Published in final edited form as:

Environ Res. 2011 November ; 111(8): 1148–1155. doi:10.1016/j.envres.2011.06.007.

Hospital admissions for asthma and acute bronchitis in El Paso, Texas: Do age, sex, and insurance status modify the effects of dust and low wind events?

Sara E. Grineski¹, Joan G. Staniswalis², Priyangi Bulathsinhala², Yanlei Peng³, and Thomas E. Gill⁴

Sara E. Grineski: segrineski@utep.edu

¹Department of Sociology and Anthropology, University of Texas at El Paso, 500 W. University Ave., El Paso, TX 79902, US, 915 747 8471 (tele), 915 747 5505 (fax)

²Department of Mathematical Sciences, University of Texas at El Paso

³Department of Statistics, University of South Carolina

⁴Department of Geological Sciences and the Environmental Science and Engineering Program, University of Texas at El Paso

Abstract

Background—El Paso County (Texas) is prone to still air inversions and is one of the dust “hot spots” in North America. In this context, we examined the sub-lethal effects of airborne dust and low wind events on human respiratory health (i.e., asthma and acute bronchitis) between 2000 and 2003, when 110 dust and 157 low wind events occurred. Because environmental conditions may not affect everyone the same, we explored the effects of dust and low wind within three age groups (children, adults, and the elderly), testing for effect modifications by sex and insurance status, while controlling for weather and air pollutants.

Methods—We used a case-crossover design using events matched with referent days on the same day-of-the-week, month, and year with conditional logistic regression to estimate the probability of hospital admission, while controlling for apparent temperature (lag 1), nitrogen dioxide, and particulate matter of 2.5 micrometers or less.

Results—Children (aged 1–17) were 1.19 (95% confidence interval: 1.00–1.41) times more likely to be hospitalized for asthma three days after a low wind event, and 1.33 (95% CI: 1.01–1.75) times more likely to be hospitalized for acute bronchitis one day after a dust event than on a clear day. Girls were more sensitive to acute bronchitis hospitalizations after dust events (1.83, 95% CI: 1.09–3.08) than boys, but less sensitive than boys to acute bronchitis hospitalizations after low wind events (0.68, 95% CI: 0.46–1.00). We found general trends with regard to dust and low wind events being associated with increased odds of hospitalization for asthma and bronchitis amongst all ages and adults (aged 18–64). Adults covered by Medicaid and adults without health insurance had higher risks of hospitalization for asthma and acute bronchitis after both low wind and dust event

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Correspondence to: Sara E. Grineski, segrineski@utep.edu.

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Conclusions—Results suggest that there were respiratory health effects associated with dust and low wind events in El Paso, with stronger impacts among children and poor adults. Girls and boys with acute bronchitis were differentially sensitive to dust and low wind events.

Keywords

Dust events; low wind; inversions; asthma; bronchitis; effect modification; case-crossover design; conditional logistic regression; El Paso; Texas

1. Introduction

Both high wind and low wind conditions raise levels of pollutants and particulates in the air (Hosiokangas et al., 2004), and are thus public health concerns. In El Paso, Texas and the surrounding Chihuahuan Desert, blowing dust with high winds is a typical weather phenomenon, especially in the spring (Novlan et al., 2007; Rivera Rivera et al., 2009), whereas in the winter months, stagnant air is more common as atmospheric temperature inversions trap urban air pollution (Li et al., 2001). A prior quantitative evaluation of health impacts of coarse particulate matter in El Paso found that high wind was associated with 10% lower non-accidental mortality than low or average wind speeds, suggesting that low wind might be more detrimental to health than high wind (Staniswalis et al., 2005). Building on that study, we focus on hospital admissions for asthma and acute bronchitis as related to dust and low wind events in El Paso, and explore whether different social groups, defined based on age, sex and insurance status, are differentially affected by dust and low wind events.

There is a vast literature on the respiratory health effects of daily levels of individual anthropogenic air pollutants (e.g., Peng et al., 2005; Ho et al., 2007; Szyszkowicz, 2008; Burra et al., 2009; Gurjar et al., 2010; Halonen et al., 2010), but relatively few studies (primarily in Asia) have explored the respiratory health effects of dust events, and especially low wind events. Several studies have found a link between dust from sources far upwind (i.e., Saharan or Asian) and respiratory exacerbations in distant communities (e.g., Trinidad, Taiwan, and Korea) (Gyan et al., 2005; Bell et al., 2008; Lee et al., 2008). Respiratory health impacts have also been associated with dust events in communities like El Paso that are near dust source areas (Hefflin et al., 1994; Bener et al., 1996; Meng and Bin, 2007)

There has been relatively little research on the health effects of surface atmospheric air inversions associated with low wind conditions (Abdul-Wahab et al., 2005), although several studies have shown an association. While low wind itself may not have health effects, low wind events represent conditions under which a mixture of pollutants from a variety of known and unknown sources build up in the air in urban areas (Norris et al., 2000). Norris et al. (2000) found a significant relationship between air stagnation and emergency room visits for asthma in Seattle and Spokane. In Oman, researchers found that daily counts of hospital admissions for asthma increased with increasing depth and strength of the inversions (Abdul-Wahab et al., 2005). When just considering average wind speed (as opposed to a binary indicator for low wind), researchers have not found strong associations with asthma or acute bronchitis (Holmen et al., 1997; Nastos et al., 2006; Falagas et al., 2008).

While there is substantial evidence that not all social groups are impacted by daily levels of air pollution to the same degree (O'Neill et al., 2003; Lipfert, 2004), effect modification analyses have generally not been conducted for dust and low wind events. In investigations of air pollution's respiratory effects, socio-economic status (Grineski et al., 2010), sex (Szyszkowicz, 2008), and age (Yamazaki et al., 2009) have been found to modify the effects

of air pollution on health. While age is sometimes investigated in dust studies (Gyan et al., 2005; Prospero et al., 2008), sex is less often explored (see Meng and Bin, 2007 and Kanatani et al., 2010 for exceptions) and insurance status has not been studied for either dust or low wind events.

The analysis presented in this paper contributes in three key ways to previous studies. First, we explored the respiratory effects of near-source airborne dust in an understudied North American context. Second, we investigated the respiratory health effects of low wind inversions, an understudied topic, and compared them to the health effects of dust events. Third, we explored effect modifications for dust and low wind events. In making these contributions, we addressed the following research questions:

1. Are airborne dust and low wind events associated with an increase in asthma and acute bronchitis hospitalizations in El Paso after adjustments for the effects of weather and air pollution for all ages, ages 1–17 years, 18–64 years, and over 65 years of age?
2. Are the effects of airborne dust and low wind events on asthma and acute bronchitis hospitalizations in El Paso modified by insurance status and sex in each age group, adjusting for the effects of weather and air pollution?

2. Materials and Methods

2.1 Study Community

El Paso County, Texas is located in the far west corner of Texas and across the Rio Grande from its Mexican counterpart, Ciudad Juárez. The county spans 2,600 square kilometers; in 2009, it was home to 750,000 people, 82% of which were Latino (US Bureau of the Census, 2010). Located in one of North America's dust "hotspots" (Prospero et al., 2002), El Paso is arguably the dustiest city in the United States (Rivera Rivera et al., 2009). Dust events are caused by wind erosion of desert basins, rangelands, and agricultural lands primarily to the south and west of the city (Rivera Rivera et al., 2010). El Paso is also known for still air inversions (Lauer et al., 2009), making it a unique laboratory for this comparative investigation between dust and low wind events.

2.2 Data

To measure respiratory health, we obtained hospital admissions for asthma and acute bronchitis in El Paso County between 2000 and 2003 from the Texas Health Care Information Council in Austin, Texas (Texas Health Care Information Council, 2000). From this dataset, we extracted patients living in El Paso County that were hospitalized for asthma (ICD-9 code 493) or acute bronchitis (ICD-9 code 466) during the study period. The final data set included the following patient characteristics: age group code, sex, insurance status, and date of admission. To prepare the data for analysis, we collapsed the 22 age group codes into the following categories: 1–17 years, 18–64 years, and 65 years and older.

We also re-coded the primary insurance provider into *Private* (i.e., health insurance from a private company, which usually requires that patients pay a co-payment [e.g., \$30 to visit a doctor at a clinic]), *Medicare* (i.e., government insurance for people over 65 years old and the disabled that provides free health care and prescription drug assistance), *Medicaid* (i.e., government insurance for the poor, including the State Children's Health Insurance Program that provides free and low cost care to poor people of all ages that qualify), *No Insurance* (e.g., people that must pay full price for care and/or visit charity clinics because they do not have insurance assistance), and *Other Public* (e.g., Civilian Health and Medical Program of Uniformed Services, which provides low cost care to military members and their families). In El Paso, Medicare is primarily accessed by the elderly and Medicaid by children: over

90% of elderly asthma and bronchitis cases were covered by Medicare, and 59% of children's asthma cases and 68% of children's acute bronchitis hospitalizations were covered by Medicaid.

We used individual-level health insurance status to reflect socioeconomic status, a common practice in effect modification studies (Gwynn and Thurston, 2001; Chang et al., 2009; Grineski et al., 2010). Insurance status is a reasonable surrogate for socioeconomic status for adults and children, but not for the elderly because Medicare is available to elderly citizens of the US independent of their social class. If an insurance provider group had less than 20 cases (Table 1), we excluded it from the insurance analysis.

We obtained weather data (i.e., average daily temperature, dew point, and average wind speed) and the daily weather record from the US National Weather Service, based on observations at El Paso International Airport. In accordance with Novlan et al. (2007), we coded a day as a dust event if the daily weather record indicated "blowing dust", "widespread dust", "drifting dust", "blowing sand", "drifting sand", "sand storm", "widespread sand", "dust storm", "dust haze", or other related suspensions of mineral aerosols in the air sufficient to reduce visibility to less than 10 kilometers. In total, there were 110 days with dust events during the study period, more than in many other studies (Kwon et al., 2002; Chen et al., 2004; Yang et al., 2005; Chan et al., 2008; Perez et al., 2008).

We preferred this definition of a dust event to using levels of coarse particulate matter at air monitors to define dust events (e.g. in Bell et al., 2008) for several reasons. First, there are only two such monitors in the city and they were not operating continuously during the study period. Second, particulate matter comes from a variety of sources including smoke and anthropogenic emissions; a large fire (relatively common in the study area) could cause a peak in particulate matter that is unrelated to a dust event. Third, this method ensured that only significant dust events, such as those that reduce visibility across the metropolitan area, were captured.

We transformed average wind speed into a dichotomous indicator of low wind events. If a day had an average wind speed of less than or equal to the 10th percentile for the study period (i.e., 2 meters per second), we designated it as a day with a low wind event. Our decision was supported by observations from an eight week study in a portion of the El Paso metropolitan area; peaks in evening levels of particulate matter occurred 90% of the time that wind speed fell below 2 meters per second (Li et al., 2005). There were a total of 157 low wind events during the study period. Low wind and dust events never occurred on the same day during the study period. We refer to days that had neither low wind nor dust events as 'clear days' for lack of a better concise descriptor.

We acquired PM_{2.5} (i.e., particulate matter of 2.5 micrometers or less) and nitrogen dioxide data for the study period from the Texas Commission on Environmental Quality continuous air monitoring stations in an hourly format disaggregated by pollution monitor. In the El Paso metropolitan area, the Commission operated two monitors that captured hourly PM_{2.5} and four monitors for hourly nitrogen dioxide. While they also operated two PM₁₀ (i.e., particulate matter of 10 micrometers or less) monitors, PM₁₀ was not included because of missing data (i.e., one monitor was missing data for 2000–2001, and the other was missing all but December 2003). To create a daily variable from PM_{2.5} hourly data, we computed the mean across monitors of the daily 24-hour average. For nitrogen dioxide, we identified the maximum 24-hour reading at each of the stations and then averaged them.

2.3 Methods

We employed conditional logistic regression (as implemented in Proc PHREG in SAS Version 9.2) for the case-crossover design (Jaakkola, 2003), which is equivalent to Poisson regression for time-series modeling (Lu and Zeger, 2006) except that seasonality is controlled for by design (i.e., by self-matching) instead of in the regression model. Exposures on the index date (i.e., date of hospitalization) were compared with exposures on referent dates selected to fall on the same day-of-week, month and year as the index date (Janes et al., 2005; Perez et al., 2008; Belleudi et al., 2010). Others have instead matched on month, year, and apparent temperature, and then controlled for day-of-week using dummy variables, but both strategies yield similar results (Zanobetti and Schwartz 2005).

When using conditional logistic regression for the case-crossover design, the modifying effect of patient characteristics, such as age, sex, and insurance status, on the association between dust/ low wind events and health cannot be estimated directly (as a main effect) because each patient serves as his/her own control. However, an advantage of this approach is that interactions between patient characteristics and dust/low wind events can be estimated, as was done here, allowing for the investigation of effect modification by age, sex, and insurance status.

The odds ratios computed from the model coefficients provide an estimate of relative risk of hospitalization related to exposure to dust or low wind while controlling for apparent temperature, nitrogen dioxide and PM_{2.5}. Apparent temperature reflects a person's perceived temperature and is calculated using metric units for temperature and dew point: $22.653 + (0.9946 * \text{Air Temperature}) + (0.01536 * \text{Dew Point}^2)$ (Steadman, 1979; Zanobetti and Schwartz, 2006). When studying human health, apparent temperature is more appropriate than temperature alone (Lawrence, 2002) since it allows for consideration of both temperature and dew point without the collinearity problems that can accompany inclusion of both separately, while avoiding specification bias from leaving one out. We included apparent temperature on the previous day in the regression model using a linear regression spline with three degrees of freedom to control for lagged and nonlinear effects of temperature (Zanobetti and Schwartz, 2006; Maynard et al., 2007).

For use in the modeling, we created two different control variables for each pollutant: average over lags 0–1, and average over lags 0–3. We used both sets of control variables (in separate analyses) because there is no consensus in the literature in terms of the most health relevant one. In addition to the indicator variables for “dust” and “low wind” events, we created three lagged terms (i.e., lag 1, lag 2 and lag 3) to account for the time needed to mount a respiratory response to the dust or low wind event. The lags represent 1, 2 and 3 days after the dust or low wind event.

For the analyses of asthma and acute bronchitis, first, we selected dust and low wind event lags with the largest odds ratio for all ages for inclusion in the models (Perez et al., 2008; Yi et al., 2010). Then, we reported the adjusted odds ratios for dust and low wind for all ages. We examined a possible effect modification by age (following Perez et al., 2008) by A) including age interaction terms in the model allowing for a direct comparison of children and the elderly to adults, and B) through a subgroup analysis by age (1–17, 18–64 and over 65 years). With the first approach, it was implicitly assumed that age did not modify the effect of the control variables (i.e., apparent temperature, nitrogen dioxide, and PM_{2.5}) in the models for all ages. With the second approach, the effects of control variables were allowed to vary across the age strata. We then explored possible effect modifications by insurance status and then by sex for all ages and within each of the three age subgroups. Controlling for apparent temperature (lag 1), we ran all models twice controlling for nitrogen dioxide and PM_{2.5}: once using an average over lags 0–1, then using an average over lags 0–3,

tabulating both sets of results. However, in sections 3.1–3.5, we present only the point estimates using the average over lags 0–1 for nitrogen dioxide and PM_{2.5} for parsimony.

We conducted a sensitivity analysis of the reported odds ratios to the definition of low wind event and to adjustment by PM_{2.5}, and results are reported in section 3.5. We explored the 5th percentile of average wind speed (1.7 meters per second), resulting in 77 low wind events for the study period, as an alternative to the 10th percentile (2.0 meters per second) cutoff for a low wind event. We performed the sensitivity analysis for the definition of low wind events for all ages only, with and without a PM_{2.5} adjustment.

3. Results

Table 1 provides a descriptive summary of asthma and acute bronchitis hospital admissions stratified by age, sex and insurance status. The mean for daily asthma admissions was 2.40 (range: 0–12, standard deviation=1.92) and 0.98 (range: 0–8, standard deviation =1.32) for acute bronchitis admissions. During the 1,258 days with non-zero admissions for asthma, the mean was 2.79 (standard deviation =1.79); over the 756 days with non-zero admissions for acute bronchitis, the mean was 1.90 (standard deviation =1.29). Table 2 presents summary information for the weather and pollution variables. The correlations for weather and pollution variables were −0.29 (95% CI: −0.24, −0.33) and −0.024 (95% CI: −0.08, 0.03) for apparent temperature and nitrogen dioxide, and apparent temperature and PM_{2.5} respectively. The correlation between nitrogen dioxide and PM_{2.5} was 0.28 (95% CI: 0.23, 0.33). Table 3 shows odds ratios for hospitalizations associated with a 10 unit increase in PM_{2.5} and nitrogen dioxide, while adjusting for apparent temperature, without the inclusion of dust and low wind to allow for a comparison between El Paso and other cities.

Figure 1 presents odds ratios for hospital admissions associated with lags 0, 1, 2 and 3 for dust and low wind events. Same day dust (lag 0) and low wind three days before (lag 3) had the largest odds ratios for prediction of asthma; for acute bronchitis admissions, dust lag 1 and low wind lag 2 had the largest odds ratios (Figure 1). Tables 4 and 5 present odds ratios with 95% confidence intervals for the association of dust and low wind events with asthma and acute bronchitis.

3.1. Asthma & Dust Events

People of all ages in El Paso were 1.11 (95% CI: 0.96–1.28) times more likely to be hospitalized for asthma on a dust event day than on a clear day (Table 4), with similar findings in the subgroup analysis for children and adults. Those without insurance were generally more likely to be hospitalized for asthma on a dust event day than those with private insurance (Table 4).

3.2. Asthma & Low Wind Events

People of all ages were 1.07 (95% CI: 0.96–1.21) times more likely to be hospitalized three days after a low wind event than on a clear day (Table 4). Children and adults with Medicaid tended to be at increased risk. For example, children were 1.19 (95% CI: 1.00–1.41) times more likely to be hospitalized after a low wind event than on clear day (Table 4).

3.3. Acute Bronchitis & Dust Events

In the all ages analysis, people were 1.23 (95% CI: 0.99–1.55) times more likely to be hospitalized one day after a dust event than on a clear day (Table 5). Females were more likely to be hospitalized after a dust event than were males, and this pattern emerged for all age groups except the elderly. Children were 1.33 (95% CI: 1.01–1.75) times more likely to be hospitalized after a dust event than a clear day. Girls were more sensitive: they were 1.83

(95% CI: 1.09–3.08) times more likely than boys to be hospitalized after a dust event. Adults with Medicaid were also at increased risk compared to those with private insurance (Table 5).

3.4. Acute Bronchitis & Low Wind Events

People of all ages were 1.11 (95% CI: 0.94–1.31) times more likely to be hospitalized two days after a low wind event than on a clear day (Table 5). Those of all ages covered by Medicaid were generally at increased risk. Children were 1.19 (95% CI: 0.98–1.44) times more likely to be hospitalized after a low wind event than on a clear day. Children with Medicaid and boys were at higher risk for hospitalization. For example, girls were 0.68 (95% CI: 0.46–1.00) times less likely to be hospitalized than boys after a low wind event. Adults with Medicaid and with no insurance were more likely than adults with private insurance to be hospitalized after a low wind event (Table 5).

3.5. Sensitivity Analysis

In a sensitivity analysis, we found that the parameter estimates were stable across the models fitted with and without $PM_{2.5}$ (using both definitions of a low wind event), so only the results with adjustment for $PM_{2.5}$ were reported (Tables 4 and 5). Our choice of low wind event definition (5th or 10th percentile) within all ages had little to no effect on the estimate of the parameters for dust events or on the estimates of the main effects for low wind events for both asthma and bronchitis admissions. However, when using the 5th percentile of average wind speed, the estimates of the odds ratios for the interaction effects with low wind indicated greater modifying effects (but in the same direction as the 10th percentile analysis reported in Tables 4 and 5) of insurance status and age on the association of low wind with asthma hospitalizations, and also for insurance and sex on the association of low wind with bronchitis (see complete results in the online appendix). In using the more restrictive low wind definition (i.e., 5th percentile), three additional findings became statistically significant, despite fewer event days: children were more likely than adults to be hospitalized for asthma after a low wind event (1.50, 95% CI: 1.02–2.08), females were less likely than males to be hospitalized for bronchitis after a low wind event (0.63, 95% CI: 0.42–0.96), and people covered by Medicaid were more likely to be hospitalized for bronchitis than those with private insurance after a low wind event (1.71, 95% CI: 1.05–2.81).

4. Discussion

The results showed a general pattern whereby hospitalizations for asthma and acute bronchitis were associated with the occurrence of dust and low wind events in El Paso. While many studies have linked asthma to air quality (e.g., Ho et al., 2007), acute bronchitis has less often been studied even though particulate matter can influence the ability of an immature immune system to fight off bacteria and other pathogens (Ostro et al., 2009). Others have found increases in particulate matter associated with bronchitis (Barnett et al., 2005; Ostro et al., 2009) and bronchitis admissions were related to dust events in El Paso, underscoring the need to consider respiratory diseases beyond asthma in health effects studies.

Our findings confirm those previously reported. A near source dust study from China found a significant relative risk of respiratory hospitalizations for all ages (i.e., 1.14, 95% CI: 1.01–1.29 for males to 1.18, 95% CI: 1.00–1.41 for females) attributable to local dust events (lag 3) (Meng and Bin, 2007), which was higher than our asthma findings, but lower in magnitude than our acute bronchitis findings. In looking at children, Ueda et al. (2010) found a 1.21 (95% CI: 0.95–1.55) times increase in asthma hospitalizations associated with

Asian dust events in Japan, which was slightly higher than our reported odds ratio for El Paso. Our findings for asthma were slightly higher than the 1.08 (95% CI: 0.97–8.76) relative risk of asthma admissions (all ages) attributable to dust events (lag 2) in Taiwan (Yang et al., 2005), but lower than 1.7 (95% CI: 1.1–2.5) odds ratio for children's asthma and dust found for children in Japan (Kanatani et al., 2010)

While operationalizing low wind differently, we had similar results to Norris' et al. (2000) in that they found that air stagnation (lag 3) was associated with significant increases in asthma hospitalizations for children in Seattle and Spokane, Washington. In analyzing the lag structure of dust and low wind in El Paso, dust seemed to have a more immediate impact on health (lag 0 selected for asthma and lag 1 for bronchitis) than did low wind (lag 3 for asthma and lag 2 for bronchitis). While the low wind lag was similar to Norris et al. (2000), the short lag times for dust found in El Paso differed from Meng and Bin (2007), who also studied people living near a dust source, but were similar to Kanatani et al. (2010), who studied people exposed to dust from a distant source. Our study found that dust events were generally associated with larger odds ratios than were low wind events, which contrasts with Staniswalis et al. (2005)'s finding that low wind had a larger impact on non-accidental mortality than did high wind (their surrogate for a dust event) for all age groups in El Paso.

Children emerged as the most sensitive group (i.e., had the largest odds ratio of the three age groups) for bronchitis after low wind and dust events, and for asthma after low wind events to a statistically significant degree. Children are likely to be more sensitive because only eighty percent of alveoli in the lungs are formed after birth and the lungs continue to change and develop through adolescence; very young lungs are highly vulnerable to damage (Szyszkowicz, 2008). In addition, children spend more time outdoors than adults and have higher levels of physical activity, increasing their exposure to air pollution (Szyszkowicz, 2008).

We found evidence of an effect modification by sex. While girls were significantly more likely to be hospitalized for bronchitis after dust events, the reverse was found for low wind: boys were significantly more likely to be hospitalized than girls. While no one has examined a sex-based interaction related to low wind, Meng and Bin (2007), studying dust events, found a stronger association between pneumonia and upper respiratory tract infections for males of all ages, than for females; but when all respiratory illnesses were combined, they reported a stronger association for females. Our focus was not on pneumonia and upper respiratory tract infections, so the results are not directly comparable. In Japan, Kanatani et al. (2010) found that the risk of asthma hospitalization on the day of a dust event was greater for boys than for girls aged 1 to 15. The majority of sex-modification studies have focused on differential sensitivity to air pollution (e.g., nitrogen oxides, carbon monoxide, and ozone), as opposed to dust and low wind, and females have emerged as generally more sensitive (Chang et al., 2009; Delfino et al., 2009). However, more research is needed as some studies have found boys to be more sensitive than girls to air pollution (Granados-Canal et al., 2005; Szyszkowicz, 2008).

Patterns emerged regarding differences in likelihood of hospitalization based on insurance status. In general, we found the largest odds ratios within the insurance interactions in the adult subgroup, and it was generally adults covered by Medicaid and those without insurance (i.e., poor adults) that were at increased risk for asthma and bronchitis admissions after dust and low wind events. Our finding is consistent with previous studies which have shown that persons with low socio-economic status are more susceptible to asthma hospitalizations from anthropogenic air pollution (Delfino et al., 2002; Burra et al., 2009).

4.1 Limitations

While El Paso County was an ideal location to conduct this study because of the high frequency of dust and low wind events, not having coarse particulate data and a relatively small population were limitations. Our indicator variable for dust events should account for acute exposures to PM₁₀. While some have controlled for PM₁₀ in dust event studies (Yang et al., 2005), others have not (Gyan et al., 2005; Lee et al., 2008), and some use it to create their dust event indicator (Bell et al., 2008). In terms of the population, we had small counts of admissions in some categories, such as children without insurance, which translated into low power for the detection of effects in a subgroup analysis.

Asthma may also have been misdiagnosed among the young children since asthma diagnoses become more accurate as children age. In very young children, asthma is difficult to diagnose because young children frequently suffer from colds and respiratory infections which are difficult to distinguish from asthma (National Heart Lung and Blood Institute, 2011). Asthma is also difficult to differentiate from bronchiolitis in infants, so infants were excluded from this analysis (as per Burra et al., 2009). Misdiagnosis may still have been a problem amongst the young children hospitalized for asthma in the 1–17 age group. But, given the age group codes, we were unable to separate out the youngest children (e.g., those aged 1–2) within the 1–4 age group code. Nonetheless, all children given asthma diagnoses (i.e., the asthma ICD-9 code) in the hospital would have had severe enough difficulties breathing to be treated for asthma.

We did not consider admissions due to chronic obstructive pulmonary disease, which may have been important for the elderly (Chiu et al., 2008). Also, we did not investigate racial and ethnic characteristics (other important axes of difference in effect modification studies) as nearly the entire population of El Paso is Hispanic (82%). Lastly, in a border context, residents do cross the US-Mexico border for health care (Rivera et al., 2009), and we did not capture those El Paso residents who sought care in Ciudad Juárez, Mexico.

5. Conclusion

We found that low wind events were significantly associated with children's asthma hospitalizations, and that dust events were significantly associated with children's acute bronchitis admissions. Girls were significantly more sensitive than boys to bronchitis admissions after low wind events with the reverse being found for dust events. Dust and low wind events were associated with increased odds of hospital admissions for asthma and acute bronchitis amongst all ages and children, and the same was true for adults and dust. Adults covered by Medicaid or without health insurance had higher risks of hospitalization for asthma and acute bronchitis after both low wind and dust events. These results suggested that there were respiratory health effects associated with dust and low wind events in El Paso, with stronger impacts among children and the poor. The sex-based findings for children need to be validated. Future research should continue to investigate how patient sex modifies the relationships between dust, low wind events, and respiratory health and the reasons behind boys' and girls' differential sensitivity including the underlying biological and/or social mechanisms.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding:

The authors would like to acknowledge the UTEP Center for Environmental Resource Management (CERM), the Southwest Consortium for Environmental Research and Policy (SCERP), and the US Environmental Protection Agency (EPA). This project (SCERP Project number EH 08-4) was supported by EPA Cooperative Agreement EM 83395501. The content is solely the responsibility of the authors and does not necessarily represent the official views of CERM, University of Texas at El Paso, SCERP or the US EPA. Dr. Staniswalis acknowledges support from RCMI grants 2G12 RR008124-16A1 and S06-GM08012 for computing facilities and software licenses.

Human Subjects:

IRB approval was obtained through the Texas Department of State Health Services (IRB # 08-021) and University of Texas at El Paso (IRB # 95279-1).

We thank Poorva Mudgal for her help in preparing the data set and Xiaohui Xu at the University of Florida for sharing his SAS code for matching in the case-crossover design with us.

References

- Abdul-Wahab SA, Bakheit CS, Siddiqui RA. Study the relationship between the health effects and characterization of thermal inversions in the Sultanate of Oman. *Atmospheric Environment*. 2005; 39:5466–5471.
- Barnett A, Williams G, Schwartz J, Neller A, Best T, Petroeschevsky A, Simpson R. Air pollution and child respiratory health: a case-crossover study in Australia and New Zealand. *American Journal of Respiratory and Critical Care Medicine*. 2005; 171:1272–8. [PubMed: 15764722]
- Bell ML, Levy JK, Lin Z. The effect of sandstorms and air pollution on cause-specific hospital admissions in Taipei, Taiwan. *Occupational and Environmental Medicine*. 2008; 65:104–111. [PubMed: 17626134]
- Belleudi V, Faustini A, Stafoggia M, Cattani G, Marconi A, Perucci CA, Forastiera F. Impact of Fine and Ultrafine Particles on Emergency Hospital Admissions for Cardiac and Respiratory Diseases. *Epidemiology*. 2010; 21:414–423. [PubMed: 20386174]
- Bener A, Abdulrazzaq YM, Al-Mutawwa J, Debusse P. Genetic and environmental factors associated with asthma. *Human Biology*. 1996; 68:405–15. [PubMed: 8935321]
- Burra TA, Moineddin R, Agha MM, Glazier RH. Social disadvantage, air pollution, and asthma physician visits in Toronto, Canada. *Environmental Research*. 2009; 109:567–574. [PubMed: 19406394]
- Chang J, Delfino R, Gillen D, Tjoa T, Nickerson B, Cooper D. Repeated respiratory hospital encounters among children with asthma and residential proximity to traffic. *Occupational and Environmental Medicine*. 2009; 66:90–98. [PubMed: 19151227]
- Chen YS, Sheen PC, Chen ER, Liu YK, Wu TN, Yang CY. Effects of Asian dust storm events on daily mortality in Taipei, Taiwan. *Environmental Research*. 2004; 95:151–155. [PubMed: 15147920]
- Chiu H-F, Tiao M-M, Ho S-C, Kuo H-W, Wu T-N, Yang C-Y. Effects of Asian Dust Storm Events on Hospital Admissions for Chronic Obstructive Pulmonary Disease in Taipei, Taiwan. *Inhalation Toxicology*. 2008; 20:777–781. [PubMed: 18645716]
- Delfino RJ, Zeiger RS, Seltzer JM, Street DH, McLaren CE. Association of Asthma Symptoms with Peak Particulate Air Pollution and Effect Modification by Anti-inflammatory Medication Use. *Environmental Health Perspectives*. 2002; 110:A607–A617. [PubMed: 12361942]
- Delfino RJ, Chang J, Wu J, Ren C, Tjoa T, Nickerson B, Cooper D, Gillen DL. Repeated hospital encounters for asthma in children and exposure to traffic-related air pollution near the home. *Annals of Allergy Asthma & Immunology*. 2009; 102:138–144.
- Falagas ME, Mourtzoukou EG, Vardakas KZ. Sex differences in the incidence and severity of respiratory tract infections. *Respiratory Medicine*. 2007; 101:1845–1863. [PubMed: 17544265]
- Grineski SE, Staniswalis JG, Peng Y, Atkinson-Palombo C. Children's asthma hospitalizations and relative risk due to nitrogen dioxide (NO₂): Effect modification by race, ethnicity and insurance status. *Environmental Research*. 2010; 110:178–188. [PubMed: 19944410]
- Gurjar BR, Jain A, Sharma A, Agarwal A, Gupta P, Nagpure AS, Lelieveld J. Human health risks in megacities due to air pollution. *Atmospheric Environment*. 2010; 44:4606–4613.

- Gwynn RC, Thurston GD. The burden of air pollution: Impacts among racial minorities. *Environmental Health Perspectives*. 2001; 109:501–506. [PubMed: 11544154]
- Gyan K, Henry W, Lacaille S, Laloo A, Ebanks CL, McKay S, Antoine RM, Monteil MA. African dust clouds are associated with increased paediatric asthma accident and emergency admissions on the Caribbean island of Trinidad. *International Journal of Biometeorology*. 2005; 49:371–376. [PubMed: 15692817]
- Halonen JI, Lanki T, Tiittanen P, Niemi JV, Loh M, Pekkanen J. Ozone and cause-specific cardiorespiratory morbidity and mortality. *Journal of Epidemiology and Community Health*. 2010; 64:814–820. [PubMed: 19854743]
- Hefflin BJ, Jalaludin B, McClure E, Cobb N, Johnson CA, Jecha L, Etzel RA. Surveillance for Dust Storms and Respiratory-Diseases in Washington-State, 1991. *Archives of Environmental Health*. 1994; 49:170–174. [PubMed: 8185387]
- Ho W-C, Hartley WR, Myers L, Lin M-H, Lin Y-S, Lien C-H, Lin R-S. Air pollution, weather, and associated risk factors related to asthma prevalence and attack rate. *Environmental Research*. 2007; 104:402–409. [PubMed: 17316602]
- Holmen A, Blomqvist J, Frindberg H, Johnelius Y, Eriksson NE, Henricson KA, Herrstrom P, Hogstedt B. Frequency of patients with acute asthma in relation to ozone, nitrogen dioxide, other pollutants of ambient air and meteorological observations. *International Archives of Occupational and Environmental Health*. 1997; 69:317–322. [PubMed: 9192215]
- Hosiokangas J, Vallius M, Ruuskanen J, Mirmé A, Pekkanen J. Resuspended dust episodes as an urban air-quality problem in subarctic regions. *Scandinavian Journal of Work and Environmental Health*. 2004; 30:28–35.
- Jaakkola JJK. Case-crossover design in air pollution epidemiology. *European Respiratory Journal*. 2003; 21:81s–85s. [PubMed: 12762580]
- Janes H, Sheppard L, Lumley T. Case-Crossover Analyses of Air Pollution Exposure Data: Referent Selection Strategies and Their Implications for Bias. *Epidemiology*. 2005; 16:717–726. [PubMed: 16222160]
- Kanatani K, Isao I, Wael A-D, Yuichi A, Mathews WC, Ramsdell JW. Desert Dust Exposure Is Associated with Increased Risk of Asthma Hospitalizations in Children. *American Journal of Respiratory and Critical Care Medicine*. 2010; 182:1475–1482. [PubMed: 20656941]
- Kwon H-J, Cho S-H, Chun Y, Lagarde AF, Pershagen GR. Effects of the Asian Dust Events on Daily Mortality in Seoul, Korea. *Environmental Research Section A*. 2002; 90:1–5.
- Lauer FT, Mitchell LA, Bedrick E, McDonald JD, Lee WY, Li WW, Olvera H, Amaya MA, Berwick M, Gonzales M, Currey R, Pingitore NE, Burchiel SW. Temporal-spatial analysis of US-Mexico border environmental fine and coarse PM air sample extract activity in human bronchial epithelial cells. *Toxicology and Applied Pharmacology*. 2009; 238:1–10. [PubMed: 19410595]
- Lawrence DA. Psychologic Stress and Asthma: Neuropeptide Involvement. *Environmental Health Perspectives*. 2002; 110:A230. [PubMed: 12003764]
- Lee EC, Leem J, Hong YC, Kim H, Kim HC. Effects of Asian Dust Storm Events on Daily Admissions for Asthma and Stroke in Seven Metropolitans of Korea. *Epidemiology*. 2008; 19:S145.
- Li W-W, Orquiz R, Garcia JH, Espino TT, Pingitore NE, Gardea-Torresdey J, Chow J, Watson JG. Analysis of temporal and spatial dichotomous PM air samples in the El Paso- Cd. Juarez Air Quality Basin. *Journal of the Air and Waste Management Association*. 2001; 51:1551–1560. [PubMed: 11720102]
- Li W, Cardenas N, Walton J, Trujillo D, Morales H, Arimoto R. PM source identification at Sunland Park, New Mexico, using a simple heuristic meteorological and chemical analysis. *Journal of the Air and Waste Management Association*. 2005; 55:352–64. [PubMed: 15828677]
- Lipfert FW. Air pollution and poverty: Does the sword cut both ways? *Journal of Epidemiological Community Health*. 2004; 58:2–3.
- Lu Y, Zeger SL. On the equivalence of case-crossover and time series methods in environmental epidemiology. *COBRA*. 2006; 49:803–821.

- Maynard D, Coull BA, Gryparis A, Schwartz J. Mortality Risk Associated with Short-Term Exposure to Traffic Particles and Sulfates. *Environmental Health Perspectives*. 2007; 115:751–755. [PubMed: 17520063]
- Meng Z, Bin L. Dust events as a risk factor for daily hospitalization for respiratory and cardiovascular diseases in Minqin, China. *Atmospheric Environment*. 2007; 41:7048–7058.
- Nastos PT, Paliatatos AG, Priftis KN, Kaldellis JK, Panagiotopoulou-Gartagani P, Tapratzi-Potamianou P, Zachariadi-Xypolita A, Kotsonis K, Kassiou K, Saxoni-Papageorgiou P. The effect of weather types on the frequency of childhood asthma admissions in Athens, Greece. *Fresenius Environmental Bulletin*. 2006; 15:936–942.
- National Heart Lung and Blood Institute, Asthma. US Department of Health and Human Services, National Institutes of Health; 2011. Available at: http://www.nhlbi.nih.gov/health/dci/Diseases/Asthma/Asthma_Diagnosis.html
- Norris G, Larson T, Koenig J, Claiborn C, Sheppard L, Finn D. Asthma aggravation, combustion, and stagnant air. *Thorax*. 2000; 55:466–470. [PubMed: 10817794]
- Novlan, D.; Hardiman, M.; Gill, T. A Synoptic Climatology of Blowing Dust Events in El Paso, Texas from 1932–2005 (paper J3.12). 16th Conference on Applied Climatology, American Meteorological Society; San Antonio, TX. 2007.
- O'Neill MS, Jerrett M, Kawachi L, Levy JL, Cohen AJ, Gouveia N, Wilkinson P, Fletcher T, Cifuentes L, Schwartz J. Health, wealth, and air pollution: Advancing theory and methods. *Environmental Health Perspectives*. 2003; 111:1861–1870. [PubMed: 14644658]
- Ostro B, Roth L, Malig B, Marty M. The Effects of Fine Particle Components on Respiratory Hospital Admissions in Children. *Environmental Health Perspectives*. 2009; 117:475–480. [PubMed: 19337525]
- Peng RD, Dominici F, Pastor-Barriuso R, Zeger SL, Samet JM. Seasonal analyses of air pollution and mortality in 100 US cities. *American Journal of Epidemiology*. 2005; 161:585–594. [PubMed: 15746475]
- Perez L, Tobias A, Querol X, Kunzli N, Pey J, Alastuey A, Viana M, Valero N, Gonzalez-Cabre M, Sunyera J. Coarse Particles From Saharan Dust and Daily Mortality. *Epidemiology*. 2008; 19:800–807. [PubMed: 18938653]
- Prospero JM, Blades E, Naidu R, Mathison G, Thani H, Lavoie MC. Relationship between African dust carried in the Atlantic trade winds and surges in pediatric asthma attendances in the Caribbean. *International Journal of Biometeorology*. 2008; 52:823–832. [PubMed: 18773225]
- Prospero JM, Ginoux P, Torres O, Nicholson SE, Gill TE. Environmental Characterization of Global Sources of Atmospheric Soil Dust Identified with the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) Absorbing Aerosol Product. *Reviews of Geophysics*. 2002; 40:1002.
- Rivera JO, Ortiz M, Cardenas V. Cross-Border Purchase of Medications and Health Care in a Sample of Residents of El Paso, Texas, and Ciudad Juarez, Mexico. *Journal of the National Medical Association*. 2009; 101:167–173. [PubMed: 19378635]
- Rivera Rivera NI, Gill TE, Gebhart KA, Hand JL, Bleiweiss MP, Fitzgerald RM. Wind modeling of Chihuahuan Desert dust outbreaks. *Atmospheric Environment*. 2009; 43:347–354.
- Rivera Rivera NI, Gill TE, Bleiweiss MP, Hand JL. Source characteristics of hazardous Chihuahuan Desert dust outbreaks. *Atmospheric Environment*. 2010; 44:2457–2468.
- Staniswalis JG, Parks NJ, Maldonado YM. Temporal analysis of airborne particulate matter reveals a dose-rate effect on mortality in El Paso: Indications of differential toxicity for different particle mixtures. *Journal of the Air & Waste Management Association*. 2005; 55:893–902. [PubMed: 16111129]
- Steadman R. The assessment of sultriness. Part II: Effects of wind, extra radiation and barometric pressure on apparent temperature. *Journal of Applied Meteorology*. 1979; 18:874–885.
- Szyzskowicz M. Ambient air pollution and daily emergency department visits for asthma in Edmonton, Canada. *International Journal of Occupational Medicine and Environmental Health*. 2008; 21:25–30. [PubMed: 18468973]
- Tecer LH, Alagha O, Karaca F, Tuncel G, Eldes N. Particulate matter (PM_{2.5}, PM_{10-2.5}, and PM₁₀) and children's hospital admissions for asthma and respiratory diseases: A bidirectional case-

- crossover study. *Journal of Toxicology and Environmental Health-Part a-Current Issues*. 2008; 71:512–520.
- Texas Health Care Information Council. User Manual For Texas Hospital Inpatient Discharge Public Use Data File. Austin, TX: 2002. p. 1-52. Available at: <http://www.dshs.state.tx.us/thcic/hospitals/HospitalData.shtm>
- Ueda K, Nitta H, Odajima H. The effects of weather, air pollutants, and Asian dust on hospitalization for asthma in Fukuoka. *Environmental Health and Preventative Medicine*. 2010; 15:350–357.
- US Bureau of the Census. Quick Facts about El Paso County. Washington DC: 2010. Available at: <http://quickfacts.census.gov/qfd/states/48/48141.html>
- Yamazaki S, Shima M, Ando M, Nitta H. Modifying Effect of Age on the Association between Ambient Ozone and Nighttime Primary Care Visits Due to Asthma Attack. *Journal of Epidemiology*. 2009; 19:143–151. [PubMed: 19398846]
- Yang CY, Tsai SS, Chang CC, Ho SC. Effects of Asian dust storm events on daily admissions for asthma in Taipei, Taiwan. *Inhalation Toxicology*. 2005; 17:817–821. [PubMed: 16282159]
- Yi O, Hong Y, Kim H. Seasonal effect of PM(10) concentrations on mortality and morbidity in Seoul, Korea: a temperature-matched case-crossover analysis. *Environmental Research*. 2010; 110:89–95. [PubMed: 19819431]
- Zanobetti A, Schwartz J. The Effect of Particulate Air Pollution on Emergency Admissions for Myocardial Infarction: A Multicity Case-Crossover Analysis. *Environmental Health Perspectives*. 2005; 113:978–982. [PubMed: 16079066]
- Zanobetti A, Schwartz J. Air pollution and emergency admissions in Boston, MA. *Journal of Epidemiological Community Health*. 2006; 60:890–895.

Low wind events were significantly associated with children's asthma hospitalizations

Dust events were significantly associated with children's acute bronchitis admissions

Girls were significantly more sensitive than boys to bronchitis after low wind events

Girls were significantly less sensitive than boys to bronchitis after dust events

Figure 1.

Odds Ratios with 95% Confidence Interval for the associations between dust and low wind events with asthma and acute bronchitis adjusted for nitrogen dioxide (average over lags 0–1), $PM_{2.5}$ (average over lags 0–1), and apparent temperature (lag1). Adjustment by nitrogen (average over lags 0–3), and apparent temperature (lag1) dioxide (average over lags 0–3), $PM_{2.5}$ gave similar results.

Descriptive summary of the study population in El Paso, Texas: asthma and bronchitis hospital admissions by age, sex, and insurance status, 2000–2003

Table 1

Asthma Admissions	Patient Sex		Patient Insurance Status				
	Female	Male	Total	Private	Medicare	Medicaid	None
	Total	Other public	Total	Medicare	Medicaid	None	Total
Age (1–17)	610	1046	1656	592	1	970	57
Age (18–64)	917	247	1164	585	167	289	104
Age (65)	503	182	685	31	637	13	1
Total	2030	1475	3503	1208	805	1272	162
Bronchitis Admissions	Patient Sex		Patient Insurance Status				
	Female	Male	Total	Private	Medicare	Medicaid	None
	Total	Other public	Total	Medicare	Medicaid	None	Total
Age (1–17)	419	542	961	276	0	650	25
Age (18–64)	131	75	206	95	50	36	21
Age (65)	186	81	267	13	247	6	1
Total	736	698	1434	384	297	692	47

Note: Totals for sex and insurance status are not equal due to missing data

Table 2

Summary statistics for temperature, dew point, nitrogen dioxide, and PM_{2.5} in El Paso, Texas, 2000–2003

Variables (unit) ^a	N	Min	5 th centile	25 th centile	Median	Mean	75 th centile	95 th centile	Max	SD ^d
Temperature (°C)	1461	-1.1	4.4	11.1	20	18.8	26.7	30.6	33.3	8.7
Dew Point (°C)	1461	-21.1	-9.4	-3.9	1.7	2.4	9.4	14.4	20	8.0
Apparent Temperature (°C)	1461	-3.1	2.9	8.8	17.7	17.1	25.9	29.5	32.6	9.1
Nitrogen Dioxide (ppb)	1461	7	16	27	35	35.0	43	54	99	12.0
Nitrogen Dioxide L01 ^a	1460	10.0	20.0	28.0	34.5	35.0	41.0	52.0	76.0	10.1
Nitrogen Dioxide L03 ^b	1458	13.3	22.8	29.3	34.5	35.0	40.0	49.8	65.8	8.2
PM _{2.5} ^c (μg per meter ³)	1461	1.3	4.3	7.4	10.7	12.8	15.6	26.6	119.1	9.0
PM _{2.5} L01 ^a (μg per meter ³)	1460	1.8	4.9	8.2	11.3	12.8	15.4	26.0	68.2	7.4
PM _{2.5} L03 ^b (μg per meter ³)	1458	2.5	5.6	8.8	11.6	12.8	15.3	23.9	55.2	6.1

^aL01, average over lags 0–1

^bL03, average over lags 0–3

^cPM_{2.5}, particulate matter with an average aerometric diameter less than 2.5 microns

^dSD, standard deviation

Table 3

Odds ratios for hospitalizations associated with a 10 unit increase in PM_{2.5} and nitrogen dioxide for asthma and acute bronchitis within all ages adjusting for apparent temperature (lag 1)

	Odds Ratio (95% Confidence Interval) for 10 Unit Increase in Pollutant	
	Asthma Admissions	Acute Bronchitis Admissions
<u>PM_{2.5} (µg per meter³)</u>		
lag 0	1.02 (0.98, 1.06)	1.02 (0.98, 1.06)
lag 1	1.00 (0.96, 1.05)	1.00 (0.96, 1.05)
lag 2	1.00 (0.97, 1.04)	1.00 (0.97, 1.04)
lag 3	1.01 (0.97, 1.05)	1.01 (0.97, 1.05)
Average over lags 0–1	1.02 (0.97, 1.07)	0.97 (0.90, 1.05)
Average over lags 0–3	1.02 (0.96, 1.09)	1.01 (0.92, 1.12)
<u>Nitrogen Dioxide (parts per billion)</u>		
lag 0	0.99 (0.96, 1.02)	0.96 (0.91, 1.01)
lag 1	1.01 (0.97, 1.04)	1.01 (0.96, 1.06)
lag 2	1.03 (1.00, 1.06)	1.03 (0.98, 1.08)
lag 3	1.03 (1.00, 1.06)	1.03 (0.98, 1.08)
Average over lags 0–1	1.00 (0.96, 1.04)	0.98 (0.92, 1.04)
Average over lags 0–3	1.03 (0.98, 1.09)	1.03 (0.95, 1.12)

Table 4

Odds ratios for the association of dust (n=110) and low wind (n=157) events with asthma admissions for all ages, children, adults and the elderly, with effect modifications by age, insurance status, and sex indicated with an asterisk (*)

Odds Ratio (95% Confidence Interval)			
Main Effects and Interaction Effects	Exposure Prior to Admission for Asthma		
	Lag ^a	Dust - Lag 0 (Same Day)	Low Wind – Lag 3 (3 Days Before)
<u>All ages</u>	L01	1.11 (0.96, 1.28)	1.07 (0.96, 1.21)
	L03	1.13 (0.98, 1.29)	1.06 (0.94, 1.19)
Children* ^b	L01	0.96 (0.71, 1.31)	1.19 (0.92, 1.54)
	L03	0.96 (0.71, 1.31)	1.19 (0.92, 1.54)
Elderly* ^b	L01	0.81 (0.57, 1.17)	0.93 (0.66, 1.31)
	L03	0.82 (0.57, 1.18)	0.93 (0.66, 1.31)
Medicare* ^c	L01	0.89 (0.63, 1.27)	0.74 (0.54, 1.02)
	L03	0.90 (0.63, 1.27)	0.74 (0.54, 1.03)
Medicaid* ^c	L01	0.95 (0.69, 1.32)	0.92 (0.70, 1.21)
	L03	0.95 (0.69, 1.32)	0.92 (0.70, 1.21)
Other Public* ^c	L01	0.48 (0.15, 1.59)	1.25 (0.51, 3.09)
	L03	0.48 (0.15, 1.60)	1.26 (0.51, 3.11)
None* ^c	L01	1.34 (0.68, 2.66)	1.03 (0.57, 1.85)
	L03	1.34 (0.68, 2.64)	1.02 (0.57, 1.84)
Female* ^d	L01	0.92 (0.70, 1.21)	0.94 (0.74, 1.19)
	L03	0.92 (0.71, 1.21)	0.94 (0.74, 1.19)
Subgroup Analysis			
<u>Children (age 1–17)</u>	L01	1.16 (0.94, 1.43)	1.19 (1.00, 1.41)
	L03	1.15 (0.94, 1.41)	1.16 (0.98, 1.37)
Medicaid ^c	L01	0.87 (0.58, 1.32)	0.74 (0.52, 1.05)
	L03	0.86 (0.57, 1.32)	0.74 (0.52, 1.05)
Other Public* ^c	L01	0.76 (0.20, 2.80)	0.68 (0.21, 2.20)
	L03	0.76 (0.20, 2.80)	0.68 (0.21, 2.21)
None* ^c	L01	1.02 (0.33, 3.22)	1.04 (0.41, 2.63)
	L03	1.02 (0.33, 3.22)	1.04 (0.41, 2.63)
Female* ^d	L01	1.00 (0.66, 1.52)	1.01 (0.72, 1.41)
	L03	1.01 (0.66, 1.53)	1.00 (0.71, 1.41)
<u>Adults (age 18–64)</u>	L01	1.16 (0.91, 1.50)	1.01 (0.82, 1.23)
	L03	1.18 (0.93, 1.50)	1.01 (0.82, 1.24)

Odds Ratio (95% Confidence Interval)			
Main Effects and Interaction Effects	Exposure Prior to Admission for Asthma		
	Lag ^a	Dust - Lag 0 (Same Day)	Low Wind - Lag 3 (3 Days Before)
Medicare* ^c	L01	1.16 (0.59, 2.30)	0.77 (0.41, 1.46)
	L03	1.16 (0.59, 2.30)	0.77 (0.41, 1.46)
Medicaid* ^c	L01	1.09 (0.61, 1.95)	1.20 (0.75, 1.94)
	L03	1.09 (0.61, 1.95)	1.20 (0.75, 1.94)
None* ^c	L01	1.56 (0.66, 3.69)	1.11 (0.51, 2.39)
	L03	1.56 (0.66, 3.68)	1.11 (0.51, 2.39)
Female* ^d	L01	0.76 (0.43, 1.32)	0.92 (0.55, 1.51)
	L03	0.76 (0.43, 1.32)	0.92 (0.55, 1.51)
<u>Elderly (age ≥ 65)</u>	L01	0.96 (0.71, 1.30)	0.94 (0.71, 1.25)
	L03	1.03 (0.77, 1.38)	0.93 (0.70, 1.24)
Medicare* ^c	L01	1.28 (0.24, 6.99)	0.70 (0.21, 2.33)
	L03	1.30 (0.24, 7.08)	0.73 (0.22, 2.43)
Female* ^d	L01	0.93 (0.50, 1.73)	1.19 (0.63, 2.25)
	L03	0.95 (0.51, 1.77)	1.20 (0.64, 2.26)

^a L01 means that PM_{2.5} and nitrogen dioxide were adjusted for with the average over lags 0–1; L03 means that PM_{2.5} and nitrogen dioxide were adjusted for with the average over lags 0–3. All models also adjust for apparent temperature (lag 1).

^b The reference category is adults.

^c The reference category is private insurance.

^d The reference category is male.

Table 5

Odds ratios for the association of dust (n=110) and low wind (n=157) events with acute bronchitis admissions for all ages, children, adults and the elderly, with effect modifications by age, insurance status, and sex indicated with an asterisk (*)

Odds Ratio (95% Confidence Interval)			
Main Effects and Interaction Effects	Exposure Prior to Admission for Acute Bronchitis		
	Lag ^a	Dust - Lag1 (1 Day Before)	Low Wind - Lag2 (2 Days Before)
<u>All ages</u>	L01	1.23 (0.99, 1.55)	1.11 (0.94, 1.31)
	L03	1.21 (0.97, 1.52)	1.09 (0.93, 1.29)
Children* ^b	L01	1.05 (0.57, 1.91)	1.49 (0.87, 2.56)
	L03	1.21 (0.65, 2.26)	1.47 (0.85, 2.52)
Elderly* ^b	L01	0.83 (0.40, 1.74)	1.22 (0.64, 2.33)
	L03	0.90 (0.42, 1.93)	1.21 (0.63, 2.31)
Medicare* ^c	L01	0.69 (0.37, 1.32)	0.94 (0.58, 1.53)
	L03	0.72 (0.37, 1.38)	0.94 (0.58, 1.53)
Medicaid* ^c	L01	1.01 (0.61, 1.68)	1.38 (0.94, 2.02)
	L03	1.12 (0.67, 1.89)	1.36 (0.93, 1.99)
None* ^c	L01	0.44 (0.11, 1.74)	0.89 (0.30, 2.68)
	L03	0.45 (0.12, 1.81)	0.89 (0.30, 2.66)
Female* ^d	L01	1.45 (0.95, 2.21)	0.80 (0.58, 1.10)
	L03	1.40 (0.91, 2.15)	0.80 (0.58, 1.11)
Subgroup Analysis			
<u>Children (age 1–17)</u>	L01	1.33 (1.01, 1.75)	1.19 (0.98, 1.44)
	L03	1.34 (1.02, 1.76)	1.16 (0.95, 1.40)
Medicaid* ^c	L01	0.92 (0.52, 1.63)	1.33 (0.88, 2.00)
	L03	0.95 (0.53, 1.71)	1.32 (0.87, 1.99)
None* ^c	L01	0.34 (0.04, 3.31)	0.50 (0.10, 2.52)
	L03	0.33 (0.04, 3.16)	0.52 (0.10, 2.59)
Female* ^d	L01	1.83 (1.09, 3.08)	0.68 (0.46, 1.00)
	L03	1.88 (1.11, 3.18)	0.68 (0.46, 1.00)
<u>Adults (age 18–64)</u>	L01	1.20 (0.66, 2.16)	0.82 (0.49, 1.37)
	L03	1.04 (0.57, 1.88)	0.85 (0.51, 1.43)
Medicare* ^c	L01	0.71 (0.16, 3.17)	0.56 (0.16, 1.99)
	L03	1.05 (0.22, 5.08)	0.54 (0.15, 1.92)
Medicaid* ^c	L01	1.63 (0.41, 6.42)	1.31 (0.27, 6.30)
	L03	2.40 (0.56, 10.32)	1.32 (0.27, 6.36)

Odds Ratio (95% Confidence Interval)			
Main Effects and Interaction Effects	Exposure Prior to Admission for Acute Bronchitis		
	Lag ^a	Dust - Lag1 (1 Day Before)	Low Wind - Lag2 (2 Days Before)
None* ^c	L01	0.69 (0.10, 4.93)	1.99 (0.37, 10.70)
	L03	1.03 (0.14, 7.72)	1.92 (0.36, 10.30)
Female* ^d	L01	1.41 (0.41, 4.80)	1.56 (0.51, 4.74)
	L03	1.20 (0.34, 4.16)	1.64 (0.54, 5.02)
<u>Elderly (age ≥ 65)</u>	L01	0.97 (0.57, 1.66)	0.99 (0.66, 1.50)
	L03	0.98 (0.58, 1.66)	0.96 (0.64, 1.45)
Female* ^d	L01	0.65 (0.22, 1.93)	1.55 (0.60, 4.00)
	L03	0.62 (0.21, 1.86)	1.53 (0.59, 3.93)

^aL01 means that PM_{2.5} and nitrogen dioxide were adjusted for with the average over lags 0–1; L03 means that PM_{2.5} and nitrogen dioxide were adjusted for with the average over lags 0–3. All models also adjust for apparent temperature (lag 1).

^bThe reference category is adults.

^cThe reference category is private insurance.

^dThe reference category is male.