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1 **The Evolution of Minimum Mortality Temperatures as an Indicator of Heat Adaptation: The**
2 **Cases of Madrid and Seville (Spain)**

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8

9 Abstract

10 The increase in the frequency and intensity of heat waves is one of the most unquestionable
11 effects of climate change. Therefore, the progressive increase in maximum temperatures will
12 have a clear incidence on the increase in mortality, especially in countries that are vulnerable
13 due to geographical location or their socioeconomic characteristics. Different research studies
14 show that the mortality attributable to heat is decreasing globally, and research is centred on
15 future scenarios. One way of detecting the existence of a lesser impact of heat is through the
16 increase in the so-called temperature of minimum mortality (TMM). The objective of this study
17 is to determine the temporal evolution of TMM in two Spanish provinces (Seville and Madrid)
18 during the 1983-2018 period and to evaluate whether the rate of adaptation to heat is
19 appropriate. We used the gross rate of daily mortality due to natural causes (CIEX: A00-R99)
20 and the maximum daily temperature (°C) to determine the quinquennial TMM using
21 dispersion diagrams and realizing fit using quadratic and cubic curvilinear estimation. The
22 same analysis was carried out at the annual level, by fitting an equation to the line of TMM for
23 each province, whose slope, if significant ($p < 0.05$) represents the annual rate of variation in
24 TMM. The results observed in this quinquennial analysis showed that the TMM is higher in
25 Seville than in Madrid and that it is higher among men than women in the two provinces.

26 Furthermore, there was an increase in TMM in all of the quinquennium and a clear decrease in
27 the final period. At the annual level, the linear fit was significant for Madrid for the whole
28 population and corresponds to an increase in the TMM of 0.58 °C per decade. For Seville the
29 linear fits were significant and the slopes of the fitted lines was 1.1°C/decade. Both Madrid
30 and Seville are adapting to the increase in temperatures observed over the past 36 years, and
31 women are the group that is more susceptible to heat, compared to men. The implementation
32 of improvements and evaluation of prevention plans to address the impact of heat waves
33 should continue in order to ensure adequate adaptation in the future.

34

35 **Introduction**

36 One of the effects that is directly related to the impacts of climate change on health is the
37 increase in maximum daily temperatures, and therefore, the increase in the frequency and
38 intensity of heat waves (IPCC, 2013). Different studies indicate that these heat waves are going
39 to have a clear incidence in the increase in daily mortality associated with the high
40 temperatures that are projected to occur in the future, along with their associated economic
41 impact (Hajat et al., 2014; Guo et al., 2018; Díaz et al., 2019).

42 Much of this research begins with the assumption of a constant impact of mortality
43 attributable to heat over time. This is to say that the increase in mortality due to each degree
44 of increase in temperature during a heat wave is constant. It also supposes a heat wave
45 definition temperature that remains constant over time (Roldán et al., 2016; Guo et al., 2018;
46 Díaz et al., 2019). However, the assumption of a constant impact of heat on mortality is not
47 realistic. Studies show that the impact of mortality attributable to heat is decreasing globally
48 (Coates et al., 2014; Barreca et al., 2016; Vicedo-Cabrera et al., 2018; Díaz et al., 2018), which
49 causes us to believe in the existence of possible adaptation to heat, due to multiple factors
50 related both to the existence of prevention plans (Ebi and Rocklow 2014; **Martínez et al.,**

51 2019) as well as social, cultural (Bobb et al., 2014), health, and economic factors and
52 infrastructure improvements (Sheridan et al.2018; Linares et al., 2020a).

53 Another way of detecting that existence of a lower impact of heat on mortality is through the
54 increase in the threshold temperature that gives way to an increase in heat-related mortality,
55 which is to say that in each place, a higher and higher temperature would be needed to
56 produce fatalities due to high temperatures. This temperature is referred to as the
57 temperature of minimum mortality (TMM) (Astrom et al., 2016), and it corresponds to the
58 vertex of the traditional V form detected epidemiologically for the relationship between
59 temperature and mortality (Alberdi et al., 1998; Montero et al., 2012; Díaz et al., 2002a).

60 From the point of view of the evaluation of existing prevention plans in different locations in
61 Europe, evaluation lies in the decrease in mortality in specific places (Fouillet et al., 2008; de
62 'Donato et al., 2018; Linares et al., 2015) and in determined age groups, especially the elderly
63 (de 'Donato et al., 2018; Pascal et al., 2019) using diverse methodologies with results that are
64 difficult to compare. This complicates the development of measures for improvement of
65 prevention plans (**Martínez et al., 2019**).

66 Therefore, another way to evaluate the adaptation to heat and the effectiveness of
67 institutional measures adopted (such as those adopted autonomously by the population) is to
68 look at whether the temporal evolution of the TMM has occurred at the same rate as other
69 climate models in which different scenarios and time horizons estimate an increase in daily
70 temperature as a consequence of global warming (Martínez et al., 2019; Linares et al., 2020a).

71 Thus, "complete adaptation" would occur when the percentile that corresponds to TMM in
72 relation to the series of maximum daily temperatures of the summer months remains constant
73 over time (Martínez et al., 2017; 2018; Díaz et al., 2019a). This would suppose, for example,
74 that for the period 2031-2080 the TMM must increase by at least 1.4 °C in Spain and 1.7 °C in
75 Finland in a RCP4.5 scenario and 2.2 °C in Iceland or 3.3 in Moldova in a RCP 8.5 scenario,

76 according to data from Guo et al. (Guo et al., 2018). In this sense, the determination of the
77 temporal evolution of the TMM seems a key point to the evaluation of these current
78 prevention plans.

79 Despite the importance of TMM as an indicator of processes of adaptation to heat, its
80 evolution has been studied infrequently. Studies carried out in Stockholm during the 1901-
81 2009 period are worth highlighting (Astrom et al., 2016); as well as the study carried out in
82 various Spanish cities during 1975-2003 (Mirón et al., 2008), the country-wide study in Japan
83 during 1972-2012 (Chung et al., 2018) and in France during 1968-2009 (Todd and Valeron,
84 2015). All of these studies found an increase in TMM that authors explain according to the
85 incidence of different demographic (Mirón et al., 2008) or socioeconomic factors (Sheridan et
86 al., 2018) and adaptation (Bobb et al., 2014; Todd and Valerón, 2015). In these studies, the
87 analyses were carried out at the general population level and for all causes of mortality,
88 without consideration of the differences that might exist between the sexes.

89 However, an analysis at a smaller than state level of the mortality associated with high
90 temperatures is also called for. This is because of factors like population age (Montero et al.,
91 2012), geographic location (Allen and Sheridan, 2018), socioeconomic level (Paz and Semenza
92 2013), level of acclimatization (Van Loenhout et al., 2016), and even factors related to urban
93 character such as the existence of the thermal island effect (Burkart et al., 2016) and the age of
94 the building structures (López-Bueno et al., 2019).

95 The objective of this study was to determine the temporal evolution of TMM in two Spanish
96 cities in which there has been a sudden decrease in the impact of heat, such as the case of
97 Seville, and in other where this decrease has been much more moderate, such as the case of
98 the city of Madrid, for the period 1983-2018 (Díaz et al., 2018). Comparing the rate of variation
99 in TMM with the rate of increase in maximum temperature foreseen for these cities in other
100 studies for the horizon 2050-2100 for an RCP 8.5 scenario (Díaz et al., 2019a) serves to

101 evaluate whether the rate of adaptation to heat in these provinces is that which is necessary
102 to avoid an increase in the number of heat waves during the period, and thus, in the
103 associated mortality due to heat waves. This study provides for differences in sex, given that
104 women are especially susceptible to heat, as mentioned earlier (Gagnon et al., 2013).

105

106 **Methodology**

107 Variables:

108 The dependent variable in this study was daily mortality due to natural causes (CIEX:
109 A00-R99) that took place in the province of Madrid and Seville during the 1983-2018 period.
110 Mortality refers to the mortality in municipalities of more than 10,000 inhabitants in these
111 provinces. These data were provided by the National Statistics Institute (INE). The daily
112 population at the province level was calculated based on annual population data (also
113 provided by INE), using linear interpolation. Mortality data and population data were used to
114 obtain the gross mortality rate per 100,000 inhabitants for each province and for each of the
115 specific causes already described. The data were disaggregated by sex.

116 The independent variable was maximum daily temperature (Tmax) in degrees Celsius
117 (°C) during the period mentioned, measured in the observatories of reference in Madrid and
118 Seville, established by the State Meteorological Agency (AEMET), which also provided these
119 data.

120 Determination of the maximum daily temperature of minimum mortality (TMM)

121 The determination of TMM was made along two scales for the data of the two provinces
122 analysed. The first five year scale grouped mortality rates and maximum daily temperatures
123 during the periods: 1983-1988 (first quinquennium); 1989-1993 (second quinquennium); 1994-

124 1998 (third quinquennium); 1999-2003 (fourth quinquennium); 2004-2008 (fifth
125 quinquennium); 2009-2013 (sixth quinquennium) y 2014-2018 (seventh quinquennium). Based
126 on the daily values of Tmax and daily mortality rates, we analysed the functional relationship
127 through dispersion diagrams, which situated Tmax on the X axis in intervals of °C and average
128 daily mortality on the Y axis.

129 Later adjustment was made by means of a quadratic and cubic curvilinear estimation choosing
130 the curve with the best fit. The temperature of minimum mortality is the minimum point on
131 the fitted curves. In this way, a maximum daily temperature of minimum mortality was
132 obtained for each quinquennium and province, representing the temporal evolution each five
133 years. This same analysis was carried out at the annual level, and the evolution of the TMM for
134 each province from 1983 to 2018 was represented by fitting the evolution to the equation of a
135 line, whose slope, if significant ($p < 0.05$), represents the annual rate of variation in TMM.

136

137 **Results**

138 Descriptive statistics of the dependent and independent variables for the provinces of Madrid
139 and Seville are shown in Tables 1 and 2, respectively. In these tables it should be noted that
140 the average maximum daily temperature in the first quinquennium in Madrid rose from 19.7
141 °C (IC95% 19.3 20.1) to 21.3 °C (IC95% 20.9 21.7) in the last, representing an increase of 1.6 °C,
142 which is a statistically significant difference. In the case of Seville the average maximum daily
143 temperature rose from 24.8 °C in the first quinquennium (IC95% 24.1 25.1) to 26.0 °C (IC95%
144 25.6 26.4) in the last, with a statistically significant difference of 1.2°C ($p < 0.05$).

145 In terms of TMM at the quinquennium level, in all cases the best curvilinear fit was that of a
146 third degree polynomial. At the annual level and for the general population, the best
147 curvilinear fit was for a third degree polynomial except for the years 2000 and 2016, in which

148 case the best fit was a quadratic function. For the case of men, the cubic fit was the best,
149 except for the years 1989 and 2009, in which the quadratic was best. In the case of women,
150 only in the year 2016 was the cubic fit substituted for the quadratic fit.

151 Figures 1a and 1b show the temporal evolution of TMM for the provinces of Madrid and
152 Seville, both for the general population as well as disaggregated for men and women. These
153 figures show that the TMM was higher Seville than in Madrid, and furthermore, it was more
154 elevated in men than in women. Also, there is was increase in this TMM in all of the
155 quinquennium, with a clear decrease in TMM in the last quinquennium, especially in the case
156 of Madrid.

157 Figure 2 shows the annual change for the city of Madrid, both in terms of TMM and in the
158 annual rates of mortality in winter (the months of November to May) and summer (the
159 months of June to September). The Pearson's correlation coefficients among the series of
160 TMM and the rates in summer and winter for the total of the series were -0.27 and -0.13,
161 respectively, but not statistically significant. For the case of the periods of 1999-2003 and
162 2014-2018, the correlation coefficient between TMM and the mortality rate in summer was -
163 0.658, which is significant at $p < 0.05$.

164 Figures 3a and 3b show the temporal evolution in the TMM corresponding to mortality due to
165 natural causes with more detail for Madrid and Seville, respectively. They show the TMM for
166 each year, both for men and for women as well as the slope of the corresponding linear fit.

167 For the case of Madrid for the general population for both men and women, the linear fit is
168 significant at $p < 0.05$. The case of the whole population corresponds to the slope of a line of
169 $0.0577 \text{ } ^\circ\text{C}/\text{year}$, or an increase in the TMM of $0.58 \text{ } ^\circ\text{C}/\text{decade}$. For the case of men, the slope
170 of the fitted line is $0.65 \text{ } ^\circ\text{C}/\text{decade}$, and for women it is $0.56 \text{ } ^\circ\text{C}/\text{decade}$.

171 Figure 3b shows the results of the province of Seville, for which the fitted lines are significant
172 at $p < 0.05$. The slopes of the lines of TMM both for the general population as well as for men
173 and women were greater than those found in the province of Madrid. Specifically, in the case
174 of the whole population the slope of the fitted line was $1.1^{\circ}\text{C}/\text{decade}$, greater than the result
175 obtained for Madrid. In the case of men, in the same way as for Madrid, the slope of the fitted
176 line of $1.2^{\circ}\text{C}/\text{decade}$ was greater than that of women at $1.0^{\circ}\text{C}/\text{decade}$.

177

178 **Discussion**

179 The countries in the Mediterranean basin are those that are most affected by climate change
180 (Negev et al., 2015). The current average annual increase in temperatures compared to those
181 of the nineteenth century, is 1.4°C , which is higher than the global warming of the planet
182 (Cramer et al., 2018). In our case, the increases in the average maximum daily temperatures
183 found between the quinquennia 1983-1988 and 2014-2018 of 1.6°C in the case of Madrid and
184 1.2°C in the case of Seville are similar to the increases described for the Mediterranean
185 (Cramer et al., 2018). However, it should be taken into account that our case is not compared
186 with the average of the whole century, and our data refer to the maximum daily temperatures
187 and not the average temperatures.

188 Figures 1a and 1b show clearly that the TMM for men is greater than that of women, which
189 indicates greater vulnerability to the impact of heat among women compared to men. These
190 results agree with results found in other studies carried out in **Madrid (Díaz et al., 2002a)** and
191 **Seville (Díaz et al., 2002b)**. According to these studies, the percentage increase in mortality for
192 each degree above the temperature definition of a heat wave was 12.6 percent for men over
193 age 75, while for women it reached 28.4 percent. In Seville, the impact per degree for men
194 over age 65 was 29 percent, while for women it reached 46 percent. These results also

195 coincide with those found in other locations and establish that, in general, the risk of death
196 due to heat in women is greater than it is in men (Kovats **and** Hajat, 2008).

197 In addition to health differences in the context of gender, there are physiological differences in
198 thermoregulatory function between men and women that could explain the greater impact of
199 heat in women, including: body size, physical condition and/or state of adaptation (Gagnon
200 **and** Kenny, 2012). There are also added factors such as greater body fat among women and
201 the role played by sexual hormones in thermoregulatory mechanisms (Guyton **and** Hall, 2011).

202 In general, the most noteworthy results of the quinquennial analysis of the evolution of TMM
203 shown in Figures 4a and 4b is the decrease in TMM found in the quinquennium of 1999-2003,
204 and especially during 2014-2018, thanks to the low TMM in the year 2015, especially in the
205 case of Madrid. Figure 2 shows this behavior, showing the temporal evolution of TMM versus
206 the mortality rate in winter periods (the months of November to March) and summer periods
207 (months of June to September) for Madrid. A negative correlation coefficient between TMM
208 and the mortality rate in summer indicates a high summer mortality related to lower minimum
209 mortality temperatures. Therefore, the decrease in TMM found in these periods is related to
210 the high rate of mortality produced in those years due to circulatory causes but not for
211 mortality due to respiratory causes, which agrees with the results found in Madrid and in other
212 places in Spain that show that it is circulatory causes that have the greatest association with
213 summer mortality (Díaz et al., 2002a; Díaz et al., 2002b; Montero et al., 2012; Mirón et al.,
214 2015).

215 Another of the results obtained in this study is that a better fit in the dispersion diagrams of
216 maximum daily temperature-mortality rate is, in the majority of cases, a third degree
217 polynomial. A fit of a third degree polynomial supposes the existence of a maximum and
218 minimum value in the fitted curve. The maximum value in the mortality rate corresponds to a
219 low temperature, thus there is a relationship with winter mortality, while the minimum value

220 of the mortality rate corresponds to the TMM value that is the concern of this study.
221 Therefore, the fit of the third degree polynomial indicates that maximum mortality continues
222 to occur in the winter, despite the increase in the maximum daily temperature seen in this
223 study. These result agrees with the results found in other studies, which show that winter
224 mortality does not decrease in a significant way, despite global warming (Ebi and Mills; 2013;
225 Staddom et al., 2014; Martínez et al., 2018; Díaz et al., 2019a), probably due to the fact that a
226 better adaptation to high temperatures is accompanied by a “de-adaptation” to low ones, and
227 what currently does not constitute a cold wave will probably do so in the near term future
228 (Díaz et al., 2019b).

229 The slope of the line that corresponds to the fit of TMM across the 2983-2018 period indicates
230 that that minimum mortality temperature is increasing at a rate of 0.58 °C/decade for Madrid
231 and 1.1°C for Seville. The value for Madrid was less than that of the city of Stockholm, which
232 established this increase of 0.8 °C/decade in TMM (Astrom et al., 2016) and that of Japan of
233 1.4 °C/decade (Chung et al., 2018), but similar to that obtained for other places in the
234 Mediterranean part of Europe such as some French cities, at 0.53 °C/decade (Todd and
235 Valleron, 2015). According to studies carried out in Madrid (Díaz et al., 2019a), in an RCP8.5
236 scenario, the average maximum daily temperatures will rise from 29.9°C in the 2000-2009
237 period to 34.8 in 2050-2100. This represents an increase of 0.54 °C/decade, which means
238 going from 22 heat waves/year with an associated mortality of 230 deaths/year in 2000-2009
239 to 74 heat waves/year in the 2050-2100 period and an associated mortality of 2250
240 deaths/year. Therefore, the rate at which TMM would need to increase in order to avoid an
241 increase in mortality is very similar to that which currently exists. It is also true that this rate
242 would have been 0.78 °C/decade, if the behavior of the anomalous years of 2015 and 2018
243 was eliminated.

244 For the case of Seville, the rate of increase in TMM for both sexes was 1.14 °C/decade, much
245 higher than Madrid, France (Todd and Valleron, 2015) and Stockholm (Astrom et al., 2016)
246 and similar to that of Japan (Chung et al., 2018). The average of the maximum daily
247 temperatures in Seville in the 2000-2009 period was 34.4 °C with 7 heat waves/year and an
248 associated mortality of 63 deaths/year. In 2050-2100 it will increase to 39.8 °C, which
249 represents an increase of 0.6 °C/ decade. On this time horizon there will be 64 heat
250 waves/year with 1050 deaths/year. In this case, the rate of increase in TMM is greater than
251 that which is needed to avoid an increase in mortality due to heat in Seville.

252 A greater rate of increase in TMM than rate of increase in the temperature results in an
253 increase in the percentile values of TMM related to the series of maximum daily temperatures.
254 This is especially clear in the case of Seville, in which the average maximum temperature has
255 increased at a rate of 0.3°C/decade, while TMM have increased by 1.1 °C/decade, and
256 therefore the TMM percentiles have increased over the time of study.

257 The fact that the rate of evolution of TMM for Seville was higher than for Madrid indicates that
258 the places with high temperatures are less vulnerable to heat than those with more temperate
259 climates, which is consistent with other studies carried out in different locations (Chung et al.,
260 2015, 2017; Gasparrini et al., 2015; Linares et al., 2015b; Montero et al., 2012), and the
261 adaptation to high temperatures is greater (Chung et al., 2018). The same result was observed
262 by sex, thus, the rate of increase in TMM in the case of women, a more vulnerable population,
263 was lower than that of men, which agrees with the gender and physiological differences
264 already described (Gagnon et al., 2013).

265 As limitations of this study, it should be noted that from a methodological point of view, the
266 causality between daily mortality and daily maximum temperature cannot be inferred with the
267 scatter plots performed. The objective in this study, is to see how the temperature of
268 minimum mortality (TMM) evolves and not to observe changes in daily mortality attributable

269 to heat. This last analysis can be reach with a process of pre-whitening of the series and the
270 representation of the residuals of the daily mortality data against temperature to speak strictly
271 about mortality attributable to heat. In addition, this methodology to calculate TMM has been
272 used previously in other studies (Miron et al., 2007; Mirón et al., 2008, Alberdi et al., 1998). On
273 the other hand, the possible effect on daily mortality of other variables such as: Relative
274 humidity (Díaz et al., 2015), chemical atmospheric pollution by ozone (Díaz et al., 2002), an
275 increase in particulate material, caused by anthropogenic origin (Ortíz et al., 2017) or caused
276 by advection of dust from the Sahara (Díaz et al., 2017) seems to have few relevant effect in
277 the different analysis conducted in Spain. To finish, in all of the studies that analyze the effect
278 of environmental variables on health variables, there is a problem of misalignment (Gelfand
279 AE, 2010; Barceló et al., 2016).

280 It can be concluded from the results of this study in terms of the evolution of TMM that both
281 Madrid and Seville are adapting to the increase in temperatures that has been observed in the
282 past 36 years. This had already been detected through the decrease in RA attributable to
283 mortality due to heat waves that was especially important in the case of Seville (Díaz et al.,
284 2018). This supports the evolution of TMM shown in this work. The results of this study show
285 that women are a group that is more susceptible to heat, compared to men, and therefore
286 measures for adaptation should be aimed especially at women.

287 On the other hand, that the rate of adaptation that was obtained in the studied period has
288 helped avoid greater mortality due to heat as a consequence of registered temperature
289 increases does not guarantee that the same will occur in the future. Therefore, the challenge
290 lies in continuing with adaptation. From the perspective of “planned” adaptation (that is to
291 say, institutional adaptation), this includes continuing to progress in terms of implementation,
292 evaluation and improvement in prevention plans (Linares et al., 2020b), greater governance

293 and stakeholder involvement (Martinez et al., 2019), interventions at the urban and healthcare
294 level, and improvements in infrastructure and population education.

295 **Disclaimer**

296 This paper reports independent results and research. The views expressed are those of the
297 authors and not necessarily those of the Carlos III Institute of Health (*Instituto de Salud Carlos*
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304

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Table

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Natural Causes	1983-1988				1989-1993				1994-1998				1999-2003				2004-2008				2009-2013				2014-2018			
	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD
MR All	0.2	3.3	1.6	0.3	1.0	3.1	1.8	0.3	1.1	3.3	1.8	0.3	0.9	3.1	1.9	0.3	1.1	3.3	1.7	0.3	1.1	2.8	1.7	0.2	1.0	3.0	1.8	0.3
MR Men	0.1	4.0	1.7	0.4	1.0	3.5	1.9	0.4	0.9	3.2	2.0	0.3	0.6	3.5	2.0	0.4	0.9	3.5	1.8	0.3	0.8	2.8	1.7	0.3	0.8	3.2	1.8	0.3
MRWomen	0.3	3.7	1.5	0.4	0.8	2.9	1.6	0.3	0.8	3.4	1.7	0.3	0.7	3.5	1.8	0.4	0.9	3.2	1.7	0.3	0.9	2.9	1.7	0.3	0.6	3.2	1.8	0.4
Tmax (°C)	1.1	39.0	19.7	8.7	2.2	40.0	19.8	8.8	1.1	39.5	20.2	8.2	1.6	38.6	20.1	8.6	2.4	38.4	20.1	8.6	0.1	40.6	20.5	9.3	2.8	40.0	21.2	9.0

Table 1. Descriptive statistics for daily mortality rate (number of deaths per 100,000) (MR) and daily maximum temperature (Tmax) by five-year period in Madrid.

Natural Causes	1983-1988				1989-1993				1994-1998				1999-2003				2004-2008				2009-2013				2014-2018			
	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD	Min	Max	Mn	SD
MR All	0.5	4.2	2.0	0.5	0.7	4.2	2.0	0.5	0.7	5.5	2.1	0.5	0.8	4.5	2.1	0.5	0.7	4.3	2.1	0.5	0.9	4.1	2.0	0.4	0.8	4.3	2.1	0.5
MR Men	0.4	4.3	2.0	0.6	0.5	4.6	2.1	0.6	0.6	5.3	2.2	0.6	0.6	5.1	2.2	0.6	0.3	4.9	2.2	0.6	0.7	4.0	2.1	0.6	0.7	4.6	2.1	0.6
MRWomen	0.2	4.5	2.0	0.6	0.5	4.4	1.9	0.6	0.5	7.0	2.0	0.6	0.4	4.7	2.1	0.6	0.4	4.6	2.0	0.6	0.6	5.0	1.9	0.6	0.5	4.8	2.1	0.6
Tmax(°C)	5.4	42.6	24.8	7.7	7.8	44.8	25.4	7.9	9.4	46.6	25.8	7.4	9.9	45.2	25.6	7.7	6.7	44.3	25.7	7.9	4.0	45.9	25.9	8.3	7.6	44.8	26.0	8.0

Table 2. Descriptive statistics for daily mortality rate (number of deaths per 100,000) (MR) and daily maximum temperature (Tmax) by five-year period in Sevilla.

Figure 1a. Temporal evolution of TMM in Madrid for five years period, both for the general population as well as disaggregated for men and women

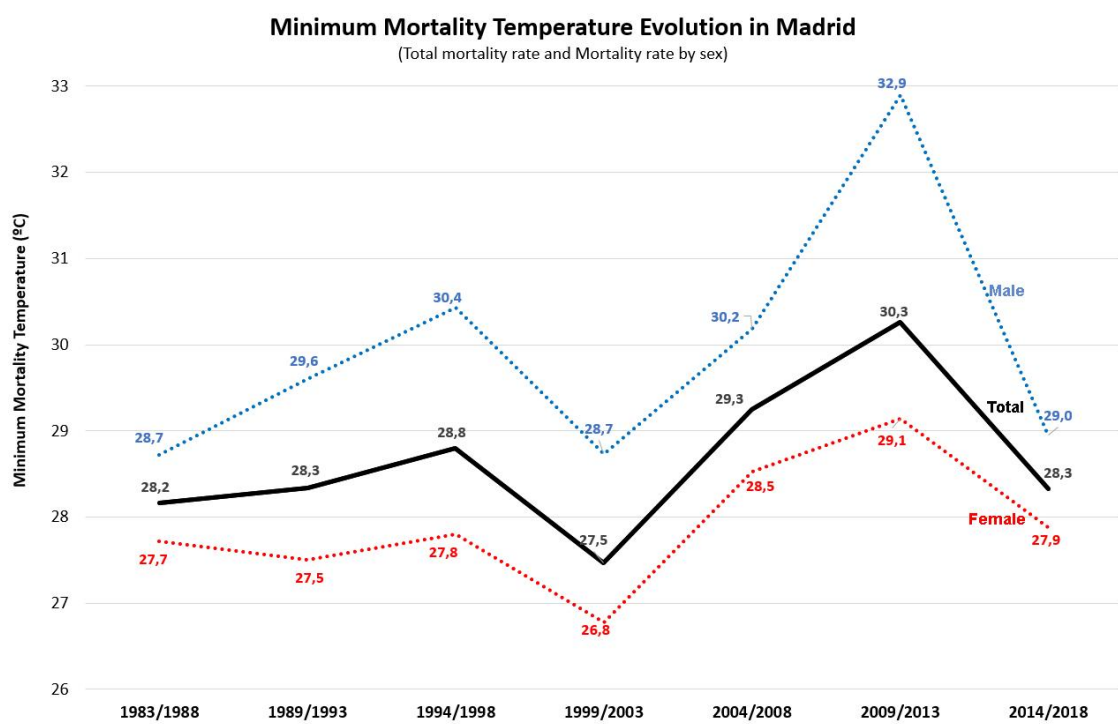
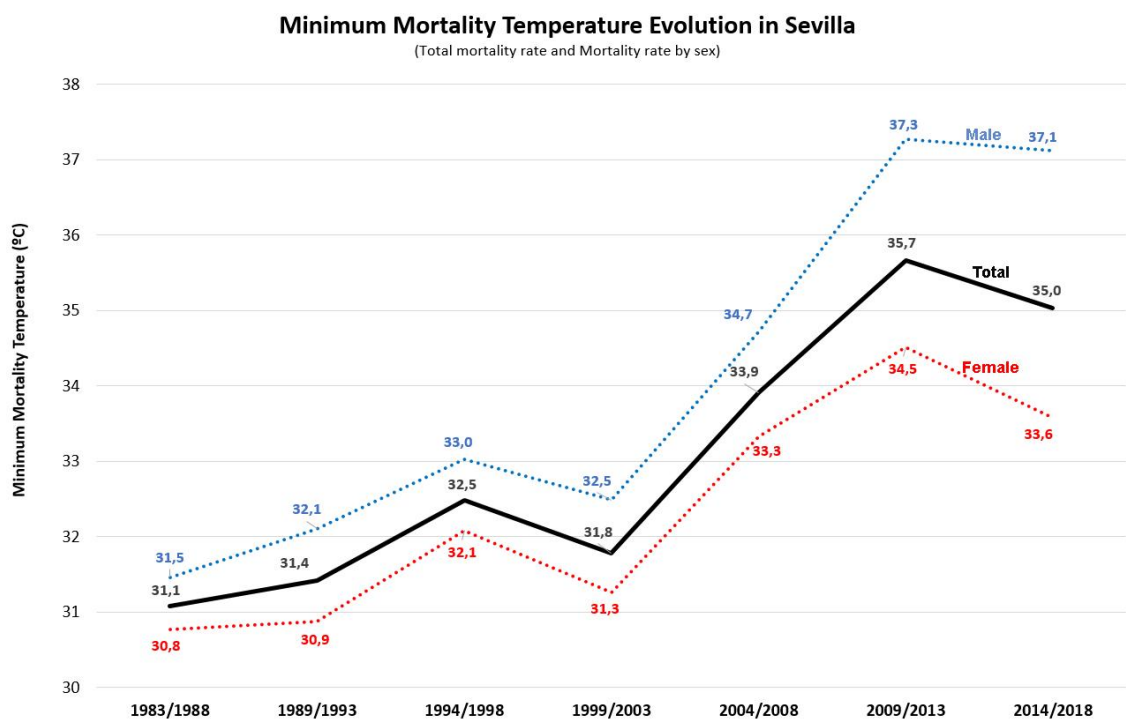


Figure 1b. Temporal evolution of TMM in Seville for five years period, both for the general population as well as disaggregated for men and women



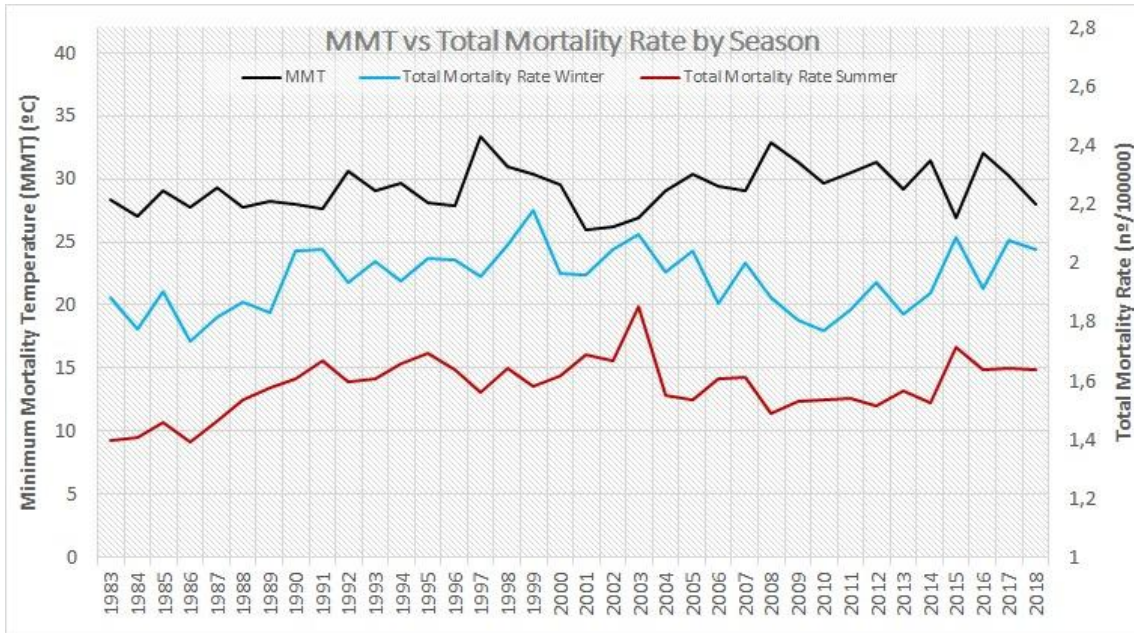


Figure 2. Evolution of Temperature Minimum Mortality (TMM) and Total Mortality Rate by seasons in Madrid (1983-2018)

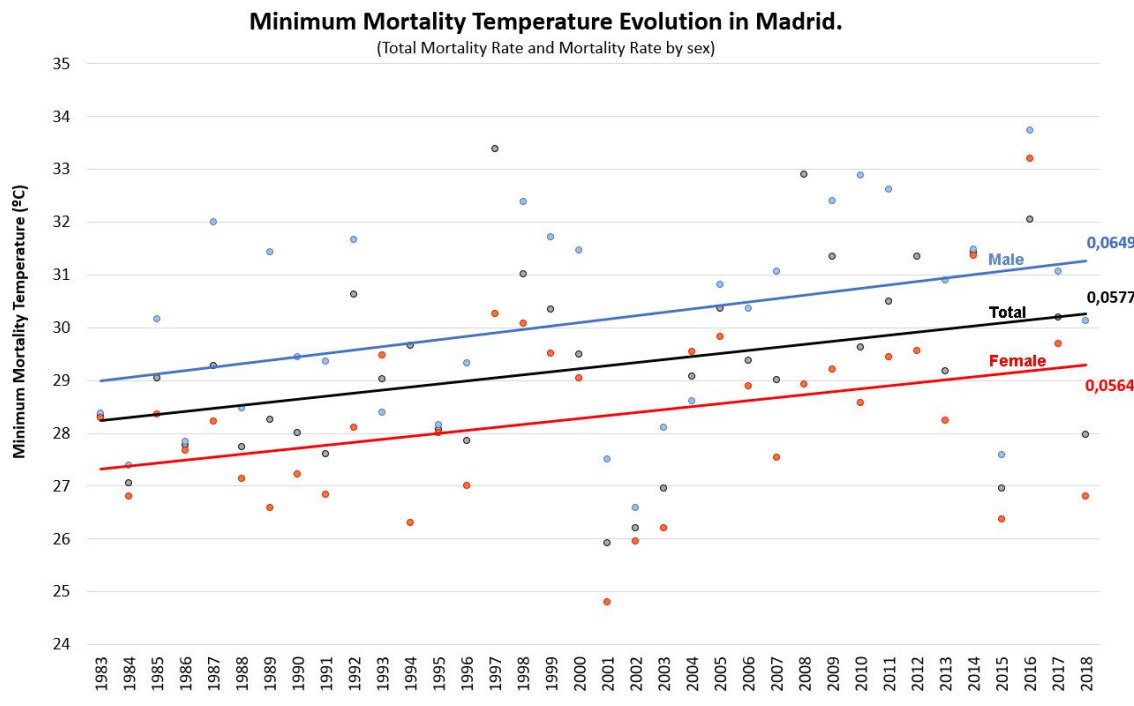


Figure 3a. Temporal evolution of TMM in Madrid for annual period, both for the general population as well as disaggregated for men and women. The TMM annual increase is showed (°C/year).

Minimum Mortality Temperature Evolution in Sevilla. (Total Mortality Rate and Mortality Rate by sex)

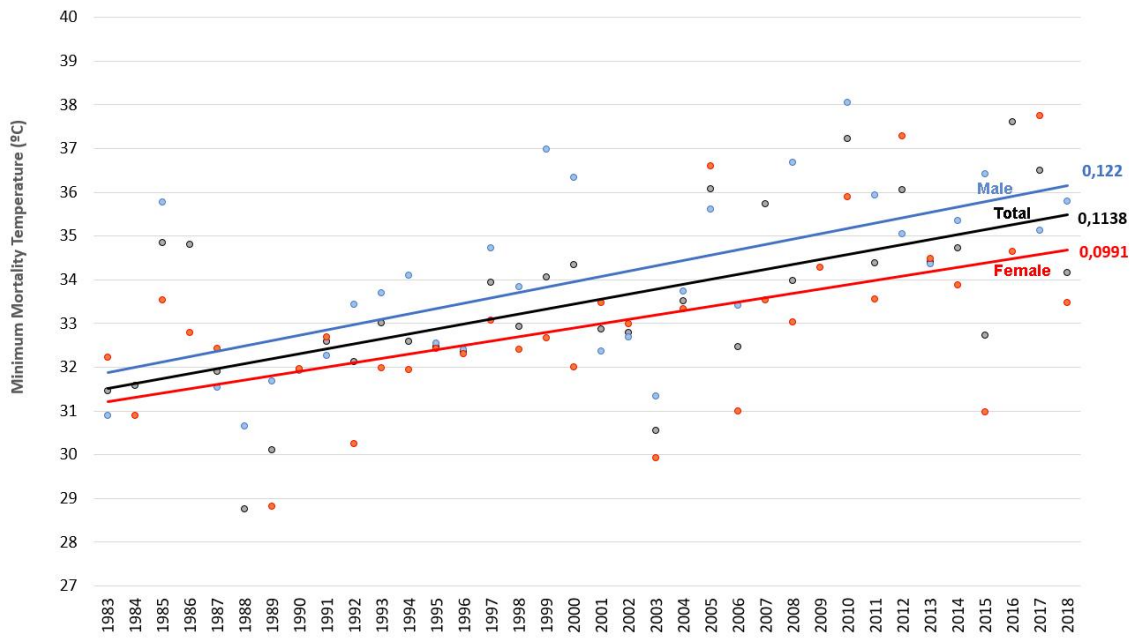


Figure 3b. Temporal evolution of TMM in Madrid for annual period, both for the general population as well as disaggregated for men and women. The TMM annual increase is showed (°C/year).

Credit author Statement:

Follos F : Study design; Analysis of data; Elaboration and revision of the manuscript.

Linares C. Original idea of the study. Study design; Elaboration and revision of the manuscript.

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