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Comparison of the effects of extreme temperatures on daily mortality in Madrid (Spain), by age group: The need for a cold wave prevention plan

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ABSTRACT

A number of studies have shown that there is a time trend towards a reduction in the effects of heat on mortality. In the case of cold, however, there is practically no research of this type and so there is no clearly defined time trend of the impact of cold on mortality. Furthermore, no other specific studies have yet analysed the time trend of the impact of both thermal extremes by age group.

We analysed data on daily mortality due to natural causes (ICD-10: A00-R99) in the city of Madrid across the period 2001–2009 and calculated the impact of extreme temperatures on mortality using Poisson regression models for specific age groups. The groups of age selected coinciding with the pre-existing age-groups analyzed in previous papers. For heat waves the groups of age used were: < 10 years, 10–17 years, 18–44 years, 45–64 years, 65–74 years and over-75 years. For cold waves the groups of age used were: < 1 year; 1–5 years, 6–17 years, 18–44 years, 45–64 years, 65–74 years and over-75 years. < 1, 1–17, 18–44, 45–66, 65–74 and over-75 years. We controlled for confounding variables, such as air pollution, noise, influenza, pollen, pressure and relative humidity, trend of the series, as well as seasonalities and autoregressive components of the series. The results of these models were compared to those obtained for the same city during the period 1986–1997 and published in different studies.

Our results show a lightly reduction in the effects of heat, especially in the over-45-year age group. In the case of cold, the behaviour pattern was the opposite, with an increase in its effect. Heat adaptation and socio-economic and public-health prevention and action measures may be behind this amelioration in the effects of heat, whereas the absence of such actions in respect of low temperatures may account for the increase in the effects of cold on mortality. From a public health point of view, the implementation of cold wave prevention plans covering all age groups is thus called for.

1. Introduction

Studies conducted in different parts of the world conclude that the impact of heat on mortality, far from remaining constant, is changing over time, with a trend towards a minimisation of such effects (Schifano et al., 2012; Morabito et al., 2012; Coates et al., 2014). This impact is most pronounced in mortality due to cardiovascular causes (Ha and Kim, 2013), while in the case of respiratory causes the effect remains practically constant (Mirón et al., 2014). This behaviour pattern, particularly in patients with cardiovascular diseases, seems to be linked, not only to improvements in health services, but also, in general, to socio-economic improvements and the provision of infrastructures for better living conditions, the activation of prevention plans (Abrahamson et al., 2008), or merely the acclimatisation of the population to heat (Konkel, 2014). In view of the fact that the "socio-economic" factors which appear to influence the shifts in the relationship between temperature and mortality are not local and are, thus, extrapolatable to a great proportion of the developed countries, their relevance is self-evident (Bobb et al., 2014). This finding is confirmed by a study undertaken in 7 countries which detected: a significant decrease in mortality in three of them (Japan, USA, Spain); a non-significant decrease in Canada; and no clear behaviour pattern in Australia, South Korea and the UK (Gasparrini et al., 2015a).

When it comes to extremely low temperatures, however, this is

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a phenomenon that has attracted far less attention than heat-wave analysis, though its impact on mortality is at least comparable (Linares et al., 2014a), with some studies undertaken in the UK and Australia even indicating that cold-related deaths are of an order of magnitude greater than those related to heat (Vardoulakis et al., 2014). A study conducted in 13 countries serves to underscore the fact that the effect of low temperatures is 20 times greater than that of heat (Gasparrini et al., 2015b). This lower degree of attention may perhaps be because its influence on mortality is less pronounced and longer term (Alberdi et al., 1998), and because there are other concomitant infectious winter factors (Healy, 2003), though these would not wholly account for high winter respiratory-cause mortality (Ebi and Mills, 2013). Furthermore, despite the fact that the leading cause of winter mortality is respiratory in origin, a relationship has also been found between low temperatures and morbidity–mortality due to circulatory causes (Chau et al., 2014; Xie et al., 2013; Davídkovová et al., 2014). With regard to the time trend of the effect on cold-related mortality, there are practically no studies addressing this aspect, and those that have been conducted report a behaviour pattern similar to that of heat (Mirón et al., 2012; Díaz et al., 2015a).

In addition, there are many studies which indicate that the population over the age of 65 years is the age group most affected by extreme temperatures (Díaz and Linares, 2008; Wanka et al., 2014). Indeed, all the prevention plans implemented to minimise the effects of heat on health indicate that this is the age group of special vulnerability (Heudorf and Schade, 2014), and the same occurs in the case of low temperatures (Ryti et al., 2015).

This in turn raises the following questions: (i) has the reduction detected in the effects of heat been similar across all age groups?; (ii) is the behaviour pattern of heat- and cold-related mortality similar by age group?; (iii) should prevention plans be drawn up in the event of cold?; and if so, (iv), for which age groups?

To answer these questions, this study was conducted in the city of Madrid (Spain) across the period 2001–2009, with the aim of analysing the effect of both thermal extremes by age group and comparing the results to those obtained in other Madrid-based studies in the period 1986–1997.

The results of our study are relevant when it comes to understanding the time trend obtained by other studies for the effects of extreme temperatures, and are thus extremely useful in a public health context, inasmuch as the detection of special risk groups is crucial to ensuring the correct implementation of heat and cold wave prevention plans.

2. Material and methods

As the main variable of analysis, data on daily mortality due to natural causes (International Classification of Diseases-10th revision (ICD-10): A00-R99) in the Madrid municipal area during the period 1 January 2001 to 31 December 2009 were sourced from the Madrid Regional Inland Revenue Authority (*Consejería de Economía and Hacienda de la Comunidad de Madrid*).

The groups of age selected coinciding with the pre-existing age-groups analyzed in previous papers. For heat waves the groups of age used were: <10 years, 10–17 years, 18–44 years, 45–64 years, 65–74 years and over-75 years. For cold waves the groups of age used were: <1 year; 1–5 years, 6–17 years, 18–44 years, 45–64 years, 65–74 years and over-75 years.

Maximum and minimum daily temperature data recorded at Madrid's Retiro Observatory for this same period were supplied by the State Meteorological Agency (*Agencia Estatal de Meteorología-AEMET*).

To ascertain the effect of heat waves on mortality, we created the variable T_{cal}, defined on the basis of the trigger or threshold temperature of daily heat-related mortality obtained in previous studies covering the period 1986–1997, and then compared our results to these studies (Díaz and Linares, 2008). This threshold temperature was set at a maximum daily temperature of 36.5 °C, such that:

2.1. Effect of heat

$$T_{hot} = 0 \quad \text{if} \quad T_{max} < 36.5 \ ^\circ C$$

$$T_{hot} = T_{max} - 36.5 \quad \text{if} \quad T_{max} > 36.5 \ ^\circ C$$

Similarly, to consider the effect of cold, the variable T_{cold} was created, with cold-wave days being defined as those on which the maximum daily temperature failed to exceed 5 °C (Díaz et al., 2005), such that:

2.2. Effect of cold

$$T_{cold} = 5 - T_{max} \quad \text{if} \quad T_{max} < 5 \ ^\circ C$$

$$T_{cold} = 0 \quad \text{if} \quad T_{max} > 5 \ ^\circ C$$

Given that the effect of a heat or cold wave on mortality may not be immediate, the following lagged variables were calculated: T_{cal} (lag 1), which takes into account the effect of the temperature on day "*d*" on mortality, one day later, "$d+1$"; T_{cal} (lag 2), which takes into account the effect of the temperature on day "*d*" on mortality, two days later, "$d+2$"; and so on successively. An analogous procedure was performed for $T_{frío}$.

The number of lags were selected on the basis of the literature, which establishes that, while the effect of heat is short-term (T_{cal}: lags 1–5), cold may also have effects in the medium term ($T_{frío}$: lags 1–14) (Alberdi et al., 1998).

2.3. Control variables

2.3.1. Other meteorological variables

We considered the variables, mean daily air pressure and mean daily relative humidity as recorded by the Madrid-Retiro Observatory and furnished by the *AEMET*, since other studies conducted in Madrid have shown the influence of these meteorological parameters on mortality due to both heat and cold waves (González et al., 2001; Díaz et al., 2002, 2005).

2.3.2. Variables of chemical air pollution

Based on previous studies (Linares et al., 2006; Jiménez et al., 2009), PM_{10}, $PM_{2.5,}$ and NO_2 were assumed to have a linear relationship with mortality with a lagged effect up to day 5. Accordingly, the pertinent lagged variables were created, following the same procedure as that used for temperature. In the case of ozone, the functional relationship obtained by other studies was U-shaped (Díaz et al., 1999), with a minimum daily mean concentration of around 60 μg/m^3. This non-linearity in ozone has been taken into account into two branches, as follows:

$$O_{3high} = 0 \quad \text{if} \quad O_3 \ \text{concentration} \leq 60 \ \mu g/m^3$$

$$O_{3high} = O_3 - 60 \mu g/m^3 \quad \text{if} \quad O_3 \ \text{concentration} > 60 \ \mu g/m^3$$