Relation between climate and mortality in Vienna based on human-biometeorological data

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Abstract

The relation between heat stress and mortality has been analyzed for the period 1970-2007 in Vienna. PET (Physiologically Equivalent Temperature) was applied, to assess heat stress in a thermo-physiological manner. A significant increase of mortality was found for days with PET ≥ 29° C at 14 CET. For lower PET the mortality between April-October is significant below the baseline (-1.8 %). The highest values occur on days with extreme heat stress (PET ≥ 41° C) with +13 %. The mortality of women during heat stress is significant higher compared to men, and a slight increase was found for cardiovascular and respiratory diseases, compared to the overall mortality.

1. Introduction

The influence of the thermal environment on the human body is known since many years and is not reduced to single heat waves. An increase in mortality was found for cold stress too (Eurowinter, 1997). Additionally the influence is not limited to mortality, but mortality data is often used as an indicator for the general effect on human health, since mortality is recorded in many countries for a long time (Kovats und Shakoor 2008).

Thermal stress is a combination of many factors. Important meteorological components are the air temperature, water vapor, wind speed and different radiation fluxes. But also physiological components are involved; thermal sensation is influenced, by age, sex, activity level and others factors. Hence, simple meteorological indexes do not consider all the terms that are important for the human body.

In this study, the Physiologically Equivalent Temperature (PET) was used for an assessment of the thermal environment (Höppe und Mayer 1987). PET is based on the human energy balance model MEMI (Munich energy-balance model for individuals) (Höppe, 1984). It describes the thermal environment using all important meteorological components and combines them with physiological component. PET is defined as a distinct air temperature related to fixed standard indoor conditions where the heat balance of the human body shows the same core and skin temperature equal to the outdoor conditions assessed (Höppe, 1999). Compared to other thermal indices PET has the advantage of using a commonly known unit (°C), which makes the result easily understandable, also for people who may be unfamiliar with the human-biometeorological terminology.

Matzarakis and Mayer (1996) made an assignment of PET ranges to nine different grades of physiological stress for middle European countries, like Austria. The assignment reaches from extreme cold stress to extreme heat stress.

The relation between thermal stress and mortality varies from region to region (Keatinge et al. 2000). In this study, the relation between heat stress and mortality was analyzed using the 1.6 million population of Vienna.

2. Data and Methods

The analysis is based daily mortality data for the period 1970-2007. The data is classified by gender and cause of death according ICD-10.

The ZAMG climate station (Central Institute for Meteorology and Geodynamics) "Hohe Warte" in Vienna was selected to be representative for the population of Vienna. Climate data for 7, 14 and 19 CET was selected; the period is limited to the month April till October, since heat stress is absent in the other months.

Based on the climate data, the thermo-physiological conditions were assessed by the human-biometeological parameter PET. The calculation of PET and the required mean radiant temperature (T_{mrt}) is estimated by the RayMan model (Matzarakis et al., 2007).

Heat waves in early summer are known to have a higher impact on the human body compared to heat waves of the same magnitude in later summer (Hajat et al., 2002), since the body adapts physiologically to the thermal conditions (e. g. the sweat productions becomes more effective) and the people change their behavior (e. g.. the clothing selected). Due to this, an approach developed by Koppe and Jendritzky (2005) was applied to consider the short-term adaption effects. The approach uses the grades of physiological stress (Matzarakis and Mayer, 1996) and modifies the upper and lower limit of thermal comfort (PET 18° C and 23° C) to reflect the short-term adaption. The thermal conditions of the prior 30 days are described by an one-fold Gaussian smoother (Schönwiese, 2006). If this values is above the thermal comfort range, the upper limit is modified, by adding 1/3 of the Gaussian smooth value to the static threshold; for values below 18° C, one third is subtracted. The modification of the upper threshold (23° C) was done using the PET of 14 CET, for the lower threshold (18° C) the morning value was used. The limits of the other stress grades are moved accordingly.

To identify the additional mortality due to thermal stress, a baseline mortality was calculated. In this analysis a complex smoothing approach developed by Koppe and Jendritzky (2005) was used to calculate the baseline mortality. Basically this approach is based on a Gaussian smooth of one year, which is modified to reflect the real annual amplitude of the mortality values. This expected mortality was used to calculate the percentage daily deviations, which are called relative mortality below.

The analysis of the relation between thermal stress and mortality in Vienna is structured into different parts. First the general relation was examined by scatterplots of daily mortality and daily PET a 2 p. m in combination with a lowess smooth with a bandwidth of 0.75 (Cleveland and Devlin, 1988). In a second step the temporal reaction to thermal stress was studied. All days of the reference period were classified according grades of thermo-physiological stress (Matzarakis and Mayer; 1996). For each class, the mean mortality on the day and the following 30 days was calculated. To assess the impact of duration of heat stress situations, the mean mortality for subsequent days with PET ≥ 35° C and PET ≥ 41° C was calculated. The main analysis is based on four different grades of thermal stress, since the prior results allowed reducing of table 1. The heat stress grades above 29° C were retained, but all grades below 29° C were combined to one grade.

For each class, the mean mortality was calculated and checks for significant differences in the mean value were done using T-tests. First the overall mortality, for men, women and all causes of death was used, afterwards differences between men and women as well as for death due to cardiovascular or respiratory diseases (C+R) were analyzed. This was done for the period 1970-2007 and per decade.

Sensitivity changes - changes in the relation between thermal stress and relative mortality - were analyzed by calculating the mean mortality for each thermal stress grade and each year and fitting a linear regression. Significant trend in this regression line were analyzed by T-tests.

The impact of the three heat stress classes was calculated, by combing the mean mortality per grade with the number of days for each grade and year for 1970-2007 and per decade. The product of both, the mean mortality and the number of days, is called cumulated heat related mortality and it describes the cumulated daily deviations of the mortality from the expected value for one year.

5. Results

Mortality rises sharply with PET values between 28° and 30°C. At lower values the mean relative mortality is slightly below the baseline and for higher values a sharp increase in the mean mortality was found. On the other side of the PET scale a slight increase was found. For cold stress this increase would be higher if the winter month and/or a lag of some days are considered.

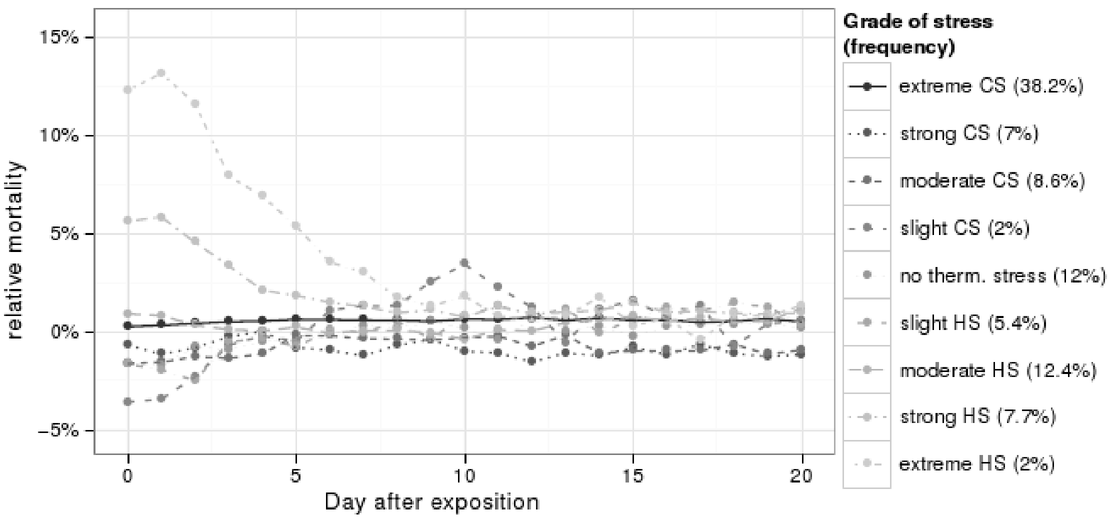

Fig. 1: Temporal reaction to different grades of thermal stress (Vienna, 1970-2007)

Figure 1 shows, that a strong increase of mortality exists on and after days with strong (PET 35-41° C) or extreme (PET ≥ 41° C) heat stress. In both cases, the mortality increases on the second day, but the differences were not significant. For strong and extreme the mortality stays eight days significantly above the baseline. Also the mortality due to moderate (PET 29-25° C) heat stress is slightly raised. For this figure, the whole year was considered, to analyze the impact of cold stress classes. This shows that all other classes, except strong cold stress, are characterized by mortality values below the baseline, with a minimum on and after days with slight cold stress.

Strong cold stress is not of importance during April to October. Hence, the grades of physiological stress (table 1) were simplified and only the four highest heat stress levels and a large class with PET < 29° C ("thermal acceptability") were considered.

The previous approach does not consider the thermal conditions following days zero. Analyzing heat periods, were the thresholds 35° C or 41° C was exceeded on consecutive days, it was found that, the mean relative mortality rises during the first days. For days with PET ≥ 35° C from 2.6 % (CI: 1.4, 3.8) to 15.6 % (CI: 10.1, 21.2) on the sixth days. Periods with PET ≥ 41° C are characterized by a mean mortality of 8.9 % (CI: 6.4, 11.5) on the first day, increasing to 27.4 % (CI: 13.6, 41.3) on the fourth day.

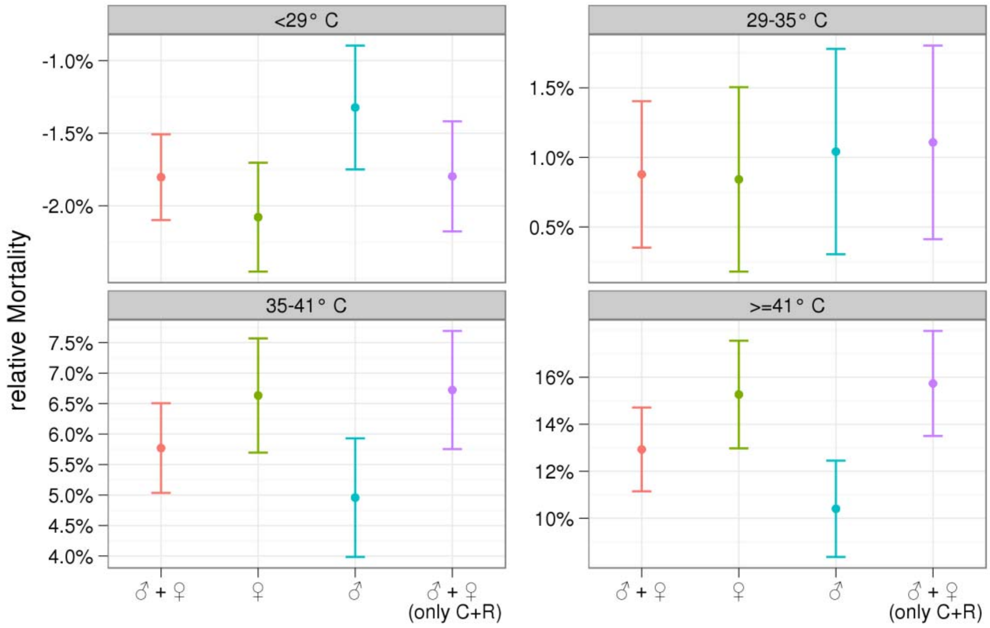

Fig. 2: Mean relative mortality and confidence interval for all causes and both sexes, women, men and cardiovascular and respiratory diseases (Vienna, 1970-2007)

Using the four levels of thermo-physiological stress (Fig. 2), it was found, that mortality is significant below the baseline on days with thermal acceptability (-1.8 %, CI: -2.1,-1.5). On days with heat stress, a significant increase was notices, with 0.9 % (CI: 0.4, 1.4) on days with moderate heat stress, 5.8 % (CI: 5.0, 6.5) on days with strong heat stress and 13.0 % (CI: 11.1, 14.7) on days with extreme heat stress. The differences between the classes were in any case significant. For women, the mortality was even higher with 15.3 % (CI: 13.0, 17.6) compared to men (10.4 %, CI: 8.4, 12.5) on days with extreme heat stress. The differences between men and women were significant, except on days with moderate heat stress. Additionally the mortality was higher for the causes of death groups cardiovascular or respiratory diseases (C+R). But the differences were only in the highest grade significant (significance level 90%).

The mean mortality per grade was not constant during 1970-2007 (Fig. 3). The mean mortality per grade and year shows a significant decline of mean mortality on days with moderate (-0.08 % per year, CI: -0.05, -0.11) and strong (-0.10 % per year, CI: -0.06, -0.13) heat stress, whereas the number of days with heat stress increased during the last decades.
To assess the impact of the different heat stress levels for the heat related mortality during a typical year, the mean mortality has been combined with the number of days per stress grade. The product, the cumulated heat-related mortality, is highest on days with strong heat stress, but the differences to the extreme heat stress grade, where not significant. During the period of examination the relation changed, due to the significant decreases in mean mortality in the mid-grades. In 2001-2007 the days with extreme heat stress were responsible for the majority of heat related deaths.

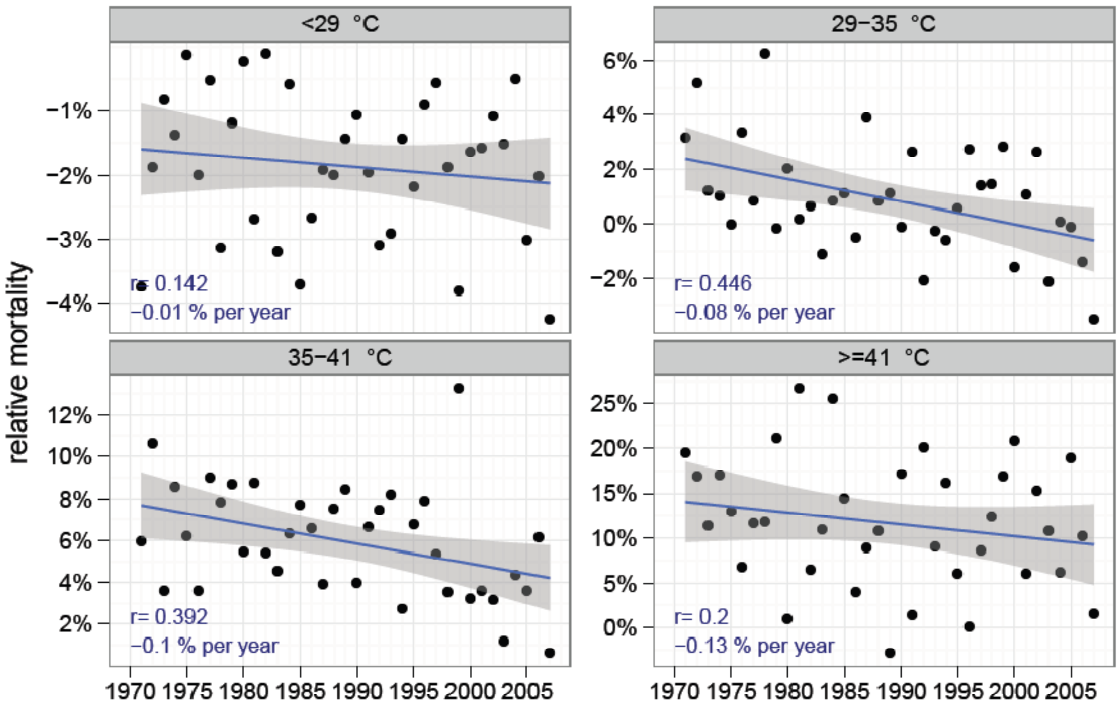

Fig. 3: Sensitivity changes in Vienna 1970-2007: Relative mortality per thermal stress grade and year and fitted linear regression with confidence interval

4. Conclusions

A strong relation between heat stress and mortality was found for Vienna. As in other regions (Koppe, 2005) an inverse relation exists, between the mean mortality and the frequency of heat stress situations.

The threshold between thermal acceptability in Vienna is situated around 29° C (PET). No changes of this threshold were found during the period of examination. Above this threshold, the increase of mortality is significantly higher for women compared to men. Additionally, patients with cardiovascular or respiratory diseases are at higher risk.

A significant decrease in mean mortality on moderate and strong heat stress grades was found between 1970 and 2000. This could indicate a successful adaptation process. On days with strong heat stress, a slight but not significant decrease was found. This could be the effect of a slight adaptation, combined with an increase in the absolute values of thermal stress.

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