05$: differences were estimated by the χ_2 test.

steroids, there were no significant differences of maintenance treatment between each survey.

Air pollutants, airborne pollen and metal components

Eight ADS days were identified during March between 2007 and 2010, including March 28 and 29 in 2007; March 4 in 2008; March 16 and 17 in 2009; and March 13, 16 and 21 in 2010. Table 3 shows the daily average or maximum values for weather conditions, air pollutants, pollen and natural and man-made metals. SPM levels were highest in 2010, but airborne pollen levels were low on ADS days in 2010 (around 1/cm^2/day). In contrast, pollen levels were high on ADS days in the other years, especially in 2009. The levels of air pollutants (SO_2, NO and NO_2) and those of natural and anthropogenic metals varied widely. Most of the metal components identified were natural metals such as Fe, Al and Ca.

Table 3. Weather conditions and concentration of air pollutants, air pollution levels, pollen, and natural and anthropogenic metal components on ADS day(s) in March of each year

	March 29–30 2007	March 4 2008	March 16–17 2009	March 21 2010
Temperature* (°C)	12.9	6.3	15.0	9.2
Humidity* (%)	72.0	78.0	50.3	60.6
Atmospheric pressure* (hPa)	1009.3	1011.0	1014.1	1015.3
SPM (mg/m^3)				
Average	32.0	42.0	41.3	151.0
Maximum	55.5	136.0	69.7	602.0
SO_2 (ppb)				
Average	1.0	1.0	2.7	1.0
Maximum	2.5	4.0	8.7	3.0
NO (ppb)				
Average	3.0	2.0	1.0	0
Maximum	9.5	6.0	3.3	1.0
NO_2 (ppb)				
Average	10.0	6.0	7.0	5.0
Maximum	26.5	21.0	25.0	17.0
Pollen (/cm^2/day)	46	20	165	1
Fe (μg/m^3)	2.4	2.0	7.6	16.7
Al (μg/m^3)	1.6	1.0	9.0	8.3
Ca (μg/m^3)	2.9	2.2	9.1	11.1
Cd (μg/m^3)	0.001 >	0.001	0.002	0.002
Mn (μg/m^3)	0.037	0.047	0.234	0.718
Ni (μg/m^3)	0.004	0.003	0.026	0.036
Cu (μg/m^3)	0.006	0.006	0.161	0.043
Cr (μg/m^3)	0.007	0.005	0.030	0.048
Pb (μg/m^3)	0.003	0.016	0.071	0.064

ADS, Asian Dust Storm; SPM, suspended particulate matter.
Average, average concentration on ADS days; maximum, highest concentration on ADS days.
* Average.

Telephone surveys

The results of the telephone surveys are displayed in Table 4. Worsening of lower respiratory tract symptoms was reported by 12 out of the 46 patients (26.1%) in the 2007 survey, 8 out of the 46 patients (17.4%) in the 2008 survey, 12 out of the 46 patients (26.1%) in the 2009 survey and 5 out of the 46 patients (10.9%) in the 2010 survey. The frequency of worsening symptoms did not differ significantly between the surveys. Worsening of upper respiratory tract symptoms was reported by 7 patients (15.2%) in 2007 and 2008, 10 patients (21.7%) in 2009 and 1 patient (2.2%) in 2010, with a significant difference by the χ_2 test. Worsening of ocular symptoms was reported by 4 out of the 46 patients (8.7%) in the 2007 survey, 2 out of the 46 patients (4.3%) in the 2008 survey, 9 out of the 46 patients (19.6%) in the 2009 survey and 1 out of the 46 patients (2.2%) in the 2010 survey. There were significant differences between the surveys by the χ_2 test. Although the SPM level was highest in 2010, the number of patients with worsening of upper respiratory tract and ocular symptoms was markedly lower than that in other years. None of the patients was hospitalized for exacerbation of asthma in any of the years investigated.

Table 5 shows the number of patients with worsening of lower respiratory tract symptoms on ADS days across the four surveys. There were 9 of the 46 patients with worsening of lower respiratory tract symptoms in only one survey, including 2 patients in 2007, 5 patients in 2009 and 2 patients in 2010. All patients with deterioration of lower respiratory tract symptoms in 2008 also experienced worsening of symptoms in other years. Seven patients had worsening of lower respiratory tract symptoms in two surveys, including 3 patients in both 2007 and 2008, 3 patients in both 2007 and

2009 and 1 patient in both 2008 and 2009. Two patients had worsening of lower respiratory tract symptoms in three surveys (2007, 2008, 2009 for 1 patient and 2007, 2008, 2010 for another). Finally, 2 patients noted worsening of their lower respiratory tract symptoms in all four surveys. Even in the same patient, the influence of ADS on lower respiratory tract symptoms often varied widely. Twenty-six out of the 46 patients (56.5%) did not complain of worsening of lower respiratory tract symptoms throughout the four surveys (Table 6), and 22 patients (47.8%) did not have worsening of any symptoms on ADS days.

Multiple logistic regression analysis using the forward selection method and calculation of the likelihood ratio was performed to investigate the association of worsening of lower respiratory tract symptoms with air pollutants, pollen, metal components and maintenance therapy for asthma (Table 7). As a result, worsening of lower respiratory tract symptoms was significantly associated with the maximum hourly concentration of NO_2 on ADS days and the daily dose of inhaled corticosteroids, but not with the levels of SPM, pollen, SO_2, NO and natural or anthropogenic metal components.

Table 4. Results of the annual telephone surveys

	2007 survey	2008 survey	2009 survey	2010 survey
Patients with any symptoms	33 (71.7)	35 (76.1)	31 (67.4)	40 (87.0)
Patients with worsening of either symptom	14 (30.4)	12 (26.1)	16 (34.8)	7 (15.2)
Patients with worsening of lower respiratory tract symptom	12 (26.1)	8 (17.4)	12 (26.1)	5 (10.9)
Cough	9 (19.6)	7 (15.2)	8 (17.4)	4 (8.7)
Sputum	8 (17.4)	4 (8.7)	8 (17.4)	3 (6.5)
Wheezing	1 (2.2)	1 (2.2)	4 (8.7)	0 (0)
Dyspnea	5 (10.9)	5 (10.9)	5 (10.9)	1 (2.2)
Patients with worsening of upper respiratory tract symptom*	7 (15.2)	7 (15.2)	10 (21.7)	1 (2.2)
Sneezing	6 (13.0)	6 (12.8)	7 (15.2)	0 (0)
Stuffiness	2 (4.3)	2 (4.3)	3 (6.5)	1 (2.2)
Itching	0 (0)	1 (2.2)	0 (0)	0 (0)
Patients with worsening of ocular symptom*	4 (8.7)	2 (4.3)	9 (19.6)	1 (2.2)
Tearing	1 (2.2)	0 (0)	0 (0)	1 (2.2)
Itching	3 (6.5)	2 (4.3)	9 (19.6)	0 (0)
Mucus	1 (2.2)	0 (0)	1 (2.2)	1 (2.2)
Pain	0 (0)	0 (0)	0 (0)	0 (0)
Patients with worsening of skin symptom	0 (0)	0 (0)	0 (0)	0 (0)
Hospitalization for exacerbation of asthma	0 (0)	0 (0)	0 (0)	0 (0)

( ), %.
* $P < 0.05$: the χ_2 test was used to assess differences among the surveys in the frequency of patients with worsening of any symptoms, upper or lower respiratory tract symptoms, ocular symptoms or skin symptoms.

Table 5. Patients with worsening of lower respiratory tract symptoms on ADS days in each survey

	Number
2007 survey	2
2008 survey	0
2009 survey	5
2010 survey	2
2007 and 2008 survey	3
2007 and 2009 survey	3
2007 and 2010 survey	0
2008 and 2009 survey	1
2008 and 2010 survey	0
2009 and 2010 survey	0
2007, 2008 and 2009 survey	1
2007, 2008 and 2010 survey	1
2007, 2009 and 2010 survey	0
2008, 2009 and 2010 survey	0
2007, 2008, 2009 and 2010 survey	2

ADS, Asian Dust Storm.
Nine patients had worsening of lower respiratory tract symptoms on ADS days in one survey as well as 7 patients in two surveys, 2 patients in three surveys and 2 patients in all four surveys.

Discussion

The present study showed that the influence of ADS on lower respiratory tract symptoms, upper respiratory tract symptoms, ocular symptoms and skin symptoms was often different for each ADS day in patients with asthma. Only 4% of the patients consistently showed exacerbation of lower respiratory tract symptoms on every ADS day. Also, 48% of the patients were completely unaffected by the ADS

and worsening of symptoms was unrelated to the SPM level, suggesting that other factors may have aggravated the symptoms of asthma patients in addition to Asian dust.

We previously reported that some asthma patients had worsening of lower respiratory tract symptoms on ADS days and that pollen augmented the influence of ADS on symptoms (Watanabe et al., 2011a, 2011b). Dust from deserts in Mongolia and northern China has been found to exacerbate pulmonary and bronchial inflammation in animals (Let et al., 2004; Hiyoshi et al., 2005; Ichinose et al., 2006). However, it was not clear that the worsening of symptoms on ADS days was only due to desert dust, because the levels of anthropogenic metals (such as Cd, Mn and Ni) and SO_2 were significantly higher on ADS days than non-ADS days in Tottori (Watanabe et al., 2011a, 2011b). It has been reported that Cd, Mn, Ni and SO_2 can induce airway inflammation and/or bronchoconstriction (Lazarus et al., 1997; Lison et al., 1997; Gavett et al., 2003; Zhang et al., 2003; Jakubowski et al., 2004; Liu et al., 2009).

Our previous study revealed that the daily PEF was significantly associated with the SPM level in patients with worsening of upper and/or lower respiratory tract symptoms during ADS (Watanabe et al., 2011). In contrast, the present study showed that the influence of ADS on asthma symptoms varied even in the same patient. In 2010, the SPM level was the highest among all four surveys, but the smallest percentage of patients with exacerbation of lower respiratory tract symptoms was found in the 2010 survey. It is known that SO_2 itself induces airway inflammation and/or bronchoconstriction (Lazarus et al., 1997). Therefore, our findings suggest that the worsening of lower respiratory tract symptoms during ADS was not only due to desert dust.

Table 6. Patients without worsening of symptoms on ADS days in any survey

	Number (%)
Patients without worsening of any symptoms	22 (47.8)
Patient without worsening of lower respiratory symptoms	26 (56.5)

ADS, Asian Dust Storm.
Four patients did not experience of worsening of lower respiratory tract symptoms, but had worsening of upper respiratory tract symptoms or ocular symptoms.

According to Hong et al. (2010), exposure to metals bound to dust particles during ADS reduced the pulmonary function of children, but we could not find any association between worsening of lower respiratory tract symptoms in asthma patients on ADS days and the levels of natural and/or anthropogenic metals. In this study, the maximum concentration of NO_2 was significantly associated with worsening of lower respiratory tract symptoms according to multiple logistic regression analysis, but the levels of metals did not show any association. Many studies have indicated that NO_2 is associated with airway inflammation and bronchoconstriction in asthma patients after even short-term exposure (Mann et al., 2010; Di Giampaolo et al., 2011). Accordingly, the deterioration of lower respiratory tract symptoms during ADS in asthma patients was probably not only related to dust, but also to other air pollutants such as NO_2.

The results of our study differed from those of Hong et al. (2010) possibly because the levels of PM and metal components during ADS are lower

Table 7. Adjusted odds ratio for the influence of weather conditions, air pollutants, maintenance treatment on worsening of lower respiratory tract symptoms during ADS (multiple logistic regression analysis)

	Partial regression coefficient	Odds ratio	95% confidence interval	*P* value
NO_2 (maximum)	0.135	1.15	1.008–1.248	< 0.05
Daily dosage of inhaled corticosteroids	0.801	2.23	1.252–3.969	< 0.01

ADS, Asian Dust Storm.
NO_2 (maximum) is the maximum hourly concentration of NO_2 on ADS days.

in Tottori than in Korea. However, the most important difference may be related to the age of the subjects. Some studies reported an increased risk of hospitalization during ADS in children with asthma (Kanatani et al., 2010; Ueda et al., 2010), so the influence of ADS or other air pollutants may differ between adults and children. According to Devalia et al. (1994), exposure to a combination of SO_2 and NO_2 enhances the airway response to inhaled allergens compared with the effect of SO_2 or NO_2 alone in patients with asthma. Thus, allergens may induce bronchoconstriction more easily on ADS days than non-ADS days, because SO_2 levels were significantly higher on ADS days than non-ADS days in Tottori (Watanabe et al., 2011b).

A higher daily dosage of inhaled corticosteroids was also a risk factor for deterioration of lower respiratory tract symptoms during ADS. If patients need high doses of inhaled corticosteroids to control asthma, their airway inflammation may not be fully suppressed even though they were classified as having moderate asthma. This means that desert dust and/or air pollutants could readily induce bronchoconstriction and aggravate airway inflammation in patients on high-dose inhaled corticosteroids.

In this study, 22 of the 46 patients (47.8%) also had allergic rhinitis and 3 of the 46 patients (6.5%) had non-allergic rhinitis. However, the ratio of use of antihistamines was below 18%, and that of nasal corticosteroids were below 22% through the four surveys. Especially in 2007 and 2008, the number of patients using intranasal steroids was 0 and 1, respectively. Thus, the asthma patients with rhinitis in this study may have had poorly controlled rhinitis, although leukotriene receptor antagonists were used by 39.1% to 47.8%. In patients with rhinitis, dry air and PM can easily reach the lower airways, because the ability of the nasal passages to warm and humidify air is impaired (Ingelstedt and Ivstam, 1951; Togias, 2003). To prevent the exacerbation of lower respiratory tract symptoms on ADS days in asthma patients using high-dose inhaled corticosteroids, treatment of upper airway conditions may be more beneficial than more intensive therapy for asthma.

In conclusion, the influence of ADS on the symptoms of asthma patients differed between surveys, even in the same patient. The reason for this finding may be differences in the levels of natural or anthropogenic metals air pollutants, and pollen on each ADS day. The level of NO_2 was significantly associated with the exacerbation of lower respiratory tract symptoms during ADS, and the dust storms had more influence on symptoms in patients using higher daily doses of inhaled corticosteroids whose asthma may have been poorly controlled. The desert dust itself may influence airway inflammation in Japanese asthma patients, but further studies are needed to define the role of other air pollutants and materials bound to the dust such as natural and anthropogenic metals.

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Reference

1 Choi JC, Lee M, Chun Y, Kin J, Oh S. Chemical composition and source signature of spring aerosol in Seoul, Korea. J Geophys Res 2001;106:18067–18074.
2 Devalia JL, Rusznak C, Herdman MJ, Trigg CJ, Tarraf H, Davies RJ. Effect of nitrogen dioxide and sulphur dioxide on airway response of mild asthmatic patients to allergen inhalation. Lancet 1994;344:1668–1671.
3 Di Giampaolo L, Quecchia C, Schiavone C, Cavallucci E, Renzetti A, Braga M, et al. Environmental pollution and asthma. Int J Immunopathol Pharmacol. 2011;24(1 Suppl):31S–38S.
4 Duce RA, Unni CK, Ray BJ, Prospero JM, Merrill JT. Long-range atmospheric transport of soil dust from Asia to the tropical north pacific: temporal variability. Science 1980;209:1522–1524.
5 Gavett SH, Haykal-Coates N, Copeland LB, Heinrich J, Gilmour MI. Metal composition of ambient PM2.5 influences severity of allergic airways disease in mice. Environ Health Perspect 2003;111:1471–1477.
6 Global Initiative for Asthma (GINA). Global strategy for asthma management and prevention: NIH Publication No 02-3659 issued January, 1995 (update 2002).
7 Han YJ, Holsen TM, Hopke PK, Cheong JP, Kim H, Yi SM. Identification of source locations for atmospheric dry deposition of heavy metals during yellow-sand events in Seoul, Korea in 1998 using hybrid receptor models. Atmos Environ 2004;38:5353–5361.
8 Hiyoshi K, Ichinose T, Sadakane K, Takano H, Ni-

shikawa M, Mori I, et al. Asian sand dust enhances ovalbumin-induced eosinophil recruitment in the alveoli and airway of mice. Environ Res 2005;99:361–368.
9 Hong YC, Pan XC, Kim SY, Park K, Park EJ, Jin X, et al. Asian Dust Storm and pulmonary function of school children in Seoul. Sci Total Environ 2010; 408:754-759.
10 Ichinose T, Sadakane K, Takano H, Yanagisawa R, Nishikawa M, Mori I, et al. Enhancement of mite allergen-induced eosinophil infiltration in the murine airway and local cytokine/chemokine expression by Asian sand dust. J Toxicol Environ Health A 2006;69:1571–1585.
11 Ingelstedt S, Ivstam B. Study in the humidifying capacity of the nose. Acta Otolaryngol 1951;39:286–290.
12 Jakubowski M, Abramowska-Guzik A, Szymczak W, Trzcinka-Ochocka M. Influence of long-term occupational exposure to cadmium on lung function tests results. Int J Occup Med Environ Health 2004;17:361–368.
13 Japanese Society of Allergology. Japanese guidelines for allergic disseases. Allergol Int 2011;60:115–145.
14 Kanatani KT, Ito I, Al-Delaimy WK, Adachi Y, Mathews WC, Ramsdell JW. Toyama Asian Desert Dust and Asthma Study Team. Desert-dust exposure is associated with increased risk of asthma hospitalization in children. Am J Respir Crit Care Med 2010;182:1475–1481
15 Kwon HJ, Cho SH, Chun Y, Lagarde F, Pershagen G. Effects of the Asian dust events on daily mortality in Seoul, Korea. Environ Res 2002;90:1-5.
16 Lazarus SC, Wong HH, Watts MJ, Boushey HA, Lavins BJ, Minkwitz MC. The leukotriene receptor antagonist zafirlukast inhibits sulfur dioxide-induced bronchoconstriction in patients with asthma. Am J Respir Crit Care Med 1997;156:1725–1730.
17 Lei YC, Chan CC, Wang PY, Lee CT, Cheng TJ. Effects of Asian dust event particles on inflammation markers in peripheral blood and bronchoalveolar lavage in pulmonary hypertensive rats. Environ Res 2004;95:71–76.
18 Lison D, Lardot C, Huaux F, Zanetti G, Fubini B. Influence of particle surface area on the toxicity of insoluble manganese dioxide dusts. Arch Toxicol 1997;71:725–729.
19 Liu L, Poon R, Chen L, Frescura AM, Montuschi P, Ciabattoni G, et al. Acute effects of air pollution on pulmonary function, airway inflammation, and oxidative stress in asthmatic children. Environ Health Perspect 2009;117:668–74.
20 Mann JK, Balmes JR, Bruckner TA, Mortimer KM, Margolis HG, Pratt B, et al. Short-term effects of air pollution on wheeze in asthmatic children in Fresno, California. Environ Health Perspect 2010;118:1497–1502.
21 Mori I, Nishikawa M, Tanimura T, Quan H. Change in size distribution and chemical composition of Kosa (Asian dust) aerosol long-range transport. Atmos Environ 2003;37:4253–4263.
22 Schatz M, Dombrowski MP, Wise R, Thom EA, Landon M, Mabie W, et al. Asthma morbidity during pregnancy can be predicted by severity classification. J Allergy Clin Immunol 2003;112:283–288.
23 Taylor DA. Dust in the wind. Environ. Health Perspect 2002;110:A80–A87.
24 Togias A. Rhinitis and asthma: Evidence for respiratory system integration. J Allergy Clin Immunol 2003;111:1171–1183.
25 Ueda K, Nitta H, Odajima H. The effects of weather, air pollutants, and Asian dust on hospitalization for asthma in Fukuoka. Environ Health Prev Med 2010;15:350–357.
26 Watanabe M, Yamasaki A, Burioka N, Kurai J, Yoneda K, Yoshida A, et al. Correlation of Asian dust storms with worsening of symptoms for patients with asthma in western Japan. Allergol Int 2011a;60:267–275.
27 Watanabe M, Igishi T, Burioka N, Yamasaki A, Kurai J, Takeuchi H, et al. Pollen augments the influence of desert dust on symptoms of adult asthma patients. Allergol Int 2011b;60:517–524.
28 Yoo Y, Choung JT, Yu j, Kim do K, Koh YY. Acute effects of Asian dust events on respiratory symptoms and peak expiratory flow in children with mild asthma. J Korean Med Sci 2008;23:66–71.
29 Zhang Q, Kusaka Y, Zhu X, Sato K, Mo Y, Kluz T, et al. Comparative toxicity of standard nickel and ultrafine nickel in lung after intratracheal instillation. J Occup Health 2003;45:23–30.

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