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Heatwaves in Vienna: effects on mortality

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Hitzewellen in Wien: Auswirkungen auf die Sterblichkeit

Zusammenfassung. *Hintergrund:* Der heiße Sommer 2003 mit erhöhten Sterberaten in Süd- und Westeuropa rückte die gesundheitliche Bedeutung von Hitzewellen in den Blickpunkt. Zu Auswirkungen von Hitzewellen auf die Sterblichkeit in Österreich gab es bisher noch keine Untersuchungen.

Methode: Daten zur täglichen Mortalität in Wien im Zeitraum von 1998 bis 2004 wurden von Statistik Austria, meteorologische Daten von der Zentralanstalt für Meteorologie und Geodynamik zur Verfügung gestellt. Zur Definition von Hitzewellen wurden die Kysely-Kriterien herangezogen. Die tägliche Sterblichkeit von Mai bis September wurde mittels „Generalized Additive Model" (Poisson-Regression und log link) unter Berücksichtigung von „Over-Dispersion" analysiert. Der jahreszeitliche Trend wurde über Splines, Wochentage mittels Dummies modelliert. Hitzetage wurden als dichotome Prädiktoren inkludiert.

Ergebnisse: In den letzten 35 Jahren stieg die durchschnittliche Temperatur (Mai bis September) in Wien um über 1,7 °C. Im Jahr 2003 zeigte sich eine Zunahme der Hitzetage auf insgesamt 44, die mit einer erhöhten Anzahl von Todesfällen einhergingen. Von diesen rund 180 Todesfällen war der Großteil nicht einem „Harvesting-Effekt" zuzurechnen. Es fand sich im Zeitraum 1998 bis 2004 an den Hitzetagen ein signifikant erhöhtes relatives Mortalitätsrisiko von 1,13 [95% Konfidenzintervall 1,09–1,17]. Diese Risikoerhöhung war bei Frauen deutlicher als bei Männern ausgeprägt. Obwohl die Sterblichkeitszunahme in allen Altersgruppen beobachtet werden konnte, waren die Ergebnisse nur bei älteren Personen (>65 Jahre) signifikant.

Diskussion: Auch wenn die Folgen der Hitzewellen nicht so ausgeprägt waren wie in Frankreich und Südwesteuropa, war in Wien im Sommer 2003 die tägliche Sterblichkeit erhöht. Zumindest 130 Todesfälle hätten in diesem Jahr durch prompte medizinische Hilfe und rechtzeitige Aufklärung der Risikogruppen zum Verhalten bei extremer Hitze verhindert werden können. Die Häufigkeit extremer Hitze-Episoden wird voraussichtlich als Folge der globalen Erwärmung zunehmen. Speziell auf die ältere Bevölkerung ausgerichtete Vorsorgeprogramme sind daher erforderlich.

Summary. *Background:* The hot summer of 2003 brought about increased mortality in southern and western Europe, highlighting the health impact of heatwaves. No Austrian mortality data have yet been reported for this summer period.

Methods: Daily mortality data for Vienna between 1998 and 2004 were obtained from Statistics Austria and meteorological data from the Austrian Central Institute for Meteorology and Geodynamics. Heatwaves were defined using the Kysely criterion. Daily mortality for May to September was predicted by a generalized additive model considering over-dispersion with Poisson deviates and a log link. Seasonal trend was accounted for by a natural spline, weekdays were modeled by dummy variables and heatwave days were included as dichotomous predictor.

Results: The average seasonal temperature for May to September in Vienna has increased by more than 1.7 °C during the last 35 years. In 2003 there was an excess of heatwave days, 44 overall, that resulted in an increased number of deaths, approximately 180, most of which were not due to 'harvesting'. Heatwave days between 1998 and 2004 were associated with a significantly increased relative mortality risk of 1.13 [95% confidence interval 1.09–1.17]. This increase was stronger in females than in males. Although excess mortality was seen in all age groups, it reached significance only in the elderly population over 65 years.

Discussion: An impact of heatwaves on mortality was apparent in Vienna, although not as pronounced as in France and south-western Europe. In 2003 at least 130 heatwave-related deaths in Vienna could have been avoided by prompt medical assistance and proper advice about how to cope with excessive thermal conditions. Preventive programs are warranted during heatwaves, especially to target elderly people, because the likelihood

of heatwaves as a consequence of global warming is increasing.

Key words: Heatwaves, mortality.

Introduction

There is now broad agreement among climatologists that climate changes observed during the past century are to a great extent the result of human activity. The Intergovernmental Panel on Climate Change (IPCC) stated recently [1]: "The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era. ... Projections using the SRES (Special Report on Emissions Scenarios) based on a range of climate models point to an increase in globally averaged surface temperature of 1.4–5.8 °C over the period 1990 to 2100. This increase is about two to ten times larger than the central value of observed warming over the 20th century, and the projected rate of warming is very likely to be without precedent during at least the last 10,000 years, based on paleo-climate data."

It is suspected that extreme weather events can affect human health through a wide range of mechanisms and for a range of diseases and health outcomes [2, 3]. Studies focusing on the impact of extreme summer heat have demonstrated that mortality from cardiopulmonary disease is increased [4–9].

In healthy individuals an efficient thermoregulatory system enables the body to cope effectively with thermal stress. Within certain limits thermal equilibrium can be maintained by appropriate regulatory responses, and physical and mental activities can be pursued without impairing health. External temperatures exceeding the regulatory limits, in both the cold and warm ranges, increase the risk of thermal death. Exposure to high temperatures may lead to circulatory distress and dangerous electrolyte changes. These effects are implicated in the increased mortality from diseases of the cardiovascular system [10].

The IPCC stated that the observed increase in maximum temperature and number of hot days over nearly all land areas in the last decades is part of a global trend that will probably lead to further increases in the frequency of heatwaves [11]. Summer 2003 was the hottest in Europe since 1500 and brought about heatwaves in many parts of western, southern and central Europe. Alarming reports on the impact of the heatwave on mortality in older people came from France, Portugal and Italy [12–14].

Although Austria was less affected by the extreme temperatures than France, Italy and the Iberian Peninsula, temperatures in August 2003 were also exceptionally high for the alpine region. Because heatwaves usually have a greater health impact in cities ('heat island effect') than in rural areas [15], we investigated the effect of the heatwaves on daily mortality in Vienna.

Materials and methods

Data on total daily mortality grouped by sex and age in Vienna for the years 1998 to 2004 were purchased from Statistics Austria. Data on daily maximum temperature at the Hohe Warte meteorological station in Vienna were provided by the Austrian Central Institute for Meteorology and Geodynamics (ZAMG). The analysis was restricted to the warm season (May – September) to reduce the influence of seasonal variations.

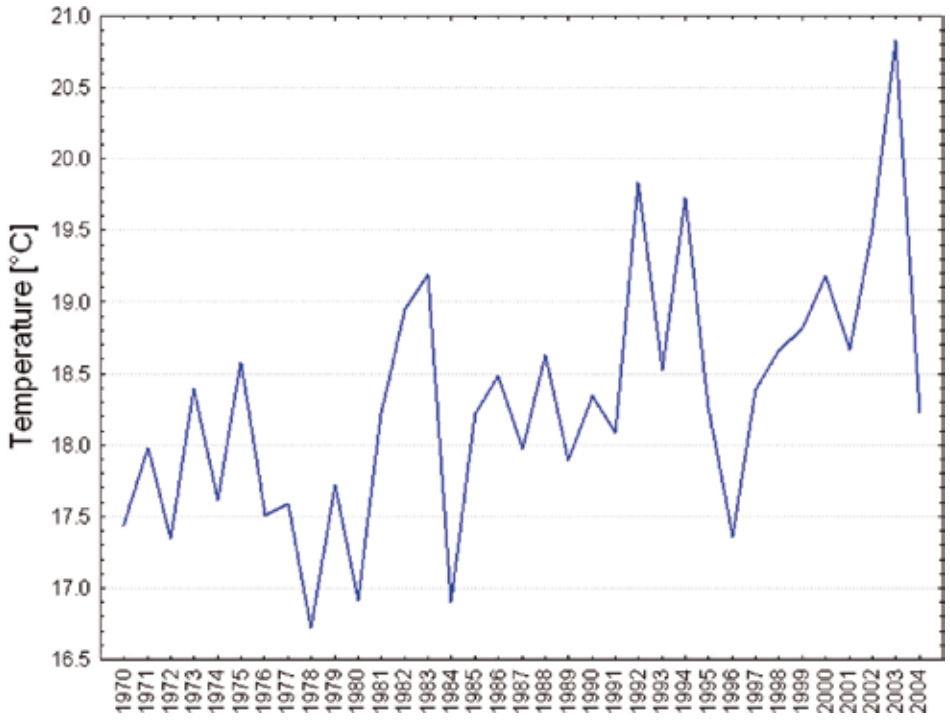

Fig. 1. Average seasonal (May – September) temperature from 1970 to 2004 in Vienna (Source: Hohe Warte meteorological station, ZAMG)

Definition of heatwaves

Heatwaves are defined as consecutive periods of at least three days during which the daily maximum temperature is ≥30.0 °C. The heatwave persists as long as the average maximum temperature of the whole period remains above 30 °C and the daily maximum temperature never drops below 25 °C. This definition of heatwaves was used in a long-term study by Kysely of heatwave occurrence in the Czech Republic [16]. To investigate a possible 'harvesting' effect, post-heatwave days were defined as three consecutive days starting one day after a heatwave.

Statistical analysis

A generalized additive model (GAM) exact procedure (S-Plus, Vers. 6.2) was applied (Poisson regression, link = log) [17]. Over-dispersion was considered by application of the quasi-likelihood algorithm. Trend effects were modeled by a natural spline (degrees of freedom were chosen to minimize residual autoregression) and day of week was modeled with dummy variables. The main independent variable was dichotomous, indicating a heatwave day (defined as a day within the heatwave according to Kysely [16]). This analysis was performed separately for the two sexes and for all ages, including babies in the first year of life and elderly persons aged 65 or older, for the period May–September.

Results

Number of heatwave days and daily temperature

During the last 35 years the average seasonal temperature for May–September in Vienna has increased by more than 1.7 °C (Fig. 1). This trend has been accompanied by annual variations of more than ±1°C average temperature. In the period 1998–2004, for which daily mortality data were available, there were on average 17 days per year with extreme temperature (heatwave days according to the Kysely definition), although with great annual variation. In 1999 and 2004 there were fewer than the average number of heatwave days and in 2003 there were more (Table 1).

Excess mortality during the heatwaves

Average daily mortality was higher on heatwave days in all subgroups of the population (Table 2). Because of changes in population size, age distribution and life expectancy there was a clear decline of daily mortality over the years; this was best described by a spline with 7 degrees of freedom. Fluctuations in mortality by day of week were minimal. Most deaths occurred on Mondays and fewest on Sundays; the difference on Sundays was significant ($p < 0.01$). On heatwave days there was approximately a 13% increase in deaths that was highly significant (Table 3). This increase was somewhat stronger in females than in males but was not more pronounced in the elderly than in the total population. In babies under 1 year old there was no significant influence of weekday or trend over the years, but the point estimate for the relative risk of heatwave days was highest in babies (25% risk increase). However, because of the low number of deaths in this age group, the confidence intervals were broad and the effect not significant. Sex-specific analysis revealed that the increased risk in babies was due to males only (Table 3).

Table 1. Number of heatwave days (Kysely criterion [16] i.e. in short: a period of at least 3 days with maximum temperature ≥30 °C) in Vienna between 1998 and 2004

Year	Heatwave days
1998	18
1999	3
2000	13
2001	9
2002	12
2003	44
2004	4

Table 2. Crude seasonal (May–September) average daily mortality and interquartiles on heatwave days (Kysely criterion [16] i.e. in short: a period of at least 3 days with maximum temperature ≥30 °C), post-heatwave days and other days in Vienna between 1998 and 2004

	Heatwave days	Post-heatwave	Other days
Total	44.2 [39–49]	39.8 [36–44]	40.2 [36–44]
Babies (<1 year)	0.27 [0–1]	0.32 [0–1]	0.23 [0–1]
Elderly (65 or over)	35.2 [30–40]	31.3 [28–34]	32.0 [28–36]

Table 3. Relative risk[1] of dying on a heatwave day (1998 to 2004) in Vienna

Population	Relative risk (95% CI)	p-value
Total	1.13 (1.09–1.17)	<0.001
Males	1.10 (1.05–1.16)	<0.001
Females	1.15 (1.10–1.20)	<0.001
Elderly persons (65 or above)	1.12 (1.08–1.16)	<0.001
Elderly males	1.08 (1.02–1.14)	0.009
Elderly females	1.15 (1.10–1.21)	<0.001
Babies (<1 year)	1.25 (0.82–1.90)	0.298
Male babies	1.55 (0.96–2.52)	0.068
Female babies	0.92 (0.50–1.71)	0.796

[1]Corrected for overall trend and weekdays.

The risk estimates were slightly stronger when the first day of each Kysely period was dropped. For example the relative risk for the total population increased from 1.13 to 1.15 ($p < 0.001$).

Discussion

Until recently, meteorological conditions were mainly used as nuisance variables in investigations of effects of air pollutants [18–20] or the study of weather sensitivity [21–22]. However, after the extremely hot summer of

2003 the impact of ambient temperature has gained in interest [12, 23–25].

During past decades the average seasonal May–September temperature in Vienna has increased considerably. This trend has also led to an increase in the frequency of periods of excessive heat. We used the Kysely [16] criterion for heatwaves as it seems to be especially suitable for middle-European climatic conditions.

The effects of heatwaves on mortality have been determined for different regions in Europe and in other continents. For summer 1995, excess deaths were detected in all age groups in England and Wales [26], most notably in females; in Chicago Semenza et al. [27] observed that the risk of heat-related death was increased in persons with known medical problems who were confined to bed or who were unable to care for themselves. Heat-associated mortality during summer 2003 has been analyzed for Frankfurt on the Main, Germany, and in Switzerland [24, 25] and both studies found excess mortality that increased with age.

In 2003, with long periods of excessive heat in southern and western Europe, a strong effect on mortality was already 'macroscopically' apparent in some regions (e.g. by observations from undertakers) and later substantiated in thorough epidemiologic analysis [12–14]. Our data suggest that the heatwaves also led to increased mortality in Vienna, although the increase was not as pronounced as observed in south-western Europe or in France. The average increase in Vienna was about 13% compared with 500% in Paris during the heatwave in August 2003 [23]. Although the relative risk of dying during a heatwave was highest in babies, this effect was not significant because the number of deaths in babies was low. Increased mortality was found in all age groups but significance was only reached in elderly people aged 65 or over, who accounted for about 80% of all deaths. Basing calculations on the population structure in Vienna, an overall excess of deaths of about 4 cases per Kysely day should be expected during heatwaves.

Whether or not this increase may be due to 'harvesting', i.e. people at terminal stages of disease dying during heatwaves instead of a few days later, was analyzed by investigating the daily number of deaths on the days after a heatwave (Table 2). There was only a slight indication of such a harvesting effect, as the number of deaths after a heatwave fell only slightly below the average daily mortality (Fig. 2). In babies there appeared to be a protracted effect of heatwaves, because the average daily mortality on post-heatwave days was higher than average. We defined the harvesting period as a three-day interval following Kysely days; extending this period to seven days abolished the harvesting effect (data not shown) and returned daily mortality to background rates. This indicates that the small harvesting effect was indeed due to the terminally ill who would have died within a few days. Thus, it has to be concluded that deaths during heatwaves are avoidable in most cases. Roughly 180 deaths in Vienna during the summer of 2003 are statistically attributable to excessive heat (Table 2), and harvesting analysis suggests that at least 130 of these cases could have been avoided by prompt medical assistance and proper advice about how to cope with excessive thermal conditions. These findings are in line with previous studies [28–30] and underline the importance of proper measures to prevent spikes in mortality during heatwaves.

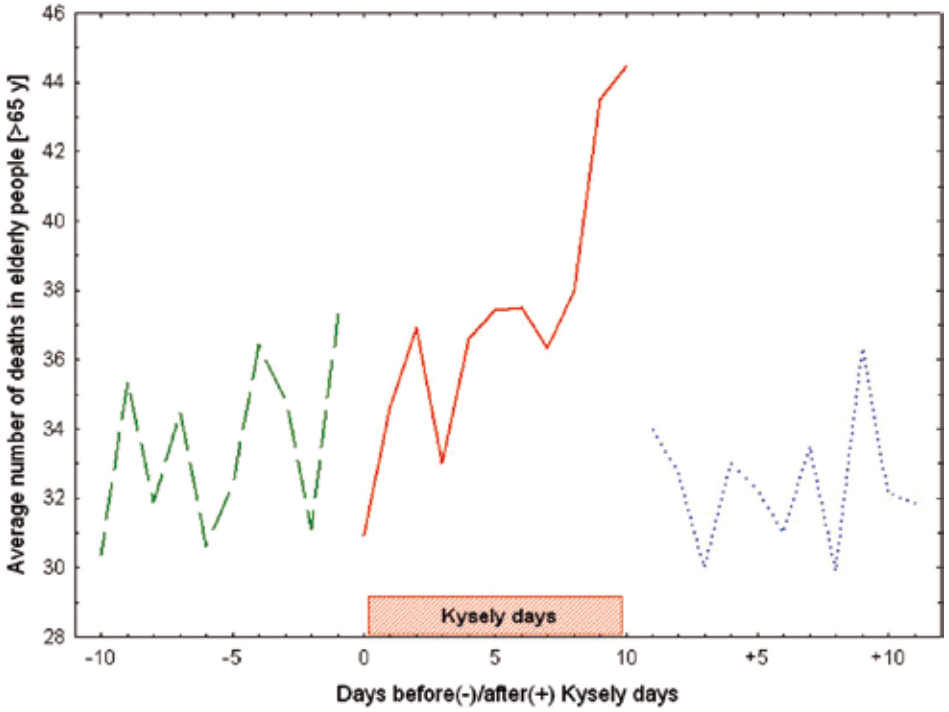

Fig. 2. Average daily number of deaths in Vienna 1998–2004 on Kysely days (i.e. in short: a period of at least 3 days with maximum temperature ≥30°C) and up to 10 days before and after a Kysely period [16]

The occurrence of heatwaves is predicted to increase as a consequence of global warming and therefore preventive programs targeting susceptible populations during heatwaves are warranted. Austrian health professionals and public health services should be prepared for this task in the future.

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