ADAPTtoCLIMATE conference

The Role of Air Pollution as a Potential Confounder of the Association Between Temperature and Mortality in Cyprus

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ΚΥΠΡΙΑΚΗ ΔΗΜΟΚΡΑΤΙΑ

Introduction

- The interest in the impact of extreme weather on human health has been growing.
- Related literature has shown consistent evidence of association between high temperatures and mortality.
- Climatic change results in increased occurrence of heat waves and the thermal stress caused by such phenomena is expected to lead to higher levels of heat-related mortality worldwide.
- Several studies have examined the role of air pollutants and have found conflicting results about their effect on the mortality-temperature relation.
- Due to the contradictory results, additional studies to examine confounding of air pollution on the relation between temperature and mortality are warranted.

Aims of the study

- This study is the first to examine the effect of extreme weather on mortality in Cyprus.
- It aims to investigate the individual effect of meteorological indicators on mortality, as well as the role of air pollution as a potential confounder of heat related health effects.

Study area: Cyprus

- Cyprus has a typical Mediterranean climate characterized by hot dry summers, rainy changeable winters and short autumn and spring seasons.
- During summertime, the island is under the influence of a shallow trough of low pressure extending from the great continental depression centered over Southwest Asia: high temperatures, cloudless skies and negligible rainfall.
- The average temperature in July and August is around 36 °C.
- Weather connected with dust events is associated with depressions from the east and south (“Saharan Events”); extreme concentrations of dust in the atmosphere, resulting in low visibility and poor air quality, responsible for increased levels of particulate matter (PM) in the atmosphere.
- The high temperatures during summertime together with the "Saharan Events" are expected to be associated with increased mortality.

Theoretical Background

Many studies examining the relation between temperature-mortality in Europe, USA and Asia have identified:

1) a non-linear relationship: V-, U-, J- or inverse J-shape, with higher mortality at temperature extremes and lower mortality at moderate temperatures.
2) a "delayed effect": Temperature can affect not only deaths occurring on the same day, but on several subsequent days, where the converse is also true: deaths on each day depend on the effect of the same day's temperature as well as the lag effects of the previous days' temperatures.

- The relationship between temperature and mortality may be confounded by several **confounders**. Confounding factors are present when a covariate is associated with both the outcome and exposure of interest, but is not a result of the exposure. Such confounders have been shown to be certain meteorological indicators, like relative humidity, as well as seasonality and long-term trends.
- Air pollution has also been used as a possible confounder in the mortality-temperature relation in many previous studies.

Data

- **Daily mortality data** were provided by the Ministry of Health, for each of the five districts in Cyprus (Nicosia, Limassol, Larnaca, Paphos, Ammochostos). They involve deaths of people that lived permanently in the free areas of Cyprus. The data include "all-cause" mortality excluding external causes.
- **Meteorological data** were collected by the Cyprus Meteorological Service in the five main urban centers of the island. They include daily values of surface maximum temperature (in °C) and mean values of relative humidity at 8:00 LST and 13:00 LST (in %).
- The **air pollutant** that has been chosen for our study is the concentration of Particulate Matter, with an aerodynamic diameter of less than 10 μm (PM_{10}). Daily data for PM_{10} were obtained from the Department of Labour Inspection of the Ministry of Labour and Social Insurance.The daily averages of PM_{10} were taken from the records of five stations (Agia Marina Xyliatou, Nicosia, Larnaca, Limassol and Paphos).
- The final period for our analysis was the years 2007-2009, concentrating on the warm periods (April to September) of each year, to examine heat effects.
- Cyprus was considered as a total area, using the combined data from all the stations, but separate analyses were also performed for Nicosia (urban area) and Limassol (coastal area).

The statistical model

- A Generalized Linear Model (GLM) was implemented, with quasi-Poisson regression to allow for overdispersion. GLM models have been widely applied in epidemiological studies of the impact of meteorology or air pollution on human health.
- A temperature function was first entered in GLM. The function was developed based on the recent methodology of Distributed Lag Non-Linear Models (DLNM), which had the advantage of capturing simultaneously any non-linearities and delayed effects of the temperature-mortality relation. More specifically, a "hockey-stick" temperature function, with a hot threshold and constraints along the strata of lags 0-1, 2-5 and 6-10, fit the data.
- The GLM was also adjusted for relative humidity, long- and short-term seasonality.
- Finally the GLM was extended to examine the confounding effect of air pollution. A linear term for air pollution was added in the model. The average of the current and the previous day (lags 0 and 1), was calculated and included in the model.

Results: Cyprus

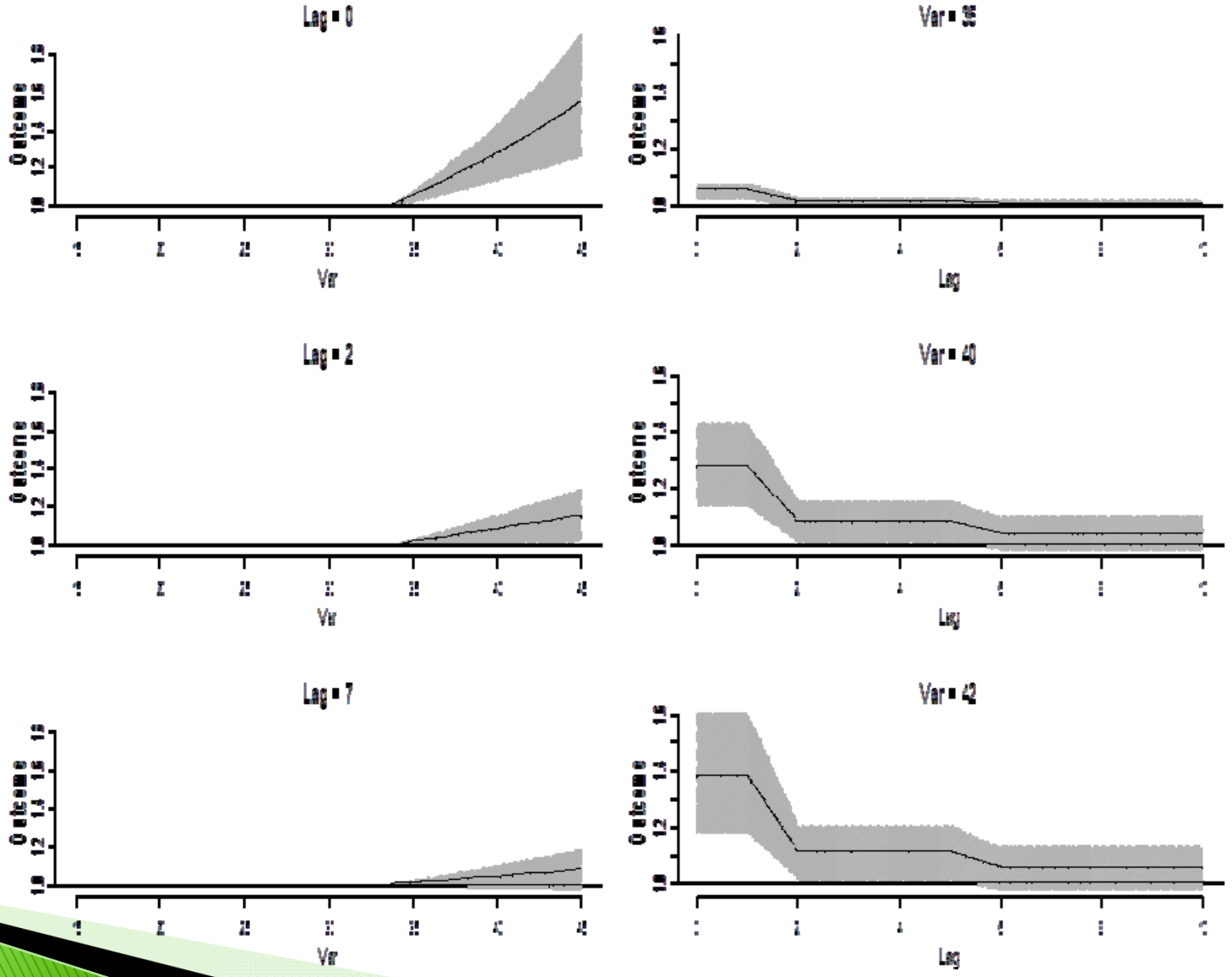
- The V-shaped temperature-mortality relation had a temperature **threshold at 33.7ºC**, above which mortality risk increased steeply.
- High temperatures had **a significant effect** on mortality in Cyprus (p-value<0.001 and p-value=0.018 for the first two components of the lag-stratified temperature function), independent of humidity and seasonality.
- The air pollution term for PM_{10} was **not found** to be significant (p-value=0.5526) in the GLM model, and the significance of the effect of temperature on mortality remained after the inclusion of air pollution in the model.

Table 1: Summary results for Relative Risk (RR) increment- Cyprus, 2007-2009 (Threshold temperature: 33.7^{0}C).

Lags	Adjusted Model[1] RR (per day) (95% CI)	Adjusted Model[1] RR (per lag interval)	Unadjusted Model[2] RR (per day) (95% CI)	Unadjusted Model[2] RR (per lag interval)
0–1	**3.948%** (2.083 to 5.848%)	**7.897%**	3.872% (2.026 to 5.752%)	7.745%
2–5	1.256% (0.221 to 2.302%)	5.025%	1.229% (0.200 to 2.269%)	4.917%
6–10	0.628% (–0.207 to 1.471%)	3.142%	0.623% (0.212 to 1.465%)	3.115%
Total : 0–10 Overall Effect	17.199% (10.842, 23.921%)		16.872 % (10.621, 23.476%)	

[1] With air pollution; [2]without air pollution

Figure 1:The risk of mortality for different lags (0, 2 and 7) and different temperatures (35^{0}C, 40^{0}C, 42^{0}C), when we adjust for air pollution (PM_{10})- Cyprus, 2007-2009 (Threshold: 33.7^{0}C).



Results for Nicosia (urban area) and Limassol (coastal area)

- Similar results for the role of air pollution as a potential confounder on the association between temperature and mortality:

1) the term for PM_{10} was not found to be significant (p-value=0.511 for Nicosia and p-value=0.417 for Limassol)

2) the significance of the effect of temperature on mortality remained after the inclusion of air pollution in the model, without any significant changes in RR between the adjusted and unadjusted models.

The effect of heat on mortality was lower for Nicosia:

RR for lags 0 and 1

Nicosia: 0.682% (95% CI: -0.949% to 2.340%)

Limassol: 21.369% (95% CI: 5.680% to 39.385%)

Overall effect for lags 0-10

Nicosia: 5.469% (95% CI: 0.7177%, 10.4445%)

Limassol: 58.4757 % (95% CI: -18.6851%, 208.8554%)

Interesting finding: RR for Limassol for lags 6-10 was negative (-9%; 95% CI: -18.5% to 1.6%) - reduction of heat-related deaths

Conclusions

- High temperatures during the warm months in Cyprus can result in increased mortality rates, independent of relative humidity, secular trends or seasonality.
- The temperature-mortality relation had a hot temperature threshold at 33.7ºC, above which mortality risk increased steeply.
- Heat has an immediate or direct health effect, with higher risk within the current and next day of a severe heat event, compared to the effect in longer lags, as we move further from the event.
- The effect on public health is much more pronounced for higher temperatures, with a sharp drop after the second day and a smoother effect for lower temperatures.
- Air pollution (PM_{10}) does not appear to be a confounder of the temperature-mortality relationship in any of the geographical areas under examination.
- The risk of mortality appeared to be lower in Nicosia compared to Limassol: adaptation to high temperatures in urban areas as opposed to coastal areas.
- An indication of the so called “harvesting effect” or “mortality displacement” appeared for Limassol (RR for lags 6-10 negative). This reduction in mortality, one week or so after the event, suggests that the heat wave affected especially those whose health was already so compromised that would have died in the short term anyway and whose events were only accelerated by a brief period of time by the effect of exposure.

The results can be used for the development of Heat-Health warning systems for Cyprus and for implementing preventive measures, targeting climatic variables.