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Heat waves and mortality in Frankfurt am Main, Germany, 2003–2013

What effect do heat-health action plans and the heat warning system have?

In August 2003, a heat wave was observed in Europe that caused over 70,000 deaths [2, 8, 9, 14, 17, 18, 20, 21, 25, 26]. The highest impact on mortality was seen in cities. Excess mortality was highest in the elderly population; other risk factors included pre-existing cardiovascular and pulmonary disease as well as preexisting psychiatric illness and previous psychotropic treatment [4, 7, 28]. In the following years many countries—including Germany—implemented early warning systems for heat waves combined with heat-health action plans (HHAP) to reduce the effects of heat waves on human health [22, 23, 29]. The HHAP in the state of Hesse, Germany, comprises information packs for the population and professionals—physicians and nurses in clinics, practices, and retirement homes—as well as inspections of retirement homes to monitor compliance with the recommendations.

New data were recently published showing that the effects observed in 2003 were not solely due to the heat wave, but that they were modified by additional air pollution [1, 9].

The aim of our paper is to study the effect of the HHAP and warning system implemented in Hesse on mortality in Frankfurt am Main compared to the heat wave in 2003. A heat wave is defined as 2 or more days with "severe heat stress" or "extreme heat stress", based on a perceived temperature ≥32°C or ≥38°C, respectively; perceived temperature is based on a combination of temperature and humidity, taking into account the weather situation during the previous 30 days [20]. Additionally, the impact of ozone and particulate matter on heat mortality was studied.

Material and methods

Mortality data included all deaths registered in the city of Frankfurt and reported to the statistical state office as preliminary data [27].

Air temperature and air pollution data were obtained from the *Hessisches Landesamt für Umwelt und Geologie* (HLUG; Hessian state office for environment and geology) website (http://www.hlug.de), where hourly values are published for many monitoring stations all over Hesse, including three stations in Frankfurt am Main. Data from the monitoring station Frankfurt Ost was selected, the only one presenting temperature data back to 2003. Frankfurt Ost is an urban station that reflects the situation in the city. Among others, temperature (°C), ozone (µg/m^3), PM10 (µg/m^3) and relative humidity (%) is monitored. Data for daily mean, daily maximum and minimum values for the summer months between June and August 2003–2013 were thus provided by the HLUG. Apparent temperature (T app), a discomfort index based on air and dew point temperature, was calculated according to D'Ippoliti et al. [8].

SPSS version 15 was used for statistical analysis, including bivariate and partial correlations between daily mortality and indices of temperature and air pollution, as well as after adjustment for air pollution. The Kruskal-Wallis test and Mann-Whitney test were used to compare meteorological and mortality data for 2003–2013, as well as for comparing the respective data during heat waves enduring more than 4 days.

Results

Meteorological data as well as data on air pollution and daily mortality in Frankfurt am Main during the summer periods (June–August) 2003–2013 are presented in ◻ **Tab. 1,** showing mean, minimum and maximum values for daily mortality, apparent, minimum, maximum and mean temperatures, as well as PM10 and ozone levels. Additionally, the respective data are exhibited for heat waves lasting more than 4 days.

Temperature data as well as air pollution and daily mortality exhibited extreme values in summer 2003 compared to all other years; never again were such temperatures and levels of air pollution reached. This is also to be seen for the periods of heat waves >4 days: here again, the meteorological, air pollution and mor-

Tab. 1 Indicators for temperature (mean, minimum, maximum and apparent temperature), indicators for air pollution (PM10 and ozone) and daily mortality in Frankfurt am Main, Germany, in the summer months (June–August) of 2003–2013, and during heat waves lasting more than 4 days in those years

	Indicators for temperature								Indicators for air pollution				Mortality	
	Daily temperature (mean) °C		Daily temperature (maximum) °C		Daily temperature (minimum) °C		Apparent temperature (mean) °C		Daily PM10 (mean) $\mu g/m^3$		Daily ozone (mean) $\mu g/m^3$		Deaths n/day	
	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
2003	22.8	30.4	28.5	38.5	17.0	23.3	35.5	51.3	34.7	70.9	80.1	162.0	20.4	52.0
2003 heat wave	*26.5*	*30.4*	*33.7*	*38.5*	*19.1*	*23.3*	*43.6*	*51.3*	*44.2*	*70.9*	*101.7*	*162.0*	*32.7*	*52.0*
2004	19.1	25.8	24.1	32.9	14.3	19.4	29.1	43.1	21.3	41.3	55.2	109.8	18.1	29.0
2005	19.3	26.8	24.4	34.3	14.2	20.2	28.9	46.9	19.1	42.5	61.6	123.1	17.6	28.0
2006	20.2	28.2	25.7	36.3	14.9	22.2	31.9	51.9	21.2	40.7	57.2	110.3	18.1	30.0
2006 heat wave >4 days	*26.0*	*28.2*	*33.8*	*36.3*	*19.7*	*22.2*	*45.8*	*51.9*	*30.7*	*40.7*	*88.9*	*110.3*	*20.6*	*25.0*
2007	19.2	28.1	24.1	36.7	14.4	21.2	29.6	53.4	17.5	37.7	48.6	98.0	17.8	33.0
2008	19.9	27.0	25.6	35.5	14.7	21.0	32.3	47.6	17.8	32.5	58.8	109.8	17.3	29.0
2009	19.7	27.9	25.5	37.1	14.2	19.6	32.1	53.4	18.2	36.7	49.1	88.0	18.6	29.0
2010	20.1	28.7	25.6	36.6	14.7	24.3	32.3	53.4	20.6	54.4	54.3	117.4	19.1	30.0
2010 heat wave >4 days	*26.8*	*28.7*	*34.4*	*36.5*	*19.6*	*24.3*	*47.8*	*53.4*	*28.5*	*32.9*	*79.7*	*99.9*	*22.6*	*25.0*
2011	18.8	26.5	24.2	35.0	14.0	19.3	29.8	47.7	15.4	33.7	49.4	112.5	18.0	32.0
2012	19.6	27.9	24.8	37.3	14.6	20.1	31.2	53.6	16.8	35.8	52.8	133.3	19.3	35.0
2013	20.3	30.4	25.9	37.5	14.7	22.8	32.7	54.2	18.3	31.2	61.8	106.1	18.3	28.0
2013 heat wave >4 days	*25.6*	*28.8*	*33.0*	*36.8*	*18.9*	*20.7*	*46.0*	*54.2*	*31.2*	*31.2*	*82.7*	*104.8*	*19.1*	*22.0*

Tab. 2 Daily mortality between 2003 and 2013 in Frankfurt am Main, Germany, in total and in different age groups, as well as daily and excess mortality during heat waves lasting more than 4 days

	All ages		<60 years		60≤80 years		≥80 years	
	Daily mortality (mean) n/day	Excess mortality during heat waves (%)	Daily mortality (mean) n/day	Excess mortality during heat waves (%)	Daily mortality (mean) n/day	Excess mortality during heat waves (%)	Daily mortality (mean) n/day	Excess mortality during heat waves (%)
All years (2003–2013)	18.4		2.8		7.5		8.1	
During heat waves >4 days								
2003	32.7	77.8[b]	3.1	12.2	12.3	63.8[b]	17.3	113.4[b]
2006	20.6	12.0	2.9	3.6	6.9	–8.0	10.8	33.3[a]
2010	22.6	22.7[a]	2.9	2.0	8.6	14.3	11.1	37.6[a]
2013	19.1	4.0	2.6	–9.2	7.4	–1.0	9.1	–15.3

[a]$p<0.01$; [b]$p<0.001$.

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Heat waves and mortality in Frankfurt am Main, Germany, 2003–2013. What effect do heat-health action plans and the heat warning system have?

Abstract

Following the heat wave of August 2003 that caused over 70,000 fatalities in Western Europe, heat-health action plans (HHAP) and heat warning systems were implemented in many European countries, including Germany. The effect of these preventive measures (informing the population as well as nursing and medical personnel) on excess mortality during heat waves in Frankfurt am Main, Germany, is studied, taking into account newly published data on a modifying effect of air pollution on heat mortality.

Material and method. Mortality data comprising all deaths registered in the city of Frankfurt was obtained from the statistical state office; air temperature and air pollution data in Frankfurt Ost were obtained from the Hessian state office for environment and geology. SPSS Version 15 was used for statistical analysis (bivariate and partial correlations, nonparametric tests/Kruskal-Wallis, and Mann-Whitney test).

Results. Temperature data as well as air pollution and daily mortality exhibited extreme values in summer 2003 compared to the summer periods 2004–2013. Never again were such levels of temperature and air pollution reached. In 2003, excess mortality was 78%, and as high as 113% among the population aged >80 years. During the heat wave of 2010, the total excess mortality was 23% (significant) and 38% in the population aged >80 years, while during heat waves in 2006 and 2013 no significant increase in total mortality was seen (total excess mortality 12% and 4%; not significant).

Conclusion. Lower excess mortality could be seen in Frankfurt am Main during heat waves following the implementation of HHAP and the heat warning system. This might be an effect of the measures implemented by the HHAP to reduce heat mortality. However, it cannot be ruled out that this might also be an effect of shorter heat wave periods and lower air pollution in the subsequent years. Therefore, further efforts are needed to improve the resilience of the population, especially the elderly population, to better cope with heat waves.

Keywords

Heat waves · Excess mortality · Heat-health action plan · Heat warning system · Elderly population

Hitzewellen und Sterblichkeit in Frankfurt am Main 2003–2013. Welchen Effekt haben die Hitzeaktionspläne und das Hitzewarnsystem?

Zusammenfassung

Hintergrund. Nach der Hitzewelle im August 2003, die zu mehr als 70.000 zusätzlichen Todesfällen in Westeuropa führte, wurden in Deutschland und in vielen anderen Ländern Aktionspläne zur Prävention hitzebedingter Erkrankungen und Todesfälle sowie Hitzewarnsysteme implementiert.

Ziel der Arbeit. Die Arbeit untersucht unter Berücksichtigung möglicher zusätzlicher Einflussfaktoren wie Luftschadstoffe (PM10 und Ozon) die Auswirkung der Hitzeaktionspläne (insbesondere Information der Bevölkerung, Information und Schulung von Pflegepersonal und Ärzten) auf die Mortalität während Hitzewellen in Frankfurt am Main.

Material und Methode. Es wurden Daten zu den Sterbefällen in Frankfurt am Main vom Hessischen Statistischen Landesamt für die Sommermonate Juni bis August der Jahre 2003–2013 ausgewertet sowie meteorologische und Schadstoffdaten (PM10 und Ozon) der Messstelle Frankfurt Ost vom Hessischen Landesamt für Umwelt und Geologie einbezogen. Statistische Tests wurden mit SPSS, Version 15 durchgeführt.

Ergebnisse. Während der Hitzewelle 2003 erreichten Temperatur- und Schadstoffwerte sowie die tägliche Sterblichkeit sehr viel höhere Werte als in den Jahren 2004–2013. In der Hitzewelle 2003 betrug die Übersterblichkeit insgesamt 78% und in der Bevölkerungsgruppe der über 80-Jährigen sogar 113%. Während der Hitzewelle 2010 lag die Übersterblichkeit in der Gesamtbevölkerung bei 23% (signifikant) und bei den über 80-Jährigen bei 38%. Hingegen wurde während der Hitzewelle 2006 und 2013 keine signifikante Exzessmortalität gefunden (12 und 4%).

Schlussfolgerung. Nach Implementierung der Hitzeaktionspläne und -warnungen ergab sich im Vergleich zum Jahr 2003 eine geringere Übersterblichkeit bei Hitzewellen in Frankfurt am Main. Einerseits könnte dies ein Effekt der Hitzeaktionspläne sein. Andererseits ist nicht auszuschließen, dass die geringere Übersterblichkeit durch die kürzere Dauer der Hitzewellen und geringere Schadstoffbelastung bedingt ist. Daher sind weitere Maßnahmen erforderlich, um die Bevölkerung, v. a. die Älteren über 80 Jahre, im Umgang mit Hitzewellen zu stärken.

Schlüsselwörter

Prävention · Übersterblichkeit · Hitzeaktionsplan · Hitzewarnsystem · Ältere Menschen

tality data of the 2003 heat wave were never reached.

Tab. 2 presents total mortality data for Frankfurt am Main during the summer periods 2003–2013, as well as for heat waves lasting more than 4 days. Daily total mortality as well as mortality in different age groups, and daily as well as excess mortality during heat waves lasting more than 4 days are shown. In the 2003 heat wave, total excess mortality (compared to mean mortality during the summer periods 2003–2013) was 78%. Excess mortality increased with age, with a 12% (not significant) increase in people <60 years old, 64% in those aged 60–79 years and 113% in persons over 80 years old. No significant increase in total mortality was seen during the heat waves in 2006 and 2013. During the heat wave in 2010, however, a significant increase (23%) in total mortality was observed, deriving from a 38% increase in mortality of people >80 years old. Hence, excess mortality comparable to the high excess mortality observed during the 2003 heat wave has never been reached.

Tab. 3 presents correlations between daily total mortality and temperature and air pollution indicators, first bivariate, then adjusted for PM10 and ozone levels. Bivariate correlations were relatively low, but significant. After adjustment

Tab. 3 Correlations between daily mortality and mean, minimum, maximum, apparent temperature, PM10 and ozone—bivariate and after adjustment for air pollution (PM10 and ozone)

	Bivariate correlation								**Partial correlation[a]**							
Age (years)	**All**		**<60**		**60–79**		**≥80**		**All**		**<60**		**60–79**		**≥80**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**R**	**p**	**r**	**p**
Temperature_mean	**0.134**	0.000	−0.023	0.461	0.057	0.073	**0.185**	0.000	0.053	0.097	−0.024	0.454	−0.007	0.835	**0.099**	0.002
Temperature_min	**0.132**	0.000	−0.002	0.942	0.039	0.214	**0.178**	0.000	**0.065**	0.042	−0.019	0.551	−0.014	0.660	**0.115**	0.000
Temperature_max	**0.126**	0.000	−0.035	0.268	0.059	0.063	**0.176**	0.000	0.020	0.520	−0.039	0.225	−0.011	0.722	**0.064**	0.044
Temperature_apparent	**0.129**	0.000	−0.033	0.288	0.060	0.055	**0.175**	0.000	0.012	0.712	−0.036	0.254	−0.017	0.594	0.055	0.087
PM10_mean	**0.154**	0.000	−0.007	0.835	0.097	0.002	**0.157**	0.000								
Ozone_mean	0.049	0.123	−0.053	0.094	0.027	0.388	0.084	0.008								

[a]Adjusted for PM10 and ozone; bold figures refer to significance (p<0.01).

for air pollution correlation between total mortality and temperature indicators grew even lower, and only the correlation remained significant. Adjusted correlations between mortality in the very elderly (>80 years old) and temperature remained significant, with the exception of apparent temperature (not significant).

In ◘ **Fig. 1a, b, c, d** daily mortality compared to daily mean (a) and apparent (b) temperatures, as well as daily mean PM10 (c) and ozone (d) concentration in the summer months, are shown for 2003–2013. The 2003 heat wave and heat warnings from 2006 on are also depicted. It is apparent that not only daily total mortality but also temperature and PM10 levels and even ozone levels were extraordinarily high in August 2003, and constantly so for over 1 week. Such mortality, temperature and PM10 levels have never been reached again.

Discussion

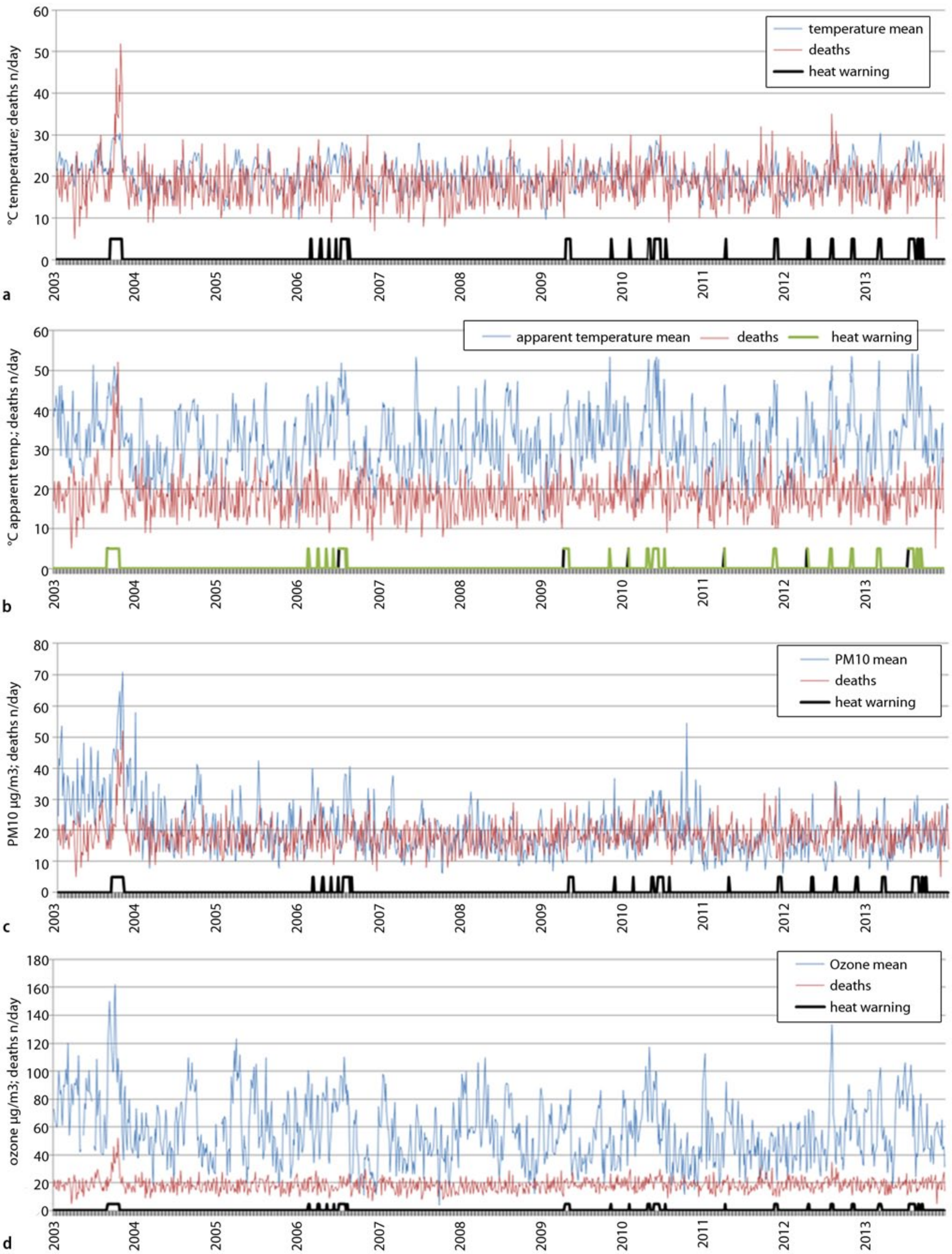
After the 2003 heat wave with high excess mortality, especially among the elderly population in Europe, HHAP have been established to avoid excess mortality during subsequent heat waves [23, 29].

In Frankfurt am Main, excess mortality from the 3rd to the 14th August 2003 was approximately 200 individuals, about 100 of these living in retirement homes and about 100 living in their private homes. Excess mortality began with a 3-day delay after the beginning of the heat wave. It also increased with age: compared to mean daily mortality in June and July 2003, excess mortality in the first half of august 2003 was 66% in those aged 60–70 years, 100% in those aged 70–80 years, 128% in the 80- to 90–year-old age group and 146% in those aged >90 years [16]. Similar observations were made in 2003 in other German regions and cities, with excess mortality up to 85% in retirement homes in Baden-Württemberg, Germany [2, 19]. Compared to other German regions, the 2003 heat wave exhibited the highest maximum and minimum temperatures (>35°C and >21°C) for a period of 13 days in the city of Frankfurt am Main, whereas the range of excess mortality was 26%–37% in other regions with lower maximum and minimum temperatures and heat duration (>30–32°C and >20°C, 7–10 days) [2, 14, 17, 20, 21].

HHAP were established in the years following the heat wave of 2003 [2], encompassing information packs for professionals and the population, information and training for nursing personnel in retirement homes and in the outpatient setting, as well as information for physicians via retraining and articles in the specialist literature [15, 24].

Recommendations for persons at risk were established, including recommendations for increased fluid and electrolyte supply, appropriate clothing, cooling of rooms and, where necessary, providing souterrain rooms for those persons in long-term care facilities whose rooms could not be cooled down sufficiently. In Hesse, retirement homes were visited by the public authority during hot days to find out whether the recommendations were being followed. Very good compliance with these recommendations was seen over subsequent years. In another Hessian region, the city and surrounding area of Kassel, the HHAP included telephone calls and visits to persons at risk, especially elderly people living alone at home with no professional nursing care [3, 12, 13].

In 2006, a nationwide heat warning system was implemented in Germany. It is triggered by a heat index called "heat stress". "Severe heat stress" is based on a perceived temperature (combination of temperature and humidity) ≥32°C but not above, with the exact threshold depending on the weather situation of the preceding 30 days, and "extreme heat stress" with


°C temperature; deaths n/day
temperature mean
deaths
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a
°C apparent temp.; deaths n/day
apparent temperature mean
deaths
heat warning
b
PM10 µg/m3; deaths n/day
PM10 mean
deaths
heat warning
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Ozone mean
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a perceived temperature ≥38°C. Warnings are published by the German Weather Services via e-mail and e-fax to retirement homes, to the public health services of the respective towns or regions and to the chamber of physicians, if thresholds are exceeded for 2 consecutive days and the minimum temperature in the night between is >16 and 18°C. The public health services are obliged to inform hospitals, physicians and emergency transport organizations by fax and the population by means of leaflets and information transmitted by the mass media.

From 2006 onwards, heat warnings were issued for Frankfurt am Main on 62 days, including three heat warning periods lasting more than 4 days: 10 days in July 2006, 7 days in July 2010 and 7 days in July 2013. Considering that increased mortality usually occurs after a delay of 3–4 days [16], excess mortality was calculated only for heat wave periods lasting more than 4 days. During the 2003 heat wave, excess mortality (compared to daily mortality in June–August 2004–2013) was 78% for the population in total, 113% for those aged >80 years and 64% for 60- to 79-year-olds. During the heat waves in July 2006, 2010 and 2013, excess mortality was much lower with a maximum of 23% overall excess mortality in 2010, and 12% and 4% in July 2006 and 2013, respectively.

Also in France, excess mortality during the 2006 heat wave was markedly lower than predicted according to the model established after the 2003 heat wave, which was interpreted as a decrease in the population's vulnerability to heat, together with an increase in awareness and preventive measures and the heat warning system [11].

However, there are doubts as to whether lower excess mortality in Frankfurt am Main in 2006, 2010 and 2013 might be an effect of the HHAP and the German warning system scheduled in 2006. While minimum and apparent temperature indices were comparable in all heat wave periods, mean and maximum temperature levels as well as PM10 levels and ozone concentrations were much higher in 2003 than during heat waves in subsequent years. Thus, lower excess mortality may be due to other meteorological situations and air pollution when allowing for new data on the modifying impact of air pollution on heat mortality [1]. Although other non-weather-related reasons cannot be excluded as well, there are no indications of additional causes.

Bivariate correlations between daily mortality and daily mean, minimum, maximum and apparent temperatures in Frankfurt am Main were 0.126–0.134 (all p<0.001), and bivariate correlations to daily mean PM10 was even higher: 0.154 (p<0.001), whereas low correlations between mortality and ozone levels were found 0.049 (not significant) The highest correlations were obtained in the >80-year-old age group. When adjusted for PM10 and ozone, correlations between daily mortality in the total population and temperature indices became lower; only the correlation between minimum temperature and mortality was still significant (r 0.065; p 0.042). Correlations to temperature indices remained significant after adjustment for PM10 and ozone only in the population over 80 years of age. The modifying effect of air pollution corresponds with the data published for nine European cities [1] and nine French cities [6].

However, there are limitations in our data: all calculations were based on temperature and air pollution data at the only measuring point in Frankfurt am Main providing data back to 2003 as a proxy for the exposure assessment of the city's population in total, although it is well known that the effective temperature values in homes may differ significantly due to different building construction, insulation, floors etc., with the highest risk posed for people living on the upper floor directly beneath the roof. However, these limitations in exposure assessment are common to all studies on heat mortality. Our data set encompasses mortality data for only one German city (population 690,000) resulting in a high variance in daily mortality, which reduces the opportunities for statistical evaluation. Hence, the focus is on a descriptive view and generalization should be avoided.

As a result, lower excess mortality could be seen in Frankfurt am Main during the heat waves in the years after implementing HHAP and the heat warning system. This might be an effect of the measures implemented to reduce heat mortality. However, it cannot be ruled out that this might also be an effect of shorter heat wave periods and lower air pollution in subsequent years. Therefore, further efforts are needed to improve the resilience of the population, especially the elderly, to better cope with heat waves.

Fig. 1 ◀ Daily mortality (*red lines*) in Frankfurt am Main, Germany, during summer months (June–August) in 2003–2013 compared with (**a**) daily mean temperature. (**b**) Daily apparent temperature, (**c**) mean daily PM10 level, and (**d**) mean daily ozone concentration at the measuring point Frankfurt Ost (HLPUG). *Bold black bars* indicate heat warning periods published by the German Weather Service

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Conflict of interest. The corresponding author states that there are no conflicts of interest.

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Transkranielle Sonografie als Diagnostik für Parkinson

Parkinson lässt sich mit Hilfe von transkranieller Sonografie diagnostizieren und von atypischen Parkinson Syndromen genauso gut unterscheiden wie mit der Positronen-Emissions-Tomografie (PET). Zu diesem Ergebnis kommen Forscher der Universität Freiburg.

Die Wissenschaftler untersuchten 36 Patienten sowohl mit Hilfe von transkranieller Sonografie und PET. Sie konzentrierten ihre Untersuchung auf die Substantia nigra, bei der sich der Eisengehalt bei Parkinson anreichert. Zur Abgrenzung von Parkinson zu atypischen Parkinson Syndromen wie Multisystematrophie oder progressive supranukleäre Blickparese schallten sie ebenfalls den Nucleus lentiformis und den dritten Ventrikel.

Beide Untersuchungen verhalfen der Mehrzahl der Patienten zur richtigen Diagnose. Vorteile für den Einsatz der transkraniellen Sonografie im Vergleich zur PET sind, dass die Patienten keiner Strahlenbelastung ausgesetzt sind und die Untersuchung jederzeit wiederholt werden kann. Zudem verursacht der Ultraschall nur geringe Kosten. Die Ergebnisse stimmen hoffnungsvoll, jedoch betonen die Forscher, dass die Ergebnisse noch mit größeren Patientenkollektiven bestätigt werden müssen.

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