Supplementary Online Content

Thunderstorms, Pollen and Severe Asthma in a Midwestern, USA Urban environment, 2007-2018

M. Luke Smith,, Richard MacLehose, John W. Chandler, Jesse D Berman.

eTable1. Table of all results as shown in manuscript figures with main model for lags -6 to +9 days with estimation of up to 3 consecutive missing days, 0-6 day lags for crude (adjusted only for day of week and seasonal spline), with weather variables only (adjusted for day of week and seasonal spline); tabular results for covariates at day zero estimating up to 3 consecutive missing days; robustness check for HIGH pollen with less than 2 lightning strikes for lags of 0 - 2 days; robustness check for low pollen with lightning >=2 for lags 0 -2 days; robustness check for up to 2 missing days estimated, adjusted for all covariates; robustness check for all missing days excluded, adjusted for all covariates.

eTable 2: Relative risk of severe asthma from adjusted models with a covariate included for thunderstorm and pollen but no main effects (Model 1), a two-stage model combining individual zip code results with meta-analysis (Model 2) and an adjusted model with main effects and an interaction term (Model 3), and the ratio of doubly exposed to neither exposed for that model 3. All results adjusted for, ozone (10 parts per billion), precipitation (mm), wind (mph) PM2.5 (μg/m3), temperature (°C), relative humidity.

eFigure1: Change in risk of emergency department visits covariates, ozone (10 parts per billion), precipitation (mm), wind (mph) PM2.5 (μg/m3), temperature (°C), and relative humidity (percent), adjusted for thunderstorm with high pollen, day of week, and seasonal cubic splines.

eResults1: Discussion of covariates as described in eFigure1.

Efigure2: Change in risk of emergency department visits for lags of -6 days to +9 days. Day 0 is highlighted. All results adjusted for, ozone (10 parts per billion), precipitation (mm), wind (mph) PM2.5 (μg/m3), temperature (°C), relative humidity (percent), day of week and seasonal cubic splines.

eTable1:

Table of all results as shown in manuscript figures with main model for lags -6 to +9 days with estimation of up to 3 consecutive missing days, 0-6 day lags for crude (adjusted only for day of week and seasonal spline), with weather variables only (adjusted for day of week and seasonal spline); tabular results for covariates at day zero estimating up to 3 consecutive missing days; robustness check for HIGH pollen with less than 2 lightning strikes for lags of 0 - 2 days; robustness check for low pollen with lightning >=2 for lags 0 - 2 days; robustness check for up to 2 missing days estimated, adjusted for all covariates; robustness check for all missing days excluded, adjusted for all covariates.

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| Association between exposure to 2+ lightning strikes and HIGH (75% any pollen). Adjusted for Ozone, PM25, precipitation, wind, humidity, temperature, day of week, and 8 knot natural cubic splines. Up to 3 missing days estimated. | | | |
| lag | RR | 95% CI low | 95% CI high |
| -6 | 0.981 | 0.950 | 1.013 |
| -5 | 0.967 | 0.936 | 0.998 |
| -4 | 0.994 | 0.963 | 1.026 |
| -3 | 1.001 | 0.969 | 1.033 |
| -2 | 0.959 | 0.928 | 0.990 |
| -1 | 0.977 | 0.947 | 1.009 |
| 0 | 1.047 | 1.012 | 1.083 |
| 1 | 1.006 | 0.975 | 1.038 |
| 2 | 0.998 | 0.967 | 1.030 |
| 3 | 0.967 | 0.936 | 0.998 |
| 4 | 0.969 | 0.939 | 1.001 |
| 5 | 0.968 | 0.937 | 0.999 |
| 6 | 0.978 | 0.948 | 1.010 |
| 7 | 0.986 | 0.955 | 1.018 |
| 8 | 1.016 | 0.984 | 1.048 |
| 9 | 0.979 | 0.948 | 1.011 |
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|  |  |  |  |
| Association between exposure to 2+ lightning strikes and HIGH (75% any pollen). Crude (adjusted for day of week, and 8 knot natural cubic splines). Up to 3 missing days estimated. | | | |
| lag | RR | 95% CI low | 95% CI high |
| 0 | 1.060 | 1.028 | 1.093 |
| 1 | 1.006 | 0.975 | 1.038 |
| 2 | 0.996 | 0.965 | 1.029 |
| 3 | 0.967 | 0.936 | 0.998 |
| 4 | 0.964 | 0.934 | 0.996 |
| 5 | 0.966 | 0.935 | 0.997 |
| 6 | 0.975 | 0.944 | 1.006 |
|  |  |  |  |
| Association between exposure to 2+ lightning strikes and HIGH (75% any pollen). Adjusted for precipitation, wind, humidity, temperature, day of week, and 8 knot natural cubic splines. Up to 3 missing days estimated | | | |
| lag | RR | 95% CI low | 95% CI high |
| 0 | 1.049 | 1.014 | 1.085 |
| 1 | 1.004 | 0.973 | 1.037 |
| 2 | 0.997 | 0.966 | 1.029 |
| 3 | 0.968 | 0.937 | 0.999 |
| 4 | 0.968 | 0.937 | 1.000 |
| 5 | 0.967 | 0.936 | 0.998 |
| 6 | 0.978 | 0.947 | 1.009 |
|  |  |  |  |
| Effect of covariates at day zero, adjusted for effect of 2+ lightning strikes in presence of HIGH pollen. Up to 3 missing days estimated. | | | |
| lag | RR | 95% CI low | 95% CI high |
| ozone | 0.994 | 0.985 | 1.002 |
| precip\_mm | 1.000 | 0.999 | 1.001 |
| wind\_mph | 1.002 | 1.000 | 1.003 |
| pm25 | 1.002 | 1.000 | 1.004 |
| tmaxc | 1.002 | 1.000 | 1.004 |
| relh | 1.000 | 0.999 | 1.000 |
|  |  |  |  |
|  |  |  |  |
| Association between Pollen HIGH (> 75th percentile), and lightning <2. | | | |
| lag | RR | 95% CI low | 95% CI high |
| -1 | 0.996 | 0.978 | 1.013 |
| 0 | 0.985 | 0.967 | 1.002 |
| 1 | 1.008 | 0.990 | 1.026 |
| 2 | 1.000 | 0.983 | 1.017 |
|  |  |  |  |
| Association between 2+ lightning & low pollen (< 25th percentile), full model. | | | |
| lag | RR | 95% CI low | 95% CI high |
| -1 | 0.999 | 0.951 | 1.050 |
| 0 | 0.987 | 0.937 | 1.040 |
| 1 | 1.000 | 0.950 | 1.053 |
| 2 | 1.029 | 0.979 | 1.082 |
|  |  |  |  |
| Missing only 3 or more days (estimated weekends) | | | |
| lag | RR | 95% CI low | 95% CI high |
| 0 | 1.047 | 1.012 | 1.083 |
| 1 | 1.007 | 0.975 | 1.040 |
| 2 | 0.994 | 0.963 | 1.027 |
|  |  |  |  |
|  |  |  |  |
| All missing days excluded: | |  |  |
| lag | RR | 95% CI low | 95% CI high |
| 0 | 1.049 | 1.013 | 1.087 |
| 1 | 1.010 | 0.976 | 1.044 |
| 2 | 1.002 | 0.968 | 1.036 |



eFigure 1: Change in risk of emergency department visits covariates, ozone (10 parts per billion), precipitation (mm), wind (mph) PM2.5 (microns per cubic meter), temperature (°C), and relative humidity (percent), adjusted for thunderstorm with high pollen, day of week, and seasonal cubic splines.

eResults 1:

Following is the description of the results as shown in eFigure 1.

After adjustment for our main exposure of 2 or more lightning strikes in a zip code with high pollen, day of week, and seasonal cubic splines, we find positive associations for wind, PM2.5, and temperature (eFigure 1). Each 1 mph increase in daily max wind is associated with slightly higher risk of ED visit (RR 1.002; 95% CI 1.000, 1.003). A 1-degree increase of daily maximum temperature in °C is associated with 1.002 times higher risk of ED visit (95% CI 1.000,1.004) and shows little heterogeneity. Each 1 microgram increase per cubic meter of PM2.5 is associated with 1.02 times higher risk of ED visit (95% CI 1.000,1.004).

There is no observed association for each 10 ppb increase in ozone on day of emergency department visit (RR 0.994; 95% CI 0.985, 1.002). There is no change in ED risk for each 1 mm change in precipitation on day of admission (RR 1.000; 95% CI 0.999,1.001). And higher daily max humidity does not show a noticeable association with risk of ED visit (RR 1.000, 95% CI 0.999, 1.000).

eTable 2: Relative risk of severe asthma from adjusted models with a covariate included for thunderstorm and pollen but no main effects (Model 1) and an adjusted model with main effects and an interaction term (Model 2). All results adjusted for, ozone (10 parts per billion), precipitation (mm), wind (mph) PM2.5 (μg/m3), temperature (°C), relative humidity.

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| Annual degrees of freedom | Exposure | Model 1: Combined Study area, both lightning + pollen vs all other | Model 2: 2 stage meta-analysis of 109 zip codes, both lightning+ pollen vs all other | Model 3: Main effects and interaction RR (95% CI) | Relative Risk Ratio of exposed to lightning and Pollen vs Neither RR (95% CI) |
| 7 | Lightning |  |  | 1.018 (0.984, 1.052) | 1.057 (1.020, 1.095) |
|  | Pollen |  |  | 0.992 (0.973, 1.012) |  |
|  | Lightning\*Pollen | 1.057 (1.022, 1.094) | 1.051 (1.022,1.0181) | 1.047 (1.002, 1.093) |  |
|  |  |  |  |  |  |
| 8 | Lightning |  |  | 1.026 (0.992, 1.060) | 1.050 (1.013, 1.089) |
|  | Pollen |  |  | 0.994 (0.975, 1.014) |  |
|  | Lightning\*Pollen | 1.047 (1.012, 1.083) | 1.043 (1.014,1.072) | 1.030 (0.987, 1.074) |  |
|  |  |  |  |  |  |
| 9 | Lightning |  |  | 1.025 (0.992, 1.059) | 1.060 (1.022, 1.098) |
|  | Pollen |  |  | 0.996 (0.977, 1.015) |  |
|  | Lightning\*Pollen | 1.056 (1.021, 1.091) | 1.049 (1.020,1.079) | 1.038 (0.995, 1.083) |  |

Chart

Description automatically generated

Efigure 2: Change in risk of emergency department visits for lags of -6 days to +9 days. Day 0 is highlighted. All results adjusted for, ozone (10 parts per billion), precipitation (mm), wind (mph) PM2.5 (μg/m3), temperature (°C), relative humidity (percent), day of week and seasonal cubic splines.