SHORT-TERM EFFECT OF FINE PARTICULATE MATTER (PM2.5) AND OZONE ON DAILY MORTALITY IN LISBON, PORTUGAL

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INTRODUCTION

Urban ambient air pollution exposures continue to be a global public health concern. Epidemiological studies show that particulate matter (PM), nitrogen oxides (NOx) and ozone (O3) exposures affect morbidity and mortality. Traditionally, epidemiological studies were conducted using PM10 as the exposure indicator, but recent evidence indicates that exposure indicators based on PM2.5 rather than PM10 should be encouraged.

While there is generally agreement that urban air pollution is hazardous to human health, the exposure response relationships differ between studies and locations. Exposure-response relationships determined within a particular country/region may thus not be readily transferable to others.

In contrast to most EU cities, PM and NOx emissions in Portugal have increased between 1990-2004. It is thus not surprising that while in most European countries no excedances above health and environmental protective thresholds are reported, the situation in Portugal is different.

Studies in the Lisbon metropolitan area show frequent exceedances of EU directive targets for air quality. However, studies focusing on the health impacts of air quality in Lisbon are surprisingly very few and none have quantitatively assessed the impacts of short-term exposure on mortality

The aim of this study is to determine the exposure-response relationships of ambient ozone and fine particulate matter (PM2.5) concentrations on daily mortality in Lisbon.

METHODS

Study area

The study area is the municipality of Lisbon. It is capital of Portugal and the westernmost capital in mainland Europe (Figure 1). Lisbon is located north of the Tagus estuary and in close proximity to the Atlantic Ocean. It is the largest urban area in Portugal with a population of about 0.5 million.

Lisbon has specific social characteristics such as large proportions (24%) of the residential population are over 65 years and it has one of the highest population densities (6134 hab/km^3) in the country. It has a mortality rate of 14.1‰, significantly higher than the national rate of 9.7‰.

Figure 1 – Location of study area (Lisbon)

Services are the main economic sectors in the city, although there is some industrial activity. The latter includes textiles, chemicals, steel, oil and sugar refining, shipbuilding and waste incineration units. However, traffic is the main source of local atmospheric emission. Apart from road traffic, the international airport located in the north of the city is also a significant contributor to local emissions.

Environmental and Health Data

Hourly data of O_3 and $PM_{2.5}$ for the period 2004-2006 were obtained from the Portuguese Environmental Agency. These hourly O_3 and $PM_{2.5}$ readings were transformed to daily mean, daily 95th percentile, daily 98th percentile and daily maximum. Only days with more than 75% of the hourly measurements for that particular day were used. Station hourly efficacies were never less than 96.4%.

Daily death counts for all-cause mortality (except external causes) (ICD-10 codes A00-R99), and for cardiovascular mortality (ICD-10 codes I00-I99) were obtained from the Portuguese Statistics Institute for the same study period and study area. Mortality data were further classified into two groups: one group for all ages and another group ≥65 year.

Daily maximum temperature and daily minimum temperature for Lisbon (2004-2006) were obtained from the European Climate Assessment & Dataset (ECA&D) and processed according to Klein Tank et al. (2002).

Statistical Analysis

In this study we conduct a time series analysis to determine the exposure-response effect from ambient ozone (O3) and fine particulate matter (PM2.5) concentrations on daily mortality in Lisbon.

Generalized additive models (GAMs) were used to link air pollution with mortality in the municipality of Lisbon. We assumed that the independent response variables followed a Poisson distribution with a log link function. Thin plate regression spline was chosen as low rank isotropic smoother with fixed degrees of freedom. The R software version 2.6.0 was used for statistical analysis with the "mgcv" package version 1.4-1.

An independent model was built for each mortality type and with each of the following explanatory variables individually: (i) temperature; (ii) O3 and (iii) PM2.5. For each explanatory variable we calculated the daily mean, maximum, 95th percentile and 98th percentile from the hourly dataset.

Each covariable was tested with different fixed degrees of freedom, to adjust the amount of smoothness. Model and variable selection was done based on the UBRE score and the Pearson statistic, respectively.

The final outcome shows the relative risk (RR) or, the risk of mortality associated with an increase of 10µg/m3 of PM2.5 and O3.

RESULTS & DISCUSSION

During the study period the daily mean O_3 concentration was 48.3µg/m^3 and the daily mean for $PM_{2.5}$ was 14.73µg/m^3. Compared to other cities in Southern Europe, the O_3 levels are slightly higher while the $PM_{2.5}$ levels lower.

Figure 2 shows model validation results for the normality and homogeneity assumptions for the exposure-response model for ozone and all-cause mortality. Results for the remaining models showed similar trends.

Figure 3 – Exposure-response model of ozone and all-cause mortality (all ages). Validation of normality and homogeneity.

Table 1 shows the percentage increase in mortality (%RR) due to an O_3 increase of 10µg/m^3. We found significant positive associations for the all-age group as well as the ≥ 65 years group for all-cause and for cardiovascular mortality. The effect was doubled in the cardiovascular mortalities when compared to all-cause mortality. Compared to other city specific studies, the O_3 exposure relative risks in Lisbon are higher, suggesting that the Lisbon population is more vulnerable to ambient O_3 levels.

Table 2 shows the percentage increase in mortality (%RR) due to an increase of 10µg/m^3 $PM_{2.5}$. Results show an important exposure-response risk of $PM_{2.5}$ on cardiovascular mortality in the ≥ 65 years group.

Table 1 - Percentage increase in mortality per 10 µg/m3 of ozone

		Observations	RR	C.I. 95%	%RR
All-cause mortality	total	1042	1.0096	(1.0056, 1.0135)	0.96%
	≥ 65 years	1040	1.0111	(1.0058, 1.0164)	1.11%
Cardiovascular mortality	total	993	1.0197	(1.0119, 1.0276)	1.97%
	≥ 65 years	978	1.0186	(1.0104, 1.0268)	1.86%

Table 2 - Percentage increase in mortality per 10 µg/m3 of PM2.5

		Observations	RR	C.I. 95%	%RR
All-cause mortality	total	1040	1.0067	(1.0019, 1.0116)	0.67%*
	≥ 65 years	1040	1.0062	(1.0010, 1.0115)	0.62%*
Cardiovascular mortality	total	993	1.0149	(1.0032, 1.0267)	1.49%*
	≥ 65 years	981	1.0239	(1.0129, 1.0350)	2.39%

**not statistically significant at the 5% significance level.*

CONCLUSION

This study shows for the for the first time significant associations between ambient O3 and PM2.5 levels on mortality in Lisbon.

For PM2.5 exposures, we found that the relative risk for cardiovascular mortality in the population group ≥ 65 years is 2.39% (95%CI: 1.29%, 3.50%) for each 10µg/m3 increase. A statistically significant cause-effect relationship for PM2.5 and mortality was not observed in other population groups.

We also report O3 exposures to be associated with an increase of 1.11% (95% C.I. (0.58, 1.64)) for all-cause mortality in the population group ≥ 65 years and an increase of 0.96% (95% C.I. (0.56, 1.35)) for the general population. When analyzing by cause of death, our results showed a stronger association between O3 exposure and cardiovascular mortality.

Further, our models clearly show two distinct patterns of air pollution related mortality. The exposure-response effect to PM2.5 is statistically significant in the same day while the exposure-response effect of O3 is seen with a 2-3 day lag.

Taking into consideration that this is the first study in Lisbon assessing the impact of air pollution on daily mortality, and that climate change is very likely to affect local O3 and PM concentrations, future work using longer time series, exploring different risks groups, seasonality as well as hospital emergency room visits is recommended to improve our understanding of the health impact of exposures to O3 and PM2.5 in Lisbon.