# Heat related mortality in warm and cold regions of Europe: observational study

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## Abstract

**Objectives** To assess heat related mortalities in relation to climate within Europe.
**Design** Observational population study.
**Setting** North Finland, south Finland, Baden-Württemberg, Netherlands, London, north Italy, and Athens.
**Subjects** People aged 65-74.
**Main outcome measures** Mortalities at temperatures above, below, and within each region's temperature band of minimum mortality.
**Results** Mortality was lowest at 14.3-17.3°C in north Finland but at 22.7-25.7°C in Athens. Overall the 3°C minimum mortality temperature bands were significantly higher in regions with higher than lower mean summer temperatures ($P = 0.027$). This was not due to regional differences in wind speeds, humidity, or rain. As a result, regions with hot summers did not have significantly higher annual heat related mortality per million population than cold regions at temperatures above these bands. Mean annual heat related mortalities were 304 (95% confidence interval 126 to 482) in North Finland, 445 (59 to 831) in Athens, and 40 (13 to 68) in London. Cold related mortalities were 2457 (1130 to 3786), 2533 (965 to 4101), and 3129 (2319 to 3939) respectively.
**Conclusions** Populations in Europe have adjusted successfully to mean summer temperatures ranging from 13.5°C to 24.1°C, and can be expected to adjust to global warming predicted for the next half century with little sustained increase in heat related mortality. Active measures to accelerate adjustment to hot weather could minimise temporary rises in heat related mortality, and measures to maintain protection against cold in winter could permit substantial reductions in overall mortality as temperatures rise.

## Introduction

People in cold regions of Europe take more effective protective measures against a standard degree of cold than people in warm regions,[1] and in the cold regions mortality rises less steeply as temperature falls. Reports of heat related mortality suggest that heat waves of a given intensity increase mortality less in subtropical or warm regions than in cooler ones.[2–11] If this finding is not due to differences in factors such as age structure, wind, humidity, or methods of analysis, it suggests that population adjustments to heat will substantially mitigate the impact of impending global warming on summer mortality.

We analysed age specific heat related mortality in the regions of west Europe covered in the Eurowinter survey of cold related mortalities,[1] omitting Palermo for which matching population data were not available. We have used only the older age group included in the Eurowinter study because the younger (50 to 59 year) age group in that study showed too little heat related mortality to analyse. We report for each region the temperature above which mortality increased, the annual increase in mortality above that temperature, and the steepness of this increase. These values were compared with cold related mortalities calculated on the same basis.

## Methods

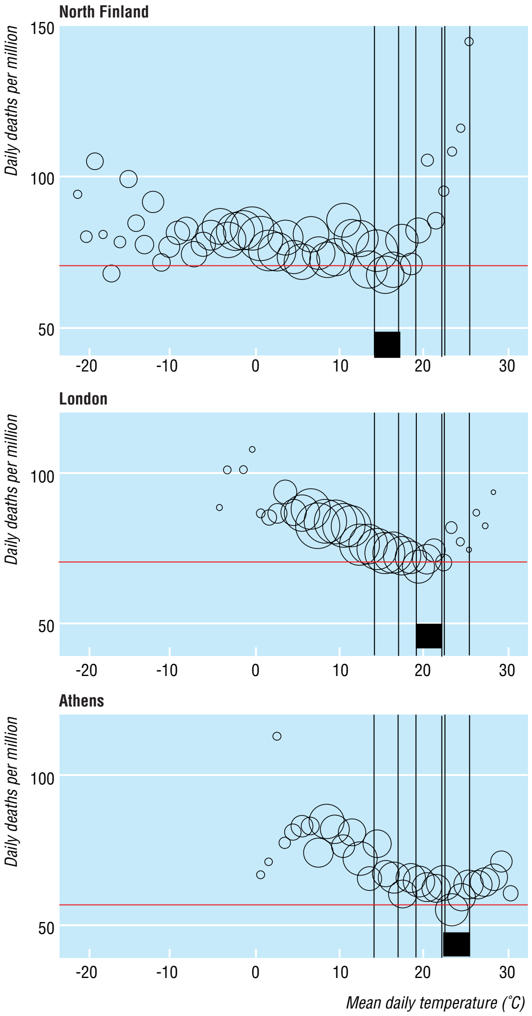
We obtained data on daily deaths of men and women aged 65-74 years in north Finland (Kuopio, Vaasa, and Oulu provinces), south Finland (provinces to the south of these), Baden-Württemberg (southwest Germany), the Netherlands, Greater London, north Italy (Imola, Bologna, Modena, and Faenza districts), and Athens (Greece).[1] Data were for 1988-92, except for Athens where daily data were available for 1992 only. All mortalities are given per million population, with population sizes derived from censuses by interpolation or extrapolation. Daily mean temperatures, wind speeds, humidities, and rainfalls for each region were supplied by the Royal Meteorological Office. Occasional missing values were filled in by interpolation.

We calculated the average mortality at successive 3°C temperature bands at increments of 0.1°C to determine the 3°C band of lowest mortality in each region. For each region, daily mortalities at temperatures above this band were then compared with daily mortalities within the baseline band, and we used the group $t$ test to give the probability and confidence limits of the difference between them. That mean difference was multiplied by the number of days per year at temperatures above the baseline band to give annual heat related mortality. Similar calculations were made of cold related deaths below the temperature band of minimum mortality for the region. Linear regressions originating from the upper and lower temperature limits of the minimum mortality band were used to provide the steepness of the increases in heat related and cold related mortalities. Linear regression was also used to relate all regional variables to mean summer temperature of the region. Data were grouped in 1°C intervals for graphs.

Unlagged data give the steepest mortality-temperature relation for heat related mortality. We therefore lagged temperature for calculation of only cold related mortality. The lag was three days, which gives the steepest mortality-temperature relation for this mortality.[9]

## Results

In all regions, mean daily mortality per million population fell as mean daily temperature rose from the lowest level experienced in the region, was roughly level over a band of 3°C, and then rose as temperature



Daily mortality of people aged 65-74 in relation to mean daily temperatures in regions with the coldest, median, and warmest summer temperatures (May to August). The black squares indicate the 3°C band of minimum mortality for the region (calculated at 0.1°C intervals) and the horizontal lines show mortality in this band

increased above this band (fig 1). The 3°C band of minimum mortality for each region was calculated and used as baseline for the region. In north Finland this band was 14.3 to 17.3°C (table 1). Above this band mortality rose, producing a total of 304 heat related excess deaths per million annually. The rise was highly significant ($P<0.001$) despite the region having the smallest population (table 2).

In regions with warm summers the 3°C bands of minimum mortality occurred at higher temperatures than in regions with colder summers, $P=0.027$ (table 1, fig 1). Consequently, the number of days warmer than the minimum mortality band was no greater in the hotter countries than in colder countries, and annual heat related mortality per million at these temperatures was not significantly greater in hotter regions. The upper limit of the minimum mortality band, marking the start of heat related mortality, was 17.3°C in north Finland, 22.3°C in London, and 25.7°C in Athens. The steepness of the rise in daily mortality with increase in temperature above the minimum mortality band was not significantly different in regions with warmer and colder summers. Neither annual mortality nor the steepness of the rise in daily mortality with temperature above the minimum mortality band was significantly related to the region's mean summer temperature if mortalities were expressed as a fraction of the mortality in the minimum mortality band (data not shown). The baseline mortalities in the minimum band show the well known tendency to higher mortality in colder countries. This is generally attributed to diet.

There were no systematic differences in wind speed, humidity, and rainfall at given temperatures, nor in the proportion of men in the population, that would account for minimum mortality occurring at higher temperatures in hot regions (table 2). Athens had higher wind speeds, lower humidity, and less rain than other regions at 22.7 to 25.7°C, the highest 3°C temperature band common to all regions. However, the second hottest region, north Italy, had the lowest wind speeds and roughly average humidity and rain in this temperature band. Wind speeds, humidities, and rainfall were not significantly related to mean summer temperature of the region in any 3°C temperature band.

Annual cold related mortality was higher than heat related mortality in all regions (table 1). Over the seven regions together, annual cold related deaths averaged 2003 per million compared with 217 per million heat related deaths (difference, $P<0.001$ by paired $t$ test). Neither annual cold related mortality nor the steepness with which daily mortality rose with falls in temperature below the band of minimum mortality was significantly related to mean summer temperature of the region. For annual cold related mortality, this remained non-significant if mortality was expressed as a fraction of mortality in the minimum band (data not shown). However, the steepness of the rise in daily mortality with falls in temperature below the band of minimum mortality became significantly related to mean summer temperature ($P=0.028$) when expressed as a fraction of mortality in the minimum band.

## Discussion

Heat related mortality occurs at higher temperatures in hotter regions than in cold regions of Europe and does not account for significantly more deaths in hotter areas. Surveys indicate that people in cold regions of Europe protect themselves better from cold stress at a given level of outdoor cold.[1] A similar explanation, better protection from heat stress in hot than cold regions, could account for our present findings. Well ventilated homes and the custom of taking a siesta at the hottest time of the day are well known features of life in southern Europe. Physiological acclimatisation is also likely to be an important factor limiting heat related mortality in hot regions. Acclimatisation to heat reduces the salt loss in sweat,[12] which causes the haemoconcentration associated with thrombotic deaths in heat waves.[2]

All regions showed more annual cold related mortality than heat related mortality. Some of those who died in the heat may not have lived long if a heat wave had not occurred. Mortality often falls below baseline for several days after the end of a heat wave, and this has been interpreted as indicating that some of the people dying during the heat wave were already close to death.[6 13 14] Some of the excess deaths in the cold

**Table 1** Annual heat and cold related mortalities per million population in people aged 65-74 living in warm and cold regions of Europe. Values are given with 95% confidence intervals in parenthesis

| | North Finland | South Finland | Netherlands | London | Baden-Württemberg | North Italy | Athens | Relation to mean summer temperature (P value) |
|---|---|---|---|---|---|---|---|---|
| Mean summer temperature† (°C) | 13.5 | 14.5 | 16.1 | 16.9 | 17.7 | 20.7 | 24.1 | — |
| 3°C band of minimum mortality (°C) | 14.3 to 17.3 | 13.3 to 16.3 | 17.3 to 20.3 | 19.3 to 22.3 | 19.0 to 22.0 | 16.8 to 19.8 | 22.7 to 25.7 | 0.027 |
| Mean daily mortality in 3°C band | 70.0<br>(65.8 to 74.2) | 72.9<br>(70.6 to 75.2) | 65.1<br>(63.7 to 66.4) | 69.8<br>(67.7 to 71.8) | 55.5<br>(54.0 to 57.0) | 51.3<br>(48.7 to 53.9) | 56.7<br>(52.0 to 61.4) | 0.040 |
| **Heat** | | | | | | | | |
| No of days/year warmer than upper limit of minimum mortality band | 25 | 46 | 18 | 5 | 22 | 89 | 63 | NS |
| Annual heat related mortality‡ | 304***<br>(126 to 482) | 248**<br>(99 to 396) | 53*<br>(12 to 93) | 40**<br>(13 to 68) | 108***<br>(56 to 159) | 325*<br>(36 to 614) | 445*<br>(59 to 831) | NS |
| Increase in daily mortality for each °C rise above minimum mortality band | 6.2***<br>(4.0 to 8.4) | 1.8***<br>(1.0 to 2.6) | 1.3**<br>(0.4 to 2.3) | 3.6**<br>(1.5 to 5.8) | 1.4**<br>(0.6 to 2.2) | 0.8**<br>(0.3 to 1.2) | 2.7*<br>(0.9 to 4.6) | NS |
| **Cold** | | | | | | | | |
| No of days/year colder than lower limit of minimum mortality band | 302 | 275 | 312 | 330 | 308 | 230 | 251 | NS |
| Annual cold related mortality‡ | 2457***<br>(1130 to 3786) | 1379***<br>(692 to 2067) | 1345***<br>(901 to 1788) | 3129***<br>(2319 to 3939) | 1936***<br>(1461 to 2412) | 1238***<br>(535 to 1940) | 2533***<br>(965 to 4101) | NS |
| Increase in daily mortality for each °C below minimum mortality band | 0.58***<br>(0.48 to 0.68) | 0.54***<br>(0.46 to 0.61) | 0.54***<br>(0.50 to 0.58) | 1.25***<br>(1.17 to 1. 32) | 0.53***<br>(0.49 to 0.57) | 0.73***<br>(0.60 to 0.86) | 1.60***<br>(1.36 to 1.83) | NS |

*P<0.05, **P<0.01, *** P<0.001.
†May to August.
‡Excess above mortality in minimum mortality band.

**Table 2** Population aged 65-74 and wind, humidity, and rainfall at various temperatures in study regions*

| | North Finland | South Finland | Netherlands | London | Baden Württemberg | North Italy | Athens |
|---|---|---|---|---|---|---|---|
| Population ($\times 10^3$) | 90 | 281 | 1098 | 530 | 737 | 132 | 242 |
| % Men | 41 | 38 | 44 | 45 | 37 | 44 | 43 |
| At 22.7-25.7°C: | | | | | | | |
| Wind (m/s) | 2.54 | 2.37 | 2.59 | 3.00 | 3.13 | 2.14 | 3.55 |
| Humidity (%) | 65.4 | 69.4 | 58.6 | 62.7 | 58.3 | 62.9 | 56.3 |
| Rain (mm/day) | 0.46 | 0.25 | 1.68 | 0.25 | 1.24 | 0.58 | 0.22 |
| At 14.3-17.3°C: | | | | | | | |
| Wind (m/s) | 3.16 | 2.56 | 2.75 | 2.97 | 4.71 | 2.29 | 3.67 |
| Humidity (%) | 74.2 | 75.9 | 68.5 | 77.0 | 70.8 | 73.9 | 67.4 |
| Rain (mm/day) | 2.33 | 2.44 | 4.38 | 3.15 | 1.44 | 3.84 | 2.80 |
| At 0.7-3.7°C: | | | | | | | |
| Wind (m/s) | 4.27 | 3.47 | 2.56 | 2.89 | 3.71 | 1.44 | 5.94 |
| Humidity (%) | 85.8 | 87.3 | 83.1 | 89.0 | 77.5 | 85.4 | 74.8 |
| Rain (mm/day) | 1.41 | 2.55 | 2.71 | 1.86 | 0.55 | 1.49 | 0.57 |

*None of the variables was significantly related to mean summer temperature.

may have resulted from non-thermal seasonal factors such as winter diet, but deaths due to such factors are likely to be few. Falls in temperature in winter are closely followed by increased mortality, with characteristic time courses for different causes of death. The increases are of sufficient size to account for the overall increase in mortality in winter, suggesting that most excess winter deaths are due to relatively direct effects of cold on the population.[9]

### Effect of global warming

The adjustment of the populations in our study to widely different summer temperatures gives grounds for confidence that they would adjust successfully, with little increase in heat related mortality, to the global warming of around 2°C predicted to occur in the next half century.[15] Although acclimatisation takes place relatively quickly, the changes in behaviour required as part of this adjustment, and particularly changes in buildings and equipment, are likely to be much slower. Short term increases in heat related mortality can therefore be expected if no pre-emptive action is taken. Spontaneous adjustments to hotter weather, even when complete, might not compensate fully for effects of higher temperatures in the hottest parts of southern Europe, where temperatures are predicted to exceed the range we have studied. Our data suggest that any increases in mortality due to increased temperatures would be outweighed by much larger short term declines in cold related mortalities, although this offers little reassurance for those affected by the heat.

Our results therefore do not negate the case for taking pre-emptive measures against heat stress in advance of global warming. The most obvious of these are to improve ventilation in homes and institutions that house vulnerable people[16] and installation of air conditioning in hotter regions. Our analysis indicates

## What is already known on this topic

Published data suggest that the same temperature in summer increases mortality less in hot than in cold countries

## What this study adds

Heat related mortality in the 65-74 age group started at higher temperatures in hot regions of Europe than in cold regions

Annual heat related mortality was no greater in hot than in cold regions

Numbers of heat related deaths were always much smaller than cold related deaths that in the regions we have studied the direct effect of the moderate warming predicted in the next 50 years would be to reduce, at least briefly, both winter mortality and total mortality. This could be continued into a large, sustained reduction in overall mortality if additional action is taken to prevent relaxation of protective measures against outdoor and indoor cold stress as winters become milder. These findings should not, of course, diminish concerns about possible indirect effects of prolonged global warming, such as flooding of low lying areas due to a rise in sea level or about direct effects of heat stress in hotter regions.

Contributors: WRK and GCD designed the study; WRK is guarantor and drafted the paper, and GCD computed the data. All authors assembled data and contributed to their interpretation and to drafting and revision of the paper.

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# Accuracy of the advanced trauma life support guidelines for predicting systolic blood pressure using carotid, femoral, and radial pulses: observational study

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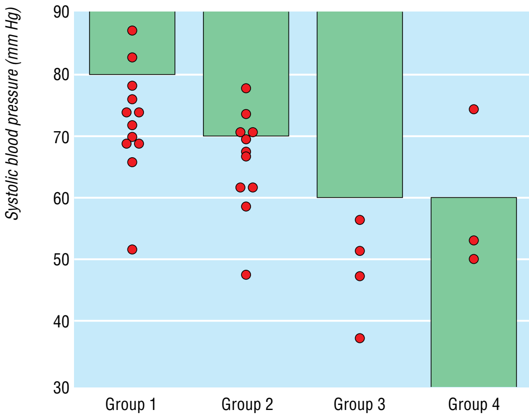
The advanced trauma life support course teaches that if only the patient's carotid pulse is palpable, the systolic blood pressure is 60-70 mm Hg; if carotid and femoral pulses are palpable, the systolic blood pressure is 70-80 mm Hg; and if the radial pulse is also palpable, the systolic blood pressure is more than 80 mm Hg.[1] The only study to examine the accuracy of this model used non-invasive blood pressure measurements, which have a tendency to underestimate systemic arterial blood pressure during hypotension.[2] No reliable data are therefore available to support the advanced trauma life support guidelines on which clinical decisions are made. We assessed whether the guidelines accurately predict systolic blood pressure by palpation of radial, femoral, and carotid pulses in hypovolaemic patients in whom blood pressure was measured using invasive arterial monitoring.

## Methods and results

After obtaining approval of the study by the ethics committee, we studied sequential patients with hypotension secondary to hypovolaemic shock and in whom invasive arterial blood pressure monitoring had been established. An observer blinded to the blood pressure palpated the radial, femoral, and carotid pulses, and the invasive systolic blood pressure was recorded.

The 20 sequential patients studied over the three year period were aged 18-79 years. Not all pulses were



Dot plot showing the distribution of systolic blood pressure according to palpable pulses (group 1: radial, femoral, and carotid pulses present; group 2: femoral and carotid pulses only; group 3: carotid pulse only; group 4: radial, femoral, and carotid pulses absent); shaded areas indicate blood pressures expected according to advanced trauma life support guidelines

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