RESEARCH REPORT

Temperature and summer mortality: geographical and temporal variations in four Italian cities

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Study objective: To investigate geographical and temporal variations in the temperature-mortality relation. **Design:** The relation between mortality and maximum apparent temperature (T_{appmax}) in 2003, 2004, and a previous reference period was explored by using segmented regression and generalised additive models.

Setting: Four Italian cities (Bologna, Milano, Roma, and Torino), included in a national network of prevention programmes and heat health watch warning systems (HHWWS) were considered.

Participants: Daily mortality counts of the resident population dying in each city during summer (June to September).

Main results: The impact of T_{appmax} on mortality differed between cities and varied in the three periods analysed. The geographical heterogeneity of the J shaped relation was seen in the reference period with T_{appmax} thresholds ranging from 28°C in Torino to 32°C in Milano and Roma. In all cities, the percentage variation in mortality was greatest in 2003. In Torino and Roma a significant increase was seen also at lower T_{appmax} values that are usually not associated to an increase in mortality (26–28°C). In summer 2004 the exposure levels were similar to the reference period; only in Torino the effect of T_{appmax} on mortality remained relevant even if reduced compared with 2003, while in Bologna no statistically significant effect was seen for any temperature range.

Conclusions: The observed heterogeneous reduction in the impact of temperature on mortality from 2003 to 2004 may be partly explained by the lower levels of exposure. Changes in the ability of individuals and communities to adjust to high temperatures as a consequence of the implementation of public health interventions, based on HHWWS, characterised by a diverse effectiveness, may also have played an important part.

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Every year, during the summer season, there is a quantifiable burden of mortality associated with the onset of hot weather in many countries worldwide. The impact of heat on health depends on the intensity of weather conditions at a given time and place. Periods of extremely high temperature and humidity, called heat waves, lead to intense and prolonged heat stress conditions with which a population can be unable to cope. Increases in their frequency and severity are expected as a consequence of the predicted climate change, making this a hot topic on the public health agenda.¹

The impact of individual heat wave events on mortality has been estimated using descriptive episode analyses.^{2–6} These studies have suggested that hot weather predominantly affects people with limited adaptive responses living in urban areas; susceptible populations include the elderly,^{7–9} infants,⁷ people with chronic diseases,^{7 9 10} and socially deprived groups.^{6 7 11}

Further evidence of heat related mortality arises from investigations on the relation between ambient temperature, as compared with heat waves, and mortality. In many studies, a U, J, or V shaped curve has been used to describe the association between temperature (minimum, maximum, or average temperature) and mortality, with the lowest mortality rates recorded at moderate temperatures that rise progressively as temperatures increase or decrease.^{12 13} Studies performed in various European cities have shown geographical heterogeneity in the temperature-mortality relation, reflecting the ability of local populations to cope with extreme temperatures.^{13–19} Temporal variations need to

be explored more in depth to explain how changes in the level of exposure and the introduction of public health interventions modify the temperature-mortality relation. A recent study carried out on 28 US cities by Davis *et al* showed a decline in summer mortality between 1964 and 1998, mainly attributable to changes in adaptation strategies.²⁰ However, to date there is limited evidence of the annual variations in the temperature-mortality relation.

During summer 2003, Europe experienced one of its worst heat waves on record; the early onset of hot weather, unusually high temperatures, and prolonged heat-stress conditions caused thousands of deaths in several European countries.²¹ In Italy, the National Institute of Health compared mortality from June to August 2003 with the same months of 2002, and estimated that in 2003 in the regional capitals of Italy, total mortality for all ages was 15% higher than in the previous year, with the greatest increase (between 31.5% and 16.8%) seen in the north western cities and among those aged 75 years and older (21%).²² Michelozzi *et al* found similar results when assessing summer 2003 cause specific mortality in Bologna, Milano, Roma, and Torino; the increase in daily mortality, compared with a reference period, was of 14%, 23%, 19%, and 33% respectively.²³ Furthermore, the greatest excess was seen in the old (75–84 years) and very old (85+ years), in women, and among the lowest socioeconomic level.²³

The dramatic health impact of the 2003 heat wave has been attributable partly to inadequate health care and social services that were unprepared to cope with such an extreme event. Since summer 2003, the Italian Department for Civil

Protection has established a national network of warning systems able to forecast oppressive weather conditions and the associated health effects, three days in advance (health watch/warning systems, HHWWS) (<http://www.protezionecivile.it>).^{24–25} Prevention programmes that targeted the elderly and other high risk subgroups were activated in each city based on the HHWWS.²⁶ Bologna, Milano, Roma, and Torino were the first cities to be included; currently the project involves 12 major Italian cities and will be progressively extended to achieve national coverage.

As previous studies of summer 2003 showed that the heat wave had a heterogeneous impact on mortality in the Italian cities,^{22–23} the objective of this study was to explore the geographical and temporal variations of the temperature-mortality curve for Bologna, Milano, Roma, and Torino in greater depth. Short term variations in the temperature-mortality relation between 2003 and 2004 were analysed considering a reference period for each city.

METHODS

The study includes four regional capitals of Italy, which vary in population size (Bologna: $n = 371\,217$; Milano: $n = 1\,256\,211$; Roma: $n = 2\,546\,804$; Torino: $n = 865\,263$), population density (inhabitants/km²) (Bologna: 2638; Milano: 6900; Roma: 1981; Torino: 6647), proportion of people aged 75 years and over (Bologna: 13.4%; Milano: 10.3%; Roma: 8.2%; Torino: 9.6%),²⁷ and in the annual number of deaths among residents dying in the city or elsewhere (Bologna: 4840; Milano: 14 422; Roma: 24 206; Torino: 8977).²⁸

Milano, Torino, and Bologna are situated in the north of Italy while Roma is in the centre near the Tyrrhenian Sea. The geographical location of these cities influences their climate; Milano and Bologna are characterised by cold and foggy winters and warm, humid summers, Torino is closer to the Alps and has cooler summers, while Roma has a typically Mediterranean climate with mild winters and warm summers.

Data

Mortality was computed as the daily number of deaths occurring in each city and was extracted from local mortality registries. All natural deaths (*International Classification of Disease*, ICD-9: 0–799) were considered among the resident population dying within the city.

Air temperature (T_{air} , °C) and dew point temperature (T_{dewpt} , °C) were obtained from the airport meteorological station located closest to the city centre and were provided by the Meteorological Service of the Italian Air Force. Apparent temperature (T_{app} , °C), an index of thermal discomfort based on air temperature and dew point temperature, was calculated as follows⁸:

$$T_{app} = -2.653 + 0.994(T_{air}) + 0.0153(T_{dewpt})^2$$

Maximum apparent temperature (T_{appmax}) was used as the exposure variable and defined as the highest between 1200UTC and 1800UTC apparent temperature values.

Statistical analyses

To examine annual variations in the relation between mortality and T_{appmax} during summer (June–September), we compared 2003, 2004, and a reference period. The latter was chosen based on the dataset available (Roma, Torino, and Milano: 1995–2002; Bologna: 1996–2002).

The relation between T_{appmax} and mortality in each city was explored initially using smoothing scatter plots (data not shown). The visual inspection showed differences between

cities both in the strength of the relation and in the threshold value above which mortality quickly increased. A segmented linear regression was performed to identify possible thresholds (break points). To estimate Poisson regression models with unknown break points, a simple linearisation technique was fitted to the data to simultaneously estimate the break point and the linear relation (that is, the slopes) above and below it.²⁹

The city specific segmented regression models for individual years (2003, 2004) were unstable because of the limited time period (four months), hence the break points and the left and right slopes were estimated only for the reference period. Furthermore, the assumption of linearity underlying the segmented regression model could be too simplistic. To overcome this limitation, city specific Poisson generalised additive models (GAMs)³⁰ were fitted for modelling the non-linear relation between the exposure and response variable. Wood's representation of GAMs in terms of penalised regression splines was performed to produce an efficient multiple smoothing parameter estimation.^{31–32} Penalised splines were smoothed with 3 degrees of freedom. The Poisson generalised additive model used was:

$$Y_i \sim \text{Poisson}(\mu_i)$$

$$g(\mu_i) = \beta_0 + f_1(T_{appmaxi}) + f_2(T_{appmaxi}) + f_3(T_{appmaxi})$$

where f_1, f_2, f_3 are the smoothing terms of T_{appmax} for the reference period, 2003 and 2004 respectively, β_0 is the intercept, and $g(\bullet)$ is the logarithm function.

The use of GAMs allowed us to estimate the T_{appmax} -mortality relation in each city for each study period. The impact of T_{appmax} on mortality was quantified using the percentage variation in the number of daily deaths for step increases (2°C up to 10°C) between 26°C and 36°C. The 26–36°C range was selected a priori on the basis of the visual inspection of the curves; where 26°C is below the threshold in all cities while 36°C is well into the right hand side slope where temperature has a strong effect on mortality. The multinormal distributions, with mean and covariance matrix given by the estimated GAMs, were used to simulate (10 000 replications) the 95% confidence intervals. The robustness of the confidence intervals was verified through an alternative bootstrap simulation and differences were negligible (data not shown). The analyses were carried out using the “segmented” and “mgcv” libraries available for the R software version 2.1.0 (The R Foundation for Statistical Computing, version 2.1.0, 2004 <http://cran.r-project.org>).

RESULTS

Table 1 summarises daily mortality and T_{appmax} for the reference period, 2003 and 2004 in Bologna, Milano, Roma, and Torino. In all cities, both the mean and the standard deviation of daily mortality were higher in 2003 than in the reference period and in 2004. The mean T_{appmax} was greater in 2003 than in the reference period in all cities (+4.9°C in Milano, +3.5°C in Torino, +2.2°C in Roma, +1.7°C in Bologna).

The T_{appmax} thresholds estimated by segmented regression models for the reference period were similar in Milano (32.0°C), Roma (31.9°C), and Bologna (29.8°C), but lower in Torino (28.0°C) (table 2). The percentage change in daily mortality for an increase of 1°C above the threshold is heterogeneous between cities, varying from +5.4% in Roma to +3.2% in Bologna.

Summer 2003 registered the highest number of total and consecutive days with T_{appmax} above the threshold in all cities (table 2). When compared with the reference period, the

Table 1 Summary statistics of daily mortality (number of deaths) and T_{appmax} (°C) in four Italian cities during summer for the reference period, 2003 and 2004

	Daily mortality (number of deaths)		T_{appmax} (°C)		
	mean	standard deviation	minimum	mean	maximum
Bologna					
1996–2002	10.4	3.5	12.3	28.4	40.0
2003	11.8	3.9	17.6	30.1	37.3
2004	9.3	3.0	15.9	27.4	35.2
Milano					
1995–2002	25.4	6.4	12.3	28.6	41.4
2003	29.2	10.4	19.1	33.5	44.4
2004	23.0	5.3	16.0	29.3	39.3
Roma					
1995–2002	51.4	9.7	13.3	28.8	38.9
2003	59.3	11.3	22.1	31.0	39.0
2004	52.5	8.0	18.3	28.6	37.1
Torino					
1995–2002	18.5	4.8	10.1	25.1	37.3
2003	23.7	9.9	13.8	28.6	39.2
2004	17.3	4.2	14.3	24.7	34.7

Table 2 Segmented regression estimates of T_{appmax} (°C) break points, percentage change (95%CI) in daily mortality for an increase of 1°C of T_{appmax} below and above the threshold and the number of total and maximum consecutive days above the threshold in four Italian cities during summer for the reference period, 2003 and 2004

Reference period*							2003				2004			
City	T_{appmax} threshold		% Change below threshold		% Change above threshold		Mean number of days above threshold†		Number of days above threshold†		Number of days above threshold†		Number of days above threshold†	
	°C	(95%CI)	%	(95%CI)	%	(95%CI)	Total	(SE)	Max. consecutive	(SE)	Total	Max. consecutive	Total	Max. consecutive
Bologna	29.8	(27.5, 32.0)	0.0	(−0.7, 0.7)	3.2	(1.9, 4.6)	52	(5)	14	(2)	72	24	35	5
Milano	32.0	(31.1, 32.9)	−0.5	(−0.8, −0.1)	5.0	(3.8, 6.1)	34	(4)	12	(2)	75	30	40	7
Roma	31.9	(31.2, 32.6)	0.2	(−0.1, 0.5)	5.4	(4.3, 6.5)	32	(4)	14	(4)	57	23	17	4
Torino	28.0	(26.6, 29.3)	−0.2	(−0.7, 0.2)	3.8	(2.5, 5.0)	36	(4)	13	(3)	73	21	25	6

*Milano, Roma, and Torino: 1995–2002; Bologna: 1996–2002. †Calculated on the basis of the threshold of the reference period.

greatest increase in the total number of days were seen in Milano and Torino. In contrast, in summer 2004 there were fewer days above the threshold than in the reference period, with the exception of Milano. The lowest number of consecutive days was recorded in 2004 in all cities (table 2).

Figure 1 describes the T_{appmax} -mortality relations estimated by GAMs in the reference period, in 2003 and in 2004 in the four cities; the dotted lines represent the 95% confidence interval bands. The distribution of the T_{appmax} actually seen in each period is displayed as a rug plot at the foot of each plot. The curves illustrate a heterogeneous pattern in the T_{appmax} -mortality relation in each city by year, as well as between the cities in the same time period. During the reference period mortality tends to increase in all cities in presence of high temperatures, suggesting a J shaped relation with a T_{appmax} threshold above which mortality increases rapidly. In summer 2003, a steeper J shaped relation is seen in Milano and Torino with a stronger impact of high temperatures on mortality, while in Bologna and Roma the curve assumes a linear trend. In 2004, temperatures remained lower (table 1) and different pattern was seen in all cities with a less steep right hand slope.

Table 3 shows the percentage change in daily mortality for T_{appmax} values between 26°C and 36°C, estimated using GAMs. It is important to consider that the temperature range used (26°C to 36°C) represents different centiles of the temperature distribution for each period in the different cities. In the reference period, the greatest impact on mortality associated with increases in T_{appmax} was registered

in Torino; in fact a statistically significant increase in mortality was also seen for low range temperatures (26–28°C). In Bologna and Roma, statistically significant increases in mortality started to be observed when T_{appmax} rose from 26°C to 30°C, while in Milano a significant effect became evident from higher temperatures (26–32°C). When temperatures rose from 26°C to 36°C the percentage change in daily mortality was greatest in Torino (+31.6%) and lowest in Milano (+16.6%).

During summer 2003, excess mortality was greater than in the reference period in all cities, especially in Torino where a threefold increase was seen (+93.4%). Torino and Roma were the only cities where an impact was also seen in the presence of lower temperatures (26–28°C) (table 3).

In 2004, a statistically significant effect was seen in Torino starting from low temperatures (26°C to 30°C, +11.7%), in Milano only over the entire range (+15.2%) and in Roma between 26°C to 34°C (+7.8%). In Bologna no statistically significant effect was seen (table 3). The effect of T_{appmax} on mortality in 2004 seems to be somewhat weaker than during the reference period in Bologna, Milano and Roma; however the reduction occurred heterogeneously. In Torino such a reduction was not seen and the percentage variation in mortality for the entire temperature range considered was 1.3 times greater.

DISCUSSION

Summer mortality in four different Italian cities (Bologna, Milano, Roma, Torino) was compared to analyse the

Figure 1 Relation between T_{appmax} (°C) and mortality (daily deaths) in four Italian cities during summer in the reference period, 2003 and 2004.

geographical heterogeneity of the temperature-mortality relation and to evaluate the effect of maximum apparent temperature on mortality in 2003, in 2004 and in a previous reference period. Results show that the temperature-mortality relation differs between the four cities and that inter-annual changes seem to have occurred heterogeneously. Summer 2003 registered the greatest impact on mortality in

all cities, while in 2004 the exposure and the effect on mortality were similar to the reference period.

These results and past studies suggest that the dramatic increase in mortality seen in all cities during summer 2003 can be explained by the extreme temperatures and prolonged heat wave periods.^{6–23} The timing, frequency, and persistence of heat wave episodes during summer are important factors

Table 3 Percentage change (95%CI) in daily mortality for increases in T_{appmax} (°C) between 26°C to 36°C in four Italian cities during summer for the reference period, 2003 and 2004

	% Change (95%CI) in daily mortality for increases in T_{appmax} (°C)				
	26–28°C	26–30°C	26–32°C	26–34°C	26–36°C
Bologna					
1996–2002	1.5 (–0.4, 3.5)	4.1 (0.7, 7.5)	8.0 (3.5, 12.5)	13.1 (7.5, 18.7)	19.0 (11.9, 26.1)
2003	1.9 (–4.7, 8.5)	5.7 (–5.2, 16.6)	11.2 (–2.1, 24.5)	18.0 (3.2, 32.8)	27.2 (8.2, 46.3)
2004	0.6 (–5.7, 6.8)	2.0 (–8.3, 12.2)	5.3 (–8.4, 18.9)	12.2 (–7.1, 31.4)	23.0 (–9.2, 55.1)
Milano					
1995–2002	–0.1 (–1.3, 1.0)	0.9 (–1.1, 2.9)	3.8 (1.3, 6.4)	9.0 (5.9, 12.1)	16.6 (12.7, 20.5)
2003	1.3 (–2.6, 5.3)	3.0 (–3.7, 9.6)	5.8 (–2.5, 14.0)	10.7 (1.6, 19.7)	19.4 (9.9, 29.0)
2004	–3.1 (–6.7, 0.4)	–4.1 (–9.8, 1.6)	–1.4 (–8.6, 5.8)	5.2 (–3.5, 13.9)	15.2 (3.6, 26.8)
Roma					
1995–2002	0.7 (–0.3, 1.7)	2.5 (0.9, 4.2)	6.6 (4.5, 8.6)	13.7 (11.2, 16.1)	23.7 (20.2, 27.1)
2003	5.9 (2.6, 9.3)	12.0 (6.8, 17.1)	18.9 (13.0, 24.8)	25.5 (19.3, 31.7)	32.0 (24.5, 39.4)
2004	0.1 (–3.0, 3.2)	1.7 (–3.1, 6.4)	4.6 (–1.3, 10.6)	7.8 (0.1, 15.5)	10.0 (–1.4, 21.4)
Torino					
1995–2002	2.4 (0.9, 4.0)	6.7 (3.9, 9.5)	13.3 (9.3, 17.4)	21.9 (15.7, 28.0)	31.6 (22.0, 41.2)
2003	7.8 (3.4, 12.2)	20.4 (12.8, 28.1)	37.5 (27.6, 47.4)	60.5 (48.8, 72.2)	93.4 (78.5, 108.4)
2004	5.2 (–0.3, 10.7)	11.7 (1.7, 21.7)	19.3 (4.5, 34.2)	29.1 (6.1, 52.1)	41.8 (4.0, 79.7)

that may influence the impact of heat on mortality.^{7 14 19} Torino and Roma were the only cities where a significant percentage variation was seen also in presence of lower T_{appmax} values (26–28°C). In 2004 the effect of temperature on mortality was lower than in summer 2003 in all cities; however in Torino, for all the temperature range, the percentage variation in mortality remained above the reference period. The reduction seen in 2004 may be explained by the lower average and cumulative level of exposure; in fact, temperatures were similar to those from the reference period. Another possible explanation is that during the 2003 heat wave most of the people at risk died, leaving a less vulnerable population for the following summer. Lastly, changes in the ability of individuals and local communities to adapt to oppressive weather conditions may have also played an important part.

In this study, we used maximum apparent temperature as an estimate of human discomfort to extreme weather exposure.⁸ Similar studies have used a variety of measures, including maximum, minimum, or average temperature, apparent temperature, humidity, and dew point temperature,^{6 9 12 14 33} but to date there is no standard indicator of heat stress. Moreover, in this study we collected airport meteorological data, but in some cases these may not be entirely representative of the weather experienced within the metropolitan area.

The maximum apparent temperature-mortality threshold differed between the four cities, higher in Milano and Roma where the right slope was steeper, suggesting that the populations of these two metropolitan areas are accustomed to hot and humid conditions. The lowest threshold was estimated in Torino; this result is probably attributable to the fact that the local population is normally exposed to milder temperatures when compared with the other cities. American¹¹ and European¹⁶ authors have already hypothe-

sised that the most sensitive populations are those living in regions where extremely high temperatures occur infrequently. Geographical variations between cities can be explained in terms of the differences in urbanisation, in the demographic and social composition of local populations and individual lifestyles, which can determine a diverse degree of vulnerability to heat stress. For example, Roma has the largest urban area and the lowest population density and Bologna has the highest proportion of elderly in its population.²⁷ A recent Italian study found that the distribution of median income by census tract, referred to income earned in 1998, differed in the four cities (the first decile was €19 465 in Bologna, €17 677 in Milano, €16 750 in Roma, €20 044 in Torino).³⁴

The ability to adjust to high summer temperatures in a particular place may depend on the demographic and socioeconomic characteristics of the local population as well as on the introduction of public health interventions and any adaptation process in general. Demographic data support the hypothesis that population vulnerability in the four cities is changing; the percentage of residents over 74 years in the period 1999–2003 has increased in all cities (Bologna: +0.9%; Milano: +0.9%; Roma: +1%; Torino: +1.3%).³⁵ Access to air conditioning is another important factor that modifies the population's ability to cope with extreme heat.^{5 7 10 36} Davis *et al* included this as a technological adaptation factor that could explain the decline in mortality rates.²⁰ Unfortunately, air conditioning data are not readily available in Italy, but it is an important area for future study.

What is already known

- Time series studies have been used to describe the association between temperature and mortality
- Geographical heterogeneity of the relation has been reported in Europe and the USA.
- To date there is limited evidence of the temporal variation in the relation.

What this paper adds

- The relation between temperature and mortality differed among the four Italian cities considered and between study periods.
- The greatest impact on mortality was registered in summer 2003 because of the exceptionally high temperatures.
- The reduction in heat related mortality between 2003 and 2004 occurred heterogeneously among cities.
- The heterogeneity of the impact of heat waves on mortality could be attributable to the different effectiveness of public health intervention programmes.

Policy implications

- Considering global climate change scenarios the impact of heat on health will assume greater public health significance in the future.
- The implementation of public health interventions supported by warning systems may help reduce the impact of temperature on mortality.
- City specific prevention strategies should be targeted to the susceptible subgroups

Different time series studies carried out in large urban areas, have shown that air pollutants are potential confounders or effect modifiers of the impact of temperature on mortality.^{12 15 18 19} Air pollution, as well as other possible confounders, were not included in this analysis as the objective was solely to explore the temporal and geographical variation of the relation between temperature and mortality. Assuming that pollution levels have remained fairly constant throughout the study period in all four cities, the possible bias in the estimated change in mortality for increases in temperature will also have remained constant and therefore not have influenced the comparisons made.

In summer 2004, prevention and mitigation plans were introduced in each city, which activated specific procedures when oppressive conditions were predicted by the warning systems.²⁶ Prevention strategies were planned taking into account local population characteristics and based on national guidelines drawn up by the Italian Ministry of Health. Prevention was targeted at the vulnerable subgroups and included different types of activities, such as informative leaflets for the general population, guidelines for health and social work professionals and helplines for the elderly.^{6 26} Registries of the susceptible subgroups were drawn up based on factors that have been associated with an increase in mortality during heat waves, such as old age,^{10 14 15 18} low socioeconomic status,^{6 11} living alone,^{5 10 11} and chronic illnesses.^{7 9 10} The characteristics of prevention programmes and their implementation differs between cities thus, effectiveness is likely to be heterogeneous.

Italian warning systems and public health interventions has not yet been formally evaluated in terms of effectiveness, but studies from North America suggest that the implementation of HHWWS is an important early step for adaptation to temperature fluctuations and may help reduce the impact of heat on health.^{37 38} In this study, we found that for the same exposure intervals, the impact of temperature on mortality was reduced from 2003 to 2004. We found a variation in the association between maximum apparent temperature and mortality between cities over time. It is reasonable to suppose that these short term variations are not attributable to differences in heat levels alone but also to the implementation of HHWWS and prevention programmes. Moreover, prevention activities should be also planned considering the short latency between the exposure to high temperatures and mortality effects^{6 13 15 19 33} and that the population at risk may vary in the short term—that is, after an influenza epidemic¹³ or in the case of mortality displacement of the frail.^{19 33 39}

The occurrence of severe weather conditions during summer in four Italian cities represents a serious health threat. The shape of the temperature-mortality curve and the magnitude of the effect varied according to local exposure. During summer 2004, the effect of temperature on mortality was smaller than in 2003 because of lower levels of exposure and although local populations continued to be at risk, the warning systems and prevention programmes activated may

have helped mitigate heat related mortality. Our results suggest that the effectiveness of public health programmes and the consequent adaptation processes vary among cities as the reduction in heat related mortality. Considering global climate change scenarios, associated to an increase in the frequency and intensity of extreme weather events, the impact of heat on health will assume greater public health significance in the future. As a result, the constant monitoring of the temperature-mortality relation and population vulnerability will be necessary to address and evaluate public health responses. Warning systems and prevention programmes, especially targeted at susceptible subgroups, will be an important resource for public health policies; the effectiveness of these systems needs to be evaluated for improvements in the future.

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