Association of Short-term Exposure to Air Pollution With Mortality in Older Adults

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Background

- US National Ambient Air Quality Standards (NAAQS) for fine particulate matter ($PM_{2.5}$) and ozone every are reviewed every 5 years.
- 2012 annual and 24-hour NAQQS for $PM_{2.5}$ is 35 μg/m^3 and 12 μg/m^3.
- 2012 8-hour NAQQS for ozone is 70 ppb, no annual standard
- Studies in large metropolitan areas have provided evidence for short-term exposure to $PM_{2.5}$ and ozone were associated with mortality.

Aim and Objectives

- Aim to study the effect of short-term exposure below daily NAQQS, and in rural and unmonitored areas.
- Aim to study the effect on sensitive subgoups such as those with low socio-economic status.

Data source and participants

- Participants: all deaths among all Medicare benficiaries from 2000 to 2012.
- Outcome: all-cause mortality. Individuals with validated date of death between January 1, 2020 and December 31, 2012 were included.
- Exposure: daily 24-hour $PM_{2.5}$, 8-hour maximum ozone, and daily air and dew point temperatures. Monitored data from the EPA, satellite-based measurements, and other data sets. Neural networks were used to predict 24-hour PM2.5 and 8-hour maximum ozone concentrations.
- Warm season: April 1 to September 30, which is the specific time window to examine the association between ozone and mortality

Case-cross over design

- Usage: the design has been widely used to study the association between c short-term air pollution exposure and the risk of an acute adverse health event.
- Main idea: for each individual case, exposure just before the event is compared with exposure at other control ("referent") times.
- Statistical method: Conditional logistic regression.

In this study
- Case day: date of the death. - Control days: on the same day of the week as the case day to control for potential confounding effect by day of week; before and after the case day to control for time trend; only in the same month as the case day to control for seasonal and subseasonal. - Time window: the death day and the day before death.

Statistical analysis

- Regression model included both pollutants as main effects and natural splines of air and dew point temperatures with 3 df to control for residual confounding by weather.
- Relative risk increase (RRI) was defined as RR $-$ 1.
- The absolute risk difference (ARD) of all-cause mortality associated with air pollution was defined as $\alpha \times (RR - 1)/RR$, where α denotes the baseline daily mortality rate.

Baseline characteristics

Table 1. Baseline Characteristics of Study Population (2000-2012)

Baseline Characteristic	Value
Case days, No.	22 433 862
Control days, No.	76 143 209
Among All Cases (n = 22 433 862), %	
Age at death, y	
≤69	10.38
70-74	13.37
75-84	38.48
≥85	37.78
Sex	
Male	44.73
Female	55.27
Race/ethnicity	
White	87.34
Black	8.87
Asian	1.03
Hispanic	1.51
Native American	0.31
Medicaid Eligibility (n = 22 433 862), %	
Ineligible	77.36
Eligible	22.64

Figure 1: Baseline Characteristics of Study Population (2000-2012)

$PM_{2.5}$ times series

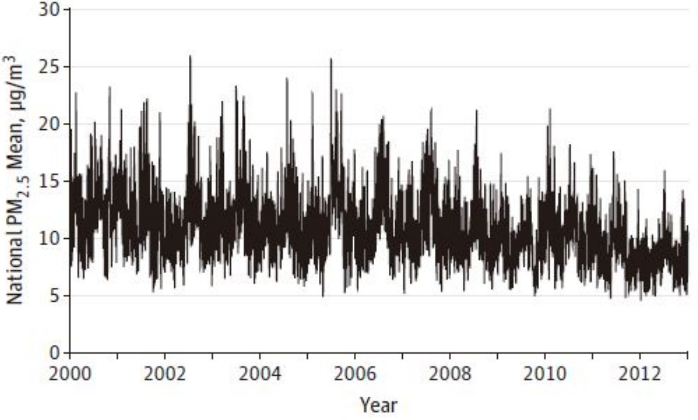


Figure 2: Daily mean fine particulate matter $PM_{2.5}$ concentrations

Ozone time series

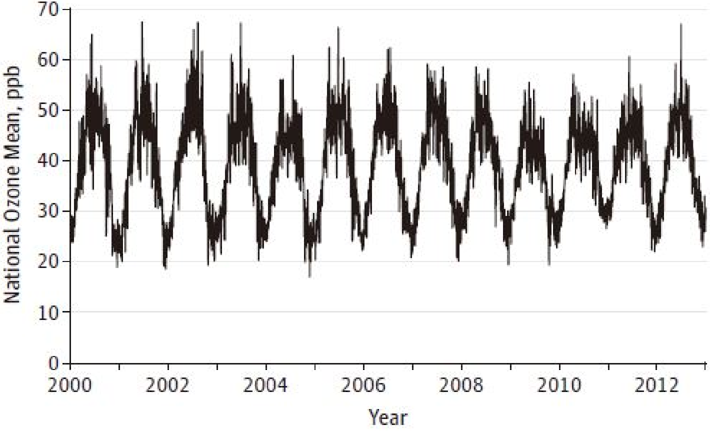


Figure 3: Daily mean 8-hour maximum ozone concentrations

Regression result

Table 2. Relative Risk Increase and Absolute Risk Difference of Daily Mortality Associated With Each 10-μg/m^3 Increase in $PM_{2.5}$ and Each 10-ppb Increase in Ozone

Air Pollutant Analysis	Relative Risk Increase, % (95% CI)		Absolute Risk Difference in Daily Mortality Rates, No. per 1 Million Persons at Risk per Day (95% CI)[a]	
	$PM_{2.5}$	Ozone[b]	$PM_{2.5}$	Ozone[b]
Main analysis[c]	1.05 (0.95-1.15)	0.51 (0.41-0.61)	1.42 (1.29-1.56)	0.66 (0.53-0.78)
Low-exposure analysis[d]	1.61 (1.48-1.74)	0.58 (0.46-0.70)	2.17 (2.00-2.34)	0.74 (0.59-0.90)
Single-pollutant analysis[e]	1.18 (1.09-1.28)	0.55 (0.48-0.62)	1.61 (1.48-1.73)	0.71 (0.62-0.79)
Nearest monitors analysis[f]	0.83 (0.73-0.93)	0.35 (0.28-0.41)	1.13 (0.99-1.26)	0.45 (0.37-0.53)

Abbreviations: $PM_{2.5}$, fine particulate matter; ppb, parts per billion.

[a] The daily baseline mortality rate was 137.33 per 1 million persons at risk per day; the warm-season daily baseline mortality rate was 129.44 per 1 million persons at risk per day.

[b] Ozone analyses included days from the warm season only (April 1 to September 30).

[c] The main analysis used the mean of daily exposure on the same day of death and 1 day prior (lag 01-day) as the exposure metric for both $PM_{2.5}$ and ozone, and controlled for natural splines of air and dew point temperatures with 3 *df*. The main analysis considered the 2 pollutants jointly included into the regression model and estimated the percentage increase in the daily mortality rate associated with a 10-μg/m^3 increase in $PM_{2.5}$ exposure adjusted for ozone and the percentage increase in daily mortality rate associated with a 10-ppb increase in warm-season ozone exposure adjusted for $PM_{2.5}$.

[d] The low-exposure analysis had the same model specifications as the 2-pollutant analysis and was constrained for days when $PM_{2.5}$ was below 25 μg/m^3 or ozone below 60 ppb.

[e] The single-pollutant analysis estimated the percentage increase in the daily mortality rate associated with a 10-μg/m^3 increase in $PM_{2.5}$ exposure without adjusting for ozone and the percentage increase in the daily mortality rate associated with a 10-ppb increase in ozone exposure without adjusting for $PM_{2.5}$.

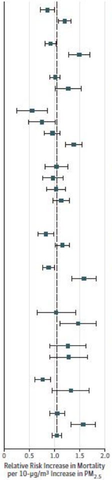
[f] $PM_{2.5}$ and ozone monitoring data were retrieved from the US Environmental Protection Agency Air Quality System, which provides the daily mean of $PM_{2.5}$ and daily 8-hour maximum ozone levels at each monitoring site. Daily ozone concentrations were averaged from April 1 to September 30. Individuals were assigned to the $PM_{2.5}$ and ozone levels from the nearest monitor site within 50 km. Those living 50 km from any monitoring site were excluded.

Figure 4:

Subgroup analysis

Figure 3. Relative Risk Increase and Absolute Risk Difference of Daily Mortality Associated With 10-µg/m³ Increase in Fine Particulate Matter ($PM_{2.5}$)

Model	Relative Risk Increase in Mortality per 10-µg/m³ Increase in $PM_{2.5}$, % (95% CI)	P Value for Effect Modification	Absolute Risk Difference in Mortality, No. per 1 Million at Risk per Day (95% CI)	P Value for Effect Modification
Sex				
Male	0.86 (0.72-1.00)	[Reference]	1.24 (1.03-1.45)	[Reference]
Female	1.20 (1.07-1.33)	<.001[a]	1.56 (1.39-1.72)	.02[a]
Medicaid eligibility				
Noneligible	0.92 (0.81-1.03)	[Reference]	1.11 (0.98-1.24)	[Reference]
Eligible	1.49 (1.29-1.70)	<.001[a]	3.59 (3.11-4.08)	<.001[a]
Race/ethnicity				
White	1.01 (0.91-1.12)	[Reference]	1.38 (1.24-1.52)	[Reference]
Nonwhite	1.27 (1.01-1.53)	.07	1.69 (1.34-2.03)	.11
Age, y				
≤69	0.55 (0.25-0.86)	[Reference]	0.27 (0.12-0.42)	[Reference]
70-74	0.75 (0.48-1.01)	.35	0.57 (0.37-0.78)	.02[a]
75-84	0.96 (0.80-1.11)	.02[a]	1.46 (1.23-1.69)	<.001[a]
≥85	1.38 (1.23-1.54)	<.001[a]	5.35 (4.75-5.95)	<.001[a]
Population density				
Low	1.04 (0.81-1.27)	[Reference]	1.43 (1.12-1.74)	[Reference]
Medium low	0.97 (0.76-1.17)	.64	1.31 (1.04-1.58)	.56
Medium high	1.03 (0.84-1.22)	.95	1.39 (1.14-1.65)	.86
High	1.13 (0.97-1.30)	.52	1.54 (1.31-1.77)	.57
Whites				
Sex				
Male	0.83 (0.67-0.99)	[Reference]	1.19 (0.97-1.42)	[Reference]
Female	1.16 (1.02-1.30)	.002[a]	1.51 (1.33-1.70)	.03[a]
Medicaid eligibility				
Noneligible	0.88 (0.77-1.00)	[Reference]	1.07 (0.93-1.21)	[Reference]
Eligible	1.58 (1.34-1.83)	<.001[a]	4.49 (3.81-5.17)	<.001[a]
Nonwhites				
Sex				
Male	1.03 (0.65-1.42)	[Reference]	1.52 (0.96-2.08)	[Reference]
Female	1.47 (1.12-1.82)	.01	1.80 (1.37-2.22)	.44
Medicaid eligibility				
Noneligible	1.26 (0.91-1.62)	[Reference]	1.40 (1.01-1.79)	[Reference]
Eligible	1.28 (0.90-1.66)	.94	2.21 (1.56-2.85)	.04[a]
Medicaid eligibility, males				
Noneligible	0.77 (0.61-0.93)	[Reference]	1.03 (0.82-1.24)	[Reference]
Eligible	1.32 (0.96-1.69)	.006	3.37 (2.45-4.28)	<.001[a]
Medicaid eligibility, females				
Noneligible	1.06 (0.90-1.21)	[Reference]	1.17 (1.00-1.33)	[Reference]
Eligible	1.57 (1.32-1.82)	<.001[a]	3.69 (3.12-4.26)	<.001[a]
Overall	1.05 (0.95-1.15)		1.42 (1.29-1.56)	



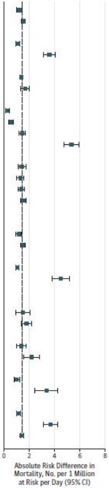


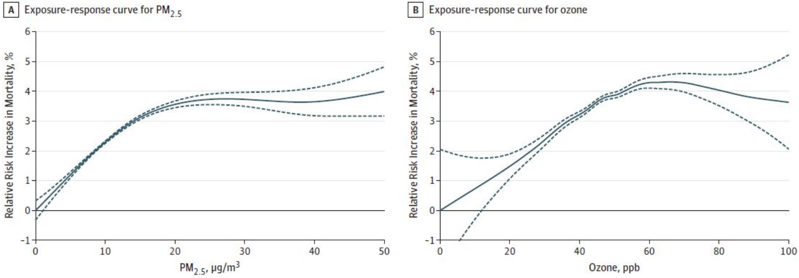
Figure 5: Subgroup analysis of $PM_{2.5}$

p-value

two sample test $Z = \frac{RR_{male} - RR_{female}}{\sqrt{(se(RR_{male})^2 - se(RR_{female})^2)}}$

Dose-response

Figure 5. Estimated Exposure-Response Curves for Short-term Exposures to Fine Particulate Matter ($PM_{2.5}$) and Ozone



A 2-pollutant analysis with separate penalized splines on $PM_{2.5}$ (A) and ozone (B) was conducted to assess the percentage increase in daily mortality at various pollution levels. Dashed lines indicate 95% CIs. The mean of daily exposure on the same day of death and 1 day prior (lag 01-day) was used as metrics of exposure to $PM_{2.5}$ and ozone. Analysis for ozone was restricted to the warm season (April to September). Ppb indicates parts per billion.

Figure 6: Estimated Exposure-Response Curves for Short-term Exposures to Fine Particulate Matter ($PM_{2.5}$) and Ozone

Conclusions

In the US Medicare population from 2000 to 2012, short-term exposures to $PM_{2.5}$ and warm-season ozone were significantly associated with increased risk of mortality. This risk occurred at levels below current national air quality standards, suggesting that these standards may need to be reevaluated.

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