How Modeled PM 2.5 Values Correlate with Asthma Inpatient Hospitalization in the Baltimore Area? A Time-Stratified Bidirectional Case-Crossover Study

Katherine C Lin, BS[1,2,*]

[1] 1st Year MHS Student, Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland 21205, USA
[2] PHASE Intern, Environmental Public Health Tracking Program, Maryland Department of Health and Mental Hygiene, Baltimore, MD 21201, USA
* E-mail: klin@jhsph.edu

Abstract

Context: Association between fine particular matter (air pollution particle with aerodynamic diameter less than 2.5 μm, PM 2.5) exposure and inpatient asthma cases was evaluated in Maryland counties within the Baltimore study area. Modeled PM 2.5 values were unevenly allocated to sparse PM 2.5 monitors. Results between modeled PM 2.5 values and inpatient hospitalization asthma data permitted circumventing the air hazard-asthma data mismatch, thereby making it possible to determine the contribution of this EPA criterion air pollutant on a prevalent respiratory disease in Baltimore City and surrounding counties.

Objective: To estimate health risk change in asthma inpatient hospitalization visits to changes in short-term ambient modeled PM 2.5 exposure.

Design, Setting, and Patients: A time-stratified bidirectional case-crossover study design and conditional logistic regression ware used to analyze 2002 asthma inpatient hospitalizations in Baltimore City and five adjacent counties. A total of 4,073 cases from 35 hospitals were available for analysis. Daily time-series also used daily data for modeled PM 2.5, temperature, and relative humidity in 12 square-kilometer grids.

Main Outcome Measures: Comparisons of aggregated daily hospital admission totals for asthma, stratified on age (≤ 5, 6-15, 16-45, 46-55, ≥ 56), gender (male and female), race (White, Black, and Other), socioeconomic status (private health insurance status used as proxy) and season (winter, spring, summer, and autumn) were carried out using different logistic regression models

Results: Asthma patients included more Blacks than Whites or persons of other races. However, Whites had higher asthma prevalence. There were age effects of more males than females only for asthma patients <15 years of age. Variability in PM 2.5 concentration was greater between than within seasons. Higher PM 2.5 readings were also obtained along I-95 corridor. Major findings for lag days based on 128 models are also summarized.

Conclusions: This is possibly the first study to evaluate the contribution of modeled PM 2.5 to asthma inpatient hospitalizations in a densely populated urban area in the Eastern United States, besides those previously reported for Boston and Philadelphia.

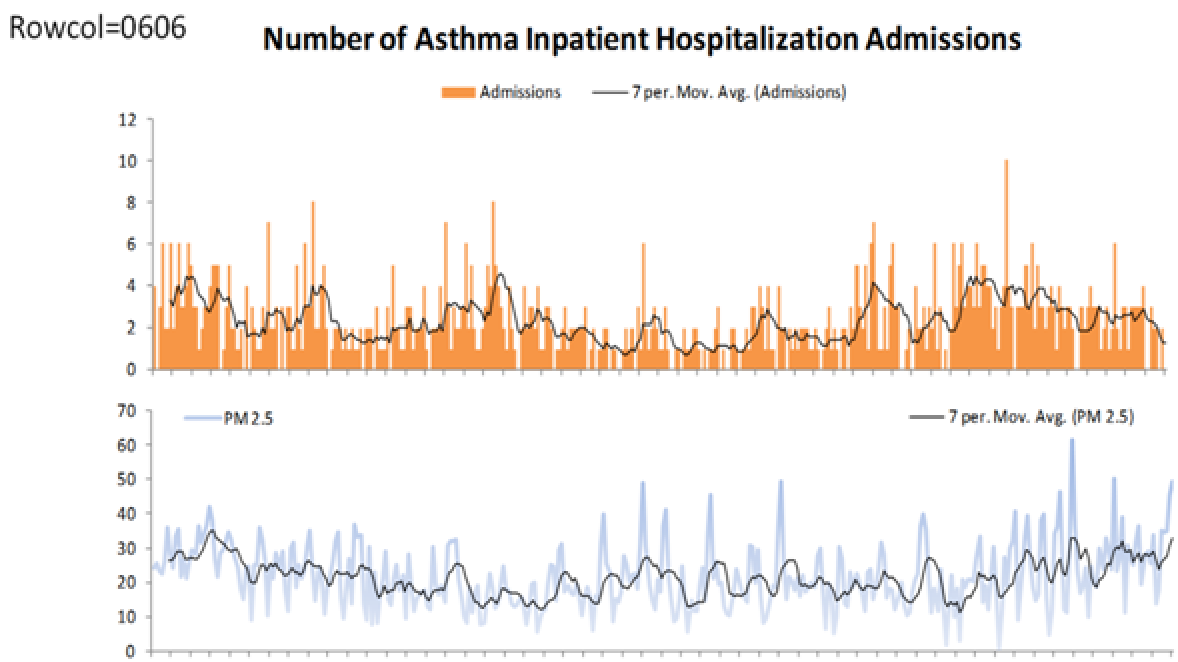
Introduction

- Asthma is more prevalent among children younger than 18 years old and non-Hispanic Black children. A secular trend of increasing asthma prevalence among children has been documented.[1]
- The reported associations between asthma and social economic classes are not consistent. Nevertheless, there is an inverse association between asthma severity and social economic status (SES).[2]
- Children with asthma are more sensitive to air pollution concentrations, which include fine particular matter with aerodynamic diameter less than 2.5 μm, PM 2.5.[3]

1. MMWR Morb Mortal Wkly Rep. 2000 Oct 13;49(40):908-11.
2. Int J Epidemiol. 1996 Apr;25(2):388-93.
3. JAMA. 2003 Oct 8;290(14):1859-67.

Research Question

By how much did the number of asthma inpatient hospitalizations vary spatially within the Baltimore study area* and temporally in 2002 due to different modeled PM 2.5 concentrations?



* Baltimore area:
  - Baltimore City
  - Baltimore County
  - Anne Arundel County
  - Howard County
  - Carroll County
  - Harford County

Study Population

The 4,073 de-identified asthma inpatient admissions were from 35 Maryland hospitals. These data came from the 2002 Maryland Health Services Cost Review Commission (HSCRC) confidential research file. Asthma had a primary ICD-9-CM code of 493.

This study used a time-stratified, bidirectional case-crossover study design to eliminate demographic confounders caused by non using controls for asthma patients.[4,5,6] Three referents were used for each asthma case. Time trends were also evaluated. A 28 day washout period was used to exclude same patients with repeated inpatient admissions. Aggregated data were analyzed using conditional logistical regression.

4. Stat Med. 2005 Jan 30;24(2):285-300. 5. Epidemiology. 1999 Sep;10(5):539-44. 6. Am J Epidemiol. 1991 Jan 15;133(2):144-53.

Measurements

Air Quality and Meteorology Data Assessment

PM 2.5 values were modeled in 12-km^2 grids. The U.S. Environmental Protection Agency Community Multiscale Air Quality (CMAQ) model was used to produce modeled PM 2.5 values for the Baltimore study area.

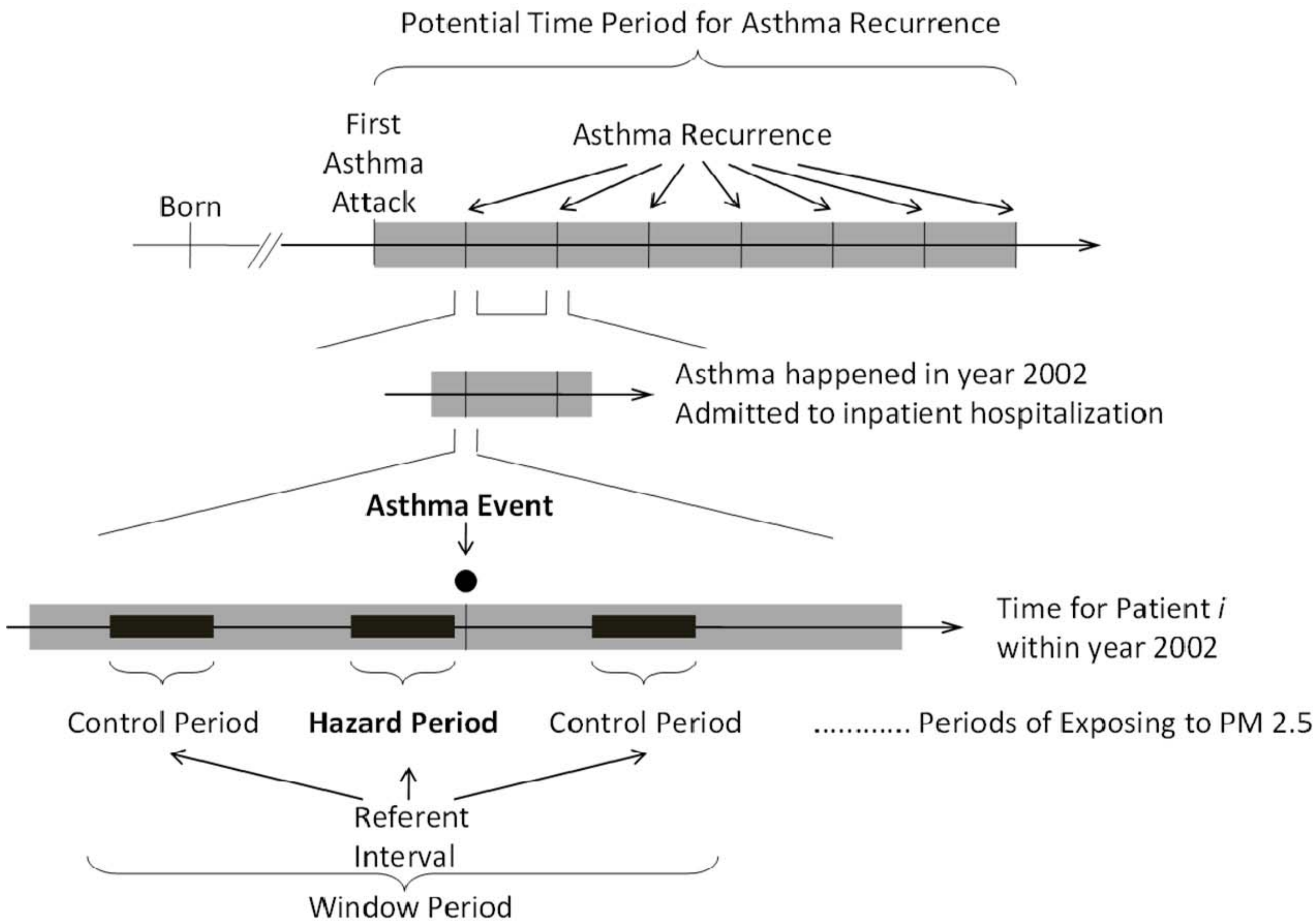
Linked Files

The inpatient hospitalization asthma cases were linked to modeled PM 2.5 values on day of exposure. Spatial linkage was based on the closest distance between population-weighted five-digit residential zip codes (where asthma cases were located) and centroids of the modeled PM 2.5 12 square kilometer grids.

Analysis

- Case-crossover analyses provided a case-only method to investigate the short-term effects of modeled PM 2.5 on asthma. Each asthma case served as his or her own control in the exposure window period. Three control days were selected for each asthma patient in the referent interval of 7 days and exposure window of 28 days.
- Lag days were used to quantify the contribution of prior modeled PM 2.5 concentration on subsequent asthma inpatient admission.
- Each model was evaluated using the Akaike Information Criterion (AIC) goodness of fit test.
- Data analyses were accomplished by using PC SAS version 9.3, Case-Crossover Analytic Tool (C-CAT) software and ESRI ArcGIS version 9.

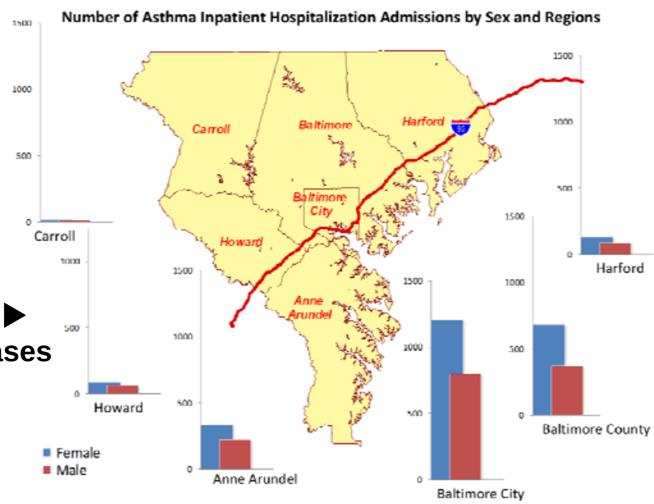
Case-Crossover Study Design



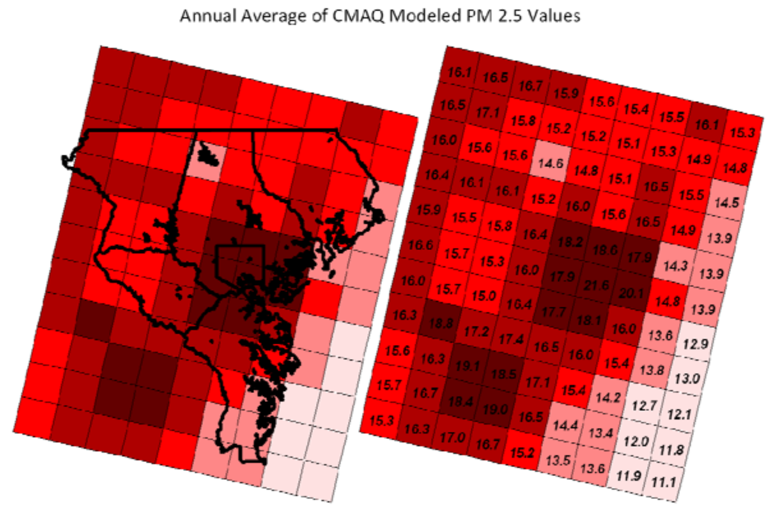
Characteristics of study population

		MALE (N=1583)		FEMALE (N=2490)		TOTAL Cases (N=4073)		TOTAL Population (N=2,512,431)	Prevalance per 10,000 people
		N	%	N	%	N	%	N	
AREA									
	Anne Arundel	224	5.50	341	8.37	565	13.87	489656	12
	Balt City	802	19.69	1211	29.73	2013	49.42	651154	31
	Baltimore	377	9.26	689	16.92	1066	26.17	754292	14
	Carroll	22	0.54	28	0.69	50	1.23	150897	3
	Harford	90	2.21	132	3.24	222	5.45	218590	10
	Howard	68	1.67	89	2.19	157	3.85	247842	6
RACE									
	Black	997	24.48	1446	35.50	2443	59.98	1683195	15
	White	550	13.50	1004	24.65	1554	38.15	696402	22
	Other	32	0.79	40	0.98	72	1.77	132834	5
	Unknown	4	0.10	0	0.00	4	0.10		
AGE (Years old)									
	0-5	491	12.05	291	7.14	782	19.20		
	6-15	324	7.95	206	5.06	530	13.01		
	16-45	418	10.26	903	22.17	1321	32.43		
	46-55	151	3.71	473	11.61	624	15.32		
	56+	199	4.89	617	15.15	816	20.03		
PRIVATE HEALTH INSURANCE STATUS									
	No	1408	34.57	1993	48.93	3401	83.50		
	Yes	175	4.30	497	12.20	672	16.50		

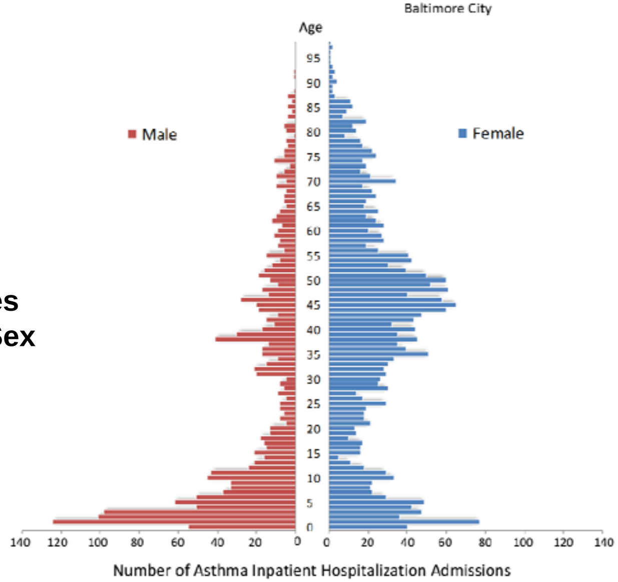
Characteristics of study population and PM 2.5



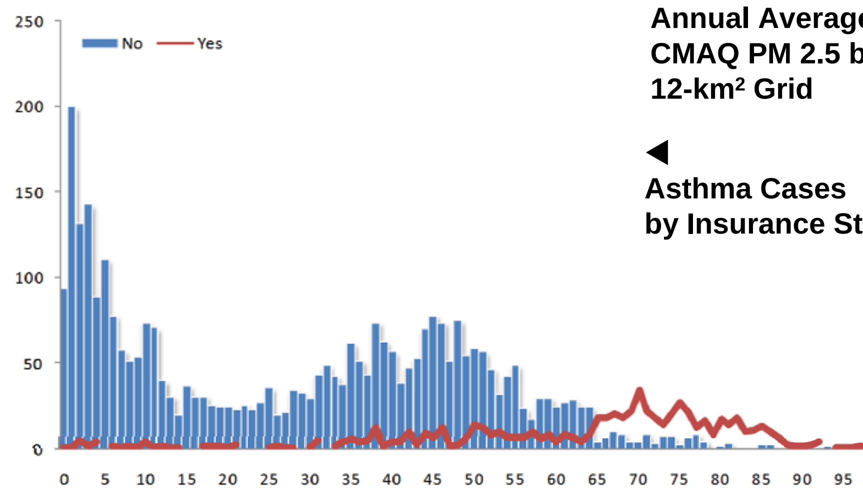
Asthma Cases by Region



Annual Average of CMAQ PM 2.5 by 12-km² Grid

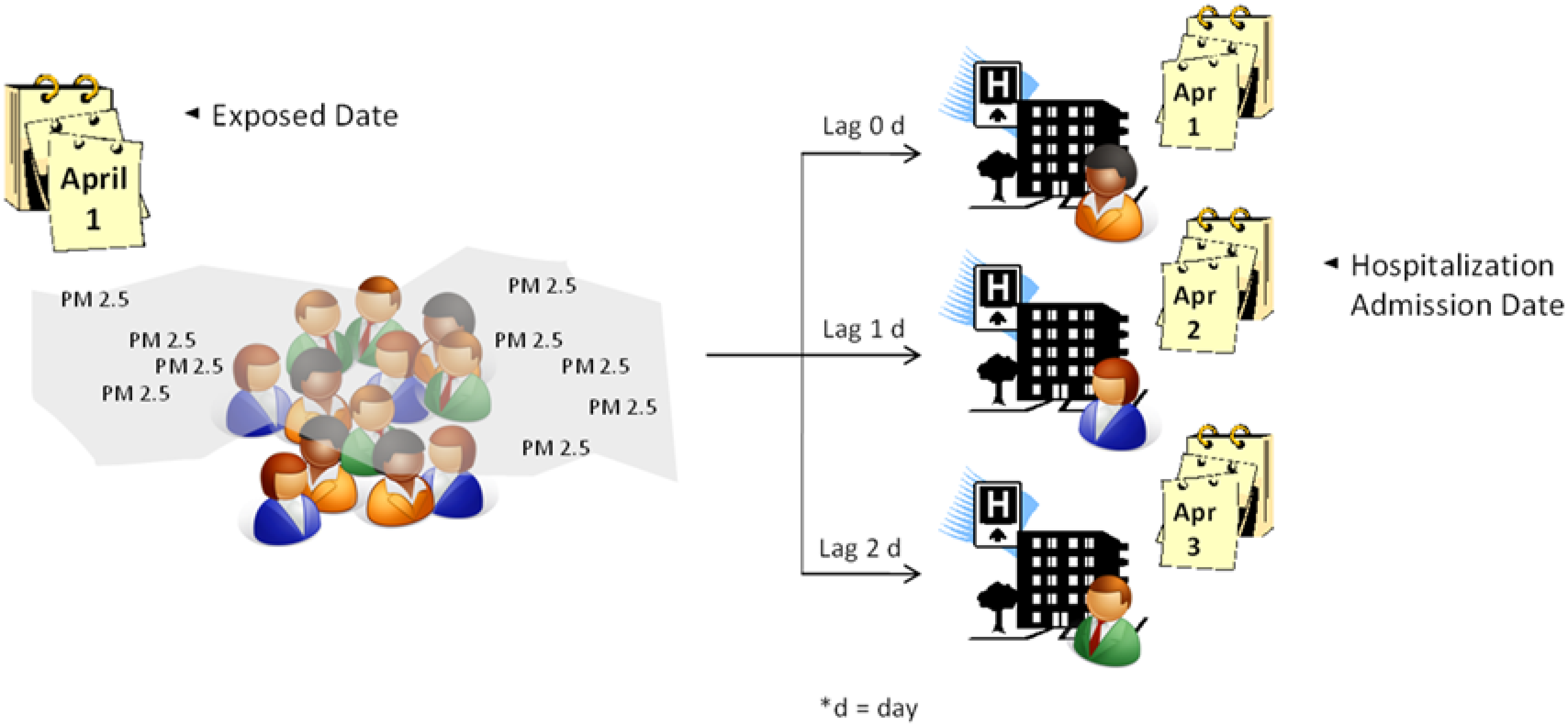


Asthma Cases by Age and Sex

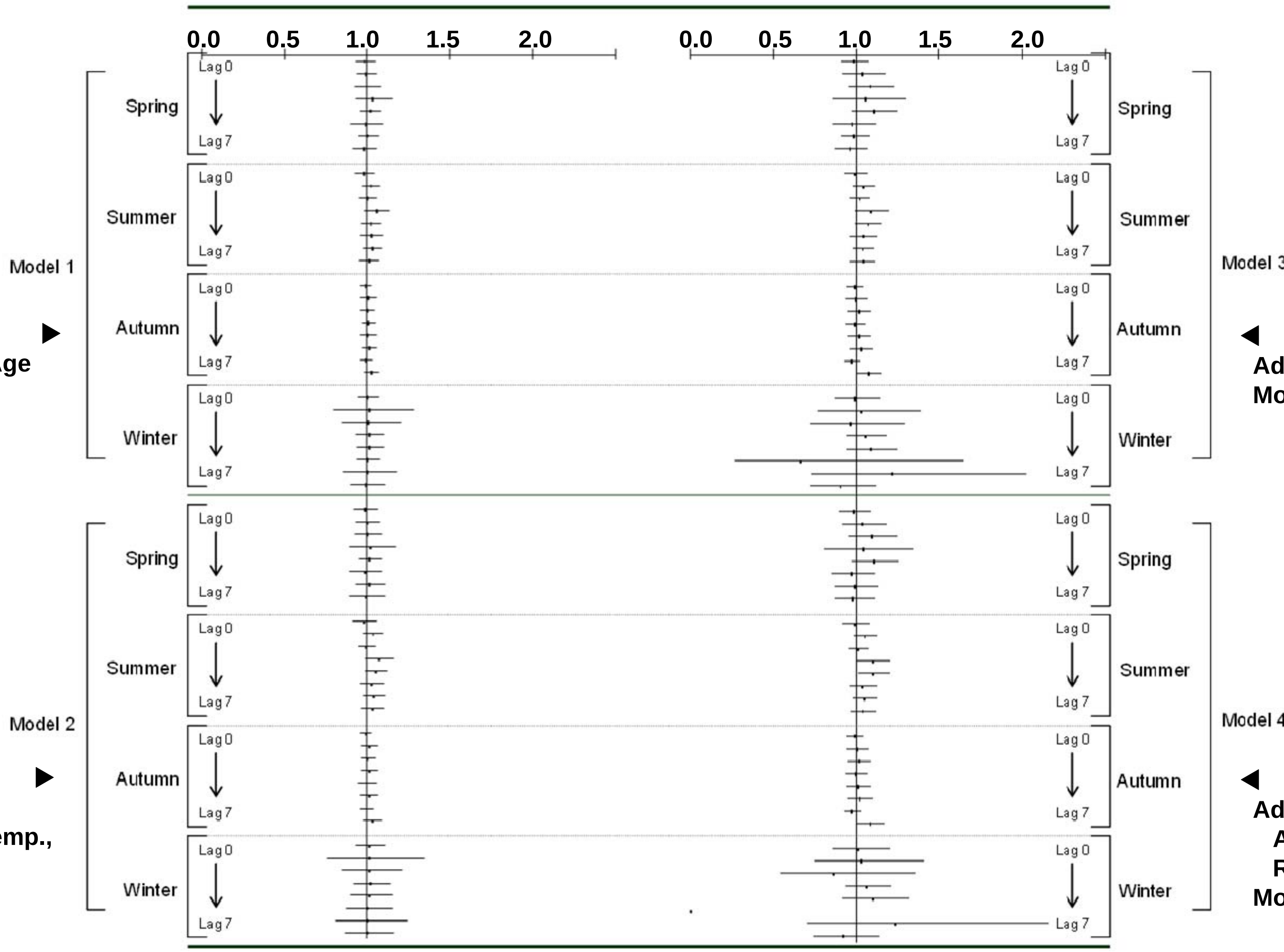


Asthma Cases by Insurance Status

Concept of Lag Days



Hazard Ratios



Adjust: Age

Adjust: Age, Temp., R.H.*

Adjust: Age
Modify: Sex

Adjust: Age, Temp., R.H.*
Modify: Sex

* Temp. = Temperature ; R.H. = Relative Humidity

Limitations

Potential misclassification

PM 2.5 readings were modeled based on 12-km grids. We assumed that all cases within the same zip code had the same modeled PM 2.5, temperature, and relative humidity environmental exposure values.

Use of longer lag days

This study only used one outcome measure for asthma inpatient hospitalizations. Emergency Department (ED) asthma visits are available, but were not used. ED asthma visits may be more sensitive to modeled PM 2.5 effects than inpatient hospitalizations because in Maryland, most ED asthma visits result in inpatient hospitalizations.

Other, more complex, lag day relationships

It is possible that there could be an underlying cumulative lag day relationship (eg. lag 0 + lag 1 + lag 2) between PM 2.5 exposure and asthma incidence, instead of a single lag day relationship.

Variability in CMAQ grids (i.e. aggregated versus individual PM 2.5 readings/cases)

Ecological data analysis designs, such as the case-crossover data analysis procedure, have been shown to produce different results, in some cases, than other analytical methods which utilize data from individual patients, with patient-specific PM 2.5 measures.

Conclusions

This study analyzed the association between modeled PM 2.5 and asthma inpatient hospitalizations by using a large sample size with daily/hourly modeled PM 2.5 readings. Use of modeled PM 2.5 values circumvented limitations of using monitor only data and excluding many asthma patients who did not live close enough to a monitor. Preliminary results for the contribution of modeled PM 2.5 effects on inpatient asthma hospitalizations--using different lag days--provided a starting point to generate different testable hypotheses about the PM 2.5 concentration-asthma hospitalization relationship.

Acknowledgement

Maryland Department of Health and Mental Hygiene

Dr Clifford S Mitchell, Dr John T Braggio, Rashid Malik, Jennifer English

Johns Hopkins University

Dr Michel Ibrahim, Dipti Shah, Dr Derek Cummings