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## Heat-related mortality in residents of nursing homes

JOCHEN KLENK<sup>1,2</sup>, CLEMENS BECKER<sup>1</sup>, KILIAN RAPP<sup>1,2</sup>

<sup>1</sup>Department of Clinical Gerontology, Robert-Bosch-Hospital, Auerbachstr. 110, 70376 Stuttgart, Germany

<sup>2</sup>Institute of Epidemiology, Ulm University, Helmholtzstr. 22, 89081 Ulm, Germany

Address correspondence to: J. Klenk. Tel: (+49) 711 8101 3175; Fax: (+49) 711 8101 3199; Email: jochen.klenk@uni-ulm.de

### Abstract

**Background:** in population-based studies, age and morbidity were associated with heat-related mortality. The nursing home population reveals both factors and may represent a highly vulnerable subgroup. Therefore, temperature–mortality relationship was examined in residents of nursing homes.

**Methods:** the association between daily ambient maximum temperature and mortality was analysed in 95,808 nursing home residents in southwest Germany between 2001 and 2005. Time series analyses were applied across age groups, sex and functional abilities. In addition, excess mortality was determined for the 2003 heat wave.

**Results:** mortality risk was lowest at maximum temperatures between 16 and 25.9°C. Risk increased by 26 and 62% at days of 32.0–33.9 and 34°C and more, respectively. In August 2003, heat caused >400 additional deaths in the observed population and was followed by only a moderate mortality displacement in the following months. The excess number of deaths during the heat wave was particularly high in residents aged ≥90 years and in residents with higher care needs.

**Conclusion:** high ambient temperature was associated with an increased mortality risk in all analysed subgroups of the nursing home population. Medical competence and supervision are available in nursing homes and should, therefore, be favourable preconditions for the implementation of preventive measures.

**Keywords:** heat wave, mortality, nursing home, elderly

## Introduction

Numerous studies have demonstrated an association between ambient temperature and mortality [1–12]. The association was shown to be a J- or V-shaped function with the lowest mortality rates at moderate temperatures and increasing mortality rates with higher or lower temperatures [8–11]. This function was observed in different countries with different climates. The temperature band with lowest mortality, however, varied between populations.

The increased risk of death associated with ambient heat affects mainly old and very old people. Furthermore, an association between morbidity and heat-related mortality is well established [1]. Residents of nursing homes reveal both risk factors to a great extent and represent, therefore, a highly relevant subgroup when evaluating heat-related mortality in the population. Furthermore, residents of nursing homes could be an important population for public health interventions since measures like emergency information systems or air condition supply could be easily applied in this setting.

Only few studies analysed the association between temperature and mortality in residents of nursing homes [2, 3, 9, 12, 13]. The largest study to date observed the temperature–mortality relationship in the Dutch nursing home population over 2 years. They found a particularly high sensitivity to heat in women, in residents with psychogeriatric and neurological conditions and in residents with high levels of dependency.

In August 2003, Western Europe was hit by a severe heat wave. France was strongly affected [4] but the south of Germany was also struck by the most severe heat wave since the start of the recording [5, 12, 14]. Several studies analysed the impact of the 2003 heat wave on mortality in institutionalised people in France [6, 15, 16] and other European countries [12, 17]. The evidence from most of these studies, however, is limited due to methodical problems [15, 17] or to low case numbers [6, 16].

We analysed the influence of moderate and high ambient temperature on all-cause mortality in a large cohort of nursing home residents of nursing homes from Baden-Württemberg, a federal state in the southwest of Germany. The temperature–mortality relationship was examined using time series analysis. In addition, excess mortality was determined for the 2003 heat wave. The sample size also allowed the evaluation of the temperature effect in different subgroups. To our knowledge, this is so far the largest study

that analysed the relationship between temperature and mortality in institutionalised people.

## Methods

### Study population

The dataset consisted of all people aged  $\geq 65$  years, insured with the Allgemeine Ortskrankenkasse (AOK) and living in or newly admitted to a nursing home between 1 January 2001 and 31 December 2005 in Baden-Württemberg, a federal state with 10.7 million inhabitants southwest of Germany. Health insurance, including cover for nursing home care, is statutory in Germany. The AOK is Germany's largest statutory health insurance company and covers >50% of all residents living in nursing homes in Baden-Württemberg. Fourteen percent of the 385,000 citizens aged  $\geq 80$  years in Baden-Württemberg are residents of one of about 1,200 nursing homes. The insured persons are free to live in a nursing home of their own choice.

### Data source

Routine data collection systems of the AOK health insurance company were utilised to gain data on sex, age, date of admission to the home, level of care (see below) and, if appropriate, date of death for each individual.

Data on daily weather was provided by the Deutscher Wetterdienst, a governmental organization [14].

### Temperature

Daily ambient maximum temperature in degrees Celsius was used to quantify heat exposure to nursing home residents. The temperature measure point was located in Stuttgart-Echterdingen in the most crowded region of the federal state which covers about 1/4 of the population of Baden-Württemberg [18].

### Outcome

Date of death was provided by the health insurance company. Cause-specific mortality was not available.

### Level of care

In 1995, long-term care insurance was introduced in the German social insurance system, which is compulsory for all

**Table 1.** Mortality rate ratio (MRR) and 95% confidence interval (95% CI) according to maximum daily temperature

Maximum daily temperature (°C)	Days (n)	Daily mortality rate per 100,000 (95% CI)	MRR (95% CI)
<0	77	103.9 (100.0; 107.8)	1.16 (1.09; 1.23)
0–3.9	195	103.2 (100.8; 105.6)	1.15 (1.10; 1.21)
4.0–7.9	213	99.0 (96.7; 101.3)	1.10 (1.05; 1.16)
8.0–11.9	260	100.8 (98.7; 102.9)	1.12 (1.08; 1.18)
12.0–15.9	239	95.3 (93.2; 97.4)	1.06 (1.02; 1.11)
16.0–19.9	298	90.0 (88.2; 91.9)	1.00 (0.96; 1.05)
20.0–21.9 <sup>a</sup>	128	89.6 (86.8; 92.4)	1.00 <sup>a</sup>
22.0–23.9	113	91.0 (87.9; 94.0)	1.02 (0.96; 1.07)
24.0–25.9	92	88.6 (85.3; 91.8)	0.99 (0.93; 1.05)
26.0–27.9	76	96.5 (92.8; 100.3)	1.08 (1.01; 1.14)
28.0–29.9	81	98.2 (94.6; 101.9)	1.10 (1.03; 1.16)
30.0–31.9	30	105.6 (99.3; 111.9)	1.18 (1.09; 1.28)
32.0–33.9	10	112.5 (101.2; 123.7)	1.26 (1.10; 1.43)
≥34.0	14	145.3 (134.5; 156.1)	1.62 (1.46; 1.80)

<sup>a</sup>Reference group.

citizens [19, 20]. In order to claim for long-term care benefits, people must need a minimum of 45 min of assistance with basic care per day. Depending from the extent of care required, recipients are categorised into three levels after an assessment by a physician (level 1, 2 and 3 requiring basic care such as washing, eating or dressing for at least 0.75, 2 and 4 h per day, respectively). The ‘level of care’ is, therefore, a measure for the need of care and the degree of functional impairment. The ‘level of care’ may change over time according to the person’s health status. For the analyses, only the ‘level of care’ present at 1 January 2001 or at admission to the nursing home (for those admitted after 1 January 2001) was available.

## Statistics

### Temperature–mortality relationship

Daily mortality rates were calculated by dividing the number of daily deaths by the number of residents living in nursing homes at the specific day. Corresponding 95% confidence limits were constructed.

Time series analyses of the relationship between daily ambient maximum temperature and daily mortality rates were performed and presented as sex-, age- and level-of-care-specific scatter plots. Furthermore, Poisson regression analyses were applied. For these analyses, ambient maximum temperature was categorised in 2°C groups >20°C and in 4°C groups <20°C, and days with maximum temperatures <0°C were combined to one single category. Temperatures between 20.0 and 21.9°C are the preferred indoor temperature in nursing homes and were therefore chosen as reference category. To account for over-dispersion, a negative-binomial link function was applied. Results are presented as mortality rate ratios with 95% confidence limits. All data between 1 January 2001 and 31 December 2005 were included in the analyses.

To quantify the observed heat–mortality relationship, mortality rate ratios associated with a 5°C increase in daily

ambient maximum temperature were calculated for temperatures over the threshold of 26°C using a simple linear model assuming a log–linear association. Stratified calculations were performed for sex, age (65–79, 80–89 and ≥90 years) and level of care.

Unlagged data give the strongest association between heat and mortality [21]. Therefore, no lag time between temperature and mortality was considered.

### Heat wave

The effect of the 2003 heat wave on mortality was analysed comparing observed mortality rates from 2003 with mean mortality rates of the same time period from the years 2001, 2002, 2004 and 2005 (reference years representing expected mortality rates). To account for structural imbalance, mortality rates were sex- and age-standardised using the study population institutionalised at 1 August 2003 as standard population.

Excess mortality was assessed by calculating the mean sex- and age-standardised mortality rate difference between 2003 and the reference years. It was calculated for different time periods each starting at the beginning of the 2003 heat wave (1 August 2003). The estimation of the absolute excess number of deaths was based on the study population institutionalised at 1 August 2003. In case of overlapping confidence intervals (CI), statistical significance at the 5% level was tested using the method published by Wolfe *et al.* [22].

All calculations were carried out with SAS version 9.1 (SAS Institute Inc., Cary, NC, USA).

## Results

The study population consisted of 74,753 (78%) women and 21,055 (22%) men aged ≥65 years living in nursing homes in Baden-Württemberg between 2001 and 2005. At enrolment, nearly half of the residents were aged between 80 and 89 years. Residents were categorised into level of care 1, 2 and 3 in 46.7, 43.6 and 9.7%, respectively. During the

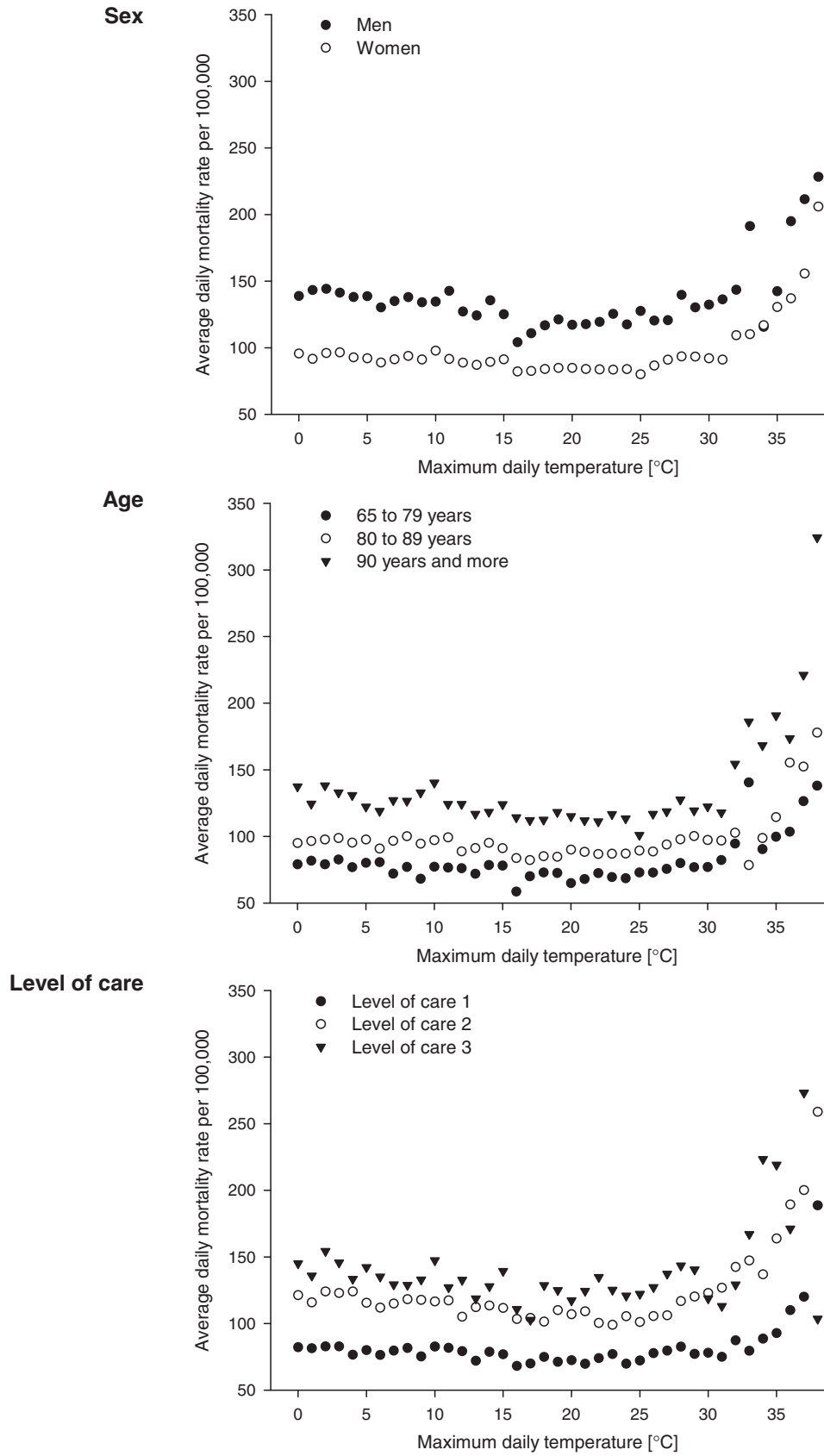


Figure 1. Relationship between maximum daily temperature and average daily mortality rate per 100,000 stratified by sex, age category and level of care.

**Table 2.** Excess mortality rate in year 2003 compared to reference years (2001, 2002, 2004 and 2005) starting at 1 August

		Time interval					
		At Day 1	1–7 days	8–14 days	15–30 days	31–90 days	1–90 days
		All					
Average daily mortality	2003	107.1	124.7	189.1	105.5	87.1	100.1
	2001, 2002, 2004, 2005	99.3	89.2	82.3	87.9	91.4	88.7
Difference of daily mortality rate <sup>a</sup>		7.8 (–30.5 to 46.1)	35.5 (20.2 to 50.8)	106.8 (88.6 to 125.0)	17.6 (8.2 to 27.0)	–4.3 (–8.8 to 0.2)	11.5 (7.6 to 15.3)
Excess numbers of death <sup>b</sup>		3	86	258	97	–89	356
		Sex					
Difference of daily mortality rate <sup>a</sup>	Women	8.9 (–31.2 to 48.9)	39.6 (23.2 to 56.1)	107.8 (88.1 to 127.5)	21.8 (11.6 to 32.0)	–3.6 (–8.3 to 1.1)	12.9 (8.8 to 17.1)
	Men	–27.5 (–127.7 to 72.6)	5.5 (–34.4 to 45.3)	109.5 (60.2 to 158.8)	8.4 (–17.0 to 33.8)	–6.7 (–19.6 to 6.2)	6.0 (–5.0 to 16.9)
		Age					
Difference of daily mortality rate <sup>a</sup>	65–79 years	16.4 (–51.7 to 84.5)	30.0 (3.6 to 56.3)	81.2 (50.0 to 112.4)	9.2 (–7.1 to 25.6)	2.9 (–5.1 to 10.8)	12.2 (5.4 to 19.0)
	80–90 years	38.1 (–18.9 to 95.1)	31.6 (9.0 to 54.2)	82.9 (57.6 to 108.2)	17.7 (3.8 to 31.6)	–9.6 (–16.0 to –3.3)	5.6 (0.0 to 11.2)
	>90 years	–51.9 (–124.5 to 20.7)	40.4 (9.2 to 71.6)	169.5 (128.5 to 210.6)	25.7 (5.9 to 45.4)	–1.3 (–10.8 to 8.3)	20.0 (11.7 to 28.3)
		Level of care					
Difference of daily mortality rate <sup>a</sup>	Level 1	–4.5 (–50.1 to 41.1)	24.6 (5.5 to 43.6)	64.1 (42.3 to 85.8)	8.7 (–3.1 to 20.5)	–3.3 (–8.9 to 2.4)	6.3 (1.4 to 11.2)
	Level 2	35.5 (–32.5 to 103.6)	48.3 (22.2 to 74.5)	146.1 (114.2 to 178.1)	26.0 (10.0 to 41.9)	–3.6 (–11.1 to 3.9)	17.3 (10.7 to 23.9)
	Level 3	–14.8 (–164.7 to 135.2)	33.3 (–26.9 to 93.5)	185.1 (109.6 to 260.5)	29.1 (–8.4 to 66.7)	0.4 (–17.8 to 18.6)	23.1 (7.4 to 38.9)

<sup>a</sup>Per 100,000 persons living in nursing homes (95% confidence interval).<sup>b</sup>Based on the study population living in nursing homes at 1 August 2003 ( $n = 34,549$ ).

period of observation, 63.1% of all participants died accounting for 60,451 deaths.

### Temperature–mortality relationship

High ambient temperature was associated with an increased mortality risk in nursing homes (Table 1). The range with the lowest mortality rates was found between maximum ambient temperatures of 16.0 and 25.9°C. Above the threshold of 26°C, increasing ambient temperatures were associated with increasing mortality rates. For example, maximum temperatures of 30.0–31.9, 32.0–33.9 and  $\geq 34^\circ\text{C}$  were associated with an increased mortality risk of 18, 26 and 62%, respectively.

A similar pattern of a J-shaped temperature–mortality relationship was observed in women and men, in all analysed age groups and in residents with different care needs (Figure 1). Mortality rate ratios associated with a 5°C increase in daily maximum temperature over the threshold of 26°C did not significantly differ between women and men or between different age groups (see Figure Appendix 1 in *Age and Ageing* online). However, residents with the lowest degree of care need (level of care 1) were found to be less susceptible to heat-related mortality than those categorised within the medium degree of care need (level of care 2).

### Heat wave 2003

Extreme temperatures of the 2003 heat wave started in 1 August and lasted for 2 weeks. During this period, a steep increase in daily mortality rates was observed (see Figure Appendix 2 in *Age and Ageing* online).

Excess mortality expressed as difference of average mortality rates between 2003 and the reference years increased up to 106.8/100,000 (95% CI: 88.6–125.0/100,000) during the second week and persisted even after 90 days (11.5/100,000; 95% CI: 7.6–15.4/100,000) (Table 2). In the observed study population, the absolute number of excess deaths amounted to 444 deaths during the first month and only moderately decreased during the following 2 months (356 deaths at Day 90).

Heat-related excess mortality was observed in all analysed subgroups. A particularly high susceptibility to these extreme weather conditions was observed among the oldest old ( $\geq 90$  years) and in residents with higher care needs (level of care 2 and 3). Excess mortality during the 2003 heat wave was not statistically different between women and men.

### Discussion

Similar to time series analyses performed in the community [8–11], our results demonstrate a J-shaped function between ambient maximum temperature and mortality. This pattern was observed independently from gender, age or care need. The vulnerability was comparable between the different age categories but residents with the lowest care need were less sensitive to heat than those with a higher

care need. This is in line with the findings from Mackenbach *et al.* [3] and supports their conclusion that morbidity and not age as such determines sensitivity to heat. Keatinge *et al.* defined 3°C bands of minimum mortality derived from population-based data [8]. The minimum mortality rates in our data were observed between 16 and 25.9°C covering a considerably larger temperature span. Increased mortality rates were not found before an ambient maximum temperature of 26°C. For the majority of days during the year, residents were exposed to temperatures below the optimal range; but between 2001 and 2005, there was still a yearly average of 42 days on which maximum temperatures exceeded the threshold of 26°C.

The heat wave of August 2003 caused a dramatic increase in daily mortality. Our data show that only a moderate displacement of deaths happened during the second and third month after the start of the heat wave ('harvesting'). But a clear excess mortality was still present even after 3 months with an additional 356 deaths caused by the heat wave. The highest number of excess deaths was observed during the second week. Only residents insured at the AOK were available for the calculations. They accounted for 51% of the nursing home population institutionalised in 2003 in Baden-Württemberg. Assuming identical mortality rates in residents insured at other companies, a total of 872 additional deaths may have occurred in residents with care need and institutionalised in nursing homes in Baden-Württemberg (10.7 million inhabitants) during August 2003. This is considerably higher than the number estimated earlier by the official health authorities [23].

All analysed subgroups were affected and contributed to the additional number of deaths. Excess mortality was particularly high in residents aged  $\geq 90$  years.

Major physiologic mechanisms for heat loss are convection by transferring heat from the skin to the air and evaporation by producing sweat. An inability to increase cardiac output because of cardiovascular disease, drugs or water depletion or to increase sweating because of drugs with anticholinergic properties can considerably impair heat tolerance [24]. If exposed to heat, looking for a cooler place is an important coping strategy. Immobilization or psychogeriatric disorders can compromise this strategy. Multimorbidity and polypharmacy are frequent in institutionalised people. Therefore, susceptibility to heat stress/heat stroke in this population is particularly high.

There is contradictory evidence from population-based studies as to whether the increase in mortality is followed by a deficit that (partly) compensates the negative effect [7, 10, 11]. Studies performed in nursing homes did not find a displacement of deaths [2, 6]. In our data, excess deaths after 3 months were still  $>80\%$  of excess deaths observed after the first month. This long-term effect of the heat wave on all-cause mortality justifies comprehensive preventive measures in nursing homes.

Air conditioning appeared to be highly effective in preventing heat wave mortality [2, 25]. As a consequence of

the 2003 heat wave, air conditioning equipment for nursing homes was included in the National Heat Wave Plan in France [26].

However, air conditioning requires capital investment and is associated with high energy expenditure. Therefore, it is still uncommon in most Middle-European countries including Germany. For these countries, additional measures have to be applied. Examples are the transfer of susceptible residents to cooler places in the building, footbaths or the washing of bedridden people with cold water. Adequate hydration is essential and can be supported by subcutaneous administration of isotonic infusions [27] and the critical review of diuretics during heat waves. Recently, Baden-Württemberg has implemented a heat health warning system, which includes the immediate information of nursing homes by fax in high-risk heat situations [28]. With respect to climate change, appropriate urban planning and building design will be a challenge for the future [29].

However, it has to be stressed that the short-term excess mortality during a heat wave only marginally influences the life expectancy in a population with such high baseline mortality rates.

Major strengths of the study are its large number of study participants, information about care need on an individual level and the availability of four reference years for the evaluation of the 2003 excess mortality.

Most studies analysing the heat–mortality relationship used as independent variable mean daily temperature, average temperature over several days or apparent temperature, which additionally accounts for humidity. We deliberately used maximum temperature as independent variable. It is easy to understand and to communicate—e.g. between caregivers or nursing staff—and, therefore, in our opinion a practical measure for increased alertness and timely prevention.

Several limitations have to be considered. Data structure did not allow assigning nursing homes to specific regions in Baden-Württemberg. Therefore, daily temperatures were derived from only one representative place near the capital of the federal state. Therefore, exposure misclassifications have occurred. Furthermore, ambient temperature is only a rough surrogate for personal exposure to heat since residents of nursing homes spend most of their time inside the house. Indoor temperature, however, is modified by many factors like level and orientation of the room, availability of a fan or the quality of insulation. Furthermore, indoor temperature may be maintained constant over a specific range. This may explain why our analyses showed increased mortality rates only at ambient temperatures  $>26^{\circ}\text{C}$ . Reliable information about the level of care was only available at study enrolment. In some residents, level of care may have changed during the observation time and produced misclassification in the analyses stratified by care need. In addition, data about cause-specific mortalities were not available.

Compared with insurances of other statutory or private insurances, persons insured at the AOK represent lower rather than higher socioeconomic levels. However,  $>50\%$  of all residents of nursing homes in the federal state of Baden-

Württemberg were covered by our analysis. The composition of the persons in nursing homes may be different in different countries and may be influenced by different social and political determinants. This could influence the external validity of our results.

In summary, high ambient maximum temperature was associated with an increased mortality risk in residents of nursing homes. All analysed subgroups were affected and contributed to the additional number of heat-related deaths. Excess mortality during the 2003 heat wave was followed by only a slight displacement of death. Nursing homes are a setting in which competence of nursing staff and supervision of susceptible persons are continuously available. These are favourable preconditions for the implementation of effective preventive measures.

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### Key points

- High ambient temperature was associated with an increased mortality risk in the observed nursing home population.
  - The heat wave in August 2003 caused a considerable excess mortality in residents of nursing homes.
  - There was only a moderate mortality displacement in the following months after the heat wave.
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### Conflicts of interest

None declared.

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### Supplementary data

Supplementary data mentioned in the text is available at *Age and Ageing* online.

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