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Mortality during heatwaves 2003–2015 in Frankfurt-Main – the 2003 heatwave and its implications

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ABSTRACT

Heatwaves have always occurred, but they are expected to intensify in frequency, duration and intensity due to climate change. Germany (like most European countries) experienced a distinct heatwave in 2003. Afterwards local heat health action plans (HHAP) were implemented in numerous regions (for example in Hesse). This analysis was designed to compare the heat wave of 2003 with the following ones in 2006, 2010 and 2015. We discuss whether measures from the Hessian HHAP were effective in reducing mortality and identify specific characteristics of the 2003 heatwave which did not allow direct comparison.

Mortality and temperature data from the city of Frankfurt collected between 2003 and 2015 was used to answer the question of whether the implemented HHAP were effective, or if the mortality in 2003, pre-HHAP implementation, was especially high due to other factors.

Excess mortality in 2003 was considerably higher for the overall population than in the heatwaves of the following years (2003: 77.8%, 2006: 12%, 2010: 22.7%, 2015: 38.1%). Heatwaves did not result in a significant excess mortality at all in some years, e.g. in 2006. Aside from the mortality rate, the duration of the heatwave (2003: 12 days; 2006: 5 days; 2010: 5 days; 2015: 5 days) was the only differing characteristic, leading to the hypothesis that heatwave duration might be a better indicator of mortality during heatwaves, than other characteristics, alone or combined. In summary regarding the effectiveness of the HHAP remains inconclusive since the pre-HHAP heatwave of 2003 differed in certain characteristics (especially the longer duration). Furthermore, the activities representing the HHAP were diverse and were implemented stepwise over some years. The effects on mortality of individual activities cannot be evaluated.

Further research should consider differences, e.g. between places (climate zones etc.) and heatwave definitions.

1. Introduction

In 2003, a heatwave occurred in central Europe, which was the “hottest” since 1500 (Kovats and Ebi, 2006). Heatwaves are not a new phenomenon but they are gaining in importance due to their association with global warming and climate changes (Bernstein et al., 2007). Numerous investigations have dealt with the increase in mortality during that heatwave (Robine et al., 2012; Kovats and Ebi, 2006; Heudorf and Schade, 2014). In the years following heatwaves, some European countries implemented heat health warning systems (HHWS) and/or health protection action plans/heat health action plans (HHAP). Recent publications have tried to analyze the validity of these preventive measures which have for example included information leaflets and website information (Hajat et al., 2010).

Published research on heatwave related mortality are difficult to compare due to differences in the basis of measurement. Some analyses work with the definition of “heat-related deaths” per time interval (Johnson et al., 2016); others with the concept of “excess mortality”. Excess mortality can be calculated as the observed deaths minus the baseline deaths. Additional measures can be estimated, including the proportion of total deaths during heatwave periods in excess and the number of excess deaths per day (Green et al., 2016). In Europe and in comparable regions of the same climate zone, the daily death frequency shows an elevation in the winter months, with the highest mortality seen in February (Robine et al., 2012). Therefore, differences in the estimation of excess mortality will also vary according to whether the baseline period of measurement is a whole year or only specific months or seasons (Kovats and Ebi, 2006).

There is evidence that the occurrence of a heatwave changes the relationship between temperature and mortality (Lee et al., 2016). The mortality increase per 1 °C increase was much higher during a heatwave year, than in years without a heatwave. The definition of a

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heatwave might also influence its impact (Tong et al., 2010). Heatwaves are either defined as the exceedance of fixed absolute values or as a deviation from normal values (exceedance of a fixed percentile of all observed values) (Robinson, 2001). Moreover their definition includes the maximum temperature, the mean and the minimum temperature classified additionally by duration and timing during summer (ĎIppoliti et al., 2010). Considering the temperature distributions in different climate zones, the location in which an analysis is conducted also effects heatwave-related mortality (ĎIppoliti et al., 2010; Dong et al., 2016).

There is much evidence that advanced age and certain chronic illnesses (such as psychiatric dispositions or illnesses which limit self-care) are associated with higher rates of heat-related mortality (Hajat et al., 2010). A number of additional personal risk factors are discussed such as gender (Robine et al., 2012; Dong et al., 2016; Johnson et al., 2016).

This analysis aims to compare the 2003 heatwave with heatwaves in the following years to identify the possible influence of the "heat-health action plan for Hesse" (HHAP), introduced after the heatwave summer of 2003. The HHAP includes a heat health warning system, disseminated via the German Weather Service (DWD, Deutscher Wetterdienst) to hospitals and care homes for the elderly. In Germany, the heat warning system of the German Weather Service was set up nationwide in 2005 (Zielo and Matzarakis, 2017). A 2-stage warning process informs people of an imminent heat wave. Further measures include the distribution of leaflets, television or radio programmes and training selected professionals, such as staff in care homes, organized by various institutions such as regional healthcare administrations (Straff et al., 2017). The implementation of a heat health warning system along with a nationwide heat health action plan was recommended by the 2008 World Health organization (WHO) guidance (Matthies et al., 2008). These activities were implemented stepwise over a period of years. New activities, mainly aiming to inform and educate the public are still coming into force. Recently, there have been some efforts to monitor the existing heat health warning systems (Grewe and Blättner, 2012; Grewe et al., 2014). In addition, HHAPs of 8 European countries were analysed to assist in the development of a structured HHAP for Hesse (Grewe et al., 2014; Grewe and Blättner, 2012)

Monitoring the effects of heat on the population is important, since although heatwaves occur infrequently in the Middle-European region, but result in an increased mortality rate (Kovats and Ebi, 2006; Bernstein et al., 2007; Robine et al., 2012). This analysis adds to earlier work from 2013, with data from a recent heatwave in 2015 (Heudorf and Schade, 2014; Heudorf and Meyer, 2005).

2. Materials and methods

Mortality data were recorded as excess mortality without analyzing for "heat-related deaths". All deaths registered in Frankfurt and reported to the Federal Statistical Office from June, July and August in the years 2003–2013 were included. For the years 2014–2015, the data was anonymized from the Frankfurt death records collected by the Public Health department, Frankfurt. For the years 2003–2013, 18,610 mortality cases were included; for the period 2014–2015, 3387 cases were included.

Data for temperature (min., max. and mean) were derived from the "State Office for Environment and Geology Hesse" (HLUG, Hessisches Landesamt für Umwelt und Geologie). The HLUG operates meteorological monitoring stations including three stations in Frankfurt. Data were taken from the monitoring station Frankfurt Ost.

In this research work the definition of a "heatwave" refers to a period of at least 5 consecutive days (> 4 days) *with a daily maximum air temperature exceeding 32 °C*. According to the heat health warning system of the German Weather Service (Deutscher Wetterdienst, DWD) daily (perceived) temperatures higher than 32 °C are regarded as "severe heat stress". If temperatures are higher than 32 °C (on 2 consecutive days; Level 1), a heat warning will be declared. *The threshold of 32 °C is not fixed, but varies depending on the previous 30 days, in order to compensate for the effects of short term adaptation. Level 2 is defined as Perceived Temperatures higher than 38 °C.*

For statistical analysis, SPSS version 15 was used. The data were calculated for means in every series. Correlation between mortality (all ages, < 60, 60–79, ≥80) and the parameters temperature (mean, max., min.) were calculated. Bivariate correlations were estimated by Spearmans Rho. The Mann-Whitney *U* test was used to check the significance of factors contributing to excess mortality.

Excess mortality is described as percentage deviation from the mean. The mortality mean was calculated as cases of death in Frankfurt/Main in the months June–August in the years 2003–2015.

3. Results

Using the definition of at least five consecutive days exceeding a maximum temperature of 32 °C, the city of Frankfurt/Main has seen four heat waves between 2003 and 2015: 02/08/2003–13/08/2003; 18/07/2006–22/07/2006; 08/07/2010–12/07/2010; 01/07/2015–05/07/2015.

Table 1 depicts various indicators of temperature, the mortality rate and specific details of each particular heatwave. Including data from the heatwave of 2015, it can be shown that only in 2003 the mortality was extraordinarily high. The duration of the 2003 heatwave was also longer than in other years (12 days, versus 5 days duration in the years 2006, 2010 and 2015). In contrast, each heatwave was comparable in terms of temperature minimum, maximum and mean (e.g. max. temperature 2003/2015 38.5 °C/39.7 °C).

In Fig. 1A and B the, temperature (min., max., mean) and mortality of the summer 2003 and 2015 are shown. 2015 was chosen because of its peaks in the daily min., max. and mean temperature, which were even higher than that measured in 2003, meaning it was the most comparable. The period between the beginning and middle of August 2003 saw a heatwave of 12 days according to the definition of a maximum temperature of at least 32 °C for more than four days. Simultaneously the minimum temperature was above 20 °C, which in central Europe is defined as *tropical night* (definition by the German Weather Service, DWD).

It could be observed that even without the presence of a defined heatwave, mortality increased with rising temperatures, as seen in July 2003. During the 2003 heatwave the mortality increased rapidly with a delay of three days after the start of the heatwave, and fell immediately to normal when the heatwave ended. In 2015 there was also an increase in mortality, however it did not reach as high a peak as in 2003. Mortality associated with the 2015 heatwave, like that in 2003, increased three days after start of the heatwave and decreased when it ended.

As expected, there was a clear correlation between temperature (mean, min., max.) and mortality, especially in the elderly population (Table 2).

Fig. 2 illustrates the temperature extremes during heatwaves of the years 2003–2015. The figure demonstrates that the daily maximum temperature changes in parallel with the minimum temperature. In 2015 the maximum as well as the mean temperatures were higher than in the previous years. In 2003, the duration of a maximum temperature of higher than 32 °C was the longest (12d). Correspondingly, 2003 also had the longest minimum temperature higher than 20 °C duration (also 12d).

Excess mortality seen in the summer months in the years 2003–2015 is given in Table 3. In 2003, there was significant excess mortality in the total population, which was primarily due to excess mortality in the elderly population. The overall population only had an excess mortality in heatwaves of 2003, 2010 and 2015. No excess mortality during heatwaves was seen in the under 60 years old population, in any heatwave period. However, the older population showed a significant