Spatial analysis of the effects of heat waves on population health in southern Spain

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Summary

This study aims to identify, examine, interpret and map mortality patterns related to the 'heat wave' phenomenon in southern Spain, Andalusia region. To perform a comprehensive spatial analysis at the largest possible scale, we use the individual-level data deriving from the Longitudinal Population Register of Andalusia (LPRA). Combining mortality data by cause of death with environmental variables such as temperature, atmospheric pressure, humidity and air pollution, this study provides a deeper understanding on the driving factors for certain diseases and depict areas of potential negative influence on human health. Moreover, this analysis involves proximity measures to evaluate current levels of healthcare accessibility in the region.

Keywords: Longitudinal population register, Population grid, Heat wave, Exploratory spatial analysis, Network analysis

1. Background

Since the early 20th century the association between abnormally high temperatures and mortality has been repeatedly reported (1-5). However, the actual magnitude of heat-related mortality may be greatly under-reported since heat-related deaths are not easy to diagnose. Heat, therefore, is not usually listed on death certificates as causing or contributing to death. The Meteorological Agency of Spain considers a "Heat Wave" to be an episode of at least three consecutive days, in which at least 10% of the stations have recorded the maximum above the 95% percentile of the series of daily maximum temperatures for the months of July and August for the period 1971-2000 (6). Since 2000, there have been recorded over 20 of such incidences in Spain, lasting from 3 days to almost a month (26 days in 2015) and affected on average 25 provinces at a time (see as an example the daily temperature and extreme heat days over the thresholds from 2002 till 2010 in Fig.1).

The negative impact of heat waves on population health is proven to be higher in urban areas due to the "Urban Heat Island" (UHI) effect, when cities exhibit temperatures several degrees higher than their rural surroundings. A direct relationship has been identified between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. During extreme weather events, such as previously described heat waves, the urban heat island has the potential to prevent the city from cooling down, maintaining night-time temperatures at a level that affects human health and comfort. Cardiovascular disease, heatstroke, heat exhaustion, heat syncope and heat cramps are some of the main stress events, particularly risky for the most vulnerable population groups such as the elderly and children (7, 8).

Moreover, some studies suggest that the UHI effect could be provoking the intensification of air pollution. As mentioned above, the inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated outdoor spaces or inner spaces of residential and commercial buildings with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide (CO_2), as well as other pollutants such as sulfur dioxide (SO_2), carbon monoxide (CO) and particulate matter (PM).

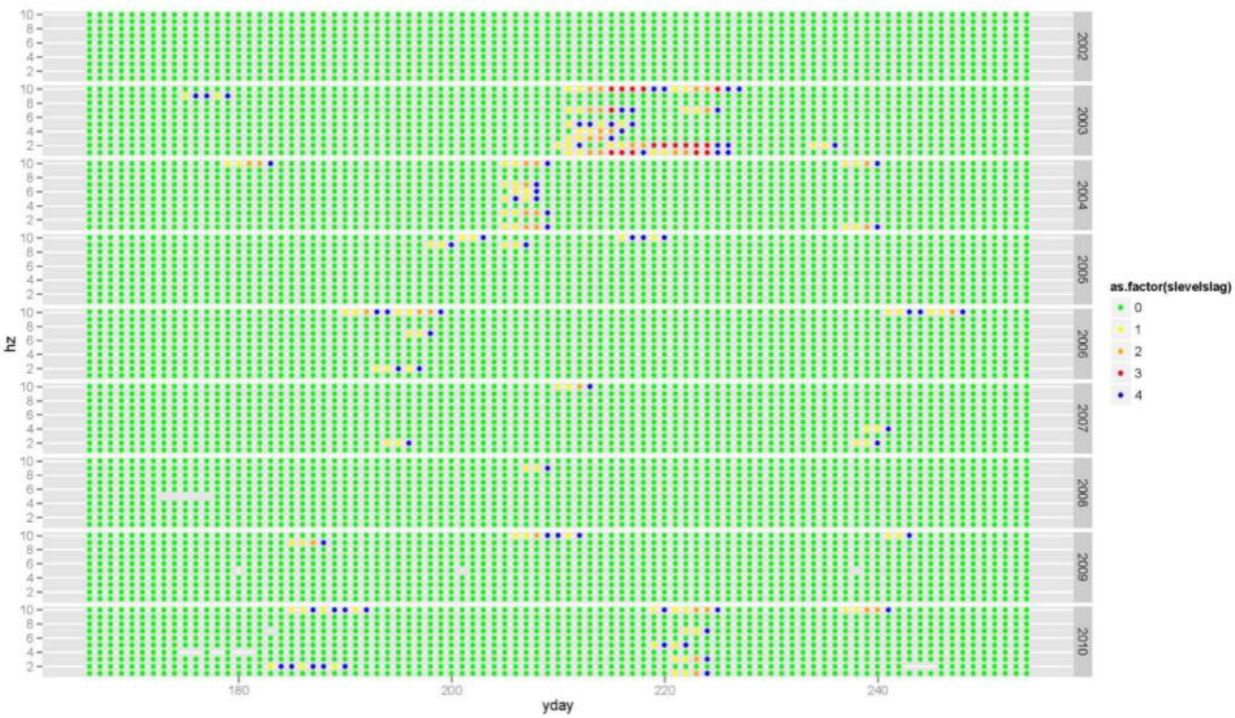

Figure 1. Daily temperature and extreme heat days over the thresholds

It was also proven that the UHI effect decreases water quality as warmer waters flow into area streams and put stress on their ecosystems.

According to the threshold values established by government, some 35% of the present country population (16 MM of inhabitants, up from 10,4 MM estimated by the WHO) were breathing polluted air in the end of 2010 (3). By that time the number of consecutive deaths was approaching 16.000 per year 1, although recent data indicates that this number may be almost 2 times folded according to the regional data providers (9, 10). Mostly, deaths caused by air pollution in Spain attribute to exposure to fine particulate matter (PM_{10} and particularly deadly $PM_{2,5}$), sulfur and nitrogen dioxides along with the ground-level ozone and the most abundant trace gas in the atmosphere, carbon dioxide. In particular, more than 90% of emissions of nitrogen and sulfur oxides are taking place due to the main contributors to industrial emissions, namely fuel combustion and power plant discharge. Interestingly, the proportions of the contamination sources in Spain - road traffic and energy production plants – are almost equal, 32,5% and 32,4% respectively. Upon the whole, Spain ranks second after the United Kingdom in NO_x polluting (9, 10).

Geographically, apart from the capital and its surroundings, the periphery of the peninsula stands out for higher levels of air pollution with País Vasco, Cataluña and Andalusia opening the list of regions with elevated contamination levels in Spain. As stated by the EEA, the portion of Andalusian population being located in the areas with the higher concentrations of suspended particles exceeds 45%. In total, 12 towns and cities in the region, including Sevilla, Motril and Cuevas de Almanzora, breach WHO safety levels for

PM_{10} and PM_2 particles, which tend to penetrate deep into the lungs. At the regional scale, the highest overall air contamination level is maintained by la Bahia de Algeciras (Cadiz), Granada and Huelva for several decades.

Considering the general predisposition of Andalusia to the elevated temperatures due its geography and the proven cause-effect linkage in between warming and a) speeds of harmful chemical compound accumulation, and b) changes in its transformation and decomposition in different mediums (e.g. air or water), we believe it will be prudent to pay special attention to the combined effect of high temperatures and environmental pollution human health in this region.

2. Data and methods

This study is based on several sources: primarily, we rely on a newly developed Longitudinal Population Database of Andalusia 1998-2016 (BDLPA from now onwards) to reconstruct the whole demographic trajectories of the population since the late twentieth century; and multiple other databases on health, meteorological and environmental data.

The core of the BDLPA data infrastructure lies in the population register of Spain (Padrón de Habitantes), vital statistics bulletins and censuses of population from 1991 to 2011. This combined information is georeferenced at individual level by postal address and displayed on a grid surface with fine spatial resolution. Over 87,000 km^2 of the Andalusian territory has been covered with 1,416,093 cells with 250 m^2 resolution (of which only 3,4% have at least one inhabitant), however for this study, we scale up to the 1 km^2 cell grid in order to achieve compliance with spatial layers deriving from other sources. These grids are available online at IECA webpage and represent the first of its kind to be developed in Spain, allowing a comprehensive view of the territorial distribution of the Andalusian population and its sociodemographic and epidemiological characteristics (Fig.2). The integration of the population census with the administrative information gives an insight into the changes in mortality depending on a wide range of personal characteristics, family environment and an infra-municipal geographic details, so far not available in any other disposable statistical source.

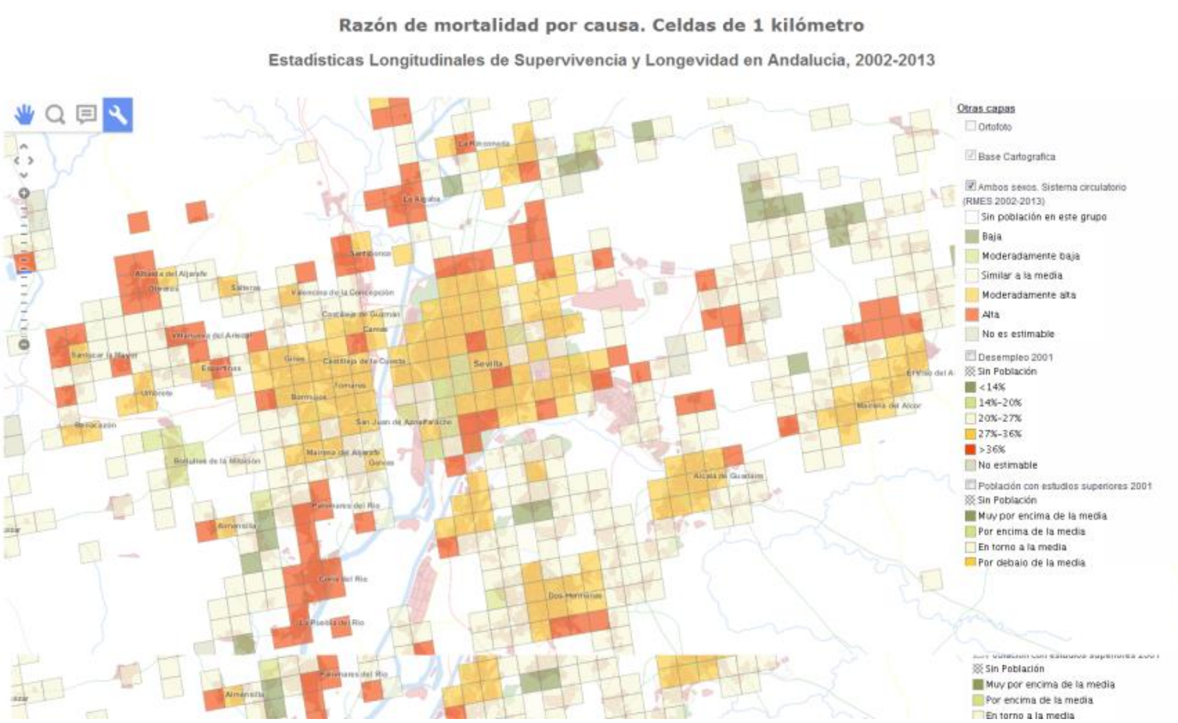

Figure 2. Mortality by cause of death represented on 1 km2 cell grid

To comprehensively study the interdependencies between mortality and heat waves, daily meteorological data provided by the state agencies is processed and interpolated to construct grid surfaces with spatial resolution compatible to LPRA grid. In the next place, spatial regression analysis is conducted to identify the type of relationship the environment is having on population. To provide the most complete analytical assessment this study accounts for the complementary factors such as living conditions, (building quality, availability of air conditioning), environment (pollution and proximity to industrial zones, urban and rural zoning), socioeconomic characteristics of the population (rental and occupational status, employment) and healthcare facility infrastructure. In order to analyse the influence of spatial location of the aforementioned facilities on health, network, locational and surface analysis are conducted. Ultimately, the surface is divided into corresponding spatial classes of a) mortality ranked by the influence of environmental factor and b) levels of accessibility to healthcare resources and therefore riskiness for population, and the resulting spatial phenomenon is mapped.

3. Expected results

Geocoded at the building level, LRPA data represents an exceptional research interest due to its scale, extent (full population of Andalusia), preciseness and variability of individual sociodemographic, socioeconomic and mobility characteristics, leaving a wide window of opportunities to analyse population in time and space from different angles. Using this data, we aim to reconstruct mortality by day at a high spatial resolution, which in conjunction with environmental and climatic data will allow us to study the direct effects of heat waves on mortality and the ways extreme environmental conditions influence the population health through time and space.

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