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Health Outcomes Associated with Smoke Exposure in Albuquerque, New Mexico during the 2011 Wallow Fire

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Introduction

The 2011 wildfire season in the southwest was record breaking, with over 1 million acres burned in both Arizona and New Mexico. The Wallow fire, which was the largest fire in Arizona history, began on May 29 and burned 538,049 acres, before it was contained on July 8. In Albuquerque, over 150 miles away, there were many days over the first two weeks of June when air quality was not in the "Good" range, according to the Environmental Protection Agency's (EPA) Air Quality Index (AQI) for particulate matter of size 2.5 microns and smaller ($PM_{2.5}$) (e.g. not under 15 ug/m^3).[1] Similar AQI values were seen in Los Alamos. As the Wallow fire was being controlled, the Pacheco fire began on June 18th just to the north of Santa Fe and adjacent to Nambe Pueblo, in the Sangre de Cristo Mountains. On June 26th, the Las Conchas fire began in the Jemez Mountains, located between Albuquerque, Santa Fe and Los Alamos. The Las Conchas fire was finally contained on August 1, after it consumed 156,593 forested acres. For safety reasons, Los Alamos was evacuated for seven days. During this time, the AQI ranged from "Unhealthy" to "Hazardous" (24-hr $PM_{2.5}$ was 68.2 ug/m^3 on 6/11/11; 258.9 ug/m^3 on 6/30/11).

Wildfire smoke is a complex mixture of carbon dioxide, water vapor, carbon monoxide, particulate matter, hydrocarbons and other organic chemicals, nitrogen oxides, and metals. Exposure to fine particulate matter such as $PM_{2.5}$ is associated with premature death, heart attacks and stroke.[2-4] Additionally, it can trigger asthma attacks among those with asthma and respiratory problems.[5]

Few studies have focused on the public health impact of wildfires. Delfino et al.[6] examined the relationship between $PM_{2.5}$ exposure during wildfires in southern California in October 2003 and cardiorespiratory hospital admissions. Asthma admissions increased during the fire across all ages by 4.8%. However, among those aged 65-99 years, there was a 10.1% increase in asthma admissions for every 10 ug/m^3 concentration increase. Additionally, admissions for chronic obstructive pulmonary disease (COPD) significantly increased among those aged 20-64 years.

A time-series study examined the associations between daily $PM_{2.5}$ concentrations and dispensations of salbutamol (a medication used to relieve exacerbations of chronic respiratory diseases) during wildfires in British Columbia, Canada between 2003 and 2010.[7] In all fire-affected populations, a 10 µg/m^3 increase in $PM_{2.5}$ concentration was associated with a 6% increase in salbutamol dispensations. No effect was observed in non-fire-affected areas.

Methods

Daily emergency department (ED) visits for 2011 were collected by the New Mexico Department of Health's (NMDOH) Epidemiology and Response Division from individual non-federal licensed facilities in the state. These visits were restricted to the locations that were exposed to wildfire smoke due to the Wallow, Las Conchas, and Pacheco fires. These included Albuquerque, Santa Fe, Los Alamos, and Espanola. ED visits were grouped by respiratory and cardiovascular diagnoses (Table 2). The selection of these diagnoses was based on previous studies.[6] A patient was counted as having a specific respiratory or cardiovascular diagnosis if the corresponding ICD-9 code appeared anywhere in the first three diagnostic fields of their ED record.

Air quality monitoring data for $PM_{2.5}$ were provided by the United States Forest Service (USFS), which compiled data from the New Mexico Environment Department's Air Quality Bureau (NMED AQB), the City of

Albuquerque (CABQ), Los Alamos National Laboratory (LANL) and mobile monitors deployed by the USFS. CABQ has two permanent monitoring stations: one in the South Valley and the other in the North Valley. Both monitoring stations recorded hourly $PM_{2.5}$ levels throughout the summer of 2011. The NMED AQB operates a mobile monitor in Bernalillo and two permanent monitors in Santa Fe. LANL operates two monitors: one in Los Alamos and one in White Rock. USFS deployed numerous monitors throughout New Mexico to supplement the current monitoring network maintained by Albuquerque, NMED, and LANL. Twenty four-hour average $PM_{2.5}$ levels were calculated using the hourly data and these levels were used to create a single exposure for each geographic area.

To account for unknown lag times between $PM_{2.5}$ exposure and ED visits and the cumulative effect of long periods of high $PM_{2.5}$ exposure on health, the average number of ED visits with selected diagnoses were compared from the period before the wildfire (May 1 – May 31) to the acute exposure period (June 1 – June 13) and following the acute exposure period (June 14th – July 8th). Poisson regression was used to calculate ED rates, standard errors and 95% confidence intervals, with the pre-wildfire period serving as the referent time. Analyses were stratified by three age groups: 0-19, 20-64, and 65+.

Results

Although Santa Fe and Los Alamos experienced high levels of $PM_{2.5}$ exposure from the Las Conchas and Pacheco fires, ED visit data from hospitals in this area were excluded from this analysis. Since there are only three major hospitals in this area and those treat significantly fewer patients than hospitals in the Albuquerque area, the number of ED visits in this region of the state prior to and during the Las Conchas fire was very low, making it difficult to detect increases in visits in relation to the wildfire. In addition, Santa Fe, Los Alamos, and Espanola experienced very heterogeneous exposures. Finally, the entire community of Los Alamos was evacuated for one week for safety reasons. Therefore, this analysis focused on exposures in the Albuquerque area due to the Wallow fire. ED data from the seven major hospitals in the Albuquerque area were pooled to better detect changes in ED visit rates in relation to the wildfire.

The period between June 1st and June 13th was chosen as the acute exposure period because 24-hr $PM_{2.5}$ levels were elevated considerably during this time (> 15 ug/m^3 all but one day). In addition, four days were above the AQI at the time for "Unhealthy for Sensitive Groups" (36 to 65 ug/m^3) and one day was above the AQI for "Unhealthy for All Groups" (66 to 150 ug/m^3). In comparison, air quality was "Good" everyday but one in the period preceding the acute exposure period and was marginally worse than good 6 non-consecutive days following the acute exposure period (Figure).

Figure. Daily 24 hour average PM 2.5 levels, Albuquerque, 5/1/11-7/8/11

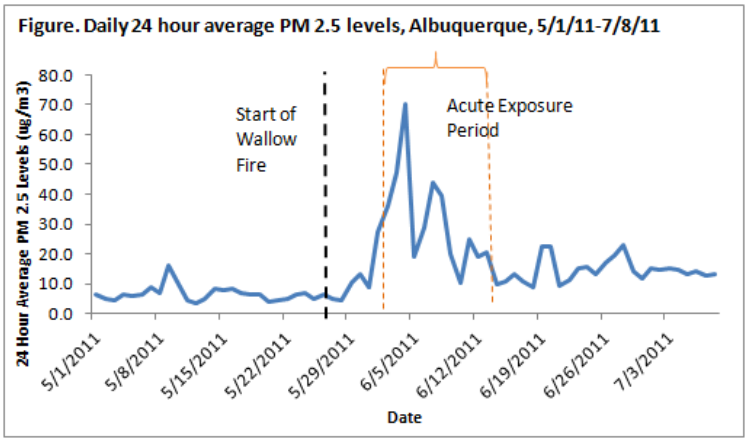

Table 1 provides descriptive statistics for $PM_{2.5}$ levels by exposure period.

Table 1. Mean 24 hour PM 2.5 Levels (ug/m3) by wildfire status, Albuquerque, 5/1/11-7/8/11

Exposure period	Dates	Mean	Range	Standard Deviation
Pre-Wallow	5/1/11-5/31/11	6.8	3.5-16.3	2.7
Acute	6/1/11-6/13/11	31.3	10-70	16
Post-acute	6/14/11-7/8/11	14.5	9-23	4

Table 2 shows relative changes in ED visits in relation to the wildfire for all ages and are stratified by age, respectively. For all ages, there was an increased risk of respiratory ED visits for conditions such as asthma (8%) and 'other diseases of respiratory system' (23%) during the acute exposure period compared to the pre-wildfire period. For the age group 65 and over, the risk of asthma ED visits increased significantly (73%, $p<.05$). Overall, there was an 8% increase in ED visits for all cardiovascular conditions ($p=.065$) during the acute exposure period compared to the pre-wildfire period. There was also a non-significant increase in ED visits for other cardiovascular conditions, e.g. cerebrovascular disease (13%) and diseases of pulmonary circulation (61%), among others. The risk of ED visits increased significantly for diseases of the veins, lymphatic and circulatory system (56%, $p=.05$) for the 65 and over age group. For the age group 20-64, there was a large significant increase in ED visits for diseases of

pulmonary circulation (142%, p<.01) and a more modest, but statistically significant increase for cerebrovascular disease (69%, p<.05). Generally, the number of ED visits by the youth age group (0-19) was too small to detect significant differences even when modest increases were observed. During the post-exposure period for all ages, the average number of ED visits for each condition except diseases of the veins were lower than during the acute exposure period.

Discussion

Analysis of $PM_{2.5}$ exposure data and emergency department visits in Albuquerque for the Wallow fire indicates that compared to the period prior to the fire, there was an increased risk of ED visits for respiratory and cardiovascular conditions during the acute period, and age mediated the risk. In contrast, following the acute period for all ages, the average number of ED visits for each condition except for diseases of the veins were lower than during the acute exposure period.

The population of 65+ was especially at risk for ED visits. There was a significantly increased risk of ED visits among the 65+ population for asthma (73%, p<.05) and for diseases of the veins, lymphatic and circulatory system (56%, p=.05).

The risk among the age group of 20 to 64 was primarily for ED visits due to diseases of pulmonary circulation (142% increase, p<.01) and a more modest significant increase for cerebrovascular disease (69%, p<.05).

During the 2011 fires, the USFS worked with the NMDOH, NMED, the Southwest Coordination Center and numerous other partners to provide the public with predictions of the path of smoke and to provide educational outreach about different levels of wildfire smoke and how to control excessive exposure. Nevertheless, exposure to $PM_{2.5}$ from the fire was associated with increased risk for emergency department visits. This means that some members of the public either did not get the information they needed, did not know how to prevent exposure, or took no preventive actions.

There are a number of limitations to this analysis. First, data were submitted by individual hospital EDs which have varied reporting systems, databases, and capacities to extract data. Second, $PM_{2.5}$ exposures from two Albuquerque monitors were averaged and may not accurately reflect the exposure of all people in the area. More accurate exposure data on an individual basis would generate more precise estimates of risk. Third, this analysis did not take into account other factors such as humidity and seasonality of ED visits.

Recommendations

Due to the ongoing drought, New Mexico is likely to continue to experience wildfires that are longer in duration and more severe. Continuing to provide health messages to the populations potentially most affected by wildfire smoke will be imperative. For the most affected, one of the key messages is that residents may be required to evacuate to prevent exposure and protect their health. In addition to effective communication, the likelihood that residents will evacuate will increase if shelters are set up which provide cooling and adequate air filtration, but also accommodations for household pets. When air quality does not require evacuation, but is still poor and temperatures are high, cooling centers should be available for those residents who do not have access to air conditioners, since most swamp coolers cannot filter out $PM_{2.5}$.

References

1.The AQI upper limit for "Good" was changed to 12 ug/m^3 in 2012: http://www.epa.gov/pm/2012/decfsstandards.pdf.

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Table 2. Relative rate of emergency department visits in relation to wildfire period by age, Albuquerque, New Mexico, 5/1/11-7/8/11

Emergency department outcome*	n**	Pre-wildfire period (referrent)	Wildfire period RR (95% CI)	Post-wildfire period RR (95% CI)
Asthma (ICD-9 493)				
All Ages	860	1.00	1.08 (0.91-1.29)	.82 (0.71-0.97)
0-19	260	1.00	1.02 (0.74-1.30)	0.79 (0.59-1.04)
20-64	524	1.00	1.02 (0.82-1.29)	0.87 (0.82-1.29
65+	76	1.00	1.73 (1.03-2.93)	0.71 (0.41-1.26)
Other diseases of the respiratory system (ICD-9 510-519)				
All Ages	424	1.00	1.23 (0.96-1.57)	0.91 (0.73-1.14)
0-19	49	1.00	1.24 (0.62-2.5)	0.75 (0.39-1.47)
20-64	259	1.00	1.15 (0.83-1.59)	0.98 (0.74-1.29)
65+	116	1.00	1.40 (0.89-2.20)	0.85 (0.55-1.31)
All cardiovascular (ICD-9 390-459)				
All Ages	4,525	1.00	1.08 (1.00-1.16)	0.96 (0.90-1.03)
0-19	65	1.00	1.35 (0.75-2.45)	0.74 (0.41-1.33)
20-64	2571	1.00	1.11 (1.00-1.23)	1.00 (0.92-1.09)
65+	1889	1.00	1.03 (0.91-1.16)	0.92 (0.83-1.02)
Diseases of pulmonary circulation (ICD-9 415-417)				
All Ages	91	1.00	1.61 (0.97-2.68)	0.97 (0.60-1.58)
0-19	3	1.00	-	-
20-64	54	1.00	2.64 (1.42-4.9)	0.91 (0.46-1.82)
65+	34	1.00	0.42 (0.12-1.44)	1.02 (0.50-2.07)
Cerebrovascular disease (ICD-9 430-438)				
All Ages	219	1.00	1.13 (0.79-1.61)	0.97 (0.72-1.31)
0-19	4	1.00	7.15 (0.74-68.77)	0
20-64	109	1.00	1.69 (1.03-2.77)	1.44 (0.93-2.21)
65+	106	1.00	0.66 (0.38-1.14)	0.68 (0.44-1.05)
Diseases of veins, lymphatics and circulatory system (ICD-9 451-459)				
All Ages	479	1.00	1.06 (0.83-1.36)	1.12 (0.92-1.36)
0-19	12	1.00	0.60 (0.13-2.8)	0.31 (0.7-1.46)
20-64	339	1.00	0.92 (0.68-1.26)	1.14 (0.90-1.44)
65+	128	1.00	1.56 (1.00-2.43)	1.18 (0.80-1.77)

*Diagnoses were coded by version 9 of the International Classification of Diseases (ICD-9)

**ED visit was counted for a specific condition if the first three diagnostic fields of the patient record included the corresponding ICD-9 code.

NOTES: Other diseases included in the analysis but not included in the table above include: hypertensive disease, ischemic heart disease, cardiac dysrythmias, congestive heart failure, and diseases of the arteries, arterioles, and capillaries