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Temperature in summer and children's hospitalizations in two Mediterranean cities

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ABSTRACT

Background and objective: Children are potentially vulnerable to hot ambient temperature. However, the evidence on heat-related children's morbidity is still scarce. Our aim was to examine the association between temperatures in summer (May to September) and children's hospitalizations in two Mediterranean cities, Rome and Valencia, during the period 2001–2010.
Methods: Quasi-Poisson generalised additive models and distributed lag non-linear models were combined to study the relationship between daily mean temperature and hospital admissions for all natural, respiratory and gastrointestinal diseases in children under 15 years of age. Associations were summarised as the percentage of change (Ch%) in admissions at 50th, 75th, 90th, 95th and 98th percentiles of temperature in summer compared to 1.) the 50th percentile in the whole year (50th(y)) and 2.) the preceding percentile in the previous series. Cumulated risks were obtained for groups of lags showing a similar pattern: 0–1, 2–7, 8–14 and 15–21 days.
Results: Almost whatever increase of temperature from 50th(y) was significantly associated with an increase of paediatric hospitalizations by all natural diseases at short term (lag 0–1), while small increases at high temperatures only had a delayed effect on this outcome. The same pattern was observed in Rome for respiratory admissions, while in Valencia only a delayed association (days 8–14) was observed. The increase of temperature from 50th to 75th percentiles was associated at short time to an increase of gastrointestinal admissions in both cities.
Conclusion: Children's hospitalizations rose with heat in Rome and Valencia. Patterns of delays and critical windows of exposure mainly varied according the outcome considered.
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1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), southern Europe and the Mediterranean area are projected to exhibit relatively high temperature changes that are greater than the global mean by 50% or more. An increase in hot days and nights and more frequent, more intense and longer heat waves and warm spells are predicted for these regions. The strongest trends are likely to occur on the Iberian Peninsula with mostly adverse implications for health (IPCC, 2014).

Children are often more sensitive than adults to environmental hazards including extreme temperatures because of their physical and physiological immaturity, their particular behaviours prone to increase exposure, and their reduced self-care abilities (Sheffield and Landrigan, 2011). In consequence, climate change represents a major threat to children's health and hence its impact has become an important public health concern over the last few years (Birnbaum and Tart, 2014; McKie, 2013; Xu et al., 2012a).

Current literature indicates the influence of hot temperature on children's mortality (Xu et al., 2012a, 2014a) and studies conducted on European, American and Asian cities also suggest that unusually high outdoor temperatures are directly related to an increase in paediatric hospital admissions for respiratory, renal and infectious diseases (Xu et al., 2014a, 2014b; Chan et al., 2013; Phung et al., 2015). Nevertheless, scientific evidence is still inconsistent and further research is needed, particularly for respiratory and gastrointestinal morbidity (Xu et al., 2012b) since, if

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climate variability increases, the burden of such diseases is expected to grow (Ebi and Paulson, 2007).

As regards Mediterranean cities, the evidence is very scarce. To our knowledge, children's health (under 15 years), looking at all natural and cause-specific hospital admissions, has only previously been analysed within the PHEWE project (Michelozzi et al., 2009). In this study, given the small count in these specific subgroups, no clear associations were found and hence results were not presented.

The main aim of this study was to assess heat-related hospitalizations of children for total, respiratory and gastrointestinal causes in two Mediterranean cities, Rome and Valencia, which share similar meteorological conditions in summer, but are quite different in terms of population size.

2. Methods

2.1. Study design, city characteristics and data

We conducted a retrospective time series study using data on outdoor temperature, and children's hospital admissions in two Mediterranean cities, Rome and Valencia, participating in the PHASE project (Public Health Adaptation Strategies to Extreme Weather Events) (Phase, 2016).

Daily data were collected from 2001 to 2010. The study period was restricted to the summer months (May to September), as high temperatures during the warmer months were the exposure of interest.

Both cities provided 3-h meteorological data (air temperature, dew point temperature, relative humidity, wind speed and barometric pressure at sea level) from the nearest airport weather station. Daily mean temperature was chosen as the exposure variable in this study because it represents the exposure throughout the whole day. Daily means of wind speed, relative humidity and barometric pressure were chosen as potential meteorological confounders. We controlled for air pollution with the aim of capturing the direct effects of temperature rather than those mediated by air pollution. Mean daily pollution levels were based on hourly concentrations of nitrogen dioxide (NO_2) provided by the respective urban monitoring networks.

Hospital admissions referred to the daily counts for all natural, non-external causes (International Classification of Diseases-9th revision/ICD-9: 001-799), respiratory diseases (ICD-9: 460-519) and gastrointestinal diseases (ICD-9: 001-009, 558, 787) in the resident population under 15 years of age. The main discharge diagnosis was considered, and only emergency admissions were selected.

2.2. Statistical analysis

Time series quasi-Poisson regression models were fitted separately to each city and outcome. Each core model included a natural cubic B-spline of the "day in period" variable to control for the long-term trend and another of the "day in summer" to control for seasonality, and a subset of the potential confounders. This model was progressively obtained by a backward procedure, testing the permanence of confounders as well as the best indicator for them and updating degrees of freedom (dfs) in smoothed terms.

This fitting process started with just the selection of dfs for the compulsory splines of trend and season in a model without exposure. The best combination of dfs between 0.8, 1 or 2 per year for trend and 0.8, 1 or 2 per month for season was chosen here to minimize the sum of absolute residuals in the partial autocorrelation function. After that, the elimination or the best indicator (linear and smoothed terms for lag averages 0–1 and 0–7) for relative humidity, wind speed, barometric pressure and NO2 concentration were decided by using the Akaike criterion. The permanence of day of the week, bank holidays and summer holidays was also decided by means of Akaike.

On the core-models, the association with temperature was addressed with a standard distributed lag non-linear model (DLNM) (Gasparrini, 2011). This class of models can describe complex non-linear and lagged dependencies through a cross-basis function (CBF), obtained by the combination of two functions that define the conventional exposure-response relationship and the additional lag-response relationship, respectively (Gasparrini, 2014). We extended the lag period to be considered to 21 days in order to capture the delay in the effects of heat and to account for short-term harvesting.

In order to choose a common CBF that was flexible enough to capture the main features of the relationship in each studied outcome in both cities, we first performed an exploratory analysis. Specifically, for the exposure-response relationship we considered different possibilities ranging from the complexity of a cubic B-spline with 6 dfs to the simplicity of a linear relationship. High threshold parameterizations, assuming a linear shape above a threshold and flat below it, were also examined using different percentiles of the temperature distribution as possible thresholds. For the lag-response relationship we considered natural cubic B-spline with an intercept and dfs from 4 to 2, linearity, low

Table 1
Summary of daily hospital admissions, meteorological and pollution statistics in summer (May to September). Study period 2001–2010.

	Rome	Valencia
Hospital admissions	*Mean* (%)	*Mean* (%)
All causes, 0–14 years	26.1 (100)	7.0 (100)
Respiratory diseases, 0–14 years	5.9 (22.6)	1.2 (17.7)
Gastrointestinal diseases, 0–14 years	3.0 (11.4)	0.4 (5.8)
All causes, 0–4 years	17.0 (100)	4.9 (100)
Respiratory diseases, 0–4 years	4.2 (24.9)	0.9 (19.0)
Gastrointestinal diseases, 0–4 years	2.3 (13.4)	0.3 (5.9)
Mean temperature (°C)		
Mean ± *SD*	22.6 ± 3.8	23.5 ± 3.4
50th *percentile (complete year)*	15.6	17.5
50th *percentile*	23	24
75th *percentile*	26	26
90th *percentile*	27	27
95th *percentile*	28	28
98th *percentile*	29	29
Maximum	31	34
Meteorological variables	*Mean* ± *SD*	*Mean* ± *SD*
Relative humidity (%)	67.9 ± 11.5	63.9 ± 9.5
Barometric pressure (hPA)	1014.2 ± 3.9	1015.6 ± 4.0
Wind speed (m/s)	3.2 ± 1.6	3.2 ± 0.9
Air pollutants	*Mean* ± *SD*	*Mean* ± *SD*
Nitrogen dioxide (μg/m^3)	52.8 ± 14.6	52.1 ± 16.1
Ozone (μg/m^3)	103.2 ± 24.3	61.7 ± 8.8
Geographic indicators[a]		
Altitude (m)	30	15
Latitude	41º 53′	39º 28′
Longitude	12º 29′	7º 04′
Distance to sea[a] (km)	38	4
Demographic indicators[b]		
Population	2,546,804	
	738,441	
Ages 0–14 (% of total)	12.8	12.8
Population density (inhab/km^2)	2175	5484
Socioeconomic and health care indicators[c]		
Gross domestic product (GDP) per capita (US$)	19,722	14,952
Health expenditure (% Of GDP)	8.2	7.2
Hospital beds × 1000 inhabitants	4.6	3.6
Unemployment rate	9.6	10.5

[a] Distance from the city centre.
[b] City level. Source: National Institute of Statistics.
[c] National level. Source: OECD Statistics extract. WHO. World Bank. Additional information may be found in Leone et al. (2013).

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