Associations between Coarse Particulate Matter Air Pollution and Cause-Specific Mortality: A Nationwide Analysis in 272 Chinese Cities

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Abbreviations: PM, particulate matter; $df$, degree of freedom.
Table S1. Percentage difference (posterior mean and 95% posterior intervals) in daily mortality per 10 μg/m$^3$ increase in 2-day moving average PM$_{2.5-10}$ concentrations in 272 Chinese cities, classified by regions and causes.

| Mortality | Nationwide (N=272) | North (N=112) | South (N=160) | p-value |
|-----------|---------------------|---------------|---------------|---------|
|           | Mean    | 95% PIs       | Mean    | 95% PIs       | Mean    | 95% PIs       |         |
| Total     | 0.23    | 0.13, 0.33    | 0.05    | -0.05, 0.14   | 0.55    | 0.35, 0.75    | <0.01   |
| CVD       | 0.25    | 0.13, 0.37    | 0.13    | 0.00, 0.25    | 0.55    | 0.26, 0.83    | 0.02    |
| CHD       | 0.21    | 0.05, 0.36    | 0.12    | -0.05, 0.30   | 0.43    | 0.11, 0.75    | 0.24    |
| Stroke    | 0.21    | 0.08, 0.35    | 0.12    | -0.04, 0.28   | 0.44    | 0.14, 0.74    | 0.08    |
| RD        | 0.26    | 0.07, 0.46    | 0.17    | -0.07, 0.42   | 0.41    | 0.09, 0.73    | 0.41    |
| COPD      | 0.34    | 0.12, 0.57    | 0.20    | -0.09, 0.49   | 0.56    | 0.20, 0.93    | 0.16    |

Note: Overdispersed generalized additive models were used to derive city-specific estimates adjusted for time trends, day of week, temperature, and humidity and Bayesian hierarchical models were used to pool the estimates. The p-value was derived by examining the difference of effect estimates between the north and south by virtue of meta-regression analysis. These data are also reported in Figure 2.

Abbreviations: PIs, posterior intervals; PM$_{2.5-10}$, particulate matter with an aerodynamic diameter between 2.5 and 10μm; CVD, cardiovascular diseases; CHD, coronary heart diseases; RD, respiratory diseases; COPD, chronic obstructive pulmonary disease.
Table S2. Percentage difference (posterior mean and 95% posterior intervals) in daily mortality per city-specific interquartile range increase in 2-day moving average PM$_{2.5-10}$ concentrations in 272 Chinese cities, classified by regions and causes.

| Mortality | Nationwide | | North | | South | | p-value |
|-----------|------------|---|---|---|---|---|---|
|           | Mean | 95% PIs | Mean | 95% PIs | Mean | 95% PIs |  |
| Total     | 0.66 | 0.39, 0.94 | 0.24 | -0.07, 0.55 | 0.97 | 0.55, 1.38 | 0.01 |
| CVD       | 0.76 | 0.39, 1.13 | 0.31 | -0.12, 0.74 | 1.10 | 0.53, 1.67 | 0.04 |
| CHD       | 0.78 | 0.29, 1.27 | 0.49 | -0.13, 1.11 | 1.07 | 0.29, 1.84 | 0.28 |
| Stroke    | 0.64 | 0.19, 1.08 | 0.12 | -0.37, 0.60 | 1.02 | 0.33, 1.71 | 0.07 |
| RD        | 0.69 | 0.18, 1.21 | 0.58 | -0.24, 1.38 | 0.76 | 0.09, 1.44 | 0.74 |
| COPD      | 0.82 | 0.25, 1.39 | 0.58 | -0.42, 1.59 | 0.94 | 0.26, 1.62 | 0.58 |

Note: Overdispersed generalized additive models were used to derive city-specific estimates adjusted for time trends, day of week, temperature and humidity and Bayesian hierarchical models were used to pool the estimates. $P$-values are derived by examining the difference of effect estimates between the north and south by virtue of meta-regression analysis.

Abbreviations: PM$_{2.5-10}$, particulate matter with an aerodynamic diameter between 2.5 and 10 μm; CVD, cardiovascular diseases; CHD, coronary heart diseases; RD, respiratory diseases; COPD, chronic obstructive pulmonary disease.
Table S3. The association of PM$_{2.5-10}$ and PM$_{2.5}$ with cause-specific mortality in single-pollutant and two-pollutant models in 272 Chinese cities.

| Mortality | PM$_{2.5-10}$ | | | PM$_{2.5}$ | | |
| --- | --- | --- | --- | --- | --- | --- |
| | Single-pollutant model | Adjusted for PM$_{2.5}$ | $p$-value | Single-pollutant model | Adjusted for PM$_{2.5}$ | $p$-value |
| Total | 0.23 (0.13, 0.33) | 0.16 (0.07, 0.25) | 0.23 | 0.22 (0.15, 0.28) | 0.13 (0.07, 0.19) | 0.20 |
| CVD | 0.25 (0.13, 0.37) | 0.14 (0.03, 0.25) | 0.23 | 0.27 (0.18, 0.36) | 0.20 (0.11, 0.28) | 0.28 |
| CHD | 0.21 (0.05, 0.36) | 0.16 (0.00, 0.32) | 0.37 | 0.30 (0.19, 0.40) | 0.17 (0.07, 0.27) | 0.27 |
| Stroke | 0.21 (0.08, 0.35) | 0.17 (0.02, 0.32) | 0.39 | 0.23 (0.13, 0.34) | 0.19 (0.05, 0.32) | 0.63 |
| RD | 0.26 (0.07, 0.46) | 0.23 (0.01, 0.44) | 0.50 | 0.29 (0.17, 0.42) | 0.27 (0.12, 0.42) | 0.87 |
| COPD | 0.34 (0.12, 0.57) | 0.25 (0.01, 0.50) | 0.35 | 0.38 (0.23, 0.53) | 0.33 (0.14, 0.53) | 0.85 |

Note: The associations were expressed as percentage difference (posterior mean and 95% posterior intervals) in daily mortality per 10 μg/m$^3$ increase in 2-day moving average concentrations, which were firstly estimated by overdispersed generalized additive models adjusted for time trends, day of week, temperature and humidity in each city and were pooled by Bayesian hierarchical models. The adjustment was performed by adding the second pollutant to the first-stage models. $p$-values were derived by examining statistical significance of the dichotomous co-pollutant variable in a meta-regression analysis with both single- and two-pollutant model estimates. These data are also reported in Figure 3.

Abbreviations: PM$_{2.5-10}$, particulate matter with an aerodynamic diameter between 2.5 and 10 μm; PM$_{2.5}$, particulate matter with an aerodynamic diameter ≤ 2.5 μm; CVD, cardiovascular diseases; CHD, coronary heart diseases; RD, respiratory diseases; COPD, chronic obstructive pulmonary disease.
Table S4. Percentage difference (posterior mean and 95% posterior intervals) in daily mortality per 10 μg/m³ increase in 2-day moving average PM$_{2.5-10}$ concentrations in single-pollutant and two-pollutant models with gaseous pollutants.

| Mortality | Single-pollutant model | Adjustment for SO$_2$ | Adjustment for NO$_2$ | Adjustment for CO | Adjustment for O$_3$ |
|-----------|-------------------------|-----------------------|-----------------------|--------------------|----------------------|
|           | Estimates               | p-value               | Estimates             | p-value            | Estimates             | p-value |
| Total     | 0.23 (0.13, 0.33)       | 0.13 (0.04, 0.22)     | 0.10 (0.02, 0.19)     | 0.04               | 0.22 (0.12, 0.32)     | 0.72     |
|           | 0.22 (0.11, 0.33)       | 0.96                  |                       |                    |                      |
| CVD       | 0.25 (0.13, 0.37)       | 0.08 (-0.02, 0.19)    | 0.14                  | 0.09 (-0.02, 0.20) | 0.08                 | 0.20 (0.09, 0.32)   | 0.67     |
|           | 0.26 (0.13, 0.39)       | 0.87                  |                       |                    |                      |
| CHD       | 0.21 (0.05, 0.36)       | 0.12 (-0.03, 0.28)    | 0.33                  | 0.11 (-0.04, 0.26) | 0.24                 | 0.17 (0.02, 0.32)   | 0.55     |
|           | 0.28 (0.08, 0.47)       | 0.79                  |                       |                    |                      |
| Stroke    | 0.21 (0.08, 0.35)       | 0.09 (-0.05, 0.22)    | 0.32                  | 0.10 (-0.04, 0.24) | 0.28                 | 0.16 (0.02, 0.30)   | 0.79     |
|           | 0.22 (0.05, 0.39)       | 0.81                  |                       |                    |                      |
| RD        | 0.26 (0.07, 0.46)       | 0.24 (0.03, 0.44)     | 0.48                  | 0.18 (-0.02, 0.38) | 0.19                 | 0.25 (0.04, 0.45)   | 0.81     |
|           | 0.25 (0.04, 0.46)       | 0.93                  |                       |                    |                      |
| COPD      | 0.34 (0.12, 0.57)       | 0.19 (-0.05, 0.42)    | 0.42                  | 0.02 (-0.21, 0.26) | 0.15                 | 0.25 (0.02, 0.49)   | 0.71     |
|           | 0.25 (0.01, 0.49)       | 0.99                  |                       |                    |                      |

Note: Overdispersed generalized additive models were used to derive city-specific estimates adjusted for time trends, day of week, temperature and humidity and Bayesian hierarchical models were used to pool the estimates. The adjustment was performed by adding the second pollutant to the first-stage models. $P$-values were derived by examining statistical significance of the dichotomous co-pollutant variable in a meta-regression analysis with both single- and two-pollutant model estimates. These data are also reported in Figure 4.

Abbreviations: PM$_{2.5-10}$, particulate matter with an aerodynamic diameter between 2.5 and 10μm; SO$_2$, sulfur dioxide; NO$_2$, nitrogen dioxide; CO, carbon monoxide; O$_3$, ozone; CVD, cardiovascular diseases; CHD, coronary heart diseases; RD, respiratory diseases; COPD, chronic obstructive pulmonary disease.
Table S5. Percentage difference (posterior mean and 95% posterior intervals) in daily mortality per 10 μg/m$^3$ increase in 2-day moving average PM$_{2.5-10}$ concentrations, stratified by subgroups in 272 Chinese cities.

| Factors | Subgroups | Total      | CVD        | RD         |
|---------|-----------|------------|------------|------------|
| Overall | -         | 0.23 (0.13, 0.33) | 0.25 (0.13, 0.37) | 0.26 (0.07, 0.46) |
| Age     | 5–64 years| 0.12 (0.00, 0.23) | 0.16 (-0.02, 0.35) | 0.09 (-0.06, 0.24) |
|         | 65–74 years| 0.18 (0.03, 0.33) | 0.21 (0.02, 0.39) | 0.34 (0.12, 0.57) |
|         | ≥75 years | 0.31 (0.20, 0.43) | 0.30 (0.16, 0.43) | 0.46 (0.14, 0.78) |
|         | p-value   | 0.69       | 0.58       | <0.001     |
| Gender  | Females   | 0.25 (0.15, 0.36) | 0.27 (0.14, 0.41) | 0.26 (-0.02, 0.53) |
|         | Males     | 0.21 (0.10, 0.32) | 0.21 (0.07, 0.34) | 0.28 (0.06, 0.51) |
|         | p-value   | 0.76       | 0.72       | 0.82       |
| Education | Less   | 0.25 (0.15, 0.34) | 0.25 (0.14, 0.37) | 0.28 (0.08, 0.48) |
|         | More     | 0.17 (-0.10, 0.44) | 0.19 (-0.16, 0.55) | 0.24 (-0.07, 0.55) |
|         | p-value  | 0.82       | 0.24       | 0.09       |
Note: Overdispersed generalized additive models were used to derive city-specific estimates adjusted for time trends, day of week, temperature and humidity and Bayesian hierarchical models were used to pool the estimates. P-values were derived by conducting likelihood ratio tests comparing the goodness-of-fit of a meta-regression model with the potential modifier to the simple meta-analysis model without this variable. These data are also reported in Figure 6.

Abbreviations: PM$_{2.5-10}$, particulate matter with an aerodynamic diameter between 2.5 and 10μm; CVD, cardiovascular diseases; RD, respiratory diseases.
Table S6. The impacts of annual-mean levels of city characteristics on the association between PM$_{2.5-10}$ and total non-accidental mortality in single-variable and combined meta-regression models.

| Characteristics | Single-variable models | Combined models with all variables |
|-----------------|------------------------|-----------------------------------|
|                 | Coefficients $^b$      | 95% PI                            | p-values       | Coefficients $^b$      | 95% PI                            | p-values       |
| PM$_{2.5-10}$   | -0.003                 | -0.006, 0.000                     | 0.009          | -0.001                 | -0.006, 0.04                      | 0.716          |
| PM$_{2.5}$      | -0.006                 | -0.011, -0.001                    | 0.016          | -0.006                 | -0.015, 0.003                     | 0.161          |
| Pearson $r$ $^a$| 0.376                  | 0.014, 0.739                      | 0.040          | 0.408                  | 0.001, 0.815                      | 0.048          |
| SO$_2$          | -0.005                 | -0.010, 0.001                     | 0.087          | -0.001                 | -0.009, 0.006                     | 0.716          |
| NO$_2$          | -0.004                 | -0.014, 0.005                     | 0.360          | 0.005                  | -0.009, 0.020                     | 0.457          |
| CO              | -0.031                 | -0.100, 0.038                     | 0.383          | -0.015                 | -0.087, 0.058                     | 0.692          |
| O$_3$           | 0.003                  | -0.005, 0.010                     | 0.523          | 0.003                  | -0.005, 0.012                     | 0.428          |
| Temperature     | 0.005                  | -0.006, 0.017                     | 0.369          | 0.003                  | -0.010, 0.015                     | 0.648          |
| Humidity        | 0.002                  | -0.003, 0.008                     | 0.371          | 0.001                  | -0.005, 0.007                     | 0.764          |

Note: $^a$ It refers to Pearson correlation coefficients for annual mean PM$_{2.5-10}$ and PM$_{2.5}$ concentrations; $^b$ They are percentage differences (posterior mean and 95% posterior intervals) in daily total non-accidental mortality per 10 μg/m$^3$ increase in 2-day moving average PM$_{2.5-10}$ concentrations in association with a 1-unit increase in annual-mean levels of city characteristics.

Abbreviations: PM$_{2.5-10}$, particulate matter with an aerodynamic diameter between 2.5 and 10μm; SO$_2$, sulfur dioxide; NO$_2$, nitrogen dioxide; CO, carbon monoxide; O$_3$, ozone; PI, posterior interval.
Figure S1. Percentage difference (posterior mean and 95% posterior interval) in daily total mortality per 10 μg/m³ increase in 2-day moving average concentrations of coarse PM, using different lag days of coarse PM, df per year in smoothness of time and lag days for controlling daily-mean temperature and relative humidity. Overdispersed generalized additive models were used to derive city-specific estimates adjusted for time trends, day of week, temperature and humidity and Bayesian hierarchical models were used to pool the estimates.

Abbreviations: PM, particulate matter; df, degree of freedom.