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SHORT COMMUNICATIONS

Evaluation of the plan for surveillance and controlling of the effects of heat waves in Madrid

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Abstract This paper presents evaluation of a plan for surveillance of and controlling the effects of heat-related mortality (PSCEHW), implemented in Madrid in 2004 through a time series analysis conducted with ARIMA modeling. From the public health point of view, prevention plans should be implemented as adaptive measures to heat waves. In 2003, the impact attributable to the heat wave was an increase in mortality per °C of 22.39 %. All heat waves since 2003 have been of lower intensity, and yet, in 2005 there was a heat wave of lower intensity that had a greater impact, i.e. an increase in mortality per °C of 45.71 %. With the methodology used here, we cannot say whether implementation of PSCEHW has resulted in a decrease of mortality attributable to high temperatures in the city of Madrid.

Keywords Heat wave · Evaluation · Surveillance

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Introduction

The summer of 2003 was considered the hottest in Europe since 1500 (Luterbacher et al. 2004). That same year, an episode of heat waves occurred in Europe (Luterbacher et al. 2004; Bilan et al. 2004; Hémon and Jougla 2004; Patz et al. 2005; Díaz et al. 2006) producing an excess of mortality of between 22,000 and 70,000 (D'Ippoliti et al. 2010). Spain registered an excess of between 6,595 and 8,648 deaths between June and August 2003 (Simón et al. 2005).

As the Intergovernmental Panel on Climate Change (IPCC) has forecast that heat waves will become more frequent and more intense (IPCC 2012), many European countries have implemented prevention plans as an adaptive measure to climate change following World Health Organization (WHO) guidelines (WHO 2009). However, although some of these plans have been in operation since 2004, few evaluations of their impact in reducing the mortality associated with heat waves have been conducted (Bassil and Cole 2010).

Here, we present the first evaluation with a new methodology of the plan for surveillance and controlling the effects of heat waves (PSCEH); (World Health Organization 2003; Pirard 2003; Montero et al. 2010), which was implemented in Madrid in 2004.

Materials and methods

We performed a ecological time series study. As a dependent variable, we used daily all cause mortality, excluding accidents, that occurred in the municipality of Madrid during the summer months (June–September) of the years 1990–2009 using ICD X: A00-R99 provided by the National Institute of Statistics (INE). The independent variable was the daily maximum temperature, because it is closely associated with mortality in Madrid (Díaz et al. 2002). Data on temperature were collected from the Madrid-Retiro Observatory, used as a reference in previous studies (Montero et al. 2010) and provided by the State Meteorological Agency (AEMET).

Several definitions of heat wave are used in public health studies; in this study, we used a definition based on previous epidemiological studies conducted in Madrid. Those studies define heat waves as days (one or more) on which the daily maximum temperature exceeds the mortality trigger temperature threshold (TUD), determined at 36.5 °C (Montero et al. 2010).

A heat wave would be characterized by the difference between the daily maximum temperature and the threshold temperature recorded. This temperature is called Tcal:

$$\mathrm{Tcal} = \begin{cases} \mathrm{T}Max - \mathrm{TUD}, & \text{if } \mathrm{T}Max > \mathrm{TUD}. \\ \mathrm{Tcal} = 0, & \text{if } \mathrm{T}Max \le \mathrm{TUD} \end{cases}$$

As a heat wave may last several days, heat wave intensity (IHW) is given by the sum of the values of Tcal during those days (Díaz et al. 2006).

Analysis with ARIMA models

We used ARIMA models for the time series analysis using Tcal as external variable (independent variable). Since preliminary studies (Montero et al. 2012a, b) have determined that the impact of heat on mortality may be delayed by up to 4 days, we also introduced a 4-day lag into the model.

Mathematically this is:

$$Wt = \underbrace{\varnothing_1 W_{t-1} + \Theta_1 a_{t-1}}_{\textit{Regular component}} + \underbrace{\beta_1 Tcal_t + \beta_2 Tcal_{t-1} + \beta_3 Tcal_{t-2} + \beta_4 Tcal_{t-3} + \beta_5 Tcal_{t-4}}_{\textit{Tcal until day 5 (with a 4-day lag)}}$$

where $\varnothing_1$ = component regular autoregressive, and θ_1 = component regular moving average.

The β values indicate the increase in mortality per day and per each degree by which the maximum daily temperature exceeds the trigger temperature.

If implementation of the prevention plan in Madrid in 2004 has had an impact on reducing mortality, a decrease in β values would be detected during the period 2004–2009 compared to those obtained during the period 1990–2003.

Data were processed using Access, SPSS 18.0 and Excel.

Results

During the period analyzed, 75 days were recorded as exceeding the trigger temperature, accounting for 32 heat waves between 1999 and 2009. The cumulative increase in temperature was 76.9 ° C, representing an average increase of 3.8 °C above the TUD (36.5 °C) per year.

In 2003, we observed an increase in mortality of 22.4 % for each °C by which the TUD was exceeded 36.5 °C.

In the years prior to 2003, there was a higher intensity of heat waves and greater impact on mortality. In 1991 mortality increased by 16.56 % for each ° C by which the threshold temperature was exceeded, with an IHW of up to 25.9 °C—the biggest temperature increase recorded in the 20 years studied (Table 1). The last heat wave prior to 2003 was recorded in 1995 (i.e. there was a 7-year interval without heat waves) and with an IHW of 12.5 °C. When analyzing the years after the launch of PSCEHW, we observed that all heatwaves after that of 2003 showed an IHW lower than that recorded in 2003.

In the year 2005, there was an increase in mortality of 45.7 % (33.7 to 57.8) for each degree that the daily maximum temperature exceeded the threshold temperature of 36.5 °C. This represents the maximum impact recorded in the period under study. Despite that, the heat waves were less intense than others occurring before implementation of PSCEHW.

Discussion

From the results presented in Table 1, it cannot be stated that the impact of heat wave is significantly decreased as a consequence of the implementation of PSCEHW since 2003.

Although the length of the series is only 20 years, and therefore not climatically representative, analysis of Table 1 cannot confirm, during the period under review, any increase in the frequency, duration, and intensity of heat waves felt in Madrid. It is also noteworthy that in the years 1991 and 1995 there were heat waves of greater intensity than that recorded in Madrid in 2003.

Comparing several years, i.e. 6 years after implementation of PSCEHW and 14 years prior, allowed comparison of the impact of the plan through the change in mortality trends. There are numerous studies in which the analysis of a single year is used to evaluate a prevention plan (WHO 2009; Weisskopf et al. 2002; Palecki et al. 2001; Fouillet et al. 2008) We believe that 1 year is not enough. First, because no two heat waves are identical in intensity, thus precluding comparison before and after implementation of PSCEHW. Secondly, other factors influencing the impact of heat wave on mortality, e.g. the season of year in which the heat wave

Table 1 Impact of heat waves on mortality in the city of Madrid 1990–2009. Source: (INE)(AEMET)/ preparation: Health Institute Carlos III-Madrid Spain. *CI* Confidence intervals

Year	Total waves per year (frequency)	Intensity of heat wave (IHW) (°C)	Total number of days with waves per year (duration)	% Increased mortality per degree centigrade (IC)
1990	2	1.3	3	33.38(1.79-64.97)%
1991	5	25.9	20	16.56(11.38-21.29)%
1992	5	8.3	9	16.41(14.00-18.82)%
1993	0	0	0	…
1994	3	3.1	5	15.15(1.40-28.91)%
1995	2	12.5	7	28.05(22.62-33.48)%
1996	0	0	0	…[a]
1997	0	0	0	…
1998	0	0	0	…
1999	0	0	0	…
2000	0	0	0	…
2001	0	0	0	…
2002	0	0	0	…
2003	3	8.2	8	22.39(14.33-30.46)%
2004	2	6.5	6	17.49(4.82-30.16)%
2005	4	4.5	6	45.71(33.68-57.74)%
2006	0	0	0	…
2007	0	0	0	…
2008	0	0	0	…
2009	6	6.6	11	11.21(1.63-20.79)%

[a] Indicates occurrence of heat waves

occurs, could potentially differ. It is also known that a first heat wave has a greater impact on mortality due to the greater number of exposed subjects (Montero et al. 2010). Thirdly, heat waves differ in duration (Díaz et al. 2006)

Finally, the influence of external factors that occur during or before each summer [e.g. epidemics of influenza during the previous winter (Ha et al. 2011)] can modify the impact of heat on mortality.

Our results regarding the duration, frequency, and intensity of heat waves are in line with those forecast by IPCC. This occurs because the time horizon of these predictions is more extensive and also because the spatial horizon is global and not local as in the specific case of Madrid.

The methodology used in this work aims to address the evaluation of prevention plans in a novel way. The use of ARIMA models introducing Tcal as an external variable allows the quantification of the mortality associated with heat and not only the excess mortality as has been done in other studies (Robine et al. 2008). The mortality excess may be due to other concomitant factors such as air pollution (Sartor et al. 1995). The proposed method calculates the excess mortality due to temperature.

A limitation of our study is that we could not quantify or compare some variables that could influence the analysis, such as the daily temperature rise in the heat wave, the number of consecutive heat wave days (Sáez et al. 1995), access to air conditioning (Kaiser et al. 2001), relative humidity, or environmental pollutants such as total suspended particulates (TSP), sulphur dioxide (SO_2), etc. Changes in these variables throughout the period of study could have influenced the results. Our research evaluated whether PSCEHW has had an impact on mortality, but does not assess specific activities within the plan or the degree of contribution of each activity, so these issues would require further research.

As a result of this study, we can conclude that the implementation of the PSCEHW in the city of Madrid has not translated into a decrease in mortality associated with high temperatures. It will need an in depth analysis by leading health authorities to articulate the necessary corrective measures in order for the PSCEHW to achieve its primary objective, which is the reduction of the mortality associated with heat.

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