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Determination of heat wave definition temperatures in Spain at an isoclimatic level: time trend of heat wave duration and intensity across the decade 2009–2018

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Abstract

Background In line with WHO guidelines for the implementation of public health prevention plans targeted at the impacts of high temperatures, a heat wave definition temperature (Tthreshold) was calculated for 182 so-called "isoclimatic zones" (IZ) in Spain. As the dependent variable for determining this Tthreshold, we analysed daily all-cause mortality data (ICD-10: A00-R99) for each IZ across the period 2009–2018. The independent variable used was the mean value of the maximum daily temperature of the summer months recorded at meteorological observatories in each IZ. We used Box–Jenkins models to ascertain mortality anomalies, and scatterplots to link these anomalies to the temperatures at which they occurred, thereby determining the Tthreshold for each IZ. We then calculated how many heat waves had occurred in each IZ, as well as their intensity, and analysed their time trend over this period.

Results The results showed that in 52.5% of the IZ, the percentile of the maximum temperatures series of the summer months to which Tthreshold corresponded was below the 95th percentile of the meteorological heat wave definition in Spain: indeed, it only coincided in 30.7% of cases. The geographical distribution of these percentiles displayed great heterogeneity as a consequence of the local factors that influence the temperature–mortality relationship. The trend in the number of heat waves analysed indicated an overall increase in Spain at a rate of 3.9 heat waves per decade, and a similar rise in mean annual intensity of 9.5 °C/decade. These time-trend values were higher than those yielded by analysing the trend in meteorological heat waves based on the 95th percentile.

Conclusions The results obtained in this study indicate the need to use a heat wave definition based on epidemiological temperature–mortality studies, rather than on values based on meteorological percentiles. This could be minimising estimated health impacts in analyses of future impacts attributable to heat.

Keywords Prevention plans, Threshold temperature, Heat waves, Mortality, Time trend

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Introduction

Within the current climate change context, the fight against the health impacts of temperatures—which are increasingly higher and translate as more frequent, more intense and more extensive heat waves [1–6]—is a priority for public health services. Protecting the health of the most vulnerable groups from the effects of heat has led to numerous studies being undertaken at an international level with the aim of enabling their results to be efficiently incorporated into prevention plans, both in terms of identifying special vulnerability groups and in terms of greater geographical specificity [7–11].

From a meteorological or climatic point of view, a general definition of heat waves are periods of temperature above a predetermined threshold lasting two or more consecutive days. These thresholds are usually identified from the 95th percentile [12]. Other definitions use different thresholds, such as other percentiles [13, 14] or other lengths, such as three or more days [15]. In addition to the different combinations mentioned, there are a series of thermal comfort index. Truly, heat waves impact on health are the results of various meteorological components, such as, atmospheric temperature, humidity, air speed and solar radiation [16, 17].

There are multiple local factors, not only climatic, but also of a social and demographic nature, such as population structure, public and private infrastructures, available health services, socio-economic level and many others, which may modify the impact of extreme temperatures on population health and decisively influence adaptation processes [18–21]. Omitting to take into account the impact and influence that such local-level factors may have on heat-attributable mortality, as well as the intensity of the temperature itself, is omitting to address all the pertinent scientific evidence comprehensively.

In 2015, the Spanish Ministry of Health, Social Services and Equality (*Ministerio de Sanidad Servicios Sociales e Igualdad*) updated the country's High Temperature Prevention Plan that is activated every summer, by setting heat wave thresholds based on mortality impact [22], rather than relying exclusively on meteorological-type thresholds. This plan is based on the existence of a specific maximum daily temperature at a provincial level which, when exceeded, triggers the public health high temperature warning system. Yet, in the search for prevention plan efficiency, very few studies have addressed the problem of the impact of extreme temperatures at a level below that of province, when it is known that within a given administrative structure defined as "province", there are different types of climatological conditions and, moreover, that the way these develop within the current climate context can differ widely.

There is a pilot study conducted in Madrid [23, 24], in which, instead of considering the impact of a single temperature at a provincial level, the impact on mortality is calculated by defining 3 so-called "isoclimatic zones" (IZ) within a single province. These zones are already predefined by the State Meteorology Agency *(Agencia Estatal de Meteorología/AEMET*) in its regionalisation of Spanish state territory and are known as Meteoalert zones (geographical zones made up of territorial areas which are uniform in terms of the climate pattern of different meteorological variables contained within a given province for weather forecast purposes). The results obtained from this analysis yielded excellent results from the standpoint of public health management, firstly in terms of the number of alerts generated, and secondly in terms of the ensuing impact. In other words, it resulted in a decrease both in the number of alerts and in the number of possible heat-attributable deaths and emergency hospital admissions.

In Spain, the first studies conducted considering emergency hospital admissions related to heat waves showed a lower incidence than in mortality data for all causes [25]. However, recent studies that look into specific causes, indicate that there is a relationship between the daily maximum temperature during heat waves and emergency hospital admissions due to neurological diseases [26, 27] and emergency hospital admissions for mental and kidney diseases [28]. Moreover, an association between heat waves and the number of premature births have been detected [29].

In the reference literature, it is not usual to find a great amount of scientific evidence at this level of geographical specificity which would serve to evaluate the improvement in heat wave prevention plans. In an area like southern Europe, where extreme meteorological phenomena are becoming more intense with every summer [30], it is of great interest to assess tools that improve the functioning of such plans. If zoning by established isoclimatic temperatures coincides with health alerts in heat waves episodes, the prevention of related impacts will also be more efficient when it comes to communicating to the public and health professionals. Issuing heat warning alerts solely when these are required on the basis of the evidence contributes to greater credibility of prevention efforts.

The aim of this study was therefore: firstly, to ascertain the temperatures used for the heat wave definition, and by extension, for activation of high temperature prevention plans for the different IZ defined by AEMET's meteorological observatories countrywide; and secondly, to evaluate how the number and intensity of heat waves have evolved over a representative time horizon from the stance of public health impacts, rather than being exclusively based on analysis from a climatological point of view.

Methods

We conducted an ecological–longitudinal epidemiological time series study. The time series analysed covered the period 1 January 2009 to 31 December 2018. The sampling units analysed were the IZ into which all Spanish territory is regionalised. These are zones determined by AEMET for weather forecast purposes and are thus considered isothermal regions [31], i.e. territorial areas that are uniform in terms of daily temperature patterns. The methodology described below was repeated for each of these zones.

Variables

The dependent variable used was the daily death count due to natural causes (International Classification of Diseases, 10th edition (ICD-10): A00-R99) in a given IZ [32]. These data were supplied by the National Statistics Institute (*Instituto Nacional de Estadística/INE*) on a municipal scale for all the country's towns, under a confidential microdata assignment agreement.

The independent variable was maximum daily temperature during summer months (June to September). This variable was chosen because it exhibits the best statistical behaviour with summer mortality [33, 34]. The daily maximum temperature used was the average of the mean of the data recorded by each meteorological observatory in each IZ. The data were provided by AEMET.

Some IZ were excluded due to having excess missing values in their temperature records (> 10% missing values). In cases where this proportion was smaller, the relevant missing values were imputed by linear interpolation or by linear model prediction controlled for seasonality, depending on whether there were isolated missing observations or longer gaps.

Determination of the heat wave threshold temperature of each isoclimatic zones (IZ)

To determine which temperature should be considered the heat wave threshold in each IZ, we performed an epidemiological analysis of the mortality–temperature association, as recommended by the WHO [35]. The methodology used has been patented by the Carlos III Institute of Health [36] and is the methodology used by the Ministry of Health to set the threshold temperatures for activation the National Preventive Action Plan against the effects of excess temperature on health [22]. Indeed, there are many papers in the literature that describe this methodology [24, 37–39] which consist in:

1) Box–Jenkins models based on Autoregressive Integrated Moving Average (ARIMA) family models [40–44] were fitted for the daily mortality series of each IZ, controlled for the variables of seasonality and trend.
2) The fit of these models represents the expected behaviour of the mortality series, based solely on the history of the series. Then, anomalous mortality values due to unconsidered external variables, such as temperature, will result in a poor model fit, and lead to an increase in the residuals of the model (difference between expected and predicted values). These residuals of the Box–Jenkins models for daily mortality of the summer months (June–September) which will be the subject of representation and analysis [45].
3) In particular, we seek to locate whether some temperatures values are statistically associated values with abnormally high mortality residuals. This indicates the association between temperature and abnormally high manifestations of summer mortality, which are unforeseeable based on the usual behaviour of mortality time series.

These temperature points associated with mortality anomalies are established with the aid of graphs. In these, the model residuals are plotted on the Y-axis, and the maximum daily temperature on the X-axis. A horizontal line marks the upper limit of the 95% confidence interval of the mean errors of the model.

Given that the impact of temperature on mortality takes place in the short term [33, 45], the moving averages of the maximum daily temperature were calculated for the three days preceding each observation [46].

Thereafter, the mean model error was calculated for temperature ranges of $i \pm 1$ °C, where i represents each degree Celsius included in the range of observed maximum temperatures [24, 46].

We calculated the mean model error for two-degree temperature intervals, which cover the entire interval of temperatures of the series and overlap. These mean residual of mortality values by temperature intervals were then plotted as mentioned.

An example of this heat-wave definition threshold temperature (Tthreshold) can be seen in Fig. 1, the value showed corresponding to the Madrid-Metropolitan and Henares IZ.

Once these heat wave threshold temperatures have been determined, to compare values between IZ we

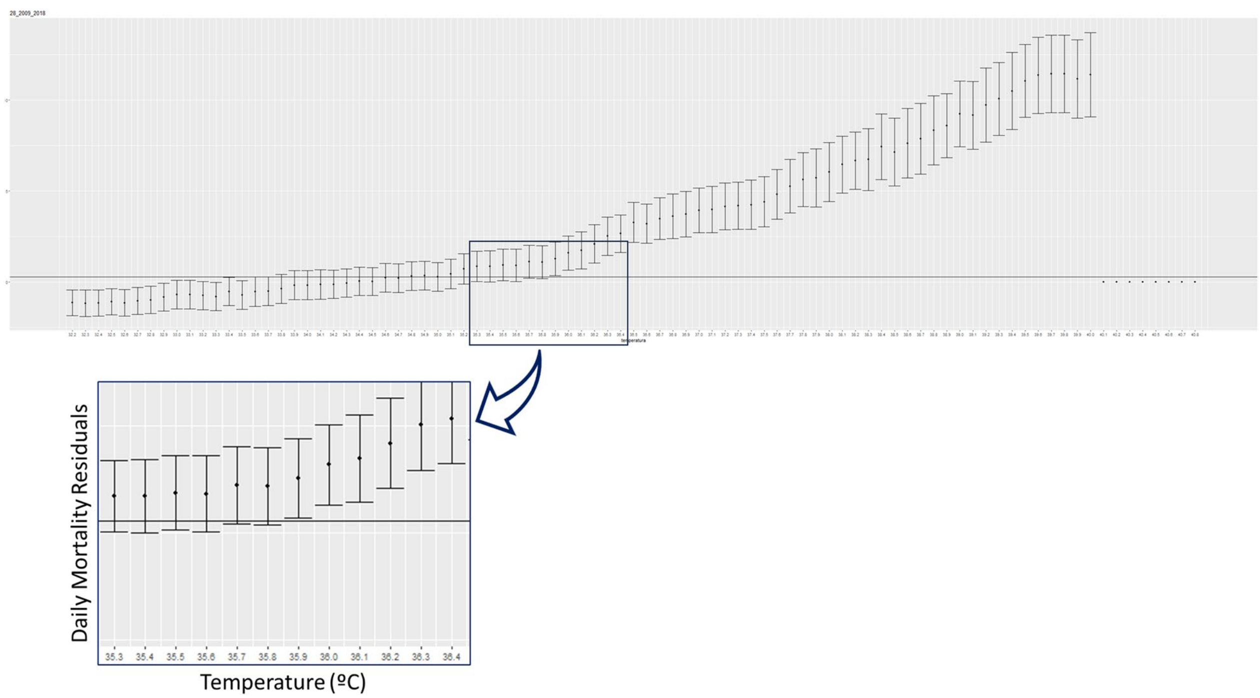

Fig. 1 Scatterplot of mortality residuals and daily maximum temperature of the isoclimatic zone: *Metropolitan-Madrid and Henares*

therefore transposed them to threshold temperature percentiles [24, 33]. In some IZ, the threshold temperature of extreme heat was not detected, probably due to the low mortality count in those zones. In such cases, the IZ's maximum daily temperature corresponding to the threshold percentile established for the province was chosen as the threshold temperature [22]. In any case where there was no percentile at a provincial level, the temperature situated at the 95th percentile of the relevant IZ was used.

For the methodology described in this section, the following two software packages were used: the free R.4.3.0. software environment to process and debug the databases and determine the threshold temperatures; and the basic IBM SPSS Statistics 29.0.0.0. software package to fit the ARIMA models.

Characterisation of the number, mean intensity and annual intensity of heat waves

The following variables were calculated to know and analyse their time trend in the period 2009–2018.

The number of hot days (Num): is the number of days, for each year on which Theat is > 0. i.e. the number of days on which Tthreshold is exceeded for each IZ (based on the established Tthreshold calculated above).

The variable Theat was defined as follows:

$$\text{Theat} = 0 \quad \text{if Tmax} \leq \text{Tthreshold}$$

$$\text{Theat} = \text{Tmax} - \text{Tthreshold} \quad \text{if Tmax} > \text{Tthreshold},$$

where Tmax is the maximum daily temperature of each IZ region.

The mean intensity (Intmean) of the heat waves occurring in each year: defined as the summatory of Theat value (°C) / Num(day).

The total intensity of heat waves (Intotal) occurring in each year: defined as the summatory of Theat in each year (°C).

Time trend in the number (Num), mean intensity (Intmean) and total intensity of heat waves (Intotal)

Based on each of the annual values of the previously calculated parameters, their linear fit was plotted. The slope of this line represents the increase per year in each of the above values, such that positive values of the slope will represent an upward trend in that parameter, and negative values will indicate a downward trend in that indicator across time.

Results

Additional file 1: Table S1 of the supplementary material shows the descriptive statistics of mortality and maximum daily temperature for each of the IZ

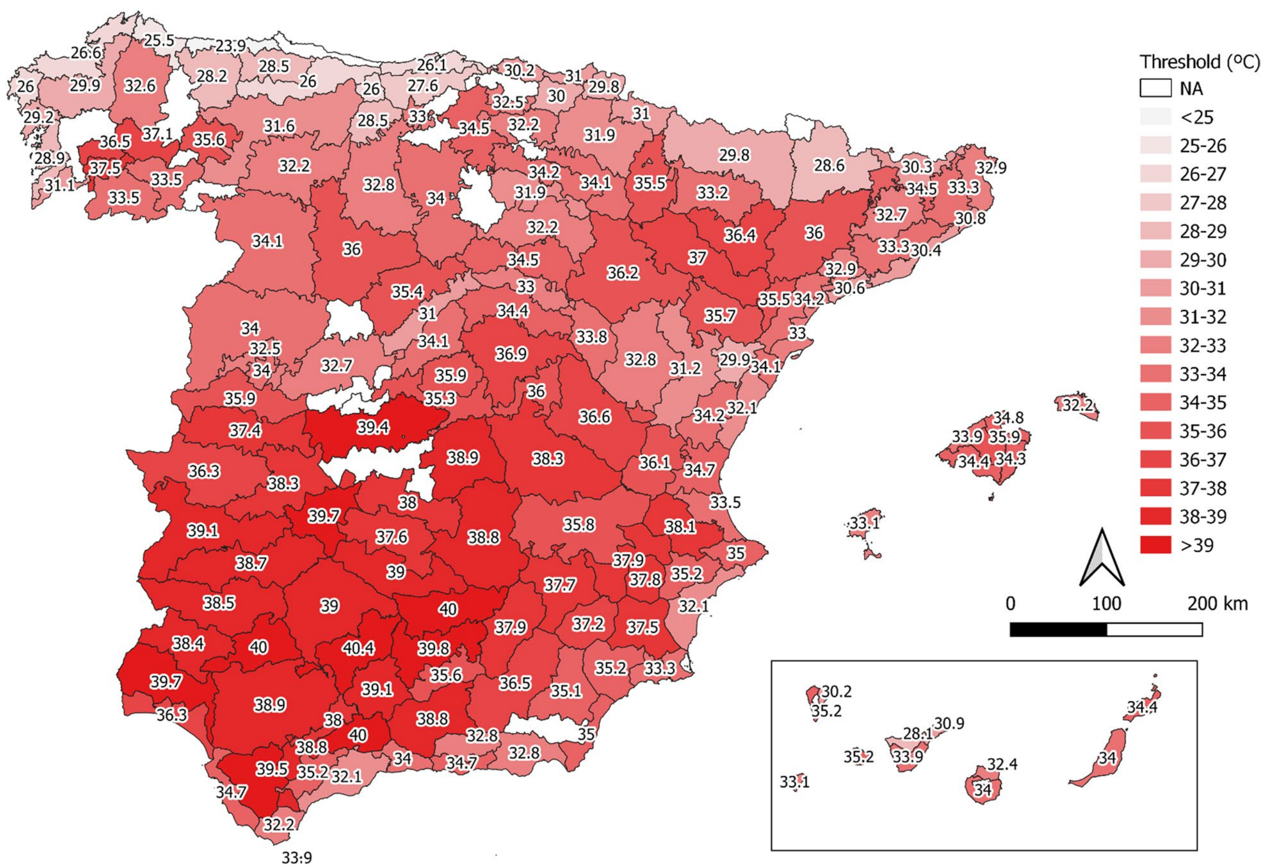

Fig. 2 Map of threshold temperatures for the different isoclimatic zones of Spain

considered. Of the total of 182 IZ established by AEMET, application of the exclusion criteria described in the Methodology section meant that Tthreshold was only determined in 162.

Figure 2 shows the Tthreshold for each of the existing IZ in Spain for which it was calculated. These values ranged from a maximum daily temperature of 23.9 °C corresponding to Asturia's Western Coastal Strip (*Litoral Occidental*) to 40.4 °C for the Cordoba Countryside (*Campiña Cordobesa*), a difference of 16.5 °C.

For the purpose of being able to compare the Tthreshold to the maximum daily temperatures recorded in each place, we established to which percentile a specific Tthreshold corresponded with respect to the maximum daily temperatures of the summer months of the period considered. Figure 3 shows these percentiles, which ranged from the 72nd percentile corresponding to the Alicante South Coastal Strip (*Litoral Sur*) to the 98th percentile corresponding to the Castellón North Coastal Strip (*Litoral Norte*) and La Mancha-Cuenca region (*La Mancha Conquense*), as well as Las Palmas de Gran Canaria and Santa Cruz de Tenerife. Using the 95th percentile corresponding to the meteorological heat wave definition in the case of the Alicante South Coastal Strip would mean that, each year, the Heat Wave Prevention Plan would not be activated on 23% of days, with the possible ensuing impact on the health of the population.

In general, in 85 IZ (52.5% of IZ) the heat wave definition threshold was below the 95th percentile and in 16.7% it was above the 95th percentile. The percentile corresponding to the Tthreshold only coincided with the meteorological heat wave definition in 30.7% of the zones (47 regions).

With respect to the time trend in the number of heat waves as per the epidemiological heat wave definition, in Spain as a whole there was a mean increase of 3.9 heat wave days across the decade analysed. The mean intensity of each heat wave day rose by 0.3 °C/heat wave day and the annual intensity rose by 9.5 °C. All these increases were statistically significant at $p < 0.05$.

Table 1 shows the overall results for the 17 Autonomous Regions and Spain as a whole, along with the situation of each Autonomous Region. From this it will be seen that the pattern was similar to that described for Spain as a whole, with a rise in the trends of the 3 parameters analysed, except in the Balearic Isles, Canary

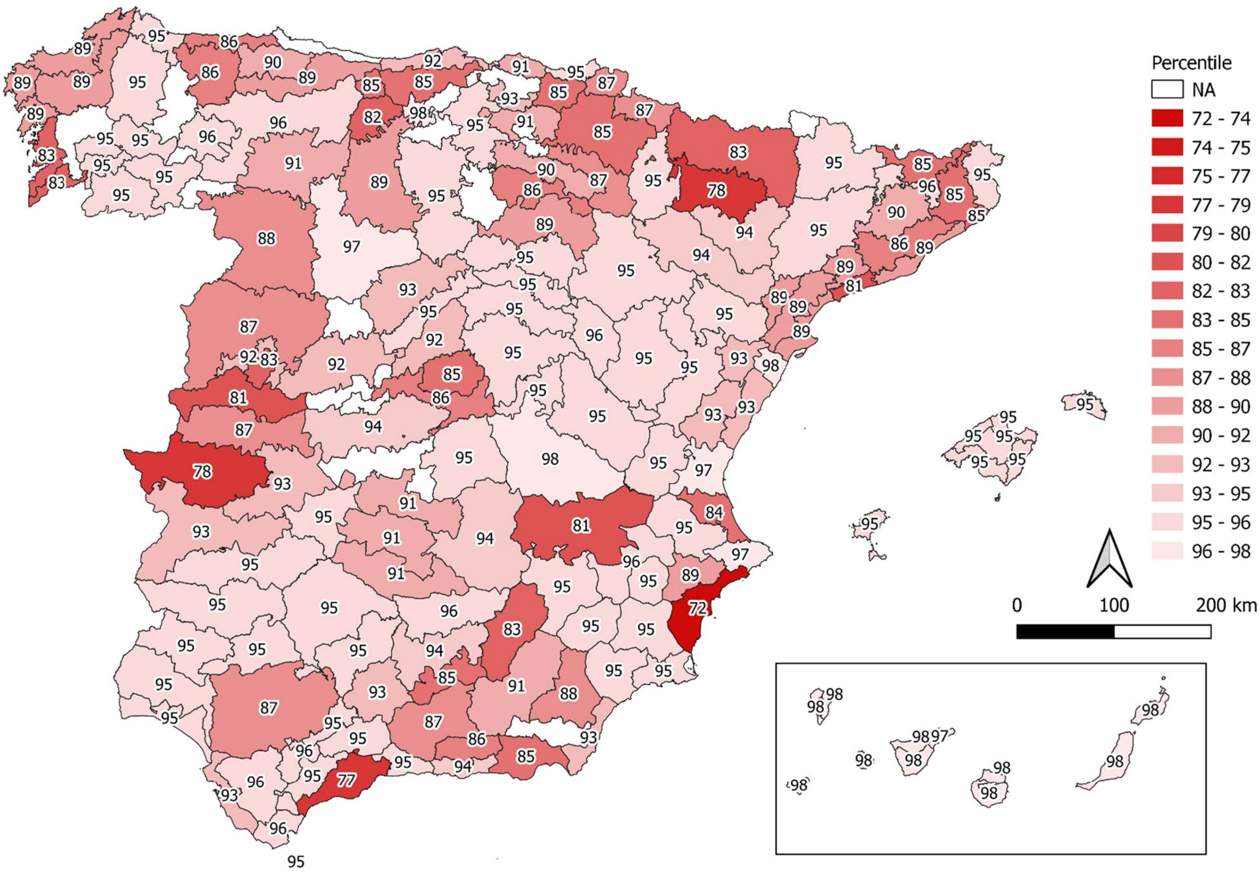

Fig. 3 Percentiles to which the threshold temperatures of each isoclimatic zone correspond in relation to the maximum temperatures series for the summer months of the period 2009–2018

Islands, and the Murcia and Navarre Regions where the three trends moved downward. In the Valencian Region and La Rioja, there was no increase in mean heat wave intensity but there was a rise in the number of days and annual intensity of heat waves.

The greatest variation in the number of heat wave days was observed in Castile-La Mancha, in which there were 10 more heat waves at the beginning of the decade than at the end. In terms of mean heat wave intensity, it was in Extremadura where heat waves were an average of 1.5 °C more intense by the end of the decade than at the beginning. When it came to the highest cumulative heat wave intensity in one year, Asturias was where the greatest variations were registered, with an increase of as much as 20 °C in mean annual intensity.

Figure 4a shows the pattern of decadal variation in heat wave days. From this map, it can be seen that, in general, the greatest increases were seen in inland areas. The same can be observed in Fig. 4b with regard to mean heat wave intensity, with the Balearic and Canary Islands and Spain's Levante region being the areas where this rise was least pronounced. Annual heat wave intensity displayed an even more uneven pattern, as can be seen from Fig. 4c.

Discussion

Based on current scientific knowledge, it is evident that the impact which heat waves have on population health is modulated by numerous factors that go beyond the values reached by maximum daily temperature, including the intensity of a given heat wave, [47]. Such factors not only cover socio-economic aspects, e.g. income level [48], but also include the demographic characteristics of the population and its vulnerability [26, 49, 50]. To cite just some of these local factors of influence, they would include the rural or urban nature of each place ($n=16$), the frequency with which it is or is not subjected to heat waves [24], the presence of urban infrastructures with or without green areas [51], and the quality of housing [52–54]. Accordingly, it is not logical for the temperature used to define a heat wave from a health standpoint to be based solely on a fixed percentile for all places in a geographical setting, a value that does not take into account the factors considered above. This is the reason why the

Table 1 Variations across the decade 2009–2018 in the number of days, mean intensity and annual intensity of heat waves, with a breakdown by the different Autonomous Regions of Spain

	Number of isoclimatic regions	Decadal trend in Num [number of hot days] (days)	Decadal trend in Intmean [mean heat wave intensity] (°C/day)	Decadal trend in Intotal [annual heat wave intensity] (°C)
Andalusia	28	6[a]	0.4[a]	12.9[a]
Aragon	9	2	0.0	5.3
Asturias	4	7[a]	0.4[a]	20.0[a]
Balearic Isles	7	−4	−0.2	−2.1
Canary Islands	10	−3[a]	−1.5[a]	−4.6
Cantabria	4	3[a]	0.5[a]	15.4
Castile & León	19	4[a]	0.8[a]	12.0[a]
Castile-La Mancha	15	10[a]	0.8[a]	15.7[a]
Catalonia	15	7[a]	0.2[a]	11.9[a]
Valencian Region	11	2[a]	−0.3	4.3[a]
Extremadura	8	5[a]	1.5[a]	18.1[a]
Galicia	13	4[a]	0.9[a]	16.0[a]
Madrid	3	1.3[a]	1.2[a]	1.1[a]
Murcia	5	−1.9	−0.6[a]	−6.4[a]
Navarre	4	−0.1	−0.3	−1.5
Basque Country	5	0.1	0.0	3.8[a]
La Rioja	2	3.4	−0.2	11.6[a]
Spain as a whole	162	3.9	0.3	9.5

Situation of the different Autonomous Regions in Spain

[a] Statistically significant increases/decreases

WHO clearly calls for the involvement of these factors at a local level when it comes to implementing prevention plans: "*Threshold levels should be based on health risks and not only on meteorological conditions*"[18].

The results of this study undertaken for Spain show that in 52.6% of cases, the percentile of the maximum temperature series of the summer months to which Tthreshold corresponds, lies below the 95th percentile, i.e. the percentile corresponding to the meteorological heat wave definition. Using this latter percentile would mean not activating the heat wave prevention plan when it is in fact required in more than half of the IZ in Spain, with the ensuing impact on mortality, something that could be prevented by activating the prevention plan in question [12]. In contrast, for regions with percentiles above the 95th percentile, using the latter as the trigger would mean activating prevention plans when they are not necessary [55, 56].

This study also signals an important advance in terms of implementation of prevention plans [22], consisting of reducing the provincial scale to an IZ scale. This advance makes it possible, in some cases, to have as many as 5 geographic zones per province, which in turn makes it possible to take into account the local factors that, in great measure, determine the different impacts on heat wave mortality [18].

A study undertaken for the Province of Madrid [57], which used thresholds for geographical zones smaller than a province to compare avoidable mortality across the period 2000–2009, concluded that 73 deaths could have been prevented in this period (95% CI 73–08) and that issuing unnecessary public health warnings could have been avoided on 570 occasions.

Furthermore, studies were conducted with the aim of estimating the health impact of temperatures based on fixed percentiles [12, 33] or so-called extreme heat [58, 59]. From our point of view, using a fixed percentile may lead to a situation where the temperature that represents this percentile does not correspond with the occurrence of a heat wave, whereas in other places the same percentile may well respond to temperatures far above the heat wave definition, which would include biases in the results obtained.

The finding of an increase in the number of heat wave days and a rise in mean heat wave intensity in Spain from a health standpoint is consistent with studies which report an increase in the number of days of extreme meteorological events with important health effects, in northern and southern Europe alike, and which even go so far as to estimate that phenomena with a high health impact, such as the 2003 heat wave that caused an excess

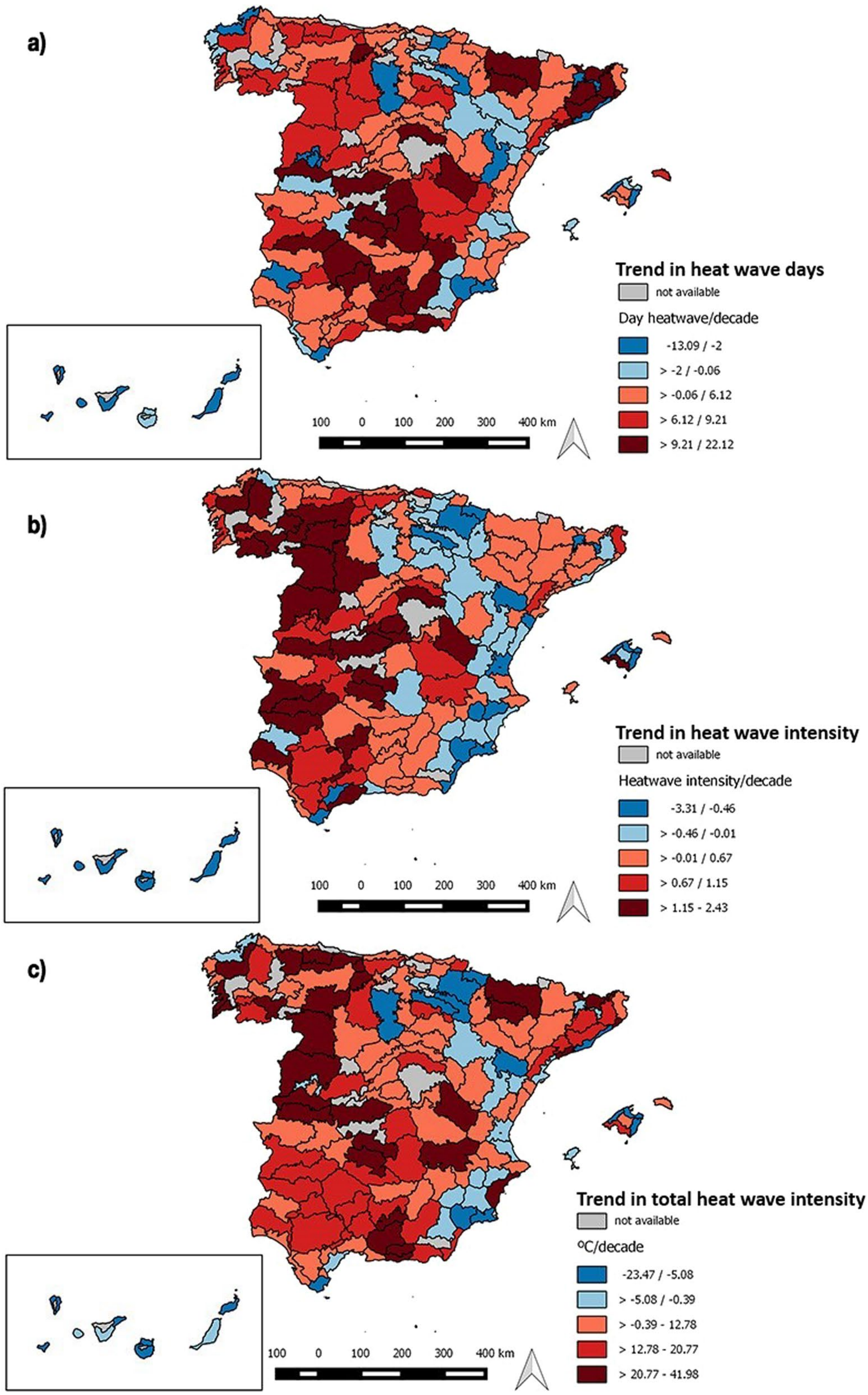

Fig. 4 Time trend in heat waves in days, intensity and annual intensity across the period 2009–2018

of 70,000 deaths across Europe [60], may become twice as frequent [61].

From the stance of the meteorological heat wave definition, from 1975 to 2019, heat waves in Spain increased at a rate of 3 days per decade [62]. This result would indicate that heat waves with a health impact, on which this study is focused, are growing at a higher rate (3.9 days/decade) than are meteorological heat waves, though the time periods of analysis are different. In addition, the increase of 9.5 °C/decade in annual mean heat wave intensity found by us is higher than the increase of 6 °C/decade reported by other studies based on the meteorological heat wave definition [63]. This may probably be due to the fact that most of the heat waves in Spain from a health standpoint are below the 95th percentile of the meteorological heat wave definition, thus making them more numerous and more intense. It would therefore seem that heat waves based on the health definition are increasing at a higher rate, both in frequency and intensity, than are meteorological heat waves, at least in Spain. Should these results be confirmed elsewhere, then studies based on the time trend in extreme temperatures established on the basis of meteorological percentiles could be minimising the consequences which extreme heat might have on human health.

The results of Fig. 4, taken together with those listed in Table 1, clearly show the wide geographical heterogeneity that exists in Spain. Whereas in some places, the trend found in the 3 parameters analysed in the heat wave time trend is clearly rising, in others, the exact opposite is the case. These results are in line with those reported by other studies conducted in Spain [41] on the future impacts of heat waves on mortality across the period 2021–2050 [64]. The places envisaged by this study as having no heat waves with a mortality impact, even under an RCP8.5 emission scenario, are Murcia, Santa Cruz de Tenerife, Las Palmas and the Balearic Isles, which are the very same zones in which no rising trend in the number of heat waves was detected by us.

The heterogeneity found, both in the percentiles to which the Tthresholds correspond, and in the time trend of their duration and intensity, is linked to the differing vulnerability to heat which exists in Spanish regions and is marked by the different income levels, housing quality, heat-wave frequency in each place, population pyramid, and rural or urban nature of these regions [19], and which underscores the need to establish heat wave prevention plans on a scale smaller than provincial, as was done here. Furthermore, the results found here should be considered essential when it comes to prioritising the geographical zones in which planning is required for the adoption of measures targeted at reducing vulnerability to high temperatures [65] and enhancing adaptation to heat waves [20].

As indicated in the methodology section, the daily maximum temperature used is obtained as the average of the mean daily maximum temperatures of each meteorological observatory in each IZ. This value is the best measure of the real exposure of the population to maximum temperatures, then the possible lack of homogeneity, such as, the elevation of the observatory or other geographical factors such as, land cover have not been taken into account. The bias that can occur when using the data thus determined, as a measure of population exposure, is the so-called Berkson-type measurement error [66] and is inherent to ecological studies such as the one conducted here.

It is evident that there are other meteorological factors that can also affect daily mortality in addition to the daily maximum temperatures, such as humidity [67, 68] or the daily minimum temperature [69, 70], which have not been considered in this study. However, it must be taken into account that this is an analysis that will serve as a basis for creating a Prevention Plan in Public Health with implications at a practical level. This means having to go from 52 daily maximum temperatures [22] to 182 across the territory, obtained from more than 1100 meteorological observatories. Including more meteorological variables such as, relative humidity or minimum daily temperature, would in practice make data handling and subsequent implementation very complicated.

Although the analysis conducted here represents an improvement for the High Temperature Plan of the Ministry of Health [22], is evident with greater geographic disaggregation, that the values of the threshold temperatures obtained here are very consistent with those of the current Plan, both quantitatively and qualitatively. For example, in both cases, the lowest heat wave definition temperatures occur in the Cantabrian area with temperatures around 26 °C. Similarly, the highest values of heat wave definition temperature occur in Andalusia with values close to a maximum daily temperature of 40 °C. In the Balearic Island the threshold temperatures are close to 33 °C, which is consistent with the data at the Provincial level, the same occurs with the Canary Island with values, in both cases, heat wave definition temperatures are between 33 and 34 °C.

Conclusions

The results obtained in this study show that the respective heat wave definitions arrived at from a health stance (through the mortality impact) and from a meteorological stance are different, since they correspond to different concepts. While the meteorological definition is obtained as a percentile of a climatological series (95th percentile), the health-based definition is obtained as the maximum daily temperature above which mortality rises statistically significantly; and though the recorded temperatures obviously exert an influence, other factors also intervene, which means that on most occasions the two definitions will not coincide. The greater number of places in which the health-based heat-wave definition threshold temperature is below the 95th percentile means that the time trend in the number of heat wave days and the mean annual intensity of such heat waves are higher than those of meteorological heat waves, something that could be minimising estimated health impacts as a result of using the meteorological rather than the health-based definition when addressing future impacts attributable to heat.

Moreover, the heterogeneity in the behaviour, both of the percentiles to which health-based heat wave temperatures correspond and their different time trends, is a result of the effect that local factors have on mortality. This clear effect of local factors renders it necessary for a scale smaller than provincial to be used for activation of high temperature prevention plans. This will result in a reduction in heat wave-attributable mortality and a decrease in the number of warning alerts that are activated every year as a consequence of high temperatures in Spain.

Abbreviations

AEMET	State Meteorology Agency
ARIMA	Autoregressive Integrated Moving Average
INE	National Statistics Institute
Intmean	Mean intensity of the heat waves
Intotal	The total intensity of heat waves
IZ	Isoclimatic Zones
Num	The number of heat waves

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12302-024-00917-6.

Additional file 1: Table S1. Descriptive statistics of the daily maximum temperature and daily mortality for each isoclimatic zone across the period 2009–2018. [1]Mortality (counts per day): mean daily mortality due to natural causes (ICD-10-ES: A00-R99). [2]Tmax (°C): Mean daily maximum temperature.

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Disclaimer

This paper reports independent results and research. The views expressed are those of the authors and not necessarily those of the Carlos III Institute of Health (Instituto de Salud Carlos III).

Author contributions

Authors' contributions JAL-B: Epidemiological study design. Providing and Analysis of data; Elaboration and revision of the manuscript. PA Providing and Analysis of data; Elaboration and revision of the manuscript. MAN-M Providing and Analysis of data; Elaboration and revision of the manuscript. IJM Epidemiological study design. Elaboration and revision of the manuscript. FB: Epidemiological study design. Elaboration and revision of the manuscript. JD: Original idea of the study. Study design; Elaboration and revision of the manuscript. CL: Original idea of the study. Study design; Elaboration and revision of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

It is an ecological analysis so the study does not involve human subjects.

Declarations

Ethics approval and consent to participate

This study works with aggregate data, therefore there are no individual data. Therefore, the consent to participate is not applicable.

Consent for publication

This study works with aggregate data, therefore there are no individual data. Therefore, the consent to publish is not applicable.

Competing interests

The researchers declare that they have no conflicts of interest that would compromise the independence of this research work. The views expressed by the authors do not necessarily coincide with those of the institutions whose affiliation is indicated at the beginning of this article.

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