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Geographical variation in relative risks associated with cold waves in Spain: The need for a cold wave prevention plan

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ABSTRACT

In general, there are few studies that analyse the impact of low temperatures on mortality and fewer still that use cold-wave-definition thresholds based on epidemiological and non-climatological criteria. Such a threshold definition, which took into account population features such as socio-economic and demographic characteristics, made it possible for a specific threshold temperature to be obtained for each of Spain's 52 provincial capitals in this study. Using generalised linear models with the Poisson regression link, and controlling for trend, autocorrelations and seasonalities of the series, and influenza epidemics, we obtained the impact of low temperatures on mortality in each provincial capital by calculating the relative risks (RRs) and attributable risks (ARs) for natural as well as circulatory and respiratory causes. The study showed higher minimum temperature thresholds in coastal areas, and an overall impact of cold on mortality in Spain due to natural causes RR = 1.13 (95% CI: 1.11–1.16), circulatory causes RR = 1.18 (95% CI: 1.15–1.22) and respiratory causes RR = 1.24 (95% CI: 1.20–1.29) slightly greater than that obtained to date for heat. From a public health standpoint, there is a need for specific cold wave prevention plans at a regional level which would enable mortality attributable to low temperatures to be reduced. These plans have shown themselves to be effective in decreasing heat-related mortality, and we feel that they are essential for reducing cold-related effects on morbidity and mortality.

1. Introduction

In contrast to the high number of studies which have assessed the impact that heat waves have on population mortality and morbidity, there are relatively few which have focused on extremely low temperatures (Montero et al., 2010; Díaz et al., 2005; Donaldson et al., 2001; The Eurowinter Group, 1997), despite the fact that their impact on mortality represents a public health threat of an importance comparable to that of heat waves (Linares et al., 2015b; Kysely et al., 2009). Indeed, some studies undertaken in the United Kingdom, Australia and The Netherlands even indicate that cold-related deaths are of an order of magnitude greater than those related to heat (Vardoulakis et al., 2014; Huynen et al., 2001), with an effect of low temperatures which, at a global level, is 20 times, and in the case of Spain, 5 times greater than that of heat (Gasparrini et al., 2015b). One study conducted in 14 European countries, indicated that Spain suffers from the second highest rate of excess winter mortality (21%, CI = 19% to 23%) after Portugal (28%, CI = 25% to 31%) (Healy, 2003). Part of the aetiology of the excess mortality observed after exceptionally cold days is known to be of an infectious nature (Kysely et al., 2009), due to the presence or absence of a pathogenic agent, whose ability to spread is, in turn, favoured by this selfsame drop in temperatures (Hajat and Haines, 2002). Specifically, influenza is the main infectious agent that is associated with winter mortality (Glezen, 1982). The infection of influenza virus is estimated to cause 250,000–500,000 deaths worldwide every year (WHO, 2014). The actual impact of influenza in overall mortality is difficult to estimate, since deaths due to influenza are usually attributed to different pathological processes. Therefore, the mortality associated with influenza is estimated indirectly by models that calculate the excess of deaths during seasonal influenza seasons, above the base line mortality in the absence of virus circulation (Rizzo et al., 2007; Thompson et al., 2009; López-Cuadrado et al., 2012; León-Gómez et al., 2015). In Spain, the annual rate of excess of deaths by all causes attributed to influenza in the group of age over 64 is estimated in the range of 5–77 deaths/100,000 inhabitants depending on the influenza epidemic considerate (León-Gómez et al., 2015). In the variation of the magnitude of the estimated rates can play an important role both the circulating influenza strain (Thompson et al., 2009; León-Gómez et al., 2015), as an interaction with low temperatures coinciding with peaks of maximum influenza activity (Jaakkola et al., 2014; Nielsen et al., 2011). Also, it's necessary to consider other respiratory infections as possible factors in the excess winter mortality (Matias et al., 2014).

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Cold waves tend to be associated with mortality over a prolonged period (Alberdi et al., 1998; Braga et al., 2001), thereby making it more complicated to establish cause–effect relationships. Added to this is the existing lack of uniformity in the definition of a cold wave. A systematic review conducted until 2013 (Ryti et al., 2015) indicated that in most studies cold waves were statistically defined on the basis of a frequency distribution (e.g., 1st-3rd percentiles) as a set of consecutive days with extreme temperatures, and found a positive association between cold waves and mortality due to all and non-accidental causes, cardiovascular diseases and respiratory diseases, as well as increased morbidity. Cold temperatures are associated with increased occurrence of respiratory tract infections (Makinen et al., 2009), respiratory diseases (Clinch and Healy, 2000; Monteiro et al., 2013), excess cardiovascular-disease mortality and morbidity (Urban et al., 2014; Kysely et al., 2009; Davidkovova et al., 2014), and cardiac arrest deaths (Medina-Ramon et al., 2006). Cold exposure is a trigger factor for certain diseases and can contribute to aggravation of prevailing chronic diseases (Rytkonen et al., 2005).

Furthermore, the trend observed across a 34-year period of analysis in Castile-La Mancha (Spain) (Linares et al., 2015a), which in itself confers an important degree of temporal representativeness, indicates that cold waves have not been accompanied by a rise in mean winter minimum temperatures and have been constant in intensity and number of days. This is in line with other studies which, in the context of climate change, indicate there are climate models which predict that extreme cold weather events are likely to occur over continental European areas, and other middle- and high-latitude regions, under 21st-century warming scenarios (Kodra et al., 2011). There are very few studies which forecast possible cold-related impacts on the basis of climate models (Vardoulakis et al., 2014), and these assume that the impact of cold on mortality will remain constant over the envisaged prediction period and that it is temperatures that will change (Linares et al., 2015a). Moreover, there has been a shift in the cold-wave pattern, with a decrease in the month of November and a substantial increase in intensity in the month of December (Linares et al., 2015a), a finding that is in line with what has been observed elsewhere in Europe, consisting of a prolongation of summer months and a more delayed, yet more

Table 1
Descriptive statistics of mortality due to natural, respiratory and circulatory causes and minimum temperature (°C) in winter months by city in Spain 2000–2009 period.

City	Natural mortality				Respiratory mortality				Circulatory mortality				Minimum temperature			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
A Coruña	34	7	14	59	5	3	0	15	13	4	2	29	9.1	2.8	0.6	16.8
Albacete	10	3	1	22	1	1	0	9	3	2	0	12	1.8	4.1	−17.0	14.3
Alicante	39	8	16	72	4	2	0	15	15	4	4	32	8.1	3.3	−2.2	19.0
Almería	12	4	3	29	2	1	0	8	4	2	0	12	10.2	2.5	0.1	18.7
Ávila	5	2	0	15	1	1	0	6	2	1	0	7	0.5	3.8	−13.2	10.8
Badajoz	19	5	5	38	2	2	0	10	7	3	1	20	5.2	4.1	−7.2	17.2
Barcelona	127	20	82	230	16	6	2	49	42	9	19	84	6.7	3.2	−3.6	16.6
Bilbao	31	7	13	60	4	2	0	17	10	3	1	27	6.4	3.9	−6.0	20.7
Burgos	10	3	0	23	1	1	0	7	3	2	0	11	0.6	4.0	−17.1	11.6
Cáceres	11	4	2	26	2	1	0	8	4	2	0	17	5.3	3.6	−4.6	15.6
Cádiz	25	6	9	48	3	2	0	13	9	3	1	22	11.2	2.9	0.2	19.4
Castellón	14	4	3	28	2	1	0	7	5	3	0	15	8.1	3.1	−2.0	19.0
Ciudad Real	14	4	2	32	2	2	0	14	5	2	0	14	3.4	3.8	−9.0	14.3
Córdoba	21	5	7	44	3	2	0	14	8	3	1	20	5.8	3.8	−8.2	17.5
Cuenca	5	2	0	14	1	1	0	5	2	1	0	8	1.4	3.7	−11.7	12.8
Girona	16	4	4	35	2	2	0	11	5	2	0	15	2.6	4.1	−10.8	16.8
Granada	22	6	7	48	3	2	0	12	9	3	1	23	3.1	3.5	−10.0	15.0
Guadalajara	5	2	0	15	1	1	0	5	2	1	0	7	0.3	4.2	−12.5	12.0
Huelva	12	4	2	28	1	1	0	8	5	2	0	15	7.7	3.4	−3.2	18.4
Huesca	6	3	0	15	1	1	0	6	2	2	0	9	2.8	3.8	−10.8	13.3
Jaén	17	5	4	46	2	2	0	15	6	3	0	17	7.1	3.3	−7.8	18.0
Las Palmas	18	5	2	35	2	1	0	8	6	3	0	19	16.0	2.0	10.9	22.7
León	16	4	4	34	2	2	0	10	5	2	0	14	0.5	3.7	−15.0	10.4
Logroño	8	3	0	19	1	1	0	6	3	2	0	9	3.3	3.7	−9.8	13.2
Lugo	14	4	3	33	2	2	0	9	5	2	0	19	2.8	4.4	−10.0	15.7
Lleida	12	4	2	29	2	1	0	9	4	2	0	14	2.6	4.0	−9.8	13.5
Madrid	119	16	69	206	19	7	4	54	37	7	16	72	4.5	3.2	−6.1	13.4
Málaga	33	7	15	58	4	2	0	14	13	4	2	30	9.4	3.1	−0.2	20.2
Murcia	28	6	11	56	4	2	0	16	11	3	2	22	11.4	2.6	0.4	21.8
Ourense	13	4	2	28	2	2	0	9	5	2	0	16	4.3	4.3	−8.6	15.6
Oviedo	36	7	17	63	5	3	0	21	13	4	3	29	5.5	3.4	−3.7	16.5
Pamplona	15	4	3	31	2	2	0	12	5	2	0	15	2.9	3.9	−11.6	16.0
P. Mallorca	22	5	7	41	3	2	0	10	8	3	1	21	5.7	3.9	−4.0	16.8
Pontevedra	23	6	6	45	3	2	0	14	8	3	0	20	7.1	3.3	−2.0	17.0
Salamanca	11	4	2	26	1	1	0	9	4	2	0	11	0.2	4.2	−12.0	12.5
Santander	16	5	5	38	2	2	0	12	5	2	0	14	6.8	3.7	−5.2	20.2
S. C. Tenerife	19	5	4	38	2	1	0	9	6	3	0	16	16.4	1.8	11.6	22.5
Segovia	4	2	0	12	1	1	0	4	1	1	0	8	1.7	3.8	−13.2	15.4
Sevilla	43	9	21	80	4	2	0	16	19	5	6	40	8.3	3.4	−3.5	18.4
Soria	3	2	0	12	0	1	0	6	1	1	0	6	−0.1	3.9	−13.6	10.6
S. Sebastián	18	5	4	36	2	2	0	14	6	2	0	16	6.9	3.6	−5.6	18.0
Tarragona	17	5	4	39	2	2	0	9	6	2	0	17	7.0	3.5	−2.6	18.0
Teruel	4	2	0	13	1	1	0	5	2	1	0	7	−0.9	4.3	−19.0	11.2
Toledo	15	4	2	34	2	2	0	12	5	2	0	17	3.2	4.0	−9.6	13.6
Valencia	63	11	32	114	8	4	1	26	23	5	8	47	8.9	3.2	−1.6	18.0
Valladolid	13	4	3	29	2	1	0	10	5	2	0	14	1.8	3.8	−10.8	11.8
Vitoria	7	3	0	16	1	1	0	7	2	1	0	10	2.2	4.0	−11.5	14.6
Zamora	7	3	0	19	1	1	0	6	2	2	0	9	2.0	4.2	−10.6	12.8
Zaragoza	26	6	11	54	3	2	0	14	9	3	1	21	4.2	3.9	−9.5	15.3