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Effects of Asian Dust Storm Events on Hospital Admissions for Chronic Obstructive Pulmonary Disease in Taipei, Taiwan

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In spring, windblown dust storms originating in the deserts of Mongolia and China make their way to Taipei city. These occurrences are known as Asian dust storm (ADS) events. These ADS events lead to enhanced PM_{10} levels over that contributed by the usual local sources. The objective of this study was to assess the possible associations of PM_{10} with hospital admissions for chronic obstructive pulmonary disease (COPD) in Taipei, Taiwan, during the period 1996–2001. We identified 54 dust storm episodes that were classified as index days. Daily COPD admissions on the index days were compared with admissions on the comparison days. We selected 2 comparison days for each index day, 7 days before the index days and 7 days after the index days. The effects of dust storms on hospital admissions for COPD were prominent 3 days after the event (relative risk = 1.057; 95% confidence interval = 0.982–1.138). However, the association was not statistically significant. There may not have been enough power to detect associations resulting from the inadequate sample size of COPD admissions on ADS events days. However, It seems worthwhile to pay more attention to the ADS events and health in the future.

Many epidemiologic studies have provided evidence of an association between airborne particles and daily mortality (Dockery and Pope, 1994; Holgate et al., 1999). Most of these studies, including the already-mentioned studies of air pollution episodes, have been conducted in urban areas where fine particles (aerodynamic diameters equal to or less than 2.5 μm) are the major type of air pollution. Fine particles typically contain a mixture of soot, acid condensates, and sulfate and nitrate particles. They are derived chiefly from combustion of fossil fuels in processes such as transportation, manufacturing, and power generation (Dockery & Pope, 1994; Holgate et al., 1999). Fine particles are of the greatest health concern because they can be inhaled most deeply into the lungs (Miller et al., 1979).

Coarse particles (between 2.5 and 10 μm in diameter), in contrast, originate primarily from geologic sources (soil and other crustal materials). Episodes of high levels of coarse particles are

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usually associated with high wind speeds that may tend to diminish the concentrations of fine particles and other combustion-related pollutants (Schwartz et al., 1999). Only a few studies have examined daily mortality in relation to episodes of high levels of coarse particles (Schwartz et al., 1999; Ostro et al., 1999; Kwon et al., 2002; Chen et al., 2004a). Schwartz et al. (1999) found no evidence that mortality was elevated on dust storm days in Spokane, WA. Ostro et al. (1999) found an association between PM_{10} and daily mortality in the Coachella Valley, a desert resort and retirement area east of Los Angles, where coarse particles of geological origin typically comprise approximately 50–60% of PM_{10} and can exceed 90% during wind events. Two studies done in Asia reported that Asian dust events were weakly associated with risk of death from cardiovascular and respiratory causes. However, the observed association was not statistically significant (Kwon et al., 2002; Chen et al., 2004a).

In spring, windblown dust storms originating in the deserts of Mongolia and China make their way to populated cities in East Asia, including Taipei city (Chan, 2002). The transport of an Asian dust storm (ADS) in late April 1998 was detected by GOES9 satellite imagery and was followed by a community of scientists in both Asia and North America. The storm led to enhanced PM_{10} levels over the usual local sources (Husar et al., 1998). Such an event contributes about 30 $\mu g/m^3$ to PM_{10} in Taiwan and up to 87% for some episodes for Taipei (Lin et al., 2005; Chou et al., 2004).

Serveral studies based on data from Taipei found that risk of adverse health events including hospital admissions for cardiovascular disease and asthma (Chen & Yang, 2005; Yang et al., 2005a) and clinical visits for conjunctivitis and allergic rhinitis (Chang et al., 2006; Yang, 2006) is higher after ADS events, although these increases were not statistically significant. However, statistically significant associations were found between ADS events and hospital admissions for primary intracerebral hemorrhagic stroke (Yang et al., 2005b). To our knowledge, no previous studies have examined the relationship between chronic obstructive pulmonary disease (COPD) admissions and episodes of high levels of coarse particles. The objective of this study was to assess the possible effects of ADS on the hospital admissions for COPD in Taipei, Taiwan, during the period 1996–2001.

MATERIALS AND METHODS

The National Health Insurance (NHI) Program, which provides compulsory universal health insurance, was implemented in Taiwan on 1 March 1995 and covers most of the population (the coverage rate was 96.16% in 2000) (BNHI, 2001). Computerized records of daily clinic visits or hospital admissions are available for each contracted medical institution. All medical institutions must submit standard claim documents for medical expenses on a computerized form, which includes the date of admission and discharge, identification number, gender, birthday, and the diagnostic code for each admission from the International Classification of Diseases, 9th revision (ICD-9). We abstracted data on the number of daily admissions for cases in which the principal diagnosis was COPD (ICD-9 codes 490–492, 494, and 496) from the medical insurance file for the period 1996–2001.

TABLE 1
Dust storm days in Taipei, 1996–2001.

Year	Date
1996	6 March, 8–10 May, 12 May.
1997	2 January, 28 April.
1998	18–19 April.
1999	7 January, 27 January, 3 February, 12 February, 19 February, 6–9 April.
2000	3 January, 5 January, 24–25 March, 28–31 March, 12 April, 22 April, 27–28 April, 1 May, 14 May.
2001	13–15 January, 1 February, 16–17 February, 21–25 February, 2–7 March, 12–13 April, 2–4 May.

Taipei, the capital city of Taiwan, is situated in a basin in the north of Taiwan, and has a population of approximately 2.6 million. No industrial sources of air pollution are present in Taipei city. Vehicular traffic is the only source of ambient air pollution. Mt. Tatun and Mt. Chihsing, both over 1000 m high, form a backdrop to the northeast of the city and now make up Yangmingshan National Park. ADS events encountered in Taiwan are associated with the northeastern winds of the winter monsoon, and therefore the air quality monitoring stations along the north and northeast coasts of Taiwan show the largest impacts of the dust-storm events (EPA/Taiwan, 2001). Yangmingshan station is a background monitoring site. Enhancements of PM_{10} at Yangmingshan station (826 m altitude), which has low background concentrations of PM_{10} due to its relatively clean mountain environment, are thus easier to identify. They can be used to identify the major ADS events in Taipei. In this study, an ADS event was defined as occurring when the level of hourly PM_{10} concentration observed in Yangmingshan station exceeded the air quality standard (125 $\mu g/m^3$) and lasted for at least 3 h for each day of the study period. In total, 54 dust storm episodes (index days) were identified between 1996 and 2001 in Taipei city (Chan, 2002) (Table 1).

Besides the Yangmingshan station, six air quality monitoring stations have been established in Taipei city by the Taiwanese Environmental Protection Administration (EPA), a central governmental agency. The monitoring stations were fully automated and provided daily readings of SO_2 (by ultraviolet fluorescence), PM_{10} (by beta-ray absorption), NO_2 (by ultraviolet fluorescence), carbon monoxide (CO) (by nondispersive infrared photometry), and ozone (O_3) (by ultraviolet photometry) levels. The pollution values from all six stations were then averaged to provide single estimates of the daily concentrations for each pollutant and were used to indicate the exposure of people living in Taipei. Daily information on mean temperature and mean

TABLE 2
Mean levels of environmental variables on dust storm days (index days) and comparison days in Taipei, 1996–2001.

Variable*	Index days ($n = 54$)	Comparison days ($n = 108$)	p-value
PM_{10}(ug/m^3)	111.68 ± 38.32	55.43 ± 24.66	<.0001
SO_2 (ppb)	4.88 ± 2.45	4.48 ± 2.41	.3224
NO_2 (ppb)	36.87 ± 10.02	36.79 ± 9.90	.9609
CO (ppm)	1.39 ± 0.42	1.40 ± 0.42	.9714
O_3 (ppb)	28.39 ± 8.06	22.10 ± 8.78	<.0001
Temperature(C)	19.66 ± 3.85	19.95 ± 3.38	.6246
Humidity(%)	68.02 ± 10.31	78.06 ± 9.79	<.0001

*Values are 24-hour averages

humidity was provided by the Central Weather Bureau's Taipei Observatory.

In the primary analysis, COPD admissions on the index days were compared with admissions on the comparison days. Comparison days were the same days of the week as the corresponding index days. We selected 2 comparison days for each index day, 7 days before the index day and 7 days after the index days. If dust storms occurred on a comparison day, the days 14 days preceding/following the index day were selected. The effects of ADS, if any, might be delayed over a period of several days. To test this hypothesis, we examined the effects on the same day and 1, 2, and 3 days after the storm events. Counts of daily admissions were modeled using Poisson regression. The rate ratio for ADS days versus non-dust-storm days was estimated in a Poisson regression model, controlling for temperature, humidity, PM_{10}, and O_3. All analyses were performed using the SAS software package; p values less than or equal to .05 (two-sided) were considered statistically significant.

RESULTS

Table 2 shows the average values for air pollutant levels and meteorologic measurements in Taipei for the index and comparison days. The average PM_{10} level for the index days was 111.68 μg/m^3, which was 56.25 μg/m^3 higher than the average for the comparison days. The levels of several other pollutants (CO, NO_2, SO_2) were very similar. However, the mean O_3 level was higher for index days than for comparison days. The correlation coefficient between O_3 and PM_{10} was 0.22. Relative humidity was lower during ADS days.

Table 3 shows the mean daily number of COPD admissions occurring on the index and comparison days by various lags with a maximum lag of 3 days for all 47 hospitals in Taipei city. There were on average 21 COPD admissions on dust storm days. The mean age of the COPD patients was 71.78 yr. The mean number of daily COPD admissions was slightly higher for index than for comparison days. The association between dust storms and COPD admissions was highest 3 days after the event. The estimated relative risk was 1.057 (95% CI: 0.982–1.138). However, the association was not statistically significant. We performed a sensitivity analysis in order to confirm the robustness of our findings. We examined the model results after consecutively deleting 1, 5, and 10% of the days with the lowest concentrations of PM_{10}. There was little change in the estimated risk of COPD admissions on dust storm days (data not shown).

DISCUSSION

As expected, we observed that the ADS led to enhanced PM_{10} levels in Taipei city. The average PM_{10} level for the index days was 56.25 μg/m^3 higher than the average for the comparison days. The average concentrations of other combustion-related pollutants (SO_2, NO_2, CO) during the events did not differ from those on the comparison days. This allows us to attribute any adverse effect of the events to PM_{10} since the "extreme points" contrast is between days with high levels of PM_{10} and the comparison days with much lower levels, although the mean levels of O_3 were also higher on the index days than the comparison days.

Studies of air pollution and daily mortality or morbidity traditionally must control for secular, seasonal, and weekly trends. We choose symmetrical comparison days 1 wk (or 2 wk) before and after the event. This method can control for confounding by long-term time trends, seasonal patterns, and, by definition, control for day of the week (Bateson & Schwartz, 1999). Moreover, autocorrelation of the exposure variables is unlikely, since the usual induction time of the short-term health effects of air pollution is thought to be shorter than 4 days (Katsouyanni et al.,

TABLE 3
Number of daily COPD admissions that occurred on "Dust-storm days" and "comparison days": relative risk (RR) and 95% confidence intervals (CI) of COPD admissions for dust storm days by various lags

Parameter	The same day	1-day lag[a]	2-day lag[b]	3-day lag[c]
Index days (n = 54)	21.04 ± 6.71	20.19 ± 5.67	19.19 ± 5.49	20.06 ± 7.30
Comparison days (n = 108)	20.76 ± 5.62	19.54 ± 5.90	18.06 ± 6.46	18.94 ± 7.13
Relative Risk (95%CI)	0.977 (0.898–1.063)	1.002 (0.928–1.081)	1.039 (0.962–1.121)	1.057 (0.982–1.138)

[a] 1 day following the dust storm days.
[b] 2 day following the dust storm days.
[c] 3 day following the dust storm days.

1997). This article implements a study design that controls for many confounders by design rather than through statistical modeling. Therefore the observed relationships cannot be attributed to confounding by any of the already mentioned factors.

The PM_{10} generated during ADS is comprised of coarse crustal particles rather than combustion-related particles. We observed a 5.7% (3 days following ADS) increase in the risk of COPD admissions during the dust events, which amounts to a 1.01% average increase in the admissions for each 10-$\mu g/m^3$ increase in PM_{10} concentration. This magnitude of the estimated risk increase is lower than that reported by Wong et al. (1999), who found that a 10-$\mu g/m^3$ change in daily PM_{10} was associated with an approximately 1.9% increase in COPD admissions.

Previous studies have not had consistent results concerning associations between PM_{10} and COPD admissions. While significant associations have been found between COPD admissions and PM_{10} in some studies (Anderson et al., 1997; Burnett et al., 1995; Chen et al., 2000, 2004b; Schwartz, 1994a, 1994b, 1994c, 1996; Wong et al., 1999), other studies have reported a lack of association between PM_{10} and COPD admission (Moolgavkar et al., 1997; Morgan et al. 1998; Wordley et al., 1997). The possibility that the large number of studies reporting positive associations compared to the number reporting nonsignificant positive associations resulting from publication bias cannot be excluded.

O_3 leads to changes in lung function after repeated exposures. It can induce bronchial hypersensitivity and cause inflammatory changes in the airways (Magnussen et al., 1998). However, there is little evidence from chamber studies that ambient levels of ozone have clinically significant effects on COPD patients (Kulle et al., 1984; Linn et al., 1983). O_3 levels have been previously found to be associated with COPD admission in Minneapolis (Moolgavkar et al., 1997; Schwartz, 1994c), Detroit (Schwartz, 1994b), Barcelona (Anderson et al., 1997), London (Anderson et al., 1997), Paris (Anderson et al., 1997), and Hong Kong (Wong et al., 1999). The mean O_3 level is also higher on the index days than on the comparison days. The correlation coefficient between O_3 and PM_{10} was low (0.22); thus collinearity was not a problem in our Poisson regression models. Therefore, on the basis of the result of our study, we were unable to rule out the possible role of O_3.

In summary, ADS events may increase the risk of daily hospital admissions for COPD in Taipei, although the association seen in this study was not statistically significant. There may not have been enough power to detect an association resulting from the inadequate sample size of COPD admissions on ADS events days. However, it seems worthwhile to pay more attention to the ADS events and health in the future.

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