SUPPLEMENT

Acute Effects of Ambient Particulate Matter on Mortality in Europe and North America: Results from the APHENA Study

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Data and methods

Data

Table 1 presents the APHENA data sets' descriptive characteristics. Data were available in Canadian cities from 1987 to 1996. The European cities contributed from three to seven years of data between 1990 and 1997. The Netherlands was considered as one urban area because of its high density and urban character. For 10 of the European cities, PM_{10} concentrations were estimated using measurements of total suspended particles (TSP) or black smoke (BS) (Katsouyanni et al. 2001). The U.S. database included the 90 largest cities in the U.S., and extended from 1987 to 1996. There exists substantial variability in city characteristics both within and between the three collaborating centers (Europe, the U.S., and Canada): Canadian cities tend to be smaller in population size and colder, with lower PM_{10} concentrations than in the other centers.

Median daily death counts are higher in the European data (reflecting the larger population sizes of the European cities) compared with the U.S. and Canadian data (Figure 1A). Both PM_{10} and ozone levels are higher in European cities, followed by the U.S. and then Canada. PM_{10} levels are slightly lower in Canada than in the U.S., although ozone levels are markedly lower (Figure 1B).

Results

Tables 2 and 3 present the effect modification patterns of PM_{10} effects, based on the average of lags 0 and 1, on total mortality for all ages combined and among those 75 years of age and older, as estimated from fixed effects models. The results are presented in terms of the percent increase in the daily number of deaths associated with an increase of 10μg/m^3 in PM_{10}, at two different values for the effect modifier, corresponding to the 25th and the 75th percentiles of the center-specific distribution. We chose to present center-specific quartiles, as the distributions for several effect modifiers differ appreciably between European and U.S. cities. The estimates can be interpreted as showing the PM_{10} effects in a city characterized by a level of the effect modifier corresponding to the 25th percentile of the distribution and in another city with a level of the effect modifier equal to the 75th percentile. Only one effect modifier at a time was included in the time-series models, and not all cities had data available for all effect modifiers. When more degrees of freedom were used for seasonality control, the effect estimates were reduced, hence weakening the evidence for effect modification. Tables 2 and 3 summarize results for effect modifiers that were significant in at least 4 out of the 8 models applied within at least one center.

Discussion

In APHENA we explored patterns of effect modification. In prior analyses lower socioeconomic status has been hypothesized to increase vulnerability to air pollution through diverse mechanisms (O'Neill et al. 2003). Within APHEA, prior analyses identified that higher NO_2 concentrations were found to be associated with larger PM_{10} mortality effect estimates. The APHEA group also found greater PM_{10} mortality risks in warmer and drier sites, as well as in locations with a higher proportion of elderly and a longer life expectancy. In NMMAPS, exploratory analyses identified several potential modifiers, most consistently including the level of PM_{10} and the percentage of residents not completing high school; the effect of PM_{10} on mortality decreased with increasing level of PM_{10} and increased with the percentage not finishing high school. The effect modification patterns identified in APHENA were in agreement with these previous findings.

In reference to the APHENA data availability as a possible drawback it should be noted that for the U.S. and Canada, nationwide reference methods for air pollution data collection are in place and deaths are captured and coded uniformly. Because data had been collected according to regulatory monitoring protocols, gaps exist in the PM_{10} data, reflecting the routine collection of data on every third or sixth day. These gaps reduce precision of estimates and also preclude the use of distributed lag models in many of the U.S. and Canadian cities. The APHEA-2 data came from 24 countries, with variable data measurement methods used in the participating countries. Well-documented approaches were used to develop air pollution concentration values that would be as complete and uniform as possible (Katsouyanni et al. 1997, 2001). Nonetheless, differing measurement error structures remains a possible source of heterogeneity.

The exploration of effect modification in APHENA was limited by the restricted umber of variables that extended across the full data set. Information was not available on the health status of the populations under study, or on the frequency of specific diseases that have been postulated as effect modifiers, such as diabetes. The primary analyses for effect modification were based on models that include only one variable (potential effect modifier) at a time. Preferable we would have adjusted for the mutual effects of the different variables considered, but the analysis was limited by the relatively small number of cities with daily data. However, when we controlled for pairs of effect modifiers, the conclusions were consistent with those observed under models involving only one effect modifier.

Table 1. Descriptive characteristics of the data base.

	Canada	Europe	U.S.
Range of city population (/1000)	103(Saint John) -2,276 (Toronto)	216 (Erfurt)-15,400 (Netherlands)	250 (Lincoln) - 9,519 (Los Angeles)
Range of mean total daily number of deaths	3 (Saint John) – 49 (Montreal)	6 (Geneva) - 347(Netherlands)	5 (Lincoln) - 198 (New York)
Range of mean daily number of deaths for those ≥75 years	1 (Saint John) -23 (Toronto)	4 (Geneva) - 204(Netherlands)	2 (Lincoln) - 96 (New York)
Range of mean daily number of deaths for those $<$75 years	1 (Saint John) – 26 (Montreal)	2 (Geneva) - 143(Netherlands)	1 (Lincoln) - 51 (New York)
Range of mean temperature (^{o}C)	2.7 (Winnipeg) - 10.5 (Vancouver)	5.9 (Helsinki) - 20.4 (Tel-Aviv)	2.7 (Anchorage) -25.5 (Honolulu)
Range of median PM_{10} (μg/m^3)	11 (Saint John) - 28 (Windsor)	13 (Stockholm) - 65 (Prague)	14 (Anchorage) - 43 (Fresno)
Range of number of observations	271 (Quebec) – 1115 (Saint John)	961 (Stockholm) - 2546 (Cracow)	441 (Fort Wayne) -3595 (Salt Lake City)

Table 2. Increase in the daily number of deaths all ages associated with an increase of 10 μg/m^3 in PM_{10} concentrations (average of lags 0 and 1)[a] at the 25th and 75th percentile of the center-specific distribution of selected[b] effect modifiers. All cities provided data on effect modifiers unless otherwise stated.

Effect modifier	Europe	Europe	U.S.A.	U.S.A
	25thcentile estimate (95% CI)	75thcentile estimate (95% CI)	25thcentile estimate (95% CI)	75thcentile estimate (95% CI)
%population>65yrs	0.25 (0.12, 0.38)	0.31 (0.18, 0.45)	0.06 (-0.11, 0.24)	0.23 (0.08, 0.37)
%population>75yrs	0.25 (0.11, 0.38)	0.32 (0.18, 0.47)	0.03 (-0.17, 0.22)	0.24 (0.09, 0.39)
Crude mortality rate	0.31 (0.18, 0.44)	0.24 (0.10, 0.38)	-0.13 (-0.37, 0.11)	0.29 (0.14, 0.44)
Mean NO_2[c]	0.17 (0.03, 0.31)	0.44 (0.28, 0.61)	0.01 (-0.26, 0.27)	0.28 (0.12, 0.45)
Mean NO_2/PM_{10}[c]	0.19 (0.05, 0.33)	0.42 (0.25, 0.59)	0.16 (-0.05, 0.37)	0.27 (0.10, 0.44)
Mean temperature	0.15 (0.00, 0.30)	0.38 (0.24, 0.51)	0.22 (0.07, 0.36)	0.16 (-0.01, 0.34)
Mean Humidity	0.38 (0.24, 0.51)	0.23 (0.11, 0.35)	-0.03 (-0.30, 0.23)	0.26 (0.11, 0.42)
%Unemployed[c]	0.27 (0.09, 0.46)	0.57 (0.37, 0.77)	0.11 (-0.13, 0.36)	0.23 (0.08, 0.38)

[a]estimated by using 8df per year to control for seasonal patterns and penalized splines

[b]those variables displaying significant effect modification in at least 4 out of 8 models applied, in at least one center (i.e. Europe or U.S.) are selected.

[c]11 U.S. cities provided data on NO_2 levels.14 European cities provided data on unemployment.

Table 3. Increase in the daily number of deaths among those ≥75 yrs old associated with an increase of 10 μg/m^3 in PM_{10} concentrations (average of lags 0 and 1) [a] at the 25th and 75th percentile of the center-specific distribution of selected[b] effect modifiers. All cities provided data on effect modifiers unless otherwise stated.

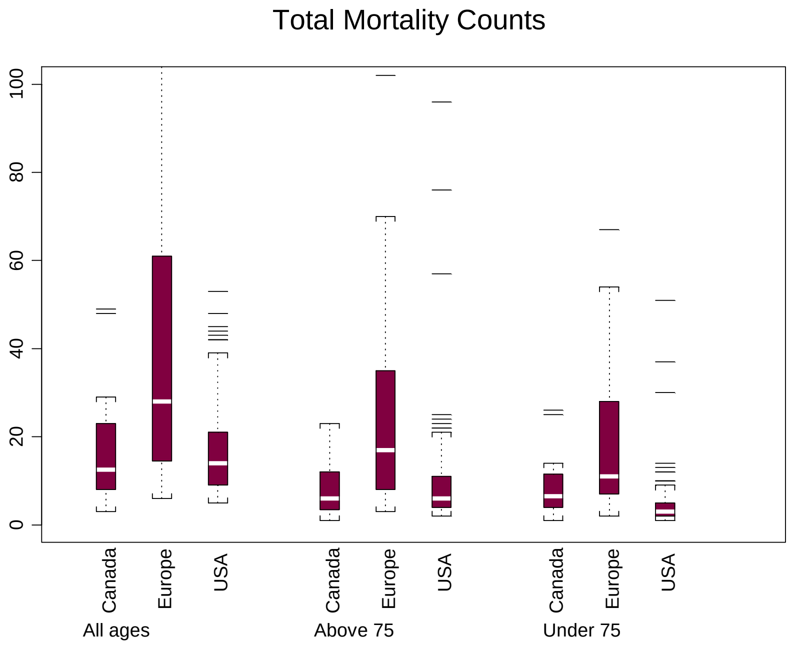
Effect modifier	Europe	Europe	U.S.A.	U.S.A
	25thcentile estimate (95% CI)	75thcentile estimate (95% CI)	25thcentile estimate (95% CI)	75thcentile estimate (95% CI)
%population>75yrs	0.31 (0.14, 0.47)	0.43 (0.24, 0.63)	0.08 (-0.19, 0.36)	0.33 (0.13, 0.54)
Crude mortality rate	0.38 (0.21, 0.55)	0.35 (0.16, 0.54)	-0.08 (-0.43, 0.26)	0.39 (0.18, 0.60)
% CVD & respiratory deaths over total	0.45 (0.27, 0.64)	0.25 (0.04, 0.46)	0.29 (0.08, 0.49)	0.38 (0.17, 0.60)
Mean NO_2 [c]	0.22 (0.05, 0.40)	0.60 (0.39, 0.82)	0.27 (-0.11, 0.65)	0.40 (0.18, 0.63)
Mean O_3 [c]	0.40 (0.22, 0.58)	0.33 (0.17, 0.49)	0.52 (0.25, 0.78)	0.12 (-0.20, 0.44)
Mean NO_2/PM_{10} [c]	0.29 (0.13, 0.45)	0.56 (0.34, 0.78)	0.36 (0.05, 0.68)	0.39 (0.15, 0.62)
Mean temperature	0.23 (0.03, 0.43)	0.47 (0.29, 0.65)	0.31 (0.10, 0.51)	0.30 (0.05, 0.55)
Mean Humidity	0.50 (0.32, 0.69)	0.31 (0.16, 0.46)	-0.03 (-0.42, 0.37)	0.38 (0.16, 0.59)
%Unemployed[c]	0.37 (0.13, 0.62)	0.69 (0.43, 0.95)	0.05 (-0.29, 0.39)	0.37 (0.15, 0.58)

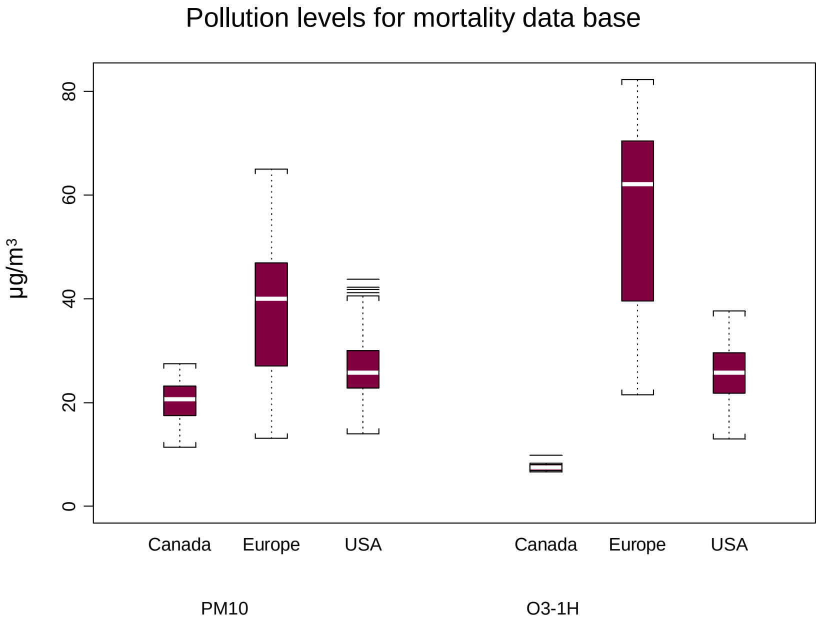
[a]estimated by using 8df per year to control for seasonal patterns and penalized splines

[b]those variables displaying significant effect modification in at least 4 out of 8 models applied, in at least one center (i.e. Europe or U.S.) are selected.

[c]11 U.S. cities provided data on NO_2 levels.13 U.S. cities provided data on O_3 levels.14 European cities provided data on unemployment.

Figure 1. Boxplots of mortality counts (A) and pollution levels (B) analyzed in Canada, Europe and U.S.


Total Mortality Counts
0
20
40
60
80
100
Canada
Europe
USA
Canada
Europe
USA
Canada
Europe
USA
All ages
Above 75
Under 75


Pollution levels for mortality data base
µg/m³
0
20
40
60
80
Canada
Europe
USA
Canada
Europe
USA
PM10
O3-1H