THE EFFECT OF TEMPERATURE AND HEAT WAVES ON DAILY MORTALITY IN BUDAPEST, HUNGARY, 1970-2000

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SUMMARY

We investigated the association weather on daily mortality in Budapest, 1970-2000, with special regard to heat waves. Budapest has a continental climate and experiences extreme heat episodes. In the past 30 years, the minimum and maximum daily temperatures in Budapest has significantly increased, as well as daily variability in summer. A 5 C^{o} increase in daily mean temperature above 18ºC increases the risk of total mortality by 10.6%% (95% CI 9.7, 14.0). The effect of hot weather on cardiovascular mortality is even greater. Six heat episodes were identified from 1993 to 2000 using standardized methods. During each episode, a short term excess in mortality occurred. During the early June heatwave in 2000, excess mortality was greater than 50% over the three day period. We conclude that temperature, especially heat waves, represent an important environmental burden on mortality in the residents of Budapest. Heat waves that occur early in the summer are particularly dangerous. There is a need to improve public health advice in order to reduce the burden of heat waves on human health in Hungary.

Introduction

Global climate change is one of the most important environmental problems facing the twenty-first century. In 1862, John Tyndall, the natural philosopher, made the prediction that anthropogenic emissions of carbon dioxide would trap the radiative energy of the sun within the earths's atmosphere and raise surface temperature (Tyndall, 1862). Global warming is accelerating at a rate far greater than that predicted a century ago. Scientists now agree that the balance of evidence indicates that recent warming is due in large part to the combustion of fossil fuels (IPCC 2001). The global mean surface temperature has increased by 0.4 ºC in the past 25 years (IPCC 2001).

Climate change threatens our health because of adverse affects to environment, ecosystem, economy and society (Haines et al. 2000, Patz and Khaliq 2002). Moreover, climate change may affect food safety, changes in vector-borne diseases patterns both in space and time, and increase the frequency of extreme weather events, such as heat waves. Global mean temperature is projected to rise by 2.5 to 5.8 ºC by the end of this century (IPCC 2001). In the Carpathian basin, a 0.5 to 1.0 ºC increase in temperature can be expected by the 2050s, with increases of 0.8 ºC and 1.0-2.5ºC in mean summer and winter temperatures, respectively. In addition, a 10% increase in the solar radiation and 20-100 mm decrease in precipitation is also projected (Mika 1988).

In response to these changing risks, the Third Ministerial Conference on Environment and Health in London in 1999 recommended developing the capacity to undertake national assessments of the potential health effects of climate variability and change, with the goal of identifying: 1) vulnerable populations and subgroups and 2) interventions that could be implemented to reduce the current and future burden of disease. Hungary has recently completed its National Environmental Health Action Program (1997). As a part of a national health impact assessment in Hungary, the effect of temperature and heat waves on daily mortality in Budapest was investigated. Ambient thermal conditions are an important type of environmental exposure and are responsible for a quantifiable burden of mortality and morbidity. A range of epidemiological methods has been used to estimate the effect of the thermal environment on mortality and morbidity and thus estimate temperature-attributable mortality. Using data on mortality from Budapest, we illustrate two of these methods: time series analysis, and episode analysis.

Analysis of time series data

Daily time series studies are considered the most robust method for quantifying the effects of temperature on mortality. Such studies have shown that the temperature-mortality relationship in temperate countries is consistently non-linear across the temperature range. Mortality increases at both low and high temperatures. The majority of studies report an approximately linear relationship above and below a minimum mortality temperature (or range of temperatures). Thus the temperature mortality relationship in temperate countries is often described as v-shaped or u-shaped (Kunst et al. 1993). The optimum or threshold temperature varies between populations and is assumed to be a function of the population adaptation to the local climate. That is, the warmer the climate, the higher the threshold temperature above which heat-related mortality is detectable.

Heat waves

Heat-waves are rare events that vary in character and impact even in the same location. Arriving at a standardised definition of a heat-wave is difficult; the World Meteorological Organisation (WMO) has not yet defined the term, and many countries do not have operational definitions for health warnings or other purposes. The Hungarian weather service does not have an operational defiinition of a heat wave, and the city does not currently have a heat health warning system.

The essential components of a heat wave should include high temperatures in the area of interest and some component of duration. A heat wave is a sustained exposure to high temperatures over several days. A heat-wave can be defined based on an absolute or a relative threshold of weather variables or as a combination of both. However, an absolute threshold fails to address the differences between populations in response to temperature, and also within a single population over time.

Studies of heat waves in urban areas have shown an association between increases in mortality and increases in heat, measured by maximum or minimum temperature, heat index (a measure of temperature and humidity), or air mass (Kalkstein and Green 1997). An infamous example is the effect of the 5-day heat wave in Chicago in 1995, in which maximum temperature reached 40^{o}C and deaths increased by 85% (CDC 1995). Increases in temperature have a direct and substantial impact on excess mortality for elderly individuals and individuals with pre-existing illnesses. Much of the mortality attributable to heat waves is a result of cardiovascular, cerebrovascular, and respiratory diseases (Koppe et al. 2004).

Material and methods

Daily mortality data for Budapest (permanent residents) from 1970 to 2000 were obtained from the Central Statistical Office. Mortality was divided into three series by cause of death: total mortality except external causes, TM (ICD9<800); cardiovascular, CM (ICD9: 430-438); and respiratory: RM (ICD9: 460-519). In 2000, the population of Budapest was approximately 1.7 million. During the 31-year data period, the number and age distribution of inhabitants in Budapest has changed and therefore mortality data were standardised for the average of the whole period. Observed daily mortality for each day was weighted by the ratio of the average mortality of the respective year to the average mortality over all 31 years.

The National Meteorological Service provided meteorological data: 24 hour average values of maximum and minimum temperature, barometric pressure and relative humidity. Data were from the “Pestlörinc” meteorological station which is situated at the Southern outskirts of Budapest, 12 km from the centre (World Meteorological Organisation station number 12843).

The effect of high temperatures on mortality was investigated using two methods. First, the relationship between mortality and temperature was investigated for the whole temperature range using regression models adapted for time series data. Second, individual heat wave episodes were identified, and the associated excess mortality during the defined heat wave periods was quantified.

The time series analysis was carried out using generalised additive models (GAM). Non-parametric smoothing techniques were used to control for season and trend. We investigated the effect on mortality of same day and previous day’s temperature and humidity, as previous studies have shown that the effect of high temperatures is short lived. The effect of temperature was investigated separately for the summer months (April to September inclusive). Influenza is known to affect daily mortality in winter, and so days with respiratory mortality over the 98 percentile (over 10 cases per day) were excluded. Previous sensitivity analyses have shown the confounding effects of influenza epidemics on the short term effect of air pollution on total mortality (Touloumi et al 2004). In this analysis, no adjustment was made for air pollution as data were not available for the whole time period.

A range of definitions has been used to define heat wave events (Koppe et al. 2004). We used a relative definition based on the temperature record. Events were identified as a minimum three-day period of days with mean temperature (lags 0-2) above the 99^{th} centile of daily mean temperature (26.6ºC) between 1990 and 2000. Baseline (expected) mortality was estimated for each heat episode with a regression model that included day of week, time of year, ozone, pm10, an influenza indicator, and smoothed functions of temperature and humidity to describe the underlying seasonal pattern. The heat wave attributable mortality was estimated by subtracting the "expected" mortality from the observed mortality during the pre-defined periods.

Results

Climate changes in Budapest

Budapest has experienced a significant warming trend since 1970. The minimum and maximum daily temperatures have both increased. Further, the number of hot days and the variance of daily temperature by year have increased. The variability of temperature changed during the 31 years. Days with mean temperature different from the mean of the previous five, ten or fifteen days became more frequent, especially during the summer period. These differences in temperature were not so common in wintertime.

Eight of the ten hottest years in the series were in the 1990s. The cause of the warming may be due, in part, to urbanisation, and, in part, to global warming, as Western and Central Europe has warmed by 0.3ºC per decade since the 1970s (Klein Tank et al. 2002). The number of hot days (daily max temperature over 32 ^{o}C) became more frequent in the nineties (Figure 1).

Relationship between meteorological factors and mortality

Mortality in Budapest shows a seasonal pattern, with deaths highest during the winter months. Seasonal respiratory infections have an important role in winter mortality, and their association with meteorological factors is uncertain. Within the summer period, the unadjusted (crude) relationship between temperature and mortality is approximately linear (ß=1,704 (95% CI 1.569;1.839) for 1^{o}C change in temperature). During the winter period, the association between temperature on same day and total mortality is negative and not so strong (ß=-0.055 (95% CI -0.108;-0.003), as the effect of cold is known to last for up to two weeks. There is no corresponding change in the slope for the effect for very cold days. The acute effect of weather variables on mortality was more pronounced during summer than winter.

Figure 3 shows the relationship between temperature and total mortality, adjusted for season and trend, and day of week. As has been shown for other cities in temperate regions, the relationship is u-shaped. Mortality is lowest when daily mean temperature (lag 0,1) is approximately 18 ºC. Above 22 ^{o}C daily mean temperature, the linear association has a steeper slope.

Assuming a linear relationship within the summer months, we quantified the slope of the relationship for each mortality series (Figure 4). A 5 ^{o}C increase in temperature increased the risk of total mortality by 10.6% (96% CI 0.97, 14.0); cardiovascular disease mortality by 18% (96% CI 11, 29); and respiratory disease mortality by 8.8% (96% CI 5.4, 23). A 5 ^{o}C increase from the previous 15-day moving average temperature also had a significant impact on mortality in both seasons.

Heat waves

Six heat wave events were identified in the data series, with two events occurring in the years 1994, 1998 and 2000 (Table 1). The episodes varied in duration, timing and magnitude. Figure 4 illustrates the peaks mortality associated with the two heat waves that occurred in the year 2000. Excess mortality (all cause) was observed during all the episodes: 22% (June 94), 12% (Aug 94), 24% (Jul 98), 26% (Aug 98), 52% (Jun 00), and 14% (Aug 2000). The greatest excess for each heat wave is in the oldest age groups (75+). Mortality in the adult age group did not appear to be affected by heat waves, except during the August 2000 event, which was associated with an excess mortality of 72% (95% CI 36.6, 116.6) during the three day episode.

Evidence from these six events, indicatest that the impact of the first heat wave in a year is greater than the second, irrespective of the magnitude of temperature during the event or the duration of the event (Figure 5). The heat wave with the greatest impact occurred in June 2000, which was neither the hottest nor the longest heat wave. The impact of subsequent heat waves in the same year, however, is likely to have been diminished by both the loss of susceptibles and the increased acclimatisation of the population to hot weather.

Discussion

The association between mortality and temperature in Budapest is U-shaped, as has been previously shown in other cities in Europe (Kunst et al. 1993). The effect of temperature on total mortality is greater than that observed for London (mortality increased by 1.2% (95% CI 1.0 to 1.3) for each degree above 18 ^{o}C), but similar to that observed in Sofia: 2.2% (95% CI 1.6, 2.9) (Pattenden et al. 2003). Between the two ends of the temperature range, a physioclimatic optimum exists where mortality is at the minimum. For example, mortality is estimated to be lowest at 14.3-17.3°C in north Finland but at 22.7-25.7°C in Athens (Keatinge et al. 2000). In Budapest, this optimum is at approximately a daily mean temperature of 18 ^{o}C.

As has been found in other studies in Europe and the US, the most sensitive age group to high temperatures was the over 75s (Paldy et al. 2001). The highest risk estimate was estimated for cardiovascular mortality, followed by total and respiratory mortality (although the differences are not statistically significant). Studies in other cities in Europe have often shown the greatest effects of high temperatures on respiratory mortality (Koppe et al. 2004). However, there are likely to important differences in the coding of cardio-respiratory deaths between countries that may explain this result.

In ecological studies, problems could arise from the fact that different populations are at risk in summertime and wintertime. This problem however is of less importance in Budapest, because the most vulnerable part of the population does not leave the city for holidays during the summertime.

Another concern that has been raised is the possibility that air pollution is a confounder of the relationship between weather and mortality, as the same meteorological conditions that cause heat waves also trap photochemical pollutants. A number of studies have proved the independent effect of air pollutants on health using different approaches for weather adjustment (Pope and Kalkstein 1996, Samet et al. 1998). Within the APHEA2 project, the effect of air pollution on short term mortality was studied and temperature as a confounder was considered. The effects of air pollutants on mortality in Budapest were weaker than that of temperature (Paldy et al. 2000). However, the combined effect of weather and tropospheric ozone should be further studied in this population.

Conclusion

Heat waves and high summer temperatures contribute to significant burden on mortality in Budapest, particularly heat wave events that occur early in summer. The elderly are most at risk from extreme hot weather, but mortality in all ages is affected.

Studies of weather-mortality relationships indicate that populations in north-eastern and Midwestern U.S. cities may experience the greatest number of heat-related illnesses and deaths in response to infrequent extremes of summer temperature (Kalkstein and Green 1997). Keatinge et al. (2000) have also reported that deaths in mid- and high latitude countries occur most frequently during conditions of extreme cold or extreme heat. Mortality in Budapest is certainly sensitive to high temperatures (above 18ºC), although these do not occur infrequently. Therefore, there may be non-climate factors that are important determinants of the temperature-mortality relationship such as a relatively high prevalence of chronic diseases (Széles et al 2003).

The August 2003 heat wave affected the population of Budapest, although temperatures were not so extreme as those experienced in France. An increase in ambulance call outs was reported (Paldy, pers com) but the impact on mortality and morbidity has not yet been reported. In response to this extreme event, the National Institute of Environmental Health distributed 15000 leaflets with advice on how to avoid heat related illness. There is a need to further improve public health advice in order to reduce the burden of heat waves on human health in Hungary.

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Table 1. Heat wave events

Heat wave event	Duration	Mean temp (average)	Max temp (maximum)
28 June to 1 July 1994	4 days	27.0	36.3
30 July to 8 August 1994	10 days	27.5	36.3
22 July to 25 July 1988	4 days	27.4	34.6
3 August to 5 August 1998	3 days	27.6	36.7
13 June to 15 June 2000	3 days	27.5	36.2
20 August to 22 August 2000	3 days	28.1	37.9

Figure legends

Figure 1. Number of hot days per year (days with maximum temperature ≥32ºC), 1970-2000.

Fig 2 . Seasonal patterns of total, cardiovascular and respiratory mortality in Budapes (data averaged for years 1970-2000).

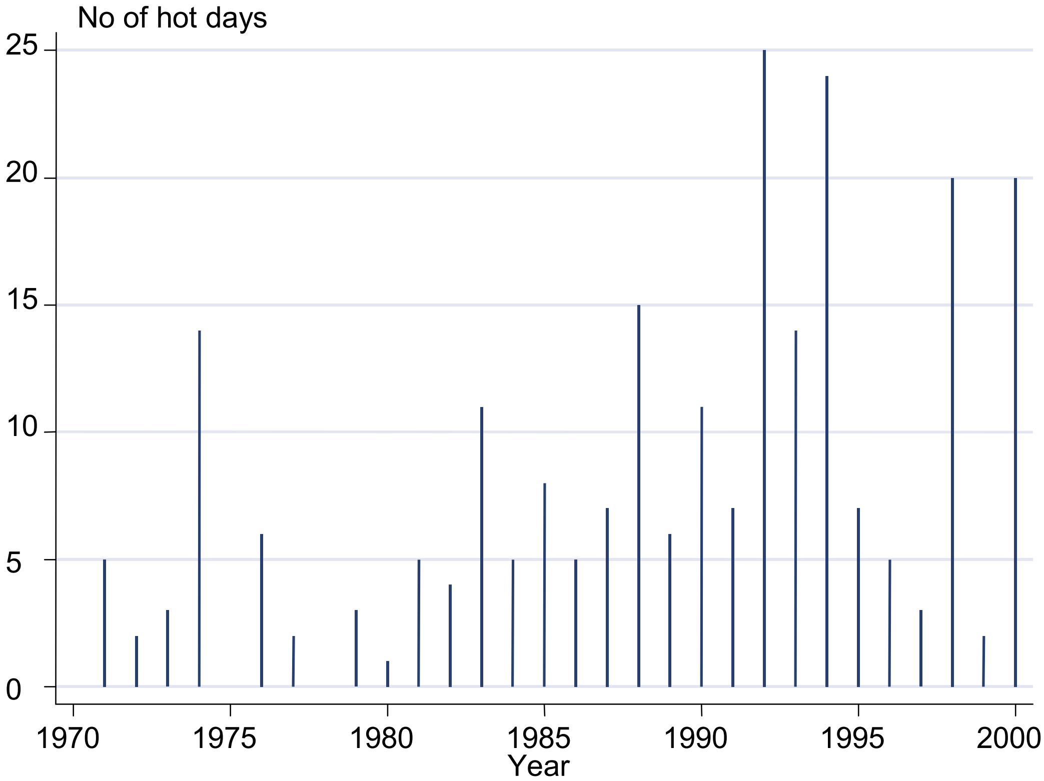
Fig. 3 Effect of temperature on daily total, cardiovascular and respiratory mortality in winter and summer (fully adjusted models).

Figure 4 Results.

Figure 5. Daily mortality in the summer of 2000.

Figure 6. Excess total mortality (%) for six heat wave episodes, 1994 to 2000.

Figure 1. Number of hot days per year (days with maximum temperature ≥32ºC)



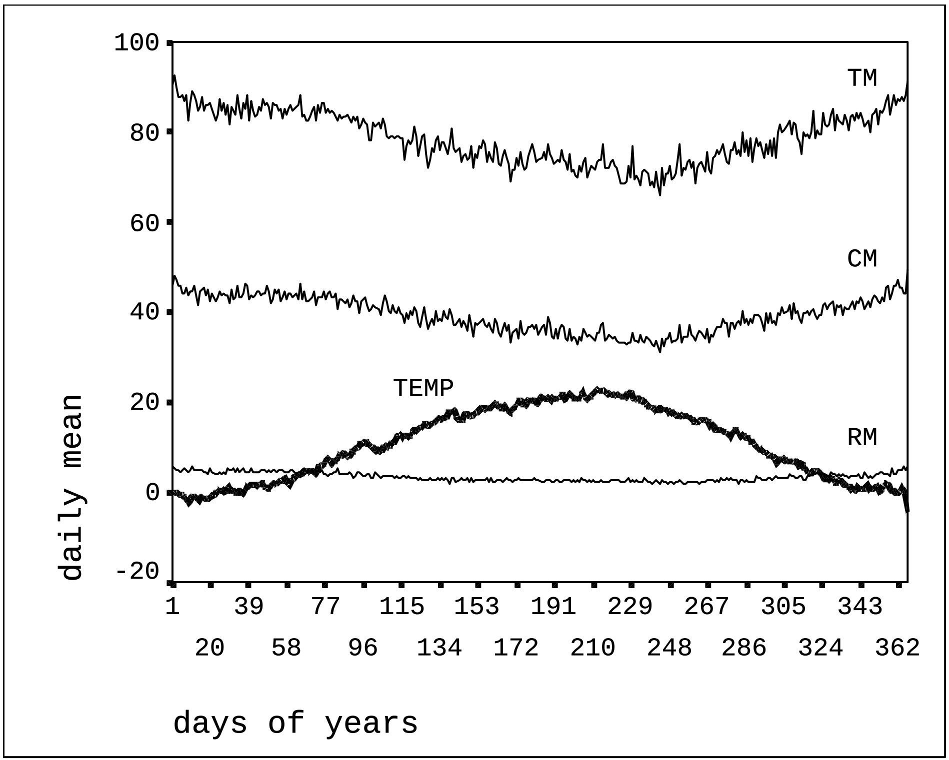


Figure 2. Seasonal pattern of daily total, cardiovascular and respiratory mortality (average of years 1970-2000).

Fig 3. Relationship between temperature and total mortality (model adjusted for season, influenza activity, day of week, trend).

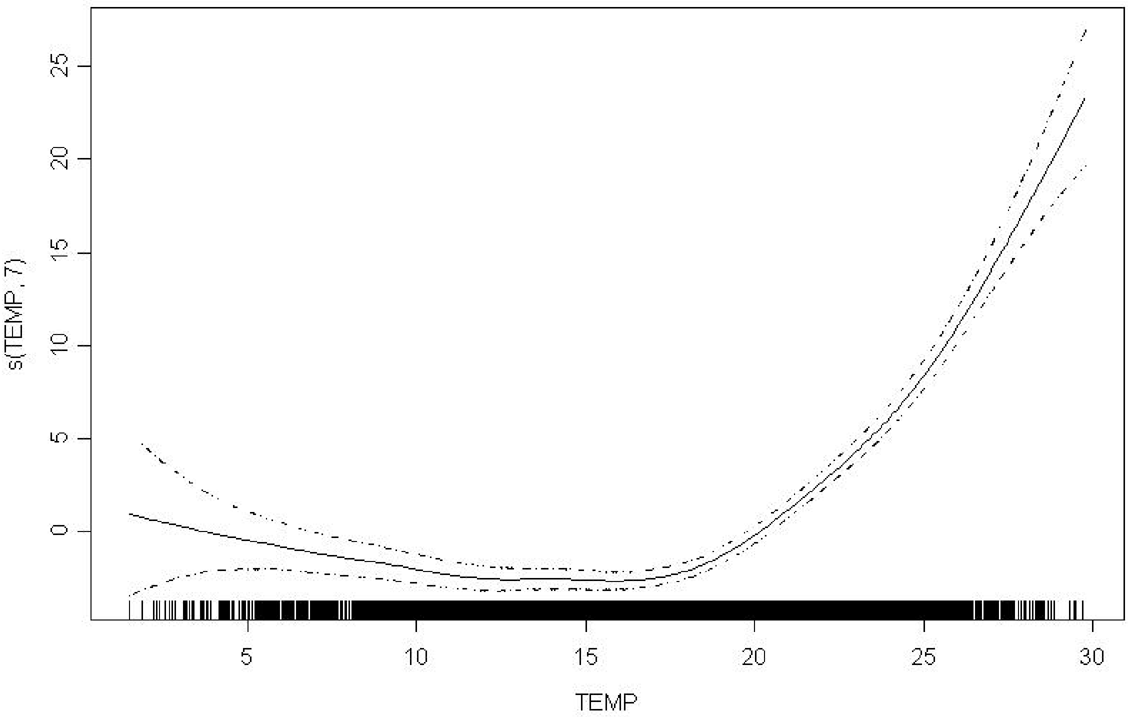
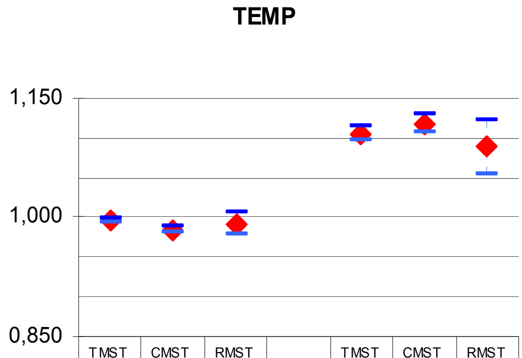
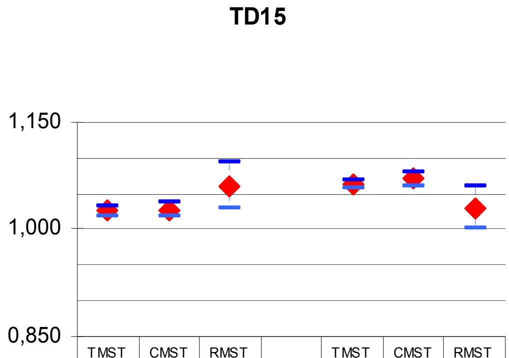


Fig. 4 Effect of temperature on daily total, cardiovascular and respiratory mortality in winter and summer, for a) daily mean temperature (no lag) and b) temperature difference compared to average of previous 15 days.



	TMST	CMST	RMST		TMST	CMST	RMST
RR	0,997	0,984	0,992		1,106	1,118	1,088
RRMIN	0,993	0,980	0,978		1,097	1,106	1,054
RRMAX	1,000	0,989	1,007		1,114	1,129	1,123



	TMST	CMST	RMST		TMST	CMST	RMST
RR	1,027	1,028	1,061		1,063	1,071	1,030
RRMIN	1,020	1,018	1,029		1,056	1,062	1,000
RRMAX	1,033	1,038	1,093		1,070	1,081	1,059

Figure 5. Mortailty and temperature series, Summer 2000.

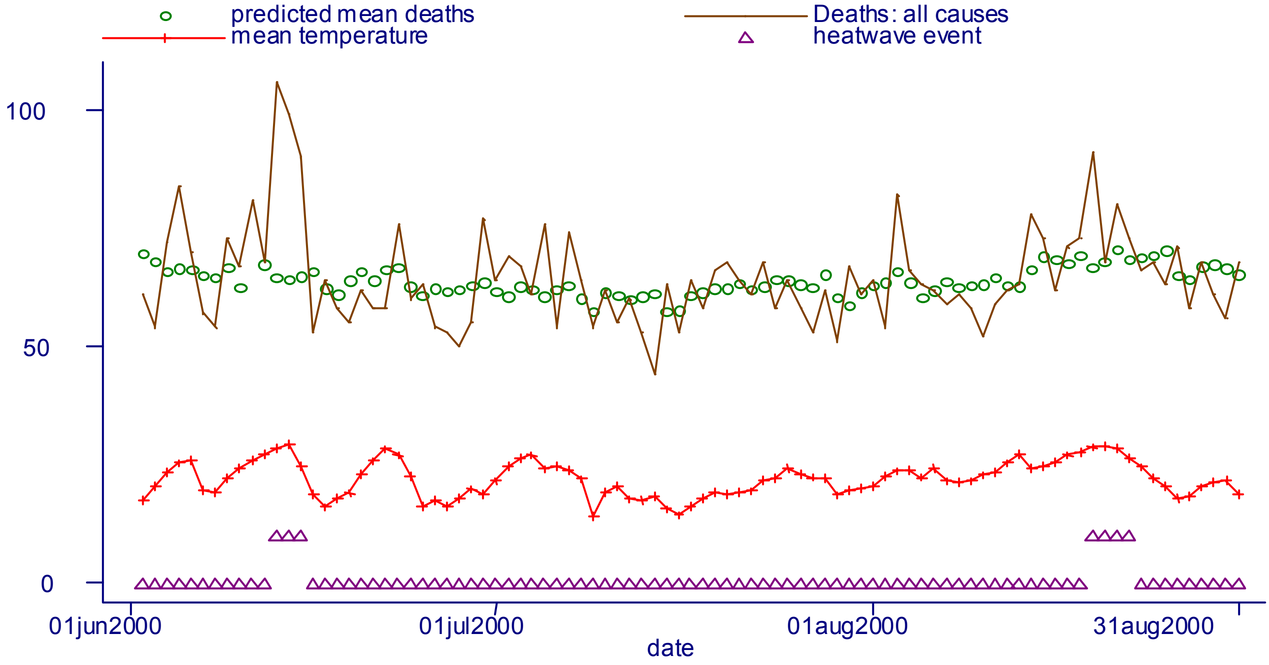


Figure 6. Excess mortality associated with each heat wave episode (%) with 95% confidence intervals. Expected mortality was estimated using a regression model.