The impact of the 2003 heat wave on mortality and hospital admissions in England

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This article quantifies the impact of the heat wave, 4 to 13 August 2003, on mortality and emergency hospital admissions in England by region and age group. The August 2003 heat wave was associated with a large short-term increase in mortality, particularly in London.

Overall in England there were 2,091 (17 per cent) excess deaths. Worst affected were those over the age of 75. The greatest increase of any region in England was in London in the over 75 age group with 522 excess deaths (59 per cent). Excess hospital admissions of 16 per cent were recorded in London for the over 75s. Temperatures in England were unusually hot. Ozone and particulate matter concentrations were also elevated during the heat wave. Estimated excess mortality was greater than for other recent heat waves in the UK.

Introduction

Like other countries in Europe, England experienced a heat wave in early August 2003. The summer throughout central Europe was atypically hot.[1] Temperature records were broken in England and Wales. Brogdale, Kent, recorded the UK's highest ever temperature of 38.5°C on 10 August. In the south east of England, maximum temperatures exceeded 32°C on three consecutive days between 4 and 6 August and then on five consecutive days between 8 and 12 August.

The heat wave originated as a persistent ridge of unusually high atmospheric pressure that stretched from the Atlantic Ocean in the west to Italy in the east and northwards to southern Scandinavia. This 'blocking' situation brought clear skies to most of Western Europe which resulted in high day-time heat loads because of high solar radiation inputs. Hot dry continental air was drawn over England and Wales from the Iberian Peninsula. This so-called 'Spanish Plume' added further to the high day time heat loads and managed to sustain night time temperatures at 6–8°C above their normal August value.

Excess mortality during the heat wave has been reported from France, Portugal and Italy. [2, 3] Preliminary estimates for mortality in England and Wales were released by the Office for National Statistics (ONS) in October 2003.[4] In this article, we investigate in more detail the impact of the heat wave in England, by estimating the attributable mortality and emergency hospital admissions by region and by age group.

Method

Mortality data were extracted from databases held by ONS, for all deaths occurring on each day in July and August 2003, and for same months in the five preceding years, by age group (0–64, 65–74, 75 and over) and by Government Office Region (GOR). Mortality in the summer is typically low and stable. There was little year-on-year variation in the summer values used in the calculation of the comparison period. Deaths were assigned to GORs based on place of residence; deaths of non-residents have not been included. Results are for England only as early analysis[4] suggested that it was regions of England that were worst affected by the heat wave. Focusing on England also allowed us to draw on Hospital Episode Statistics (HES), which were only available for England.

Provisional data on emergency hospital admissions were supplied by the Department of Health (HES). Data were obtained for the same age groups, regions and years as the mortality data. These data are provisional and are likely to be incomplete. Emergency hospital admissions were assigned to GORs based on the place of residence of the person treated.

The Met Office supplied temperatures for each GOR during the episode. Daily values were generated for a national 5km grid by interpolation of data from approximately 560 stations. Within each GOR, the maximum and minimum of the daily maxima were then identified. The London region time series, of daily data recorded at the London Weather Centre, were downloaded from the British Atmospheric Data Centre [www.badc.nerc.ac.uk]. Data for the Central England Temperature (CET) series were obtained from the Climatic Research Unit, University of East Anglia and the British Atmospheric Data Centre. Temperature anomalies were calculated by subtracting a long-term mean climatology (1971 to 2000) for the days in question from the observed data for those days.

Measurements of the ambient air concentrations of ground level ozone (daily maximum of a running 8-hour mean) and PM_{10} (particulate matter of diameter less than 10 μm) (24-hour mean) were obtained from the UK National Air Quality Archive. Concentrations were averaged across all sites in the region then population weighted to give a value for England. Excess exposure was calculated as the difference between the daily regional concentrations averaged over the heat wave period and the equivalent values observed during the same period in 2002, when mean concentrations were considered to be typical mean values for August.

Excess mortality and emergency hospital admissions for GORs were calculated for the 10-day heat wave period defined as 4 to 13 August 2003. Baseline values were the average of the 4 to 13 August in the preceding five years. This period was defined as starting when maximum daily CET first exceeded average values (1971 to 2000) by 8°C and ending when temperatures returned to average levels.

Excess mortality was calculated as observed deaths minus the baseline (average of 1998 to 2002) expected mortality. Excess emergency hospital admissions were calculated in the same way. Due to the large day of week variation in hospital admissions the baseline series was adjusted so that the appropriate day of the week in 2003 was compared with the same day of the week in each of the comparison years of 1998 to 2002. A seven-day moving average was then applied to smooth the data.

Confidence intervals (CI) were calculated for the excess values. The number of observed deaths or emergency hospital admissions was treated as a Poisson variable, the 95 per cent confidence limits for this value were then compared with expected values to generate confidence limits for excess mortality and emergency hospital admissions.

Results

In England, there were 2,091 excess deaths (17 per cent increase, CI: 15–19 per cent) during the heat wave. The impact was greatest in the southern half of England, particularly in London, where deaths increased by 42 per cent (CI: 36–48 per cent) (Table 1).

In England, mortality in the over 75s increased by 23 per cent (CI: 21–26 per cent) more than the increase seen for the other age groups (Table 1). All regions had an excess for the over 75 age group, although confidence limits for this group in the North East region did include negative values. The greatest excess in the over 75s was in the London region with a 59 per cent increase (CI:51–67 per cent). For the 0–64 age group, confidence intervals were within positive excess values for the East Midlands, Eastern, London, South East and the South West.

In order to compare the impact of this heat wave with previous heat waves in England, we re-calculated the excess using mortality methods used to derive published estimates for the 1995 heat wave[5] and the 1976 heat wave.[6] Using a baseline of a 31-day moving average of 1999 to 2002 data the excess over the 2003 heat wave period was 16 per cent in England and 41 per cent in London. A baseline of a 31-day moving average of deaths in the same year produced excess values of 11 per cent in England and 27 per cent in London.

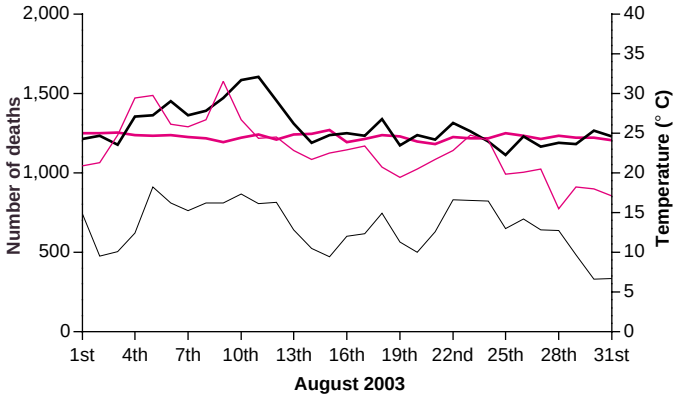
An excess of only 1 per cent (CI: 1–2 per cent) in total emergency hospital admissions was found for England; in most regions the excess was small or a deficit. However in the London region excess admissions were 16 per cent (CI: 12–20 per cent) for the over 75s and 4 per cent (CI: 1–6 per cent) for the 0–64 age group (Table 1).

Table 1 **Number and proportion of excess deaths and hospital admissions by Government Office Region and age group, 4th–13th August 2003**

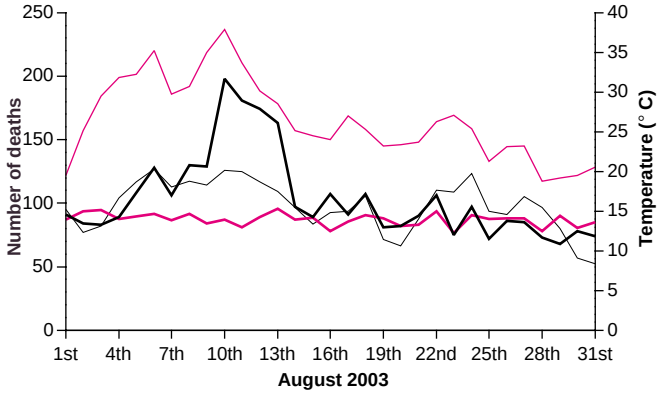
	Number (%) excess deaths				Number (%) excess emergency hospital admissions			
Government Office Region	0–64	65–74	75+	All ages	0–64	65–74	75+	All ages
London	45 (15)	49 (17)	522 (59)	616 (42)	286 (4)	-74 (-5)	464 (16)	676 (6)
South East	46 (15)	56 (17)	345 (26)	447 (23)	-401 (-5)	-167 (-9)	-53 (-1)	-621 (-4)
South West	37 (18)	24 (11)	221 (25)	282 (21)	-84 (-1)	0 (0)	304 (11)	220 (2)
Eastern	54 (27)	-26 (-11)	226 (27)	254 (20)	-263 (-5)	-159 (-11)	94 (3)	-328 (-3)
East Midlands	41 (23)	-5 (-2)	133 (21)	169 (17)	40 (1)	-55 (-4)	322 (14)	307 (3)
West Midlands	6 (2)	10 (4)	114 (14)	130 (10)	203 (3)	-25 (-2)	14 (1)	192 (2)
Yorkshire and the Humber	-2 (-1)	-14 (-6)	122 (15)	106 (8)	106 (1)	-9 (-1)	36 (1)	133 (1)
North West	-1 (0)	-9 (-2)	84 (8)	74 (4)	961 (10)	67 (3)	260 (7)	1,288 (8)
North East	10 (8)	-10 (-6)	13 (3)	13 (2)	-497 (-11)	-107 (-10)	50 (3)	-554 (-8)
England	236 (11)	74 (3)	1,781 (23)	2,091 (17)	352 (1)	-531 (-4)	1,490 (6)	1,311 (1)

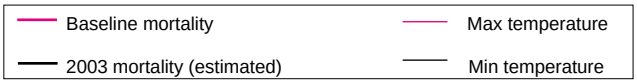
Figure 1 **Mortality, emergency hospital admissions, ozone, PM_{10} and temperature, England and London, August 2003**

a) Daily mortality and temperature, England, all ages

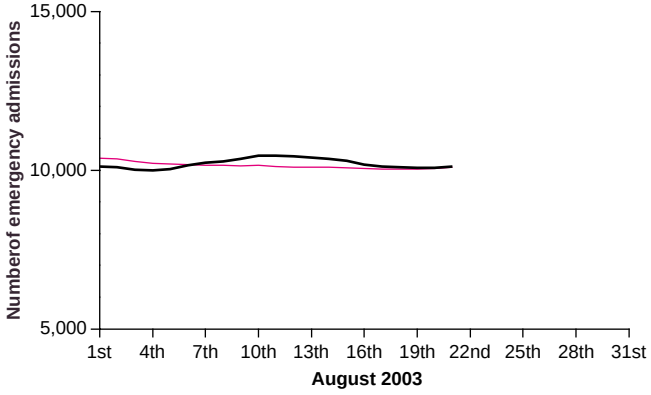


b) Daily mortality, London, 75 years and over

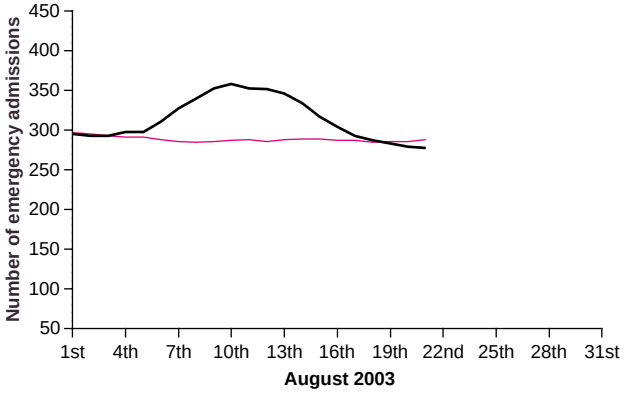


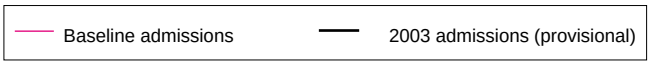


c) Daily emergency hospital admissions (7-day moving average) England, all ages

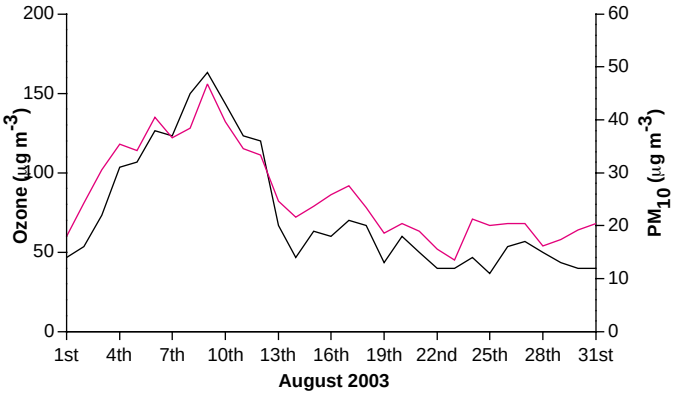


d) Daily emergency hospital admissions (7-day moving average) London, 75 years and over





e) Concentrations of ozone (daily max of running 8-hour mean) and PM_{10} (daily mean) England



f) Concentrations of ozone (daily max of running 8-hour mean) and PM_{10} (daily mean) London

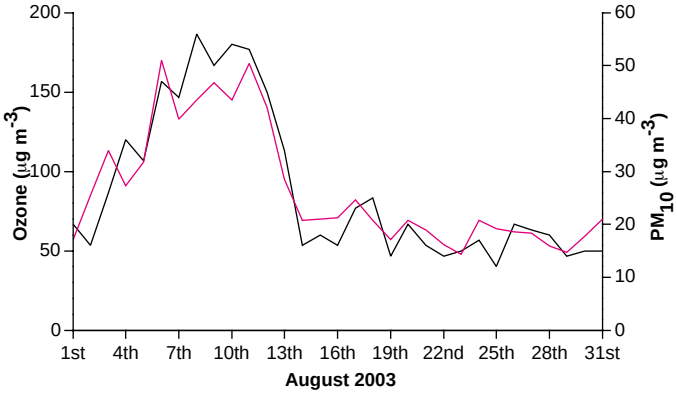
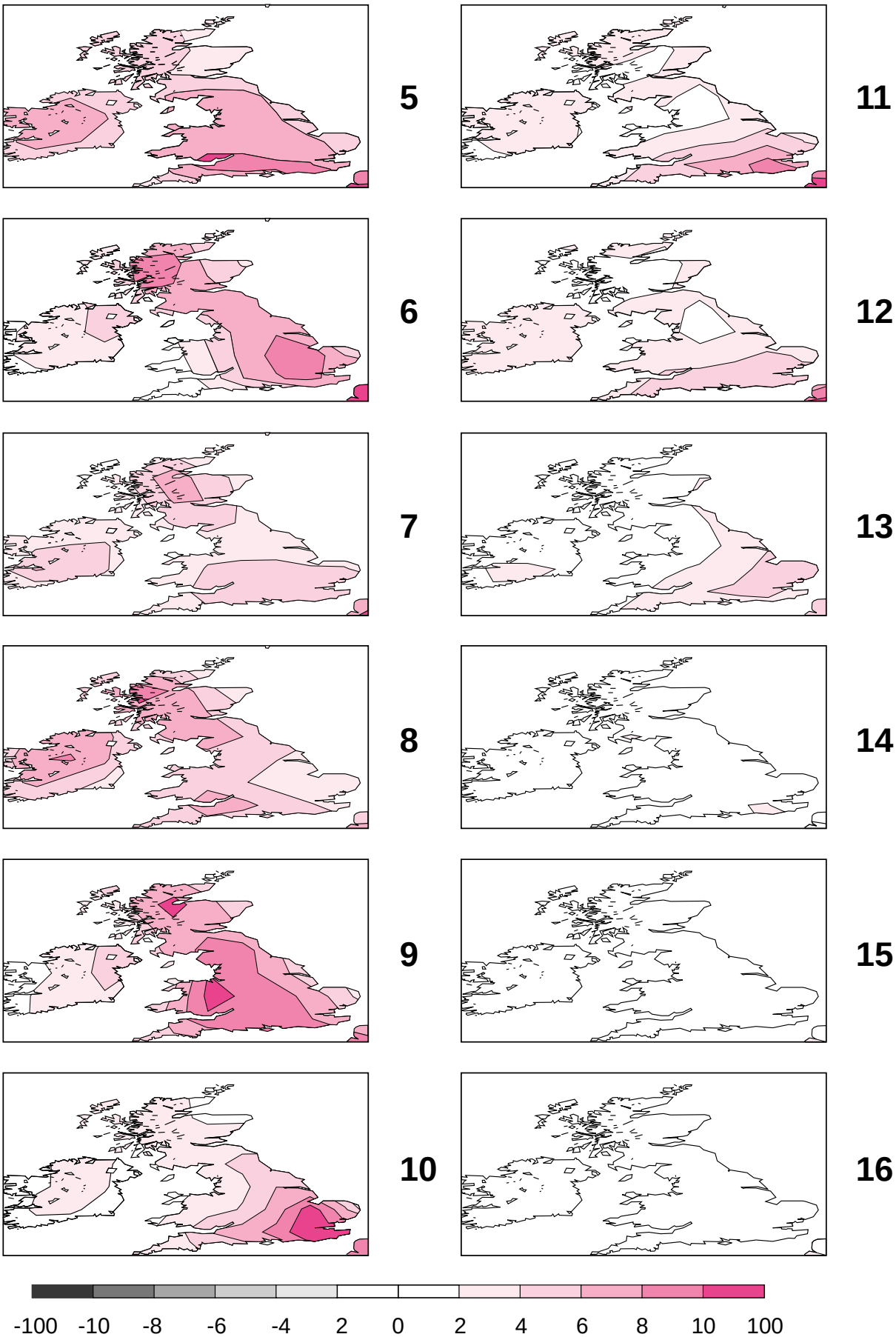


Figure 2 **UK temperature anomolies, degrees celsius difference from the mean climatology (1971–2000), 5th–16th August 2003**



Temperatures in England (CET) peaked at 31.5°C on 9 August (Figure 1). This coincided with peaks in the concentrations of ozone and PM_{10}. The peak in daily deaths in England of 1,604 deaths occurred two days later on 11 August. The peak in emergency hospital admissions appears to have occurred earlier on 10 August.

Figure 2 shows temperature anomalies across the UK from 5 to 16 August. There were unusually high temperatures across much of England on 9 August. By 10 August these temperatures had retreated to the southeast. Unusually high temperatures had the greatest duration over the area where excess mortality was reported as highest.

London experienced night time temperatures of 26–27 °C during the heat wave, and a maximum of 37.9 °C was recorded at the London Weather Centre on 10 August. Concentrations of PM_{10} and ozone peaked in London on 8 and 11 August respectively. Deaths and emergency hospital admissions peaked on 10 August (Figure 1). Excess concentrations of PM_{10} and ozone were highest in the London and South East regions respectively (Table 2).

Table 2 **Temperature (°C) and average excess exposure to ozone and particulate matter ($\mu g\ m^{-3}$) by Government Office Region, 4th–13th August 2003**

Government Office Region	Temperature (°C)		Ozone ($\mu g\ m^{-3}$)	PM_{10} ($\mu g\ m^{-3}$)
	Minimum maximum temperature	Maximum temperature	Excess	Excess
London	34.7	38.1	86	26
South East	27.5	38.5	90	20
South West	22.2	33.9	68	24
Eastern	26.6	38.1	65	20
East Midlands	23.1	35.5	61	22
West Midlands	29.0	35.0	48	17
Yorkshire & the Humber	23.7	32.9	37	21
North West	23.3	32.9	48	14
North East	24.2	30.9	31	12

Night-time temperatures in England (CET) reached 17–18 °C during the heat wave; the same maximum night-time temperatures in England were recorded in the heat waves of 1995 and 1976.

Discussion

The heat wave had a major effect on mortality in England, but not to the extent of that observed in France, Spain or Portugal.[3]

In 2003, emergency hospital admissions did not seem to be affected by the heat wave, except in London where increases were reported in the over 75s and in the 0–64 age group. These findings are consistent with other studies. The 1995 heat wave in London did not significantly increase admissions in London, although high temperatures were associated with increased admissions in children and in respiratory disease in the over 75 age group.[7] Emergency hospital admissions have been reported to increase during heat waves in the US,[8, 9] but the increases were not of a comparable magnitude to that observed in mortality.

Cities are usually more affected by increasing temperatures than surrounding areas where building density is lower.[10] The nocturnal urban heat-island in London is greatest in the summer months, and has increased since the 1960s.[11]

High ozone concentrations are an important co-exposure during heat waves in England. High ozone concentrations were reported during the 1976 heat wave.[12] Ozone has been linked with increased admissions for respiratory diseases.[13] Excess exposure to ozone and PM_{10} were recorded for all regions in England, most notably in London and the South East. Up to 21–38 per cent of the excess deaths (where excess deaths were predictions based on previous time series studies of air pollution and mortality) in the 2003 heat wave could be attributed to ozone and PM_{10}, although this study assumes no interaction between high temperatures and high pollutant exposures.[14] It is very difficult to separate the effects of pollutants and temperature as they may have a synergistic effect.

The elderly (over 75s) are most vulnerable to heat related mortality, as has been shown in other heat wave studies in the UK[6] and in other countries.[2] Where older people live on their own, they may not receive the care they need during a heat wave (for example, adequate hydration) and they are also unlikely to call for medical attention, therefore dying at home without being admitted to hospital.[9]

Smaller increases were seen in many regions in the 0–64 age group, which may reflect an increase in mortality in children and infants who are also at risk from heat-related deaths,[10] or an increase in mortality in sick adults (e.g. those with chronic cardiorespiratory disease). Further work could look at a more detailed age breakdown and presenting the underlying cause of death or hospital admission.

Excess mortality was much greater than that observed with previous heat waves in the UK. In London it was estimated that the 2003 heat wave was associated with a 42 per cent increase in mortality, compared to an excess of 16 per cent in 1995 and 15 per cent in 1976.[5, 6] The 1976 event was of comparable magnitude. Further, excess mortality in those aged 75 and over was approximately 20 per cent in 1976 compared to 59 per cent in 2003, in London. Results from this analysis have fed into the recently published Department of Heath heat wave action plan.[15]

Most of the deaths in heat waves are in the over 75s and it is this age group which makes up an increasing proportion of the UK population.[16] However this does not explain the increased excess deaths of older people living in London as the numbers of older people living in London have been decreasing.[17]

This article has presented an episode analysis, looking at the combined effects of several exposures. Future work could separate out the effects of different exposures. This type of analysis is sensitive to the definition of the heat wave period and the baseline used. Using a more conservative baseline of a 31-day moving average of deaths in the same year still produced estimated excess mortality in 2003 that was higher than estimated excess mortality for previous heat waves in the UK.

Mortality and hospital admissions have been analysed by place of residence. Although information is available on type of place of death this does not provide much useful information about those who died as most deaths occur after transfer to a hospital. No information is available on type of place of residence for mortality or hospital admissions data.

There was a small dip in mortality following the heat wave (-4 per cent from 24 to 29 August) indicating possible displacement of deaths by the heat wave. This summer excess will have had little effect on total deaths in 2003 – mortality increases during the winter months will have a much greater effect on annual totals.

The 2003 data used for mortality has been finalised. Emergency hospital admissions are incomplete, results are however consistent with other studies.

ONS and its predecessors have produced weekly national mortality data since the 1850s. The purpose of our weekly deaths system is to provide a quick estimate of any increase in deaths related to events such as an influenza outbreak, or period of exceptional weather. Our current system takes deaths which have been registered in England and Wales in the previous week and uses this to make an estimate of what the final registered numbers will be.[18] The first clear indication of a substantial increase in deaths was published on 21 August 2003. This provided a quick first estimate of the number of deaths attributable to the heat wave.

Conclusion

This study has shown that heat waves have a significant and important burden on health in England, and particularly in London and the South East. As global warming continues, heat waves are very likely to increase in frequency and intensity[19] and are likely to exacerbate London's urban heat island.[11] A heat wave action plan has recently been published by the Department of Health.[15] This plan includes the initiation of a 'Heat-Health watch' system to trigger appropriate responses, identification of those most at risk and the provision of advice and information.

Key findings

- During the heat wave in August 2003, an estimated 2,091 (17 per cent) more deaths occurred in England than the average for the same period over the previous five years.
- The increase in mortality was greatest in London, but most of Central and Southern England was also affected.
- The percentage increase in excess mortality was greater than during the heat waves of 1976 and 1995.
- The elderly were most affected by the heat wave. The percentage increase in mortality and emergency hospital admissions were greatest among the elderly in London.

The opinions expressed are those of the author and should not be taken to represent those of the Department of Health.
Information on Hospital Episode Statistics is available from: www.dh.gov.uk/PublicationsAndStatistics/Statistics/HospitalEpisodeStatistics

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