

THE EFFECT OF SHORT-TERM CHANGES IN AIR POLLUTION ON RESPIRATORY AND CARDIOVASCULAR MORBIDITY IN NICOSIA, CYPRUS

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ABSTRACT

This study investigates the effect of daily changes in levels of PM₁₀ on the daily volume of respiratory and cardiovascular admissions in Nicosia, Cyprus during 1995-2004. After controlling for long- (year and month) and short-term (day of the week) patterns as well as the effect of weather in Generalized Additive Poisson models, some positive associations were observed with all-cause and cause-specific admissions. Risk of hospitalization increased stepwise across quartiles of days with increasing levels of PM₁₀ by 1.3% (-0.3, 2.8), 4.9% (3.3, 6.6), 5.6% (3.9, 7.3) as compared to days with the lowest concentrations. For every 10µg/m³ increase in daily average PM₁₀ concentration, there was a 1.2% (-0.1%, 2.4%) increase in cardiovascular admissions. With respects to respiratory admissions, an effect was observed only in the warm season with a 1.8% (-0.22, 3.85) increase in admissions per 10µg/m³ increase in PM₁₀. The effect on respiratory admissions seemed to be much stronger in women and, surprisingly, restricted to people of adult age.

1. INTRODUCTION

To date, a substantial amount of research has shown adverse health effects – both increased hospitalization and excess mortality – of elevated ambient levels of air pollutants, and in particular particulate matter (PM). Typically, evidence on the effect of short-term changes comes from studies with a time-series design i.e. investigating the effect of day-to-day changes in concentrations of PM on daily counts of health events. More recently, evidence has been accumulating with the use of large multi-city studies or meta-analyses of several single-city time-series studies that combine and thus produce more robust estimates of the observed effects across several places. With the exception of a major European study (i.e. the APHEA project across 15-29 European cities (Aga et al, 2003)), the majority of studies have focused on US cities e.g. the National Morbidity, Mortality and Air Pollution Study (NMMAPS) (Dominici et al, 2005). Associations have not been investigated in small/medium size cities in the Eastern Mediterranean where climatic conditions (for example, sand storms from the Sahara desert) as well as socio-economic factors (including driving patterns and access to the health care) can vary considerably. This study aims to investigate associations between hospital admissions for all, respiratory and cardiovascular diseases and levels of PM₁₀ in the city of Nicosia, Cyprus during the 10-year period 1995-2004.

2. METHODOLOGY

All cardiovascular (ICD codes I00-I52) and respiratory (ICD codes J00-J99) admissions with information on gender, age, ICD code and whether a Nicosia resident were obtained from the two public hospitals in Nicosia for the period 1 Jan 1995-30 Dec 2004. In addition, the daily volume of all-cause admissions in the same period was obtained from the Cyprus Statistical Services, aggregated in 8 age/sex strata. The Air Quality Section (Ministry of Labour) provided hourly measurements of PM₁₀ from two stations: (a) located centrally on the roof of the Nicosia General Hospital and (b) in the rural location of Ayia Marina Xyliatou, 40km from Nicosia. While the latter is more representative of background pollution, measurements were only available from 1999 onwards. Daily averages of temperature (air and dew point), relative humidity, wind speed and barometric pressure (measured at 08:00 and 13:00) were provided by the Meteorological Services. These were based on hourly measurements of Thermohygrographs (i.e. instantaneous values) taken at the Athalassa Meteorological station (just south east from the centre of Nicosia).

Poisson regression was used to calculate percentage increase in daily admissions both across quartiles of increasing daily average levels of PM₁₀ (to assess non-linearity) as well as per 10µg/m³ linear increase. Due to the small number of daily cause-specific admissions, only sex-specific (i.e. all ages combined) or age-specific (younger and older than 15 years of age) associations were examined. Generalized Additive Models (GAM) with natural splines were used to remove the long-term trend (df=40) as well as penalized splines to control for possible non-linear effects of the meteorological variables on the outcome. The final model controlled for long-term trend, temperature on the same day as well as the two previous days (lag 1 and 2) and relative humidity on the same day. In order to estimate the short-term patterns, day of the week was included in the models as an

indicator variable. Only days with at least 12 hourly measurements were considered when calculating daily average concentrations of PM₁₀. Extreme values of PM₁₀ are thought to be the result of sand storms from the Sahara desert affecting Cyprus to a certain extent a few days every year. Analyses were thus repeated to (a) exclude days with average concentrations >150µg/m³ to avoid outliers (n=25) influencing the estimation of linear effects and (b) model the separate effect of sand storms – defined as days with at least one hourly measurement greater than 300µg/m³, or days in-between (total of 192 observations or 45 days). To investigate whether exposure to air pollutants can have effects over several days, same-day, lagged exposure (up to 2 days) as well as moving averages of 2- and 3-days exposure were considered. Data manipulation was performed in STATA 9.0 and non-parametric smoothing models were fitted in R 2.2.0.

3. RESULTS AND DISCUSSION

In the period under investigation, admissions in the two Nicosia hospitals nearly doubled. There has been a 3-fold increase in cardiovascular admissions with daily admissions rising from an average of 1 in the early years to 4 towards the end of the study period. For respiratory causes, admissions have increased in adults (aged >15) and decreased slightly in children (aged <15), remaining at around 4 daily admissions on average in much of the 10 years. *Table 1* shows summary statistics of the daily number of hospital admissions before and after restricting numbers to Nicosia residents. Combining all age/sex groups ensured that there would be at least 1 cardiovascular or respiratory admission in at least 85% of days. The low number of daily events meant that it was not uncommon for as many as 75% of days with no admissions if age- and sex-groups were considered separately.

Table 1: Summary statistics of (a) daily number of admissions, (b) PM₁₀ concentrations in Nicosia Central and (c) meteorological factors between 1 Jan 1995-30 Dec 2004 (N=3652 days).

| A. Hospital admissions (in parentheses, when restricting numbers to Nicosia residents only) | | | | | | | | |
|--|---------------------------------------|-----------|-----------|-------|-------|--------|-------|---------|
| | Total number (% Nicosia residents) | Mean | SD | Min | 25% | Median | 75% | Max |
| All-causes | 178091 | 48.8 | 20.1 | 4 | 31 | 50 | 63 | 111 |
| Cardiovascular | 10896 (75%) | 3.0 (2.2) | 2.4 (1.9) | 0 (0) | 1 (1) | 3 (2) | 4 (3) | 22 (11) |
| Respiratory | 14827 (86%) | 4.1 (3.5) | 3.7 (3.1) | 0 (0) | 1 (1) | 3 (2) | 6 (5) | 20 (18) |
| B. PM₁₀ in Nicosia Central (µg/m³) | | | | | | | | |
| | Observations/ Days (%) | Mean | SD | Min | 5% | Median | 95% | Max |
| Hourly values | 77788 (88.8%) | 55.37 | 69.29 | 3.00 | 16.10 | 45.70 | 119.9 | 4965.95 |
| Daily averages | 3217 (88.1%) | 55.42 | 42.69 | 5.00 | 25.85 | 50.57 | 90.81 | 1370.61 |
| C. Meteorological factors | | | | | | | | |
| Temperature | 3652 (100%) | 19.41 | 7.45 | 1.88 | 8.7 | 19.18 | 30.39 | 35.49 |
| Rel. Humidity | 3591 (98.3%) | 64.99 | 13.95 | 16.58 | 38.46 | 66.21 | 85.79 | 96.50 |

Table 1 also shows the distribution of daily average concentrations of PM₁₀ and the meteorological factors considered in the models. PM measurements were not available for as many as 354 days (10%). Restricted to days with at least 12 measurements, daily mean levels of PM₁₀ ranged from 5.00 to 1370.61µg/m³ (interquartile range: 40.04-64.11), levels comparable to southern European cities, and exceeding the European standard of 75µg/m³ between 11-57 days a year. Concentrations of PM₁₀ peaked between the hours of 7:00-9:00 and were lower during weekends, reflecting patterns of traffic in the centre of Nicosia – see *Figure 1*. Concentrations were higher during colder months. This, however, was not true in the case of the rural station where concentrations appeared lower during cold months, exhibiting a higher degree of agreement with levels in the centre during the warm season. Correlations between PM₁₀ and the meteorological factors only ranged between -0.30 and 0.17, most strongly correlating with wind speed during the cold months.

As expected, respiratory admissions showed a strong cyclic pattern with higher admissions during the colder months. With the exception of possibly lower cardiovascular admissions during the summer months and weekends, there was not a strong seasonal or weekly pattern in cardiovascular admissions. Most striking was the large drop in respiratory admissions on Tuesdays on either side of high volume on Mondays and Wednesdays – see *Figure 1*. With the exception of the elderly (aged 65+), similar patterns were observed in all other age/sex groups. It was not clear whether this was a function reduced bed availability following a high volume of demand.

It might be indicative that people admitted on a Monday were more likely to be discharged by Wednesday than any other day while those admitted on a Wednesday were more likely to be discharged by the following Monday.

Figure 1: Weekly patterns of daily number of admissions and average levels of PM₁₀ concentrations.

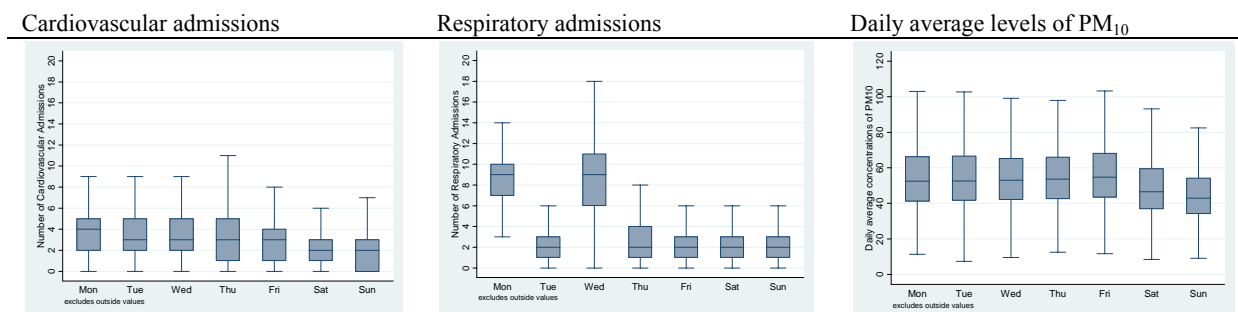


Table 2 shows the percentage increase in all- and cause-specific admissions per 10 $\mu\text{g}/\text{m}^3$ increase in PM₁₀ in Nicosia Central. Positive associations were observed with the risk of hospitalization. The effect appeared more pronounced in people of adult age (aged 15+ rather than children) and amongst men. Generally, associations were similar, if not smaller, when levels of PM₁₀ as measured in the rural station were used instead. While not statistically significant (due to the small number of events), similar, if not slightly stronger, effects were observed with admissions for cardiovascular causes. For every 10 $\mu\text{g}/\text{m}^3$ increase in daily average PM₁₀ concentrations, for instance, there was a 1.2% 95%CI (-0.1%, 2.4%) increase in cardiovascular admissions. Surprisingly, no overall effect was observed with total volume of respiratory admissions. However, the effect seemed to strengthen when analyses were repeated to exclude the 14% of all non-Nicosia residents among those admitted. This was not true in the case of cardiovascular admissions. Furthermore, the effect on respiratory admissions, if any, seemed to be restricted to people of adult age and, unlike cardiovascular admissions, was more pronounced in women. Finally, in contrast to the positive associations with hospital admissions observed with levels of PM₁₀ on the same day, no positive effects were observed with levels of PM₁₀ the 2 previous days. While lagged effects have commonly been observed with mortality in previous studies, it might not be as surprising that in the case of hospital admissions the strongest associations are observed with same day levels of pollution (Dominici et al, 2006). Perhaps, even more so in the case of Cypriot cities where easy access to health care may differ considerably from those in larger European or US cities.

Table 2: Percentage increase (and 95% CI) in all, cardiovascular and respiratory admissions per 10 $\mu\text{g}/\text{m}^3$ increase in PM₁₀ (restricted to days with daily average <150 $\mu\text{g}/\text{m}^3$) after adjusting for long- (i.e. season) and short-term (i.e. day of the week) patterns as well as the effect of weather.

| | All admissions ³ | Cardiovascular ⁴ | Respiratory | Cardiovascular + Respiratory |
|--------------------------------|-----------------------------|-----------------------------|---------------------------------|------------------------------|
| All age/sex groups | 0.85 (0.55,1.15) | 1.18 (-0.10,2.37) | 0.10 (-0.91,1.11) | 0.56 (-0.21,1.34) |
| Nicosia residents ¹ | | 0.64 (-0.69,2.00) | 0.25 (-0.84,1.36) | 0.38 (-0.47,1.23) |
| Males | 0.96 (0.54,1.39) | 1.27 (-0.15,2.72) | 0.10 (-1.32,1.53) ² | 0.63 (-0.34,1.62) |
| Females | 0.74 (0.31,1.18) | 0.99 (-1.11,3.14) | 0.58 (-1.13,2.32) ² | 0.59 (-0.68,1.87) |
| Aged <15 | 0.47 (-0.13,1.08) | | -0.46 (-1.99,1.10) ² | |
| Aged >15 | 0.98 (0.63,1.33) | | 1.00 (-0.56,2.59) ² | |

Notes: ¹ After restricting numbers to Nicosia residents, ² Only aggregate numbers of all-cause admissions were available, thus it was not possible to restrict numbers to Nicosia residents, ³ Only includes people of adult age (15+) due to the rarity of cardiovascular events in those aged less than 15.

Stepwise increases in the risk of hospitalization were observed across quartiles of days with increasing levels of PM₁₀ for either all-cause or cardiovascular admissions, with 5.6% (3.9, 7.3) and 9.2% (2.4, 16.5) increased admissions respectively in the quartile of days with the highest levels of PM₁₀. This was not the case among respiratory admissions, where the risk of adult admissions rose by 4.9% (-2.8, 13.3), 3.1% (-4.8, 11.6) and 6.1% (-2.1, 14.9) compared to the quartile of days with the lowest levels of PM₁₀. The extent of this non-linearity was further explored in models where the effect of an increase in PM₁₀ on respiratory admissions was stratified by cold and warm months – see Table 3. Interestingly, there appeared to be some pronounced differential effects by

season. While an increase in PM₁₀ concentrations did not seem to have much of an effect on respiratory admissions during the colder months, some previously undetected associations were observed during the warm season, with effects as strong as 1.8% (-0.22,3.85) increase in respiratory admissions per 10µg/m³ increase in PM₁₀. More adverse effects of PM₁₀ on warm than cold days have previously been reported (Ren & Tong, 2006). Once again, the effect on respiratory admissions seemed to be restricted to people of adult age and much stronger in women. Finally, with respect to the separate effect of sand storms, admissions were 4.7% (0.1, 9.5), 7.6% (-10.9, 29.9), and 5.6% (-10.3, 24.2) higher on sand storm days for all, cardiovascular and respiratory admissions respectively. Furthermore, some smaller lingering effects were observed the day after a sand storm, particularly with respiratory admissions. Any inference from these associations is, however, limited due to the small number of sand storm days (n=45) in the 10-year period.

Table 3: Differential effects of 10µg/m³ increase in PM₁₀ on admissions for respiratory admissions during cold and warm months separately, after adjusting for long- and short-term patterns as well as the effect of weather.

| | Percentage increase (and 95% CI) per 10 µg/m ³ increase in PM ₁₀ | |
|-------------------|--|--------------------------|
| | Cold months ¹ | Warm months ² |
| All admitted | -0.33 (-1.47,0.82) | 1.42 (-0.42,3.31) |
| Nicosia Residents | -0.22 (-1.45,1.02) | 1.80 (-0.22,3.85) |
| Males | -0.16 (-1.76,1.46) | 1.10 (-1.47,3.74) |
| Females | -0.26 (-2.18,1.70) | 3.27 (-0.00,6.65) |
| Aged <15 | -0.31 (-2.02,1.42) | -0.59 (-3.53,2.45) |
| Aged 15+ | 0.02 (-1.76,1.83) | 3.89 (1.05,6.80) |

Notes: ^{1,2} Cold months include Jan, Feb, Mar Apr, Nov and Dec, while warm months include all the rest.

4. CONCLUSIONS

Short-term exposure to PM₁₀ increases the risk of hospitalization for all-cause, cardiovascular and respiratory admissions. At around 1% increase in daily admissions per 10µg/m³ increase in PM₁₀, estimates in the city of Nicosia seem consistent with the size of effects seen across several European cities. (Le Tertre et al, 2002; Katsouyanni, 2003) An effect on respiratory admissions was observed only during the warm season and, surprisingly, only in adults. Unfortunately, the small number of events do not permit a finer cause-specific analysis so that the effect on specific respiratory events in children, e.g. the risk of asthma, can be investigated. Such effects can be further explored in a case-crossover design, an adaptation of the case-control design where each case serves as their own control and where the effect of experiencing an outcome on a certain day – and thus, concentration levels on that day – is compared to several other days that serve as the controls.

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