Quality of Life and Management of Living Resources

Assessment and Prevention of Acute Health Effects of Weather Conditions in Europe

PHEWE

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Executive summary

The PHEWE project (Assessment and Prevention of Acute Health effects of weather Conditions in Europe) is a three-year pan-European collaboration between experts in the fields of epidemiology, meteorology, and public health and researchers from 16 cities, representing a large spectrum of climatic conditions: Athens, Barcelona, Budapest, Kracow, Dublin, Helsinki, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia and Zurich.

The general aim of the study was to assess the acute health effects of weather in various European countries characterised by widely differing climatic conditions. Specific objectives are: 1)investigate the association between meteorological variables and daily mortality, and hospital admissions ; 2)examine, in different baseline climatic conditions, the form of the relationship between the meteorological variables and mortality/hospital admissions, the threshold level above which the effect is detected, the relevant time interval between the exposure and the effect, and the possibility that cumulative exposures may play a role; 3) define the specific synoptic weather categories associated with increased mortality/ morbidity in each city; 4) analyse the interaction between weather and air-pollution on mortality and morbidity and quantify the specific contribution of each environmental factor; 5) develop a heat/health watch warning system to predict in advance and to alert cities' residents of potentially oppressive weather conditions that could negatively affect health; 6) develop a framework of preventive strategies to minimise adverse health effects in Europe, and develop guide-lines for public health interventions

The centralised database that includes for each city health data, meteorological data and air pollution data for a period between 1990 and 2000, was an important milestone of the project.

Mortality data from 16 cities and hospital admission data from 12 cities were collected for ages combined and specific age groups (15-64 yrs, 65-74 yrs, 75+ yrs) for the following causes: all causes (except deaths from external causes), ICD-9: 1-799; cardiovascular diseases, ICD-9: 390-459; cerebrovascular diseases, ICD-9: 430-438; respiratory diseases, ICD-9: 460-519; influenza, ICD-9: 487 (only for hospital admissions).

For each city, data from a weather station located in the city centre as well as from the nearest airport weather station were retrieved for the period under study. The following meteorological variables, recorded every three hours, were collected: air temperature, including absolute maximum and minimum daily values, dew point temperature, wind speed, wind direction, sea level pressure, total cloud cover, solar radiation, precipitation, visibility.

Air pollution data were available for most of the cities from the APHEA-2 project. The existing data were updated and integrated by data from non-APHEA cities. The following pollutants were collected for each monitor (maximum 6): SO_2 (mean 24-hours), TSP or Black Smoke (mean 24-hours), PM10- if available-(mean 24-hours), NO_2 (maximum 1 hour, mean 24-hours), O_3 (maximum 1 hour, maximum 8-hours moving average) CO (maximum 8-hour moving average).

For each city meteorological data were analysed using a large number of single variables, synthetic indicators, and a synoptic approach.

For the analysis of the short term effect of temperature on mortality/hospital admissions a new methodology was developed for the analysis taking into account previous criticism on time series approach. The analysis of the short term effect of temperature on mortality/hospital admissions was performed separately for the warm (April-September) and the cold season (October-March); this design provided flexibility in the analysis allowing the use of different model structure for season.

The analysis of the effect of meteorological conditions on daily mortality was performed on 15 cities: Athens, Barcelona, Budapest, Dublin, Helsinki, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia, Zurich.

The analysis of the effect of meteorological conditions on daily hospital admissions was performed on 12 cities: Barcelona, Budapest, Dublin, Ljubljana, London, Milan, Paris, Rome, Stockholm, Turin, Valencia, Zurich.

The statistical analysis followed two stages. In the first stage, data from each city were analyzed to estimate the city-specific effects using a common model, defined on the basis of a sensitive analysis. The city-specific analyses were based on the Generalized Estimating Equations (GEE) models.

Common models, defined on the basis of a structured exploratory analysis, were used to model daily time series of health outcomes. The models include maximum apparent temperature which is a combination of temperature and dew point temperature as the exposure variable, outcome variables (number of deaths/hospital admissions) and several covariates (confounders, temperature, other meteorological variables). A Poisson distribution of the dependent variable was assumed. Potential confounders in the model include a dummy variable for holidays, day of the week and calendar month, linear terms for pressure, wind speed and air pollution variables and linear and quadratic terms to pick long term time trends. An indicator of influenza epidemics was included in the model for cold season analyses.

With regards to air pollution, the maximum daily value of NO_2 was used as indicator of air pollution level for all the cities, except for Dublin and Ljubljana, where we adjusted for the daily average of Black Smoke and for the daily average of SO_2, respectively.

Based on the results of previous studies the lag structure was defined a priori as 0-3 days for the summer season and 0–15 days for the winter season.

The effect of high temperatures in summer mortality was investigated focusing on the slope above the city-specific threshold of the exposure-response curve. During the cold period a linear shape was expected. The delayed effect of exposure on health outcomes was accounted for by using both constrained distributed-lag models (up to lag 40), as well as unconstrained distributed-lag models, that simultaneously included variables for the same day and up to 5, 10, 15, 20, 25 and 30 days.

In the second stage city-specific results were combined to obtain pooled estimates and to investigate heterogeneity. In order to reduce heterogeneity among cities, the results were pooled defining two city groups, the Mediterranean cities (Rome, Barcelona, Valencia, Turin, Milan, Ljubljana) and the Northern-continental cities (Prague, Budapest, Zurich, Paris, Helsinki, Stockholm London and Dublin).

Overall exposure-response curves for the two groups are obtained through a fixed effect meta-analytical approach using the pooled dataset or with a second stage meta-analytical approach. The city-specific effect estimates were pooled using a Bayesian random effects meta-analytical model. The city specific distributed-lag curves and time-varying effects are pooled applying a two-level multivariate normal hierarchical model.

Results of the effect of temperature on mortality showed a significant association of mortality to both low, and to high temperatures in all cities examined.

During summer, the main results which emerged from the analysis of the effect of apparent temperature on daily mortality was that a J-shaped relationship was observed in most cities. In the Mediterranean cities thresholds (temperature value above which an increase in temperature is associated to an increase in mortality) present high heterogeneity ranging from 21.5°C in Ljubljana to 32.7°C in Athens. The effect of heat (expressed in terms of percent variation in mortality associated to 1° C increase in apparent temperature above the city-specific threshold) ranged from 0.56% in Valencia to 5.54% in Athens.

The effect of heat was immediate (picked up by lag 0-3 analysis).

City specific thresholds and slopes were also pooled by area. The pooled threshold for the Mediterranean cities was 29.4°C, while for the northern-continental counties was 23.3°C; the percent variation in total mortality for every 1°C increase in apparent temperature above the common threshold was equal to 3.12 (95% CI: 0.60-5.72) and to 1.84 (95% CI: 0.06-3.64) respectively.
The percent variation in mortality was higher for respiratory and cardiovascular mortality. A statistically significant effect of high temperatures on cardiovascular mortality was seen when considering all age groups and in the 75+ age group in Mediterranean cities, while a significant effect in mortality by respiratory causes was observed for both Mediterranean and North Continental in all ages and the 75+ age group.
The impact of high temperatures differs within the summer season, in fact there was evidence that first episodes are the most dangerous as populations are not yet acclimatised.
A harvesting effect for total and cardiovascular mortality was observed, which was more evident in the Mediterranean cities.

During winter season a linear trend, with a negative slope, in the temperature mortality relationship was observed, suggesting mortality increasing as temperatures decline.

For total natural and cardiovascular causes of death there was a statistically significant effect in all age group and in the oldest age groups (65-74 and >75 years). The results showed an increase in the effect with increasing age. For respiratory and cerebrovascular mortality there was a statistically significant effect of similar magnitude in those 65-74 and >75 years old but the adverse effect of decreasing temperature was not nominally significant for those 15-64 years old for respiratory causes of death, and there was no effect for this age group on cerebrovascular mortality.

City-specific analysis presented heterogeneous results and there was a difference between the Mediterranean and Northern-continental cities, with an higher effect for total CVD and cerebrovascular mortality in Mediterranean cities while an higher effect was observed in Northern-continental cities for respiratory causes of deaths.

The combined curves for total, cardiovascular, respiratory and cerebrovascular mortality also have a linear trend. The pooled analysis shows that for total and cardiovascular causes of death there is a statistically significant effect in all age groups considered and there is a clear increase in the effect with increasing age. For respiratory and cerebrovascular mortality there is a statistically significant effect of similar magnitude in the 65-74 and 75+ age groups. The 15-64 age groups shows a significant effect only for respiratory causes of death.

Distributed lags models showed the delayed effect of temperature on daily mortality. While unconstrained distributed lags models showed the cumulative effect of temperature on daily number of deaths up to 30 days for 5 day intervals. There is a delayed effect of low apparent temperature that goes up to 20 days.
The analysis of the effect of temperature on hospital admissions was not always consistent with results on mortality.
In fact, during summer no effect of high temperatures was observed on cardiovascular and cerebrovascular causes for all age groups considered.
For respiratory admissions an effect of temperature on was observed only in some cities; considering all age groups only in Stockholm, Milan and London, whereas the analysis by age groups gave a better insight with a positive association between high temperatures and respiratory admissions in a larger group of cities: Stockholm (65-74, 75+), London (15-64; 65-74; 75+), Rome and Valencia for the very old (75+), in Milan in the young (0-14) and very old group (75+) and in Turin only in the 15-64 age group.

Pooled analysis was carried out on extreme summer temperatures (>90th percentile during summer). For cardiovascular and cerebrovascular disease a negative significant coefficient was observed for all cities. For respiratory disease a positive coefficient was observed for all cities and northern-continental cities. Pooled analysis (Mediterranean and northern-Continental cities) for respiratory disease by age groups illustrated a significant positive effect of high temperatures for the 15-64 and 65-74 age groups was only observed in the northern-Continental cities, while for the 75+ age group a positive effect was estimated in all cities, Mediterranean and northern-Continental cities.

During winter the effect of cold temperature showed a weak association (increase in mortality for temperature decrease) with cardiovascular causes only for the 65-74 and 75+ years age groups. City-specific results for cardiovascular admissions showed a significant effect only in Barcelona (all ages and 75+ age group), Budapest (all age groups considered) and London (all ages and 75+ age group). Cerebrovascular causes were not associated with a decrease in temperature in most cities; city-specific results showed a significant association only in Barcelona (75+ age group) and Budapest (all ages and 75+ age group).
A significant effect was observed on respiratory admissions in all age groups in Budapest, Dublin, London, Paris, Rome, Stockholm and Valencia. While for Barcelona and Milan only for total and the 75+ age group.
It's worth noting a certain degree of heterogeneity between city-specific estimates for all the three outcomes.
The pooled exposure-response curves of maximum apparent temperature and daily hospital admissions in the 75+ years age group for all cities has a linear trend, with admission rates rising progressively as temperature decreases for all the three outcomes considered, although it appears to be stronger for respiratory causes.
Considering the pooled estimates, a significant increases in hospital admission counts for a decrease in 1°C in maximum apparent temperature are visible for cardiovascular causes in the 65-74 and 75+ years age groups in all cities and only in the 75+ age group in Continental/Northern cities. Overall, no effect of low temperature was found for cerebrovascular admissions in all three groups of cities. With regards to respiratory admissions, a significant association with temperature was observed for all the age groups considered even if higher in the 75+ years age group in all cities as well as in Northern-continental cities. In Mediterranean cities the only significant association was found in the 75+ age group.

We investigated the confounding effect and interaction of air pollution on mortality both during summer and winter seasons. For the investigation of confounding, models with and without adjustment for each available pollutant were applied and their results compared.

For the cold season the observed confounding is indeed minimal. In all cases, the change after inclusion of the air pollutant variable in the model is to obtain a smaller effect estimate (less than 10%). For the warm season again the confounding effect of pollutants on the size of the apparent temperature effect estimate is small and the size of the effect estimate of apparent temperature when adjusting for an air pollution variable generally decreases, except for a few specific models concerning effects on cerebrovascular mortality.

We investigated possible interaction with separate analysis by season. For the winter season the parameters for the interaction variables are not statistically significant with a few exceptions. Exceptions are: the interactive effect of NO_2 and apparent temperature on total natural mortality, of CO and apparent temperature on total mortality, of PM_{10} and apparent temperature on respiratory mortality and finally, the interactive effect of apparent temperature and SO_2 on cerebrovascular mortality. For the summer season, more significant interactive effects are observed. Thus, for the effects of apparent temperature on total natural mortality, there is a significant but small interactive effect with CO and a larger interactive effect with ozone. For cardiovascular disease mortality, there is a significant interaction of apparent temperature with black smoke levels. These interactive effects are investigated for all temperatures above the turning point (threshold) of the temperature-mortality association.

The PHEWE project also included work packages on prevention. Pilot HHWWS warning systems were developed in Paris, Budapest, Rome, Barcelona and London. Mortality in the 65+ and 75+ was predicted using deterministic and conditional probabilistic models. The results showed that thresholds for warnings vary be region and the PHEWE project can provide guidance for local action. The models experimented became operational only in Budapest and in Rome. The indications from the PHEWE project for the future development of HHWWS are that it should be based on an efficient forecast and warning system, robust understanding of the temperature-mortality relationship and a series of effective response measure in terms of public health which include efficient infrastructures and prevention programs.

To have an overview of the prevention activities in action a survey on city preparedness was defined and a questionnaire was distributed to all the cities included in PHEWE. The aim of the survey was to describe prevention activities related to population health during extreme weather and environmental events in the 16 cities and develop guidelines on the various activities that can be put in practise during these events. Only nine cities responded to the questionnaire and results refer to these nine cities. The poor response can be attributable to a language barrier, difficulties in identifying the respondent/s and questions were too open ended. In terms of results this also made it difficult to validate the information, and who the respondent was influenced the outcome of the questionnaire.

In the context of the PHEWE study of summertime heat-related mortality in 16 European cities, we developed a probabilistic assessment of years of life lost (YoLL)
We estimate <60 excess hot temperature-related deaths per 100,000/year during 1990-2000 in each of the 16 PHEWE cities among persons aged 15-64 and 65-74. For persons of 75+, we estimate 150-200 excess deaths per 100,000/year in each of Athens, Barcelona, Budapest, Paris, and Rome. The estimated number of excess deaths in these cities is reduced by 35-60% when those occurring within 60 days of above-threshold temperatures are set aside. Certain cities, Paris and Budapest being examples, appear particularly sensitive to high temperatures. We calculate that aggregate years of life lost due to heat occur in fairly similar proportions for the three age groups once short-term mortality displacement is taken into account.

In conclusion, the results of this project documented the effect of temperature on mortality both during the summer as well as the winter seasons in all the European cities included in the project, showing a large heterogeneity of the effect attributable to the differences in local climate and to the impact this has on local populations.

For the effect of hot temperatures thresholds were higher in the Mediterranean and lower in the Northern-Continental countries indicating that people residing in the latter are susceptible to lower values of apparent temperature. We found that the effect of heat was stronger in the very old (75+ age group) than earlier in life confirming a high vulnerability of elderly populations. In general, the highest effect of heat on mortality was observed for respiratory causes.
As shown by the distributed lag analysis, the effect of high apparent temperature appears to be immediate (5-6 days) both in Mediterranean and Northern-Continental cities. A certain evidence of mortality displacement was found in both groups but the displacement effect was more prolonged in Mediterranean cities.

Concerning the effect of cold temperature during the winter months, our results documented that in European cities temperature is inversely associated with mortality, and the relationship appears to be linear. The effect of cold was observed on all causes of death, and was stronger on cardiovascular and respiratory causes. Furthermore, in warmer cities the cold temperature effect was higher than in coldest cities.

In our study we observed effects of similar magnitude on deaths from respiratory and cardiovascular causes. However, when more prolonged effects were studied with distributed lag models, it appears that the respiratory effects are more persistent through time.

Results by age groups showed that for total and CVD mortality the effects had an age gradient; the effect increased progressively with age and was greatest in the elderly. Whereas the effects of apparent temperature on respiratory and cerebrovascular deaths were only observed on those older than 65 years.

In general the impact on hospital admissions hot temperature appears to be lower than the impact on mortality. Our conclusions are that, in European cities, hot temperatures seems to have an immediate effect on susceptible subgroups that died before getting to hospital. These results may be important to understand the physiological processes, and to focus preventive actions on susceptible subgroups, especially old and very old people living alone, to prevent fatal events allowing they come to medical’s attention.

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1. General Introduction

General introduction

Interest in the impact of weather on human health is increasing, especially in the light of potential climate changes (1). According to experts, such changes would be characterised by wider temperature fluctuations and a resulting increase in heat waves and cold spells. The increased frequency and intensity of heat waves can lead to an increase in heat related deaths and morbidity episodes. The epidemiological evidences indicate that the impact would be greatest in urban areas, affecting particularly the elderly and people suffering from chronic disease (2,3). City's geographical location, the magnitude of the urban heat island effect, and housing conditions influence the magnitude of the negative health impacts associated with oppressive summer conditions.

The World Health Organisation considers the health effects of global warming, to be one of the main problems for the 21st century. Such conditions will require a concerted action between meteorological services and public health institutions to set up heat/health watch warning systems (WWS) to alert the residents of urban areas to potentially oppressive weather conditions that could have an impact on health. Before the start of any intervention, however, a scientific documentation of the short-term effects of warm weather conditions is needed.

Record temperatures were observed across Europe in 2003 and the impact on mortality reported in several countries indicates that most European countries were unprepared to cope with such an emergency.

It is well known that many aspects of human health are affected by meteorological variables, and a J- or U-shaped relationship between outdoor temperature and daily mortality has been extensively reported (4, 5). In most industrialised countries, death rates are higher in winter months than at other times of the year, with the minimum on days in which the temperature ranges between 20-25° C. A summer peak in mortality has been observed in some cities, and it has been linked with high temperatures (6). Deaths attributable to episodic increases in temperature have been specifically reported in Mediterranean cities (Rome, Athens, Barcelona) (7, 8, 9). However, current knowledge of the effects of temperature on mortality is still largely based on studies of heat waves, which have been linked to excess deaths from cardiovascular, cerebrovascular, and respiratory conditions (10, 11, 12, 13). The effects on health of weather temperature in the usual range between 24 and 30 °C, a range that characterises summertime in most European countries, have never been systematically explored.

The project "Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe" (PHEWE) is a collaborative effort to investigate the short-term health effect of weather conditions in European cities using a standardized time series approach. This multi-city study allows for the evaluation of the health effects of temperature both during hot and cold season in a wide range of climatic conditions A multi-centre study has the advantage of comparing city-specific results using the same methodological approach, giving the possibility of investigating the pattern across cities, and to explore factors related to the variability of the effect observed. The PHEWE project has the general aim the effect to analyse the short-term effects on health outcomes of both warm and cold temperature, to compare the effect among European cities, and to provide an overall overview of the effect quantifying the impact on mortality and on hospital admissions. The health end-points were total mortality, selected cause specific mortality, and hospital admissions for cardiovascular, cerebrovascular and respiratory causes.

The PHEWE project has the following objectives:

- investigate the association between meteorological variables and daily mortality, and hospital admissions
- examine, in different baseline climatic conditions, the shape of the relationship between the meteorological variables and mortality/hospital admissions, the threshold level above which the effect is detected, the relevant time interval between the exposure and the effect, and the possibility that cumulative exposures may play a role
- define the specific synoptic weather categories associated with increased mortality/ morbidity in each city
- analyse the synergy between weather and air-pollution on mortality and morbidity and quantify the specific contribution of each environmental factor
- develop a heat/health watch warning system to predict in advance and to alert cities' residents of potentially oppressive weather conditions that could negatively affect health.
- develop a framework of preventive strategies to minimise adverse health effects in European cities

Rationale

The rapid increase of greenhouse gases in the atmosphere is expected to increase both mean temperature and temperature variability around the world (14); inducing a change in the global climate. Climatologists project that, in temperate climates, a 2-3°C increase in average summer temperatures, will double the frequency of periods characterized by extremely high temperatures (15).

The vulnerability of human populations to extreme weather events is a function of their sensitivity to the exposure, of the character, magnitude and rate of the climate extreme, and of the adaptation measures and preventive actions in place (16). In healthy individuals, an efficient thermoregulatory system enables the body to cope effectively with thermal stress. Within certain limits, thermal comfort can be maintained by appropriate thermoregulatory responses; temperatures exceeding these limits, both with respect to heat and cold, substantially increase the risk of death (17). Temperature-related effects are particularly evident among the elderly (18, 19, 7, 9, 20, 21, 22, 10, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38). Studies have shown that with advancing age, thermoregulatory responses are reduced and less sensitive thermal perception may affect the behavioural response to heat or cold stress, facilitating the onset of heat- and cold-related illnesses and deaths (17, 39, 12, 40). Other susceptible subgroups include people suffering from chronic diseases (41, 42, 18, 43, 5, 21, 10, 23, 24, 26, 44, 45, 27, 28, 46, 47, 29, 36, 48), persons living in deprived areas (41, 19, 49, 33).

Hot and cold temperatures have been related to total and cause specific mortality (42, 18, 7, 50, 5, 51, 21, 52, 53, 10, 23, 54, 26, 55, 56, 57, 58) and to other health outcomes such as hospitalizations (18, 59, 60, 24, 61, 62, 63, 64, 65, 66). Most studies analysed the relation between temperature and effects on health during extreme weather events, called heat waves/cold spells. Although there is no standard definition, a heat wave/cold spell is generally defined as a period of extremely high/low temperatures associated with an excess in the risk of adverse health effects and mortality (26). The impact of such extreme weather events has been estimated using descriptive episode analysis (18, 7, 50, 51, 23). More recently, the relation between temperature and mortality was explored through the time series approach (5, 9, 21). In many time series studies, the association between temperature (minimum, maximum or mean temperature) and mortality has been described as a non linear U-, J- or V-shaped function, with the lowest mortality rates recorded at moderate temperatures, rising progressively as temperatures increase or decrease. In some regions both temperature extremes have been associated with fatal events with similar magnitude of effects (5, 21, 26, 67), whereas in other regions the susceptibility to cold and hot temperatures are more differentiated (9, 10, 68, 69, 54, 44, 45, 55, 27, 28, 56, 70).

Time series studies on the effects of both high and low temperatures on mortality have been performed in several cities in the United States (45, 55, 30, 65) and in various European areas including the Netherlands (5), several Spanish cities (9, 21, 10, 27, 28), London (71) and Rome (69). These studies have shown that the temperature level corresponding to the minimum mortality rate varies from city to city and across different latitudes according to the local climate and probably reflecting acclimatization by the local population to the temperature range in both the hot and cold season. For example, the minimum mortality is around a mean temperature of 16.5ºC in the Netherlands (5), 19ºC in London (71), 23ºC in Valencia (21), 24°C in Rome (69), 27.2°C in Miami, Florida (55) and 27.5°C in Beirut (67). To date, there is limited evidence of the impact of high and low temperatures on mortality and morbidity in developing countries (72, 58, 56). However, populations residing in these countries may be particularly vulnerable to the effect of heat and cold due to the poor housing conditions and to the limited resources for coping with thermal stress (58). Quantifying the impact of temperature extremes on these populations is needed to address future public health interventions.

Considering climate change scenarios and possible temporal changes in the individual and community factors that determine vulnerability to extreme weather events in a particular environmental-demographic setting, it is important to monitor the temporal variation of the temperature-mortality relationship, both in the long-term and in the short-term, to understand a population's capacity to adapt to new climate conditions. Studies addressing inter-annual variations are to date limited. With regards to the long-term variations, some authors have observed a long-term decline in summer mortality and suggest this can be explained by changes in adaptation strategies such as the increased use of air conditioning and public health interventions activated during extreme weather events (73, 74, 75). Similar conclusions have gained from studies comparing heat wave episodes in different years, showing a decline in heat-related mortality that, other than differences in exposure levels, could be attributable to adaptation measures and actions (76, 77, 78). Other studies have documented a substantial long term decline in excess winter mortality (79, 80); authors suggest that a general improvement in housing conditions and in public health system may have contributed to the observed trends.

The literature about the effects on mortality of moderate heat and cold has been reviewed by Martens and an aggregate estimate of heat and cold effect was derived by means of a meta-analysis and combined with projections of changes in baseline climate conditions (81). For most of the cities included, global climate change was likely to lead to a reduction in mortality rates due to decreasing winter mortality that offset increased excess summer mortality, especially in the elderly and in cities with temperate or cold climates. However, this finding may present a bias because the majority of the studies described the relation between mortality and low temperatures while only very few studies dealt with the relation between heat and mortality. This latter topic was discussed more in detail by Basu and Samet (82) in their review including forty-nine studies published after 1970 in peer-reviewed journals. Most studies reported that hot weather had a large immediate effect on mortality on the same day and on the subsequent 2-3 days and that these excess deaths were recorded among persons at high risk of dying and were compensated for by a fall in mortality in the following weeks, a phenomenon known as "harvesting effect".

To date, time series studies on the effect of hot temperatures have largely used mortality as the outcome measure; whereas the analysis of the effect of hot temperature on non fatal outcomes, such as emergency hospital admissions, is limited. Cardiovascular, respiratory and cerebrovascular diseases were the most frequent underlying causes of death during heat waves (41, 42, 18, 23, 24, 26, 46, 36), since heat produces stress on the cardiovascular and respiratory systems, especially among subjects with limited adaptive responses. Keatinge *et al.* (83) have documented some physiological changes that promote arterial thrombosis following moderately severe exposure to hot weather; after heat esposure, blood viscosity and plasma cholesterol levels increased, as a consequence of the reduction of plasma volume due to a loss of salt and water from the body (83). Moreover, heat stress causes a release of platelets into circulation whose deposition on arterial walls was the early stage of arterial thrombosis. A sudden fall in arterial pressure may precipitate cerebral as well as coronary thrombosis, that is a possible explanation to the increase of mortality for cerebral and cardiovascular disease observed after peaks of heat. The biological mechanism throughout high temperature may increase mortality for respiratory causes is unclear.

Few studies have quantified the effect of heat on hospital admissions (18, 19, 84, 24, 60, 62, 63, 65, 66).

In 12 U.S. cities (65) increases in emergency admissions for heart diseases have been observed in response to hot weather. According to the limited published literature, the effect of heat on hospital admission seems to be lower than the effect observed on mortality. A study which analysed the effect of hot weather on emergency hospital admissions in London reported a small or absent impact of heat on admissions for several causes including cardiovascular diseases (63).

Cold temperatures have been related to increases in mortality during winter in a number of time series studies both in Europe (68, 26, 44, 47, 70, 85), in the United States (30), and in other countries (67, 58). These studies have documented a geographical variability in the impact of cold on mortality but comparisons have to be made cautiously as the exposure indicator and the statistical methods employed differed. The few multi-city studies available, allowing for unbiased comparison thanks to standardization of protocols between study centers, showed a greater effect of low temperatures in populations residing in warmer than in colder regions of Europe (53) and of the U.S. (45, 55). The underlying mechanisms by which cold exposure can lead to heterogeneous responses in different populations are still not completely understood. Possible explanations consist in a different population's ability to cope with extremely low temperatures attributable, for example, to differences in home heating, clothing and in level of physical activity outdoors (53), as well as, in a diverse demographic and socio-economic structure that makes a specific population more susceptible to the effect of cold.

Direct effects of cold such as hypothermia are rarely the cause of winter deaths, at least in developed countries, and the greatest part of cold-related mortality is due to cardiovascular and respiratory diseases, especially in the elderly who have early stage arterial disease and limited thermoregulatory responses (86). Effects on morbidity usually anticipate death as suggested by the biological mechanisms underlying cold-related illnesses (87). However, the influence of cold on outcomes other than mortality has received little investigation. Time series studies performed in France (84), Italy (66) and Greece (64) have documented cold-related increases in hospital admissions for myocardial infarction or coronary disease in persons older than 65 years. On the contrary, a large multi-city study from the U.S. found a linear relation between temperature and heart disease admissions in the elderly with the lowest admission rates recorded during cold weather (65). Considering the limited and conflicting evidence available, the specific contribution of cold temperatures on hospital admissions needs to be thoroughly examined. Moreover, no study to date has systematically examined the effect of cold on both mortality and morbidity outcomes. This could be of interest when addressing the question of how well health services are able to respond to cold weather. Studies carried out during heat waves (19, 22, 24, 63) suggest that burden on hospital admissions does not reflect the magnitude of that observed on mortality, supporting the hypothesis that many heat related deaths occur before coming to medical attention. Similar studies carried out during cold weather are needed. This knowledge gap could only be filled in by studies with enough power to test the hypothesis of interest but also including different areas to ensure the results can be generalised to other areas and populations.

Overview of the project

PHEWE is a pan-European project within the Quality-of-life-and-living-resources programme of the EC, which started in August 2005 and was concluded in March 2006. Researchers from the fields of Epidemiology, Statistics, Meteorology, and Public Health collaborated involving 16 European cities representing a broad range of geographical and climatic, cultural and socio-economic conditions (Athens, Barcelona, Budapest, Dublin, Helsinki, Krakow, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia, and Zurich). The general aim was to assess the association between weather and acute health effects (daily mortality and hospital admissions) in Europe and to provide information for public health policy on preventive and adaptive actions. Meteorological, air pollution and mortality data from 16 cities and hospital admission data from 12 cities were available for the period 1990 to 2000; the short term health effects of weather conditions on daily mortality and daily hospital admissions was analyzed respectively on 15 and 12 cities through city-specific and pooled time series analysis, separately for the warm and the cold seasons. The role of air pollutants as potential confounders and/or effect-modifiers was investigated. Meteorological analysis performed, a synoptic weather classification system in different European areas was defined and synoptic categories associated with increased mortality and morbidity were evaluated. Experimental Heat/health watch warning systems (HHWWS) to predict in advance high risk weather conditions were developed for a subset of cities. Health impact assessments of weather conditions on mortality was performed and a survey on current prevention policies was conducted. The project was broken down into eight work packages, and three working groups (Epidemiology&Statistics, Meteorology, Public Health) supported and supervised the work The project results were presented to all project partners in a final meeting and to the scientific community during the International Conference on Environmental Epidemiology & Exposure.

Structure of this report

The present report is structured according to the structure of the PHEWE project itself, i.e. reflecting the division of the tasks between the different work-packages:

Chapter 2 summarises the background, objectives, and study design of the PHEWE project. Information on the data collection, management and an overview of the methodology are included, as well as a description of the city characteristics and the collected health and meteorological variables (WP1). *Chapter 3* describes the analysis of the meteorological data and the development of synoptic indices for the PHEWE cities (WP2).The methodology applied for the assessment of the short-term health effect of meteorological conditions and the results of the city-specific and pooled analysis of mortality (WP3) and hospital admission data (WP4) for the warm and the cold season are reported in *chapters 4, 5, 6, and 7.* The role of air pollution as a potential confounder and/or effect modifier is addressed in *chapter 8* (WP5). The development of heat/health watch warning systems (HHWWS) in a five pilot cities and the experiences of the implementation of the HHWWS in the city of Budapest are described in *chapters 9 and 10* (WP6). The public health related issues are reported in *chapters 11 and 12*, giving an overview of the prevention policies currently adopted by the PHEWE cities and the estimation of years-of-life-lost due to heat related mortality (WP7). The main project findings are summarised and discussed in *chapter 13.* All tables including city characteristics, health, meteorological and air pollution data are allocated in the *appendices* chapter. This also comprises the protocol for data collection, the supplementary questionnaire and the letter and questionnaire for the heat prevention survey.

References

1. WHO/WMO/UNEP, Climate and health: The potential impacts climate change. Geneva, Swizterland, 304pp, 1996.
2. Kalkstein.LS Health and climate change. Direct impacts in cities. *The Lancet* 1993; 342(8884):1397-9.
3. McMichael AJ. Global Environmental Change and Human Population Health: A Conceptual and Scientific Challenge for Epidemiology. International Journal of Epidemiology 1993;22(1):1-8.
4. Mackenbach J, Looman C, Kunst A. Air pollution, lagged effects of temperature, and mortality: The Netherlands 1979-87. J Epidemiol Comm Health 1993; (47)121-126.
5. Kunst A, Looman C, Mackenbach J. Outdoor Air Temperature and Mortality in the Netherlands: A Time-Series Analysis. Am J Epidemiol 1993; 137:(3)331-341.
6. Greenberg JH, Bromberg J, Reed CM, Gustafson TL, Beauchamp RA. The epidemiology of heat related deaths. Texas-1950, 1970-1979, and 1980. Am J Publ Health 1983;73:805-807.
7. Albertoni F, Arcà M, Borgia P, Perucci CA, Tasco C. Heat-Related Mortality. Latium Region, Summer 1983. MMWR 1984;33(37):518-521.
8. Katsouyanni K, Pantazopoulou A, Touloumi G et al. Evidence for Interaction between Air Pollution and High Temperature in the Causation of Excess Mortality. Archives of Environmental Health 1993; 48:(4)235-242.
9. Saez M., Sunyer J., Castellsagué J., Murillo C., Antó J.M. Relationship between Weather Temperature and Mortality: A Time Series Analysis Approach in Barcelona. International Journal of Epidemiology 1995; 24:(3)576-582.
10. IPCC. Climate Change 2001: Impacts, Adaptation and Vulnerability. 2001Alberdi JC, Diaz J, Montero JC, Miron I. Daily mortality in Madrid community 1986-1992: Relationship with meteorological variables. European Journal of Epidemiology1998;14:571-8.
11. Khaw KT. Temperature and cardiovascular mortality. *The Lancet* 1995;345:337-8.
12. Pan W, Li L, Tsai M. Termperature extremes and mortality from coronary heart disease and cerebral infarction in elderly chinese. Lancet 1995; 345:(353-355).
13. Katsouyanni K, Zmirou D, Spix c, Sunyer J, Schouten JP, Ponka A, Anderson HR, Le Moullec Y, Wojtyniak B, Vigotti MA, Bacharova L. Short-term effects of air pollution on health: a European approach using epidemiological time-series data. European Respiratory Journal 1995;8:1030-1038.
14. Meehl G.A., Zwiers F., Evans J., Knutson T., Mearns L., Whetton P. Trends in Extreme Weather and Climate Events: Issues Related to Modeling Extremes in Projections of Future Climate Change. Bulletin of the American Meteorological Society 2000; 81:(3)427-436.
15. IPCC. Climate Change 2001: Impacts, Adaptation and Vulnerability. 2001.
16. WHO. Methods of assessing human health vulnerability and public health adaptation to climate change. Health and Global Environmental Change 2003; 1.
17. Natsume K., Ogawa T., Sugenoya J., Ohnishi N., Imai K. Preferred ambient temperature for old and young men in summer and winter. Int J Biometeorolol 1992; 36:(1)1-4.
18. Ellis F.P., Princé H.P., Lovatt G., Whittington R.M. Mortality and Morbidity in Birmingham during the 1976 Heatwave. Quarterly Journal of Medicine 1980; New Series XLIX:(193)1-8.

19. Jones TS, Liang AP, Kilbourne EM, Griffin MR, Patriarca PA, Wassilak SG et al. Morbidity and mortality associated with the July 1980 heat wave in St Louis and Kansas City, Mo. JAMA 1982; 247:(24)3327-3331
20. Sartor F., Snacken R., Demuth C., Walckiers D. Temperature, Ambient Ozone Levels, and Mortality during Summer, 1994, in Belgium . Environmental Research 1995; 70:105-113.
21. Ballester F, Corella D, Perez-Hoyos S, Saez M et al. Mortality as a Function of Temperature. A Study in Valencia, Spain, 1991-1993. Int J Epidemiol 1997; 26:(3)551-561.
22. Whitman S., Good G., Donoghue D.R., Benbow N., Shou W., Mou S. Mortality in Chicago Attributed to the July 1995 Heat Wave. Am J Public Health 1997; 87:(9)1515-1518.
23. Rooney C., McMichael A.J., Kovats R.S., Coleman M.P. Excess mortality in England and Wales, and in Greater London, during the 1995 heatwave. J Epidemiol Community Health 1998; 52:482-486.
24. Semenza J.C., McCullough J.E., Flanders W.D., McGeehin M.A., Lumpkin J.R. Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med 1999; 16:(4)359-60.
25. Yan Y.Y. The influence of weather on human mortality in Hong Kong. Soc. Sci. Med. 2000; 50:(3)419-427.
26. Huynen M, Martens P, Schram D et al. The Impact of Heat Waves and Cold Spells on Mortality Rates in the Dutch Population. Environ Health Perspect 2001; 109:463-470.
27. Diaz J, Garcia R., Velazquez de Castro F., Hernandez E., Lopez C., Otero A. Effects of extremely hot days on people older than 65 years in Seville (Spain) from 1986 to 1997. Int J Biometeorol 2002a; 46:145-149.
28. Diaz J, Jordán A., Garcia R., López C., Alberdi J.C., Hernández E., et al. Heat waves in Madrid 1986-1997: effects on the health of the elderly . Int. Arch. Occup. Environ Health 2002b; 75:163-170.
29. Hong Y., Rha J., Lee J., Ha E., Kwon H., Kim H. Ischemic Stroke Associated with Decrease in Temperature. Epidemiology 2003; 14:(4)473-478.
30. O'Neill M.S., Zanobetti A, Schwartz J. Modifiers of the Temperature and Mortality Association in Seven US Cities. Am J Epidemiol 2003; 157:(12)1074-1082.
31. Rainham D.G.C., Smoyer-Tonic K.E. The role of air pollution in the relationship between a heat stress index and human mortality in Toronto. Environmental Research 2003; 9-19.
32. Goodman P.G., Dockery D.W. , Clancy L. Cause-Specific Mortality and the Extended Effects of Particulate Pollution and Temperature Exposure. Environ Health Perspect 2004; 112:(2)179-185.
33. Michelozzi P., de' Donato F., Accetta G., Forastiere F., D'Ovidio M., Perucci C.A. Impact of Heat Waves on Mortality - Rome, Italy, June-August 2003. MMWR 2004; 53:369-371.
34. Grize L., Huss A., Thommen O., Schindler C., Braun-Fahrländer C. Heat Wave 2003 and mortality in Switzerland. Swiss Med Wkly 2005; 135:200-205.
35. Johnson H., Kovats R.S., McGregor G., Stedman J., Gibbs M., Walton H. The impact of the 2003 heat wave on daily mortality in England and Wales and the use of rapid weekly mortality estimates. Euro Surveill 2005; 10:(7); 168-71.
36. Michelozzi P, de' Donato F, Bisanti L, Russo A, Cadum E, DeMaria M, et al. The impact of the summer 2003 heat waves on mortality in four Italian cities. Euro Surveill 2005; 10:161-165.

37. Pirard P., Vandentorren S., Pascal M., Laaidi K., Le Tertre A., Cassadou S., et al. Summary of the mortality impact assessment of the 2003 heat wave in France. Euro Surveill 2005; 10:(7)153-6.

38. Simon F., Lopez-Abente G., Ballester E., Martinez F. Mortality in Spain during the heat waves of summer 2003. Euro Surveill 2005; 10:(7): 156-61.

39. Merchandani H., Pace P., Mameli A.Z., et al. Heat-Related Deaths--United States, 1993. MMWR 1993; 42:(28)558-560.

40. Pandolf KB. Aging and human heat tolerance. Exp Aging Res. 1997; 23:(1)69-105.

41. Schuman S.H. Patterns of Urban Heat-Wave Deaths and Implications for Prevention: Data from New York and St. Louis During July, 1966. Environmental Research 1972; 5:59-75.

42. Ellis F.P., Nelson F. Mortality in the Elderly in a Heat Wave in New York City, August 1975. Environmental Research 1978; 15:504-512.

43. Lloyd E.L. The Role of Cold in Ischaemic Heart Disease: a Review. Public Health 1991; 105:205-215.

44. Keatinge W, Donaldson G. Mortality Related to Cold and Air Pollution in London after Allowance for Effects of Associated Weather Patterns. Environ Res 2001; Section A:(86)209-216.

45. Braga A.L.F., Zanobetti A, Schwartz J. The Effect of Weather on Respiratory and Cardiovascular Deaths in 12 U.S. Cities. Environ Health Perspect 2002; 110:(9)859-863.

46. Kyselý J. Mortality and displaced mortality during heat waves in the Czech Republic. Int J Biometeorol 2004; 49:91-97.

47. Wilkinson P, Pattenden S, Armstrong B, Fletcher A, Kovats S, Mangtani P, et al. Vulnerability to winter mortality in elderly people in Britain: population based study. BMJ 2004; 329:647

48. Schwartz J. Who is Sensitive to Extremes of Temperature? A Case-Only Analysis. Epidemiology 2005; 16:(1)67-72.

49. Wilmshurst P. Temperature and cardiovascular mortality. BMJ 1994; 309:1029-1030.

50. Katsouyanni K, Trichopoulos D, Zavitsanos X, Touloumi G. The 1987 Athens Heatwave. Lancet 1988; S3:573

51. Semenza J, Rubin C, Falter K et al. Heat-Related Deaths during the July 1995 Heat Wave in Chicago. N. Engl. J. Med. 1996; 335:(2)84-90.

52. Donaldson G.C., Keatinge W.R. Early increases in ischaemic heart disease mortality dissociated from and later changes associated with respiratory mortality after cold weather in south east England. J Epidemiol Community Health 1997a; 51:643-648.

53. Eurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, repiratory disease, and all casues in warm and cold regions of Europe. Lancet 1997; 349:1341-1346.

54. Braga A, Zanobetti A, Schwartz J. The Time Course of Weather Related Deaths. Epidemiology 2001; 12:(6)662-667.

55. Curriero F, Heiner K, Samet J et al. Temperature and Mortality in 11Cities of the Eastern United States. Am J Epidemiol 2002; 155:(1)80-87.

56. Gouveia N., Hajat S., Armstrong B. Socioeconomic differentials in the temperature-mortality relationship in São Paulo, Brazil. Int J Epidemiol 2003; 32:390-397.

57. Pattenden S., Nikiforov B., Armstrong B.G. Mortality and temperature in Sofia and London. J Epidemiol Community Health 2003; 57:628-633.

58. O'Neill M.S., Hajat S., Zanobetti A, Ramirez-Aguilar M., Schwartz J. Impact of control for air pollution and respiratory epidemics on the estimated associations of temperature and daily mortality. Int J Biometeorol 2005a; 50:(2)121-9.

59. Faunt J.D., Wilkinson T.J., Aplin P., Henschke P., Webb M., Penhall R.K. The effete in the heat: heat-related hospital presentations during a ten day heat wave. Aust NZ J Med 1995; 25:117-121.

60. Dematte J.E., O' Mara K., Buescher J., Whitney C.G., Forsythe S., McNamee T., et al. Near-Fatal Heat Stroke during the 1995 Heat Wave in Chicago. Annals of Internal Medicine 1998; 129:(3)173-181.

61. Watkins S.J., Byrne D., McDevitt M. Winter excess morbidity: is it a summer phenomenon? Journal of Public Health Medicine 2001; 23:(3)237-241.

62. Koken P.J.M., Piver W.T., Ye F., Elixhauser A., Olsen L.M., Portier C.J. Temperature, Air Pollution, and Hospitalization for Cardiovascular Diseases among Elderly People in Denver. Environ Health Perspect 2003; 111:(10)1312-1317.

63. Kovats S.R., Hajat S., Wilkinson. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in greater London, UK. Occupational Journal of Environmental Medicine 2004; 61; 893-898.

64. Panagiotakos D.B., Chrysohoou C., Pitsavos C., Panagiotis N., Anadiotis A., Tentolouris C., et al. Climatological variations in daily hospital admissions for acute coronary syndromes. International Journal of Cardiology 2004; 94:229-233.

65. Schwartz J, Samet J, Patz J. Hospital Admissions for Heart Disease: The Effects of Temperature and Humidity. Epidemiology 2004; 15:(6)755-61.

66. Morabito M., Modesti P.A., Cecchi L., Crisci A., Orlandini S., Maracchi G., et al. Relationships between weather and myocardial infarction: A biometeorological approach. International Journal of Cardiology 2005; 105:288-293.

67. El - Zein A., Tewtel - Salem M., Nehme G. A time-series analysis of mortality and air temperature in Greater Beirut. Science of the Total Environment 2004; 330:71-80.

68. Rossi G., Vigotti M.A., Zanobetti A., Repetto F., Gianelle V., Schwartz J. Air Pollution and Cause-Specific Mortality in Milan, Italy, 1980-1989. Archives of Environmental Health 1999; 54:(3)158-164.

69. Michelozzi P., Fano V., Forastiere F., Barca A., Kalkstein L.S., Perucci C.A. Weather conditions and elderly mortality in Rome during summer. World Meteorological Organization Bulletin 2000; 49:(4)348-55.

70. Carder M., McNamee R., Beverland I., Elton R., Cohen G.R., Boyd J., et al. The lagged effect of cold temperature and wind chill on cardiorespiratory mortality in Scotland. Occup Environ Med 2005; 62:702-710.

71. Hajat S, Kovats R, Atkinson R, Haines A. Impact of hot temperatures on death in London: a time series approach. J Epidemiol Comm Health 2002; 56:367-372.

72. Hajat S., Armstrong B.G., Gouveia N., Wilkinson P. Mortality Displacement of Heat-Related Deaths - A Comparison of Delhi, São Paulo, and London. Epidemiology 2005; 16:613-620.

73. Donaldson G.C., Keatinge W.R., Näyhä S. Changes in summer temperature and heat-related mortality since 1971 in North Carolina, South Finland, and Southeast England. Environ Res 2003; 91:1-7.

74. Davis R.E., Knappenberger P.C., Novicoff W.M., Michaels P.J. Decadal changes in summer mortality in U.S. cities. Int J Biometeorol 2003a; 47:166-175.

75. Davis R.E., Knappenberger P.C., Michaels P.J., Novicoff W.M. Changing Heat-Related Mortality in the United States. Environ Health Perspect 2003b; 111:(14)1712-1718.

76. Smoyer K.E. A comparative analysis of heat waves and associated mortality in St. Louis, Missouri - 1980 and 1995. Int J Biometeorol 1998; 42:44-50.

77. Palecki M.A., Changnon S.A., Kunkel K.E. The Nature and Impacts of the July 1999 Heat Wave in the Midwestern United States: Learning from the Lessons of 1995. Bulletin of the American Meteorological Society 2001; 82:(7)1353-1367.

78. Weisskopf M, Anderson H, Foldy S et al. Heat Wave Morbidity and Mortality, Milwaukee, Wis, 1999 vs 1995: An Improved Response? Am J Public Health 2002; 92:(5)830-833.

79. Donaldson G.C., Keatinge W.R. Mortality related to cold weather in elderly people in southeast England, 1979-94. BMJ 1997b; 315:1055-1056.

80. Lerchl A. Changes in the seasonality of mortality in Germany from 1946 to 1995: the role of temperature. Int J Biometeorol 1998; 42:84-88.

81. Martens W. Climate Change, Thermal Stress and Mortality Changes. Soc. Sci. Med. 1998; 46:(3)331-344.

82. Basu R., Samet J. Relation between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence. Epidemiologic Reviews 2002; 24:(2)190-202.

83. Keatinge W.R., Coleshaw S, Easton J, Cotter F, Mattock M, Chelliah R. Increased Platelet and Red Cell Counts, Blood Viscosity, and Plasma Cholesterol Levels during Heat Stress, and Mortality from Coronary and Cerebral Thrombosis. American Journal of Medicine 1986; 81:795-800.

84. Danet S.., Richard F., Montaye M., Beauchant S., Lemaire B., Graux C., et al. Unhealthy Effects of Atmospheric Temperature and Pressure on the Occurrence of Myocardial Infarction and Coronary Deaths: A 10-Year Survey: The Lille-World Health Organizatin MONICA Project(Monitoring Trends and Determinants in Cardiovascular Disease). Circulation 1999; 100:e1-e7

85. Diaz J, Garcia R., Lopez C., Linares C., Tobias A., Prieto L. Mortality impact of extreme winter temperatures. Int J Biometeorol 2005; 49:179-183.

86. Keatinge W.R. Winter mortality and its causes. International Journal of Circumpolar Health 2002; 61:292-299.

87. Näyhä S. Cold and the risk of cardiovascular diseases. International Journal of Circumpolar Health 2002; 61 :(4)373-80.

2. Assessment and prevention of acute health effects of weather conditions in Europe. The PHEWE project: background, objectives, design

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Abstract

Background

The project “Assessment and prevention of acute health effects of weather conditions in Europe” (PHEWE) aimed at assessing the association between weather conditions and acute health effects, during both warm and cold seasons in 16 European cities with widely differing climatic conditions and to provide information for public health policies.

Methods

The PHEWE project was a three-year pan-European collaboration between epidemiologists, meteorologists and experts in public health.

Meteorological, air pollution and mortality data from 16 cities and hospital admission data from 12 cities were available from 1990 to 2000. The short-term effect on mortality/morbidity was evaluated through city-specific and pooled time series analysis. The interaction between weather and air pollutants was evaluated and health impact assessments were performed to quantify the effect on the different populations. A heat/health watch warning system to predict oppressive weather conditions and alert the population was developed in a subgroup of cities and information on existing prevention policies and of adaptive actions was gathered.

Results

Main results were presented in a symposium at the conference of the International Society of Environmental Epidemiology in Paris on September 6th 2006 and will be published as scientific articles. The present article introduces the project, including the description of the database and the framework of the applied methodology.

Conclusions

The PHEWE project offers the opportunity to investigate the relationship between temperature and mortality in 16 European cities, representing a wide range of climatic, socio-demographic and cultural characteristics; the use of a standardized methodology allows for direct comparison between cities.

Background

Interest in the impact of weather on human health is increasing, especially in the light of potential climate changes. The rapid increase of greenhouse gases in the atmosphere is expected to increase both mean temperature and temperature variability around the world.[1][2] Climatologists project that, in temperate climates, a 2-3°C increase in average summer temperatures doubles the frequency of periods characterized by extremely high temperatures.[3] Such changes would be characterized by the increased frequency and intensity of heat waves, and could lead to an increase in heat related illness episodes and deaths.

The association between high and low temperatures and mortality has been investigated in several studies. Most investigations have focused on the effect of temperature on health during extreme events (heat waves, cold spells) through descriptive (episode analysis) and analytical (time series) approaches. A review of the epidemiological studies on the effect of high temperatures on mortality conducted after 1970 identified sensitive groups among the elderly, persons with pre-existing cardiovascular and respiratory diseases and/or those of low socioeconomic status.[4] The heat effect appears within few days of exposure and some harvesting is observed.[4][5] The heterogeneity of the impact of heat on health reflects geographical, climatic and cultural variability, as well as different capacities to adapt to extreme heat and cold and needs to be addressed more in depth in a large scale study.[4][5][6][7]

Recently, studies on the effect of high temperatures on morbidity provided evidence of an increase in emergency hospital admissions for specific causes in young children and persons over 75 years of age, though with a smaller effect for admissions than for mortality.[8] Schwartz et al. reported an effect of heat on cause-specific admissions within a few days after exposure and a short-term displacement of the events (harvesting effect).[9]

In the 1990s, the APHEA (Air Pollution and Health: an European Approach) project investigated the short-term effects of air pollution on health throughout Europe.[10] In the time series analysis performed for this project, temperature was considered an important confounder of the association between air pollution and mortality.[11]

The project “Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe” (PHEWE) was initiated in 2002, with the general aim to assess the association between weather and acute health effects (daily mortality and hospital admissions) in Europe and to provide information for public health policy on preventive and adaptive actions. The specific objectives of the program were:

- to create a European database of meteorological variables and health indicators;
- to perform time series analysis using a standardized methodology to evaluate the short term health effects of weather conditions on daily mortality and daily hospital admissions, both during warm and cold seasons;
- to investigate the role of air pollution as a potential effect-modifier using a standardized methodology;
- to define a synoptic weather classification system in different European areas, and to evaluate synoptic categories associated with increased mortality and morbidity;
- to experiment the use of Heat/health watch warning systems (HHWWS) to predict in advance high risk weather conditions;
- to produce a health impact assessments of weather conditions on mortality;
- to define public health actions aimed at the prevention of adverse health effects of weather in Europe.

Methods

The database

The project collected data from 16 European cities, representing a large spectrum of climatic conditions: Athens, Barcelona, Budapest, Krakow, Dublin, Helsinki, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia, and Zurich, including about 30 million European citizens (Table 1). The number of city residents ranges between 6,8 M (London) to 260.000 (Ljubljana), with the percentage of the elderly population (over 75 years) between 5% (Helsinki) and 10% (Barcelona). The gender and age-adjusted mortality rate is highest in Budapest (1093.6) and lowest in Milan (439.4).

Health data

Mortality data were provided from 16 cities, and hospital admission data from 12 cities for all available years in the period 1990-2000 (Table 1), all referring to the city residents, and to events that occurred in the city, except for Dublin, where hospital admissions referred also to non residents. Taking into account the results of previous studies, [12][13][14] and the biological plausibility of the health effects, [7] [15][16][17] the following causes of death and hospital admission were selected for all ages combined and specific age groups (0-14 yrs, 15-64 yrs, 65-74 yrs, 75+ yrs): all causes (excluding external causes), ICD-9: 1-799; cardiovascular diseases, ICD-9: 390-459; cerebrovascular diseases, ICD-9: 430-438; respiratory diseases, ICD-9: 460-519.

Data from cold and warm seasons were analyzed separately, defining summer as the months from April to September and winter as the months between October and March.

Table 2 gives an overview of the mean daily number of deaths by cause and season. Data on cerebrovascular mortality were not available in three cities (Athens, Paris, Zurich). For all other causes the mean daily counts were lower in the summer season.

Emergency hospital admission records for the same causes (plus influenza, ICD-9: 487) were selected, following the APHEA-2 project protocol.[10] Only main causes of admission were considered. In table 3 mean daily admission counts are summarized by cause and season. Two cities could not provide all requested causes (Paris, Zurich). Generally, admission counts were higher in the cold season, especially for respiratory diseases.

Meteorological variables

For each city, data were retrieved from a weather station located in the city centre as well as from the nearest airport weather station for the study period. The following meteorological variables, recorded every three hours, were collected: air temperature, dew point temperature, wind speed, wind direction, sea level pressure, total cloud cover, solar radiation, precipitation, visibility. Quality control included a descriptive overview of the variables in all cities, detecting possible errors and extreme values, testing for homogeneity and correcting erroneous values where possible.

Table 4 gives an overview of the daily mean values observed in the participating cities. Mean summer temperatures ranged between 12.0 °C in Helsinki and 23.5 °C in Athens, in Valencia the lowest inner-city temperature range was reported. Relative humidity levels were highest in Dublin (81%) and lowest in Athens (57%). In winter, the lowest temperature was observed in Helsinki (-0.9°C), and the highest in Valencia (13.7°C), which is also the city with lowest relative humidity (69%) and the smallest temperature range.

Previous studies have used a variety of exposure measures, including maximum, minimum or average temperature, apparent temperature, humidity and dew point temperature but to date there is no standard indicator of heat or cold stress.[18][19] [5] [20][21] In the present study, maximum apparent temperature (Tappmax) was chosen as the exposure variable, which is an index of thermal discomfort based on air temperature and dew point temperature.[22] Tappmax is defined as the highest value of the 3-hourly apparent temperature values, using the following formula:

$$\mathrm{AT} = -2.653 + 0.994\ Temp\ +\ 0.0153\,(\mathrm{Dew})^2$$

where AT is apparent temperature, Temp is the air temperature in °C and Dew is the dew point temperature in °C.[23][24]

For Barcelona, where 3 hour meteorological data were not available, the daily average apparent temperature was used.

Air pollution data

The data collected within the APHEA-2 project were updated and integrated according to that project's procedures.[10] The following pollutant measurements were recorded at each monitoring station (maximum 6): SO_2 (mean 24-hours), TSP or Black Smoke (mean 24-hours), PM10- if available-(mean 24-hours), NO_2 (maximum 1 hour, mean 24-hours), O_3 (maximum 1 hour, maximum 8-hours moving average) CO (maximum 8-hour moving average).

The selection of the monitors was based on local criteria, mainly on the completeness of measurements and representation of population exposure. A standardized procedure was used to fill-in days with missing data.[10]

Other variables

Through a complementary questionnaire information on other confounders and potential effect modifiers was gathered from each city, such as holidays and unusual events during the study period (strike in the health services or transportation, flood, earthquake), percentage of households with air conditioning facilities and annual restrictions on home heating use. Questions on the city population, and on details concerning data quality were also included, which were useful in order to characterize the different city populations (Table 1) and necessary to complete the Health Impact Assessment.

City-specific analysis

For the city-specific analyses a Generalized Equation Estimation (GEE) approach was proposed as an extension of Generalized Linear Models to analyze longitudinal data, when the observations on different subjects (clusters) can be assumed independent and the observations on the same subject correlated.[25]

For each city, there was an outcome variable (number of deaths or hospital admissions) and several covariates (confounders, apparent temperature, other meteorological variables), observed on different days. A marginal Poisson distribution of the dependent variable and correlation between observations during one summer (winter) were assumed, while observations from different summer (winter) periods were considered independent.

An exploratory analysis indicated the appropriate dependence structure within a season to be used in the GEE. Dynamic regression models were combined with a genetic algorithm for the semi-automatic selection of the best model over a large model space, covering different specifications of the correlation structure within a cluster.[26]

A first order autocorrelation structure within a season resulted to be appropriate both for mortality and hospital admissions.

The common model applied to single city analysis took into account potential confounding effects of holidays, day of the week, seasonality and long-term time trend, barometric pressure, wind speed and air pollution levels, all modeled in parametric terms.

An indicator of influenza epidemics was included in the model for cold season analyses (except for respiratory causes).[27] Models for hospital admission analysis in the warm season included the moving average of total admission counts (ICD 9: <800) to offset population reduction during summer holidays.

Exposure modeling

Based on the results of previous studies, the maximum apparent temperature of current and previous 3 days (lag 0-3) for the warm season and lag 0-15 for the cold season was chosen as the indicator of exposure; the delayed effect of the exposure was further investigated by distributed lag models in a sensitivity analysis.

The shape of the exposure-response curve between apparent temperature and log mortality/hospital admission rate was investigated, with a flexible approach, introducing a cubic regression spline for apparent temperature into the model.

For mortality, during the warm season a “turning point” or “threshold” was identified. The effect of high temperatures on summer mortality was also investigated focusing on the slope above the city-specific threshold of the exposure-response curve. City-specific thresholds were obtained a priori by a maximum likelihood approach, treating the apparent temperature corresponding to the minimum of exposure-response curve as an unknown parameter.[28]

For hospital admissions the effect of high temperatures in summer was investigated using a dummy variable for maximum apparent temperatures above the 90th percentile.

The delayed effect of exposure on health outcomes was investigated using constrained and unconstrained distributed-lag models that simultaneously included variables for the same day and up to 5, 10, 15, 20, 25, 30 and (for hospital admissions) 40 days.

The impact of high temperatures on mortality was investigated with health risk assessment analyses.

Pooled analysis

In the second stage, the city-specific effect estimates were combined to obtain pooled estimates. Overall exposure-response curves were obtained through a fixed effect meta-analytical approach using the pooled data set and through a second stage meta-analytical approach,[29] while the city-specific effect estimates and the city-specific curves for distributed-lag and time-varying effects were pooled by a hierarchical Bayesian modeling approach.

To reduce heterogeneity, pooled results were obtained grouping the cities, according to a priori defined meteorological and geographical criteria, distinguishing between Mediterranean cities and Continental/North Atlantic cities.

Second stage models including potential effect modifiers as covariates were applied in order to explore heterogeneity. Such effect modifiers included variables on climate and health of the population, variables on air pollution levels and the correlation between air pollution concentrations and the meteorological variables.

Confounding and synergistic effect of meteorological and air pollution variables

Based on the models defined in the city-specific and pooled analysis, further exploration of the confounding effects of air pollutants was carried out. Possible effect modification of the temperature-mortality effect by air pollutant levels was investigated using meta-regression models.

Heat/health watch warning system (HHWWS)

In five cities (Rome, Barcelona, London, Paris, Budapest), experimental heat/health watch warning systems were developed based on the results of the time series analysis. An air-mass-based climatologic index was developed, using a synoptic climatologic approach. Feeding the forecast data for upcoming days (up to 72 hours) into the model, can predict the arrival of an oppressive air mass.

Public health policies

An overview of existing prevention programs in the participating cities was obtained by the implementation of a questionnaire. Moreover, physiological and behavioral adaptation measures, experiences with heat health warning systems, urban planning, housing standards, and socio-economic determinants of vulnerability were summarized in a comprehensive literature review. The quantification of the effect of heat/air masses exposures in the different populations was addressed through health impact assessment (years-of-life-lost approach).

Results and Discussion

While previous studies focused on single cities, the present project investigated the health impact of weather on a large scale through a variety of climate conditions and of socio-economic and demographic characteristics, applying the same methodology, thus allowing for comparison between the city specific results.

Previous studies showed that the temperature level corresponding to the minimum mortality level varies from city to city and across different latitudes according to the local climate and probably reflecting adaptation by the local population to the temperature range in both the hot and cold season.[12] [20] [30][31][32][33][34] The analysis of the heterogeneity of the effect in European areas was accounted for in the present project, describing city-specific “change points” of the dose-response relationship and the specific shape of the dose-response curves. In the pooled analysis, heterogeneity was reduced grouping the cities according to a priori geographical and meteorological characteristics.

Few studies have examined the effect of heat on outcomes other than mortality. In Chicago, during the July 1995 heat wave an 11% increase in hospital admissions was observed, with 35% of the increase among patients over 65 years.[35] More recently, studies performed in London and 12 US cities reported an increase of admissions for specific causes in the elderly and evidence of a harvesting effect.[8][9] To date, the present study is the largest one to investigate weather and hospital admissions in Europe.

In the present study, the role of meteorological variables other than temperature was investigated, assuming that they may contribute to the negative health effects.[22][24] Therefore, an exposure indicator including dew point temperature was chosen for the time series analysis,[36][37] and the excess mortality/morbidity associated with specific air masses was explored using a climatologic classification based on synoptic indexes.[38][39][40]

This project focused on time series rather than on heat wave episodes, using an approach, that has been successfully used in the analyses of the effects of air pollution. Such methods have the advantage that the population under study serves as its own control, and covariates that vary between subjects, but not over time, are not potential confounders.[39][40]

Evidence that the increase in mortality is followed by a deficit that (partly) compensates the negative effect (harvesting) is contradictory.[41] In the present study the heterogeneity of mortality/morbidity displacement patterns between cities was systematically investigated.

There is much disagreement in literature concerning human acclimatization to changing weather.[22] [36] [42][43] While the issue was examined by comparing the threshold temperature in different geographic locations, the possibility of a short-term acclimatization was also evaluated by comparing the dose-response function in the first period of the summer with the effects modeled in the later part of the season. This allowed also for comparison of the impact of the first heat wave in one summer with the following ones.

Given the small number of events (mortality and admissions), a unique definition of winter and summer season was chosen in order to reach a reasonable statistical power, and sensitivity analysis was performed, focusing on the three central summer months (June-August).

The relationship between increase in air pollution levels and acute health effects has been well described in the USA and in Europe.[40] [11] The levels of some of the pollutants associated with increase in mortality and hospital admissions are higher during the summer period in many European areas. A synergistic effect of warm temperature and air pollution on mortality has been suggested from time series analysis conducted in Athens, whereas no effect modification detected in a study in Philadelphia, USA.[44][45] The present study investigated the independent effect of meteorological variables of that of ambient air pollution, and explored whether there is synergy between the two factors.

The development and evaluation of HHWWS in a subset of European cities represents an innovation in the field of climate and health research in Europe. After the 2003 heat wave, the need for early warning systems based on a standardized protocol and using the same evaluation criteria has become a major topic of public health policies.

These results of the health impact assessment will contribute to policy development, public health decision-making, and will be an important input for cost-benefit analysis and risk communication.

Guidelines for preventive strategies and health care actions taken to lessen morbidity and mortality effects can then be based on evidences arising from this project, namely the literature review, the investigation of the state-of-the-art in the participating cities (feasibility), and the identification of susceptible populations.

Conclusions

The PHEWE project offers the opportunity to investigate the relationship between temperature and mortality in 16 European cities, representing a wide range of climatic, socio-demographic and cultural characteristics; the use of a standardized methodology allows for direct comparison between cities. The analysis of the effect of weather on hospital admissions in 12 cities is an innovation in Europe. The evidence arising from the project's results, namely the literature review, the investigation of the state-of-the-art in the participating cities (feasibility), and the identification of susceptible populations (target groups), offer an important contribution for guidelines for preventive strategies and health care actions taken to lessen morbidity and mortality effects. The results of this project contribute to policy development, public health decision-making, and will be an important input for cost-benefit analysis and risk communication.

References

1. McMichael AJ: Global Environmental Change and Human Population Health: A Conceptual and Scientific Challenge for Epidemiology. *Int J Epidemiol* 1993, 22(1):1-8.
2. Meehl GA, Zwiers F, Evans J, Knutson T, Mearns L, Whetton P: Trends in extreme weather and climate events: issues related to modelling extreme in projections of future climate change. *Bull Amer Meteor Soc* 2000, 81:427-36.
3. WHO/WMO/UNEP: *Climate and health: The potential impacts climate change*. Geneva, Swizterland; 1996.
4. Basu R, Samet J: Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev* 2002, 24:190-202.
5. Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA: Temperature and mortality in 11 cities of the Eastern United States. *Am J Epidemiol* 2002,155:80-87.
6. Keatinge W, Donaldson G: Mortality Related to Cold and Air Pollution in London after Allowance for Effects of Associated Weather Patterns. *Environ Res 2001:* Section A[86], 209-216.
7. Eurowinter Group: Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, repiratory disease, and all causes in warm and cold regions of Europe. *Lancet* 1997,349:1341-1346.
8. Kovats RS, Hajat S, Wilkinson P: Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. *Occup Environ Med* 2004, 61(11):893-8.
9. Schwartz J, Samet JM, Patz JA Hospital admissions for heart disease: the effects of temperature and humidity. *Epidemiology* 2004, 15(6):755-61.
10. Katsouyanni K, Schwartz J, Spix C, Touloumi G, Zmirou D, Zanobetti A, Wojtyniak B, Vonk JM, Tobias A, Ponka A, Medina S, Bacharova L, Anderson HR: Short term effects of air pollution on health: a European approach using epidemiologic time series data: the APHEA protocol. *J Epidemiol Community Health* 1996, 50 Suppl 1:S12-8
11. Katsouyanni K, Touloumi G, Spix C, Schwartz J, Balducci F, Medina S, Rossi G, Wojtyniak B, Sunyer J, Bacharova L, Schouten JP, Ponka A, Anderson HR: Short term effect of ambient sulphur dioxide and particulate matter on mortality in 12 cities: results from time series date from the APHEA project. Air Pollution and Health: a European Approach. *BMJ* 1997, 314(7095):1658-63.

12. Ballester F, Corella D, Perez-Hoyos S, Saez M, Hervas A: Mortality as a function of temperature. A Study in Valencia, Spain, 1991-1993. *Int J Epidemiol* 1997, 26:551-561.
13. Kunst AE, Looman C, Mackenbach J: Outdoor air temperature and mortality in the Netherlands: a time-series analysis. *Am J Epidemiol* 1993, 137:331-341.
14. Rooney C, McMichael AJ, Kovats RS, Coleman MP: Excess mortality in England and Wales. And in Greater London, during the 1995 heatwave. *J Epidemiol Community Health* 1998, 52:482-486.
15. Keatinge WR, Coleshaw SR, Cotter F, Mattock M, Murphy M, Chelliah R: Increased platelet and red cell counts, blood viscosity, and arterial pressure during mild surface cooling: factors in mortality from coronary and cerebral thrombosis in winter. *BMJ* 1984, 289:1405-08.
16. Keatinge WR, Coleshaw SR, Easton JC, Cotter F, Mattock MB, Chelliah R: Increased Platelet and Red Cell Counts, Blood Viscosity, and Plasma Cholesterol Levels during Heat Stress, and Mortality from Coronary and Cerebral Thrombosis. *Am J Med* 1986, 81:795-800.
17. Kilbourne EM: The Spectrum of Illness During Heat Waves. *Am J Prev Med* 1999, 6[4]: 359-360.
18. Michelozzi P, de' Donato F, Accetta G, Forastiere F, D'Ovidio M, Perucci CA: Impact of Heat Waves on Mortality - Rome, Italy, June-August 2003. *JAMA* 2004, 291(21):2537-2538.
19. Schwartz J: Who is sensitive to extremes of temperature? A case-only analysis. *Epidemiology* 2005, 16:67-72.
20. Saez M, Sunyer J, Castellsague J, Murillo C, Anto JM: Relationship between weather temperature and mortality: a time series analysis approach in Barcelona. *Int J Epidemiol* 1995, 24:576-582.
21. Braga ALF, Zanobetti A, Schwartz J: The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. *Environ Health Perspect* 2002, 110:859-863.
22. Steadman RG: The assessment of sultriness: Part I: A temperature-humidity index based on human physiology and clothing science. *J Appl Meteorol* 1979, 18:861-873.
23. Kalkstein LS, Valimont KM: An evaluation of summer discomfort in the United States using a relative climatological index. *Bull Am Meteorolog Soc* 1986, 67:842-8.
24. Steadman RG: The assessment of sultriness. Part II: effects of wind, extra radiation and barometric pressure on apparent temperature. *J Appl Meteorology* 1979, 18: 874–885.
25. Liang KY, Zeger SL: Longitudinal analysis using generalized linear models. *Biometrika* 1986, 73: 13-22.
26. Chiogna, M, Gaetan G: Mining epidemiological time series: an approach based on dynamic regression. Statistical modelling 2005, 5:309-325.
27. Touloumi G, Samoli E, Quenel P, Paldy A, Anderson RH, Zmirou D, Galan I, Forsberg B, Schindler C, Schwartz J, Katsouyanni K: Short-term effects of air pollution on total and cardiovascular mortality: the confounding effect of influenza epidemics. *Epidemiology* 2005 Jan 16, 1:49-57.
28. Muggeo VM: Estimating regression models with unknown break-points. *Stat Med* 2003 Oct 15, 22(19):3055-71.
29. Samoli E, Touloumi G, Zanobetti A, Le Tertre A, Schindler C, Atkinson R, Vonk J, Rossi G, Saez M, Rabczenko D, Schwartz J, Katsouyanni K: Investigating the dose-response relation between air pollution and total mortality in the APHEA-2 multicity project. *Occup Environ Med* 2003 Dec, 60(12):977-82.
30. Alberdi JC, Diaz J, Montero JC, Miron I: Daily mortality in Madrid community 1986-1992: relationship with meteorological variables. *Eur J Epidemiol*. 1998 Sep, 14(6):571-8.

31. Diaz J, Garcia R, Velazquez de Castro F, Hernandez E, Lopez C, Otero A: Effects of extremely hot days on people older than 65 years in Seville (Spain) from 1986 to 1997. *Int J Biometeorol* 2002, 46:145-149.
32. Keatinge WR, Donaldson GC, Cordioli E, Martinelli M, Kunst AE, Mackenbach JP, Nayha S, Vuori I: Heat related mortality in warm and cold regions of Europe: observational study. *BMJ* 2000, 321:670-673.
33. Hajat S, Kovats RS, Atkinson RW, Haines A: Impact of hot temperatures on death in London: a time series approach. *J Epidemiol Community Health* 2002, 56:367-372.
34. Michelozzi P, Fano V, Forastiere F, Barca A, Kalkstein LS, Perucci CA: Weather conditions and elderly mortality in Rome during summer. *WMO Bulletin* 2000, 49:348-55.
35. Semenza JC, McCullough JE, Flanders WD, McGeehin MA, Lumpkin JR: Excess hospital admissions during the July 1995 heat wave in Chicago. *Am J Prev Med* 1999 May, 16(4):269-77.
36. Kalkstein LS, Davis RE: The development of a weather/mortality model for environmental impact assessment. *Proceedings of the 7th Conference of Biometeorology and Aerobiology 1985a*, 334-336.
37. Kalkstein LS, Jamason PF, Greene JS, Libby J, Robinson L: The Philadelphia Hot Weather-Health Watch/Warning System: Development and Application, Summer 1995. *Bull Am Meteorol Soc* 1996, 1519-28.
38. Kalkstein LS: A new approach to evaluate the impact of climate on human mortality. *Environ Health Perspect* 1991, 96:145-50.
39. Schwartz J: Air pollution and daily mortality: a review and meta-analysis. *Environ Research* 1994, 64:36-52.
40. Schwartz J: Non-parametric smoothing in the analysis of air pollution and respiratory illness. *Can J Stat* 1994, 22:471-87.
41. Hajat S, Armstrong BG, Gouveia N, Wilkinson P: Mortality displacement of heat-related deaths. A comparison of Delhi, Sao Paulo, and London. *Epidemiol* 2005, 16:613-620.
42. Rotton J: Angry, sad, happy? Blame the weather. *U.S. News and World Report* 1983, 95:52-53.
43. Ellis FP: Mortality from heat illness and heat-aggravated illness in the United States. *Environ Research* 1972, 15:504-512.
44. Katsouyanni K, Pantazopoulou A, Touloumi G, Tselepidaki I, Moustris K, Asimakopoulos D, Poulopoulou G, Trichopoulos D: Evidence for Interaction between Air Pollution and High Temperature in the Causation of Excess Mortality. *Arch Environ Health* 1993, 48(4):235-42.
45. Kalkstein LS, Greene JS: An evaluation of climate/mortality relationships in large U.S. cities and the possible impacts of a climate change. *Environ Health Perspect* 1997, 105(1):84-93.

Table 1. PHEWE cities: characteristics and data series available

City	Characteristics			Health data - Time series used	
	Population	% 75+	Mortaliy rate (x 100.000)*	Mortality	Hospital Admissions
Athens	3 188 305	6.4	663.6	1992-1996	
Barcelona	1 512 971	10.1	542.5	1992-2000	1994-1997
Budapest	1 797 222	7.3	1093.6	1992-2001	1997-2000
Dublin	481 854	5.3	826.7	1990-2000	1994-2001
Helsinki	955 143	5.0	590.0	1990-2000	
Krakow	741 510	8.9**	805.4	1990-1996	
Ljubljana	263 290	5.9	719.1	1992-1999	1997-1999
London	6 796 900	6.8	584.5	1992-2000	1992-2000
Milan	1 304 942	9.5	439.4	1990-2000	1990-1999
Paris	6 161 393	6.1	554.0	1991-1998	1991-1995
Prague	1 183 900	7.0	779.4	1992-2000	
Rome	2 812 573	7.3	497.4	1992-2000	1998-2000
Stockholm	1 173 183	8.5	576.2	1990-2000	1990-2000
Turin	901 010	9.2	479.5	1991-1999	1995-1999
Valencia	739 004	7.6	595.6	1995-2000	1996-2000
Zurich	990 000	n.a.	n.a.	1990-1996	1990-1996

* adjusted for gender and age
** >=70 years

Table 2. Mortality data: daily mean and standard deviation (sd) by cause and season.

	Total mortality (ICD-IX < 800.0)				Cardiovascular (ICD-IX: 390-459)				Cerebrovascular (ICD-IX: 430-438)				Respiratory (ICD-IX:460-519)			
	Summer*		Winter**		Summer*		Winter**		Summer*		Winter**		Summer*		Winter**	
	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*
Athens	67.46	10.79	78.26	13.18	32.62	7.58	39.46	8.4	-	-	-	-	4.19	2.21	5.08	2.57
Barcelona	35.89	6.58	42.75	9.17	12.96	3.96	16.58	5.11	3.61	2.01	4.45	2.07	3.08	1.88	4.71	3.07
Budapest	70.99	11.01	79.82	13.38	34.89	7.32	40.9	8.92	70.97	11	79.8	13.36	2.22	1.6	3.12	2.24
Dublin	11.42	3.45	13.62	4.12	4.91	2.19	5.98	2.57	0.99	1.01	1.23	1.1	11.42	1.25	2.12	1.68
Helsinki	17.05	4.18	18.45	4.6	8.23	2.96	8.81	3.1	2.42	1.56	2.66	1.65	1.37	1.18	1.79	1.47
Ljubljana	6.29	2.58	7.06	2.89	2.55	1.63	3.03	1.84	0.63	0.8	0.73	0.86	0.36	0.62	0.53	0.75
London	149.01	16.45	179.23	29.35	60.96	10.51	73.5	13.62	14.14	4.2	16.91	4.71	23.73	6	36.58	15.79
Milan	26.3	5.87	31.86	7.17	9.85	3.41	13.21	4.22	2.88	1.78	3.58	1.97	1.65	1.38	2.54	1.93
Paris	115.69	13.84	128.17	16.44	34.81	6.57	40.01	7.91	-	-	-	-	7.69	3.06	10.33	4.15
Prague	34.94	6.51	38.52	7.49	20.27	4.87	22.66	5.62	5.64	2.62	6.19	2.72	1.12	1.09	1.53	1.32
Rome	52.81	9.55	61.71	10.48	20.92	5.52	26.62	6.46	4.87	2.36	5.79	2.6	2.58	1.72	3.73	2.52
Stockholm	27.85	5.41	30.81	6.3	13.47	3.84	14.93	4.28	2.96	1.72	3.34	1.81	2.15	1.5	2.76	1.88
Turin	19.14	4.65	23.18	5.35	7.91	3.01	10.3	3.49	2.71	1.67	3.34	1.9	1.02	1.04	1.62	1.44
Valencia	14.64	4.11	17.92	5.27	5.28	2.41	6.97	2.94	1.57	1.27	1.91	1.46	1.37	1.2	2.09	1.76
Zurich	11.63	3.52	13.53	3.84	5.24	2.36	6.31	2.59	-	-	-	-	0.6	0.79	1.01	1.09

note: * April-September, ** October-March

Table 3. Hospital admission data: daily mean and standard deviation (sd) by cause and season.

City	**Cardiovascular** *(ICD-IX: 390-459)*				**Cerebrovascular** *(ICD-IX: 430-438)*				**Respiratory** *(ICD-IX:460-519)*			
	Summer*		Winter**		Summer*		Winter**		Summer*		Winter**	
	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*	mean	*sd*
Barcelona	21.8	*6.0*	25.9	*6.3*	5.0	*2.3*	5.6	*2.4*	15.9	*5.3*	23.5	*7.6*
Budapest	110.8	*50.1*	119.1	*50.0*	14.5	*7.5*	15.2	*7.6*	25.7	*10.0*	37.0	*15.3*
Dublin	25.9	*6.4*	27.3	*6.7*	5.1	*2.4*	5.5	*2.4*	22.6	*5.7*	30.3	*10.4*
Ljubljana	11.2	*4.9*	12.4	*5.4*	1.5	*1.2*	1.6	*1.3*	6.7	*4.4*	8.2	*4.6*
London	163.8	*31.8*	171.2	*34.7*	28.3	*6.8*	30.0	*7.5*	125.2	*25.3*	178.6	*52.7*
Milan	71.2	*26.3*	81.6	*24.7*	14.0	*5.1*	15.2	*4.9*	25.6	*10.4*	34.4	*11.1*
Paris	126.5	*45.3*	146.5	*44.3*	n.a.	*n.a.*	n.a.	*n.a.*	59.0	*19.4*	85.0	*22.7*
Rome	120.3	*27.0*	133.6	*26.1*	25.1	*6.1*	26.7	*6.0*	43.1	*11.4*	63.2	*18.3*
Stockholm	48.0	*12.1*	50.8	*12.2*	10.4	*3.6*	10.9	*3.7*	18.3	*6.1*	24.2	*7.9*
Turin	25.2	*6.4*	28.5	*6.8*	7.2	*2.8*	7.7	*2.9*	10.1	*4.0*	15.9	*6.4*
Valencia	12.4	*4.1*	13.6	*4.6*	3.1	*1.8*	3.2	*1.9*	9.2	*3.6*	14.4	*5.6*
Zurich	8.2	*3.4*	9.1	*4.9*	n.a.	*n.a.*	n.a.	*n.a.*	n.a.	*n.a.*	n.a.	*n.a.*

* April-September, ** October-March

Table 4a. Metereological data: daily mean values (mean, minimum and maximum) summer period (April-September).

	temperature (°C)			relative humidity (%)			sea level pressure (hPa)			wind speed (m/s)			max apparent temperature (°C)		
CITY	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**
Athens	23.5	7.6	34.3	57	23	89	1013.0	945.8	1031.3	3.3	0.3	11.6	27.9	7.9	41.6
Barcelona	21.7	8.6	34.2	66	29	99	1015.2	993.7	1030.6	6.7	0.9	22.3	23.3 *	6.5*	36.9*
Budapest	18.2	1.5	29.8	61	30	97	1014.5	992.6	1033.6	2.6	0.7	8.8	21.9	0.2	38.8
Dublin	12.5	1.4	21.0	81	53	100	1014.8	974.7	1038.5	4.7	1.1	12.0	14.7	1.5	28.5
Helsinki	12.0	-6.5	25.4	71	28	98	1012.7	982.9	1035.6	3.6	0.9	9.6	14.3	-3.7	32.8
Krakow	15.0	-1.6	26.6	77	45	98	1015.7	991.1	1033.1	2.3	0.0	10.1	19.1	-2.3	35.8
Ljubljana	15.9	0.6	26.5	75	33	98	970.8	949.2	985.4	1.6	0.2	7.0	20.1	-1.7	35.4
London	15.1	3.2	28.0	71	42	96	1015.5	984.1	1036.3	3.4	0.7	9.3	18.1	1.5	35.2
Milan	20.0	2.5	29.4	72	26	100	1014.2	991.5	1031.9	1.7	0.0	9.4	25.4	2.7	40.8
Paris	16.1	2.1	30.2	72	32	100	1015.9	988.1	1032.9	4.0	1.0	11.9	19.7	1.5	39.4
Prague	15.1	-1.7	28.7	70	31	98	972.5	947.0	990.4	3.8	0.3	12.0	17.8	-3.3	36.3
Rome	20.5	6.1	30.3	72	25	94	1014.2	992.6	1031.8	3.1	0.5	12.5	26.1	5.9	40.5
Stockholm	12.8	-3.2	26.6	72	36	99	1012.9	985.6	1036.1	3.3	0.6	8.1	15.4	-2.1	34.0
Turin	18.5	3.0	27.9	74	32	97	1014.2	993.0	1032.0	1.4	0.0	7.7	23.4	4.2	45.8
Valencia	22.3	10.5	30.0	66	32	92	1015.1	995.1	1030.9	3.3	1.1	9.9	29.5	10.6	44.9
Zurich	15.1	1.4	26.2	73	42	97	1016.4	993.2	1034.6	2.1	0.2	6.0	19.0	0.7	35.2

Table 4b. Metereological data: daily mean values (mean, minimum and maximum) winter period (October-March).

	temperature (°C)			relative humidity (%)			sea level pressure (hPa)			wind speed (m/s)			max apparent temperature (°C)		
CITY	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**
Athens	13.1	0.7	26.5	70	35	92	1018.2	988.9	1035.7	3.2	0.0	12.8	14.8	0.8	34.1
Barcelona	13.4	1.9	25.2	69	37	100	1018.3	990.2	1038.2	7.0	0.0	22.1	12.3*	0.2*	27.9*
Budapest	4.0	-12.1	19.5	77	36	100	1019.7	988.9	1045.7	2.6	0.5	8.6	5.0	-9.7	25.7
Dublin	7.0	-4.2	17.8	85	54	100	1012.2	971.1	1046.3	6.0	0.6	17.5	7.5	-4.6	19.8
Helsinki	-0.9	-24.1	14.7	85	44	99	1010.8	949.5	1054.4	4.1	0.1	11.5	-0.7	-14.5	14.8
Krakow	2.3	-21.4	17.9	86	53	100	1019.2	987.7	1046.9	2.8	0.0	11.5	3.3	-14.4	25.4
Ljubljana	3.0	-13.3	18.4	83	26	100	973.5	939.8	995.5	1.3	0.0	8.0	4.4	-9.9	24.3
London	7.5	-5.2	18.9	81	52	100	1016.1	978.6	1044.3	3.7	0.4	12.5	8.4	-5.6	24.5
Milan	7.1	-6.5	22.7	81	20	100	1019.1	986.8	1041.0	1.3	0.0	9.4	8.8	-6.3	32.6
Paris	6.9	-10.7	20.0	84	37	100	1018.1	983.3	1044.8	4.8	0.5	14.6	7.7	-9.2	25.4
Prague	2.5	-19.7	19.0	84	42	100	973.8	974.5	996.8	4.6	0.0	16.3	2.6	-13.4	22.5
Rome	10.5	-2.0	25.8	80	34	98	1017.1	990.4	1039.1	3.2	0.3	13.1	13.5	-1.0	41.5
Stockholm	1.3	-16.7	15.8	85	44	99	1010.9	947.9	1049.1	3.7	0.3	10.3	1.3	-12.9	19.4
Turin	6.0	-6.9	20.2	76	25	99	1019.5	989.2	1041.4	1.1	0.0	9.5	8.1	-5.9	29.5
Valencia	13.7	3.4	26.0	69	29	98	1018.7	993.5	1034.8	3.1	0.3	12.2	18.1	3.2	35.9
Zurich	4.0	-11.7	17.0	82	44	98	1020.7	987.2	1044.6	2.4	0.5	10.3	4.8	-9.2	23.5

* for Barcelona the mean apparent temperature is reported

3. Analysis of the meteorological data and development of synoptic indices

On the association between daily mortality and air mass types in Athens, Greece during winter and summer.

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Abstract

In this study we examined the short-term effects of air mass types on mortality in Athens, Greece in two ways: one independent and the other including temperature effects on air mass types. An ‘automated’ air mass types classification was used, based on meteorological parameters measured at the surface. Mortality data were treated with generalized additive models (GAM) and extending Poisson regression, using a LOESS smoother to control for the confounding effects of seasonal patterns, adjusting also for temperature, long-term trends, day of the week and ambient particle concentrations. The introduced air mass classification explains the daily variation of mortality to a statistically significant degree. The highest daily mortality was observed on days characterized by southerly flow conditions for both the cold (increase in relative risk for mortality 9%; with a 95% confidence interval: 3-14%), and the warm period (7%; with a 95% confidence interval: 2-13%) of the year. The southeasterly with extended cloudiness and the northeasterly flows are associated with the lowest mortality for winter and summer respectively. Effects on mortality, independent of temperature, are observed mainly for lag 0 during the cold period, but persist longer during the warm period. Not adjusting for temperature and/or ambient particle levels slightly alters the results, which then reflect the known temperature and particle effects, already reported in the literature. In conclusion, we find that air mass types have independent effects on mortality for both the cold and warm season and may be used to predict weather-related adverse health effects.

Introduction

The impact of weather on health and consequently on mortality has been known for centuries (Kilbourne, 1986). The occurrence of respiratory and heart diseases is related with cold weather leading to increased mortality of special sensitive population groups. Heat waves are also related to increases in mortality (Hadley and Webster, 1995; Rooney et al., 1998). Recently, Curriero et al (2002) found associations between extremely high or low temperatures and mortality in 11 cities of the eastern USA, while Garcia et al (2002; 2005) examined the health impacts of prevailing synoptic conditions associated with extreme summer temperatures in the Iberian peninsula. Kljakovic and Salmond, (1998) found relationships between the number of consultations for asthma and weather in New Zealand during a five years study. Projected global warming and climate change renewed the interest concerning the weather-mortality association. Guest et al (1999) applied a relationship, determined between recent climate conditions and mortality, to scenarios for climate and demographic change, to predict potential impacts on public health in Australian cities, for the year 2030. The temperature-mortality relationship is known to be ‘J-shaped’ because of the asymmetrical pattern of association with a rise in mortality counts that is steeper and rises more quickly for high rather than for low temperatures (Kunst et al., 1993). The temperature corresponding to the lowest observed mortality varies by latitude and topographical features. Thus, in Athens with latitude 38° N, it is at about 22°C (Touloumi et al., 1994), while in the Netherlands, with latitude about 53°N, it is at 16.5°C only (Kunst et al., 1993). Temperature and humidity (relative or dew point) have often been used to control for the confounding effects of weather in studies of air pollution and mortality (Katsouyanni et al., 1997).

Instead of using one or more separate meteorological variables examining possible relations between weather and mortality, investigators try to find indices combining more than one meteorological variable in an effort to express parsimoniously a variety of meteorological phenomena and thus assess simultaneously the effect of several meteorological variables on mortality. Composite indices have been developed such as human discomfort indices (Steadman, 1984), heat budgets (Jendrinski and Sievers, 1989) and synoptic climatological classifications (Kalkstein, 1991). One such index of the latter type represents a classification into air mass types, which contain all the appropriate meteorological information to characterize a day. Since it can be predicted two or three days in advance, it can be a very useful tool for providing valuable information to public health authorities. Synoptic weather systems, characterizing the prevailing weather systems in an area, have been correlated with human health effects.

There are different methods to categorize air masses. In the past manual methods were more common but now due to the high-speed computers automated methods have been popular. Both methods of classification have limitations; manual methods are time consuming, depended by the researcher and difficult to reproduce while automated methods may not produced easily interpretable results. Recent methods have incorporated the advantages of both methodologies into a hybrid scheme. Among others Kassomenos et al (1998) introduced a manual method to classify the synoptic circulation types over Athens, using 12-y meteorological data. Kassomenos et al (2001) examined the correlation of 8 a-priori defined and manually estimated synoptic circulation types at 850 and 700 hPa, with mortality in Athens, Greece.

During the recent years automated methods have come to a wide use. Specifically, Kalkstein (1991) proposed a synoptic weather classification system based on air mass type and evaluated the impact of meteorological conditions on human mortality. This system was employed for St. Louis, USA and used surface meteorological data and principal component and cluster analyses statistical techniques. He found that the worst categories are characterized by warm and humid southern air flow coming from the Caribbean Sea.

McGregor (1999) investigated the relationship between winter ischaemic disease deaths and weather, using a synoptic climatological approach for Birmingham, UK. He found that strong south flow characterized by high temperatures and humidity coming from Atlantic, combined with rapid changes in temperature, is associated with increased mortality from ischaemic heart episodes during winter. Similar conditions have been found to be associated with mortality increases in Barcelona, Spain (Saez et al., 1995) and Birmingham, Alabama, US (Kalkstein and Davis, 1989). Pope and Kalkstein (1996) and Samet et al (1998) estimated the association between ambient particulate matter and daily mortality in Utah valley and Philadelphia respectively, using a synoptic approach to control for potential confounding weather effects. The objective of these studies focused on air pollution rather than on weather effects.

Since these methods (manual and automated) develop different number of categories for one city vs. another we can not make direct comparisons from place to place about the weather types produced. Recently Sheridan, (2002) redeveloped a weather type classification scheme for North America extending the initial work of Kalkstein et al (1996). This system (Spatial Synoptic Classification System) is a hybrid one and classifies each day at a location into six weather types or a transition between two weather types. With this system direct comparison of the weather types from place to place could be done.

Whereas temperature is one of the most significant factors that affect the human mortality, as previously stated in numerous studies, the focus of the present paper is to examine the effects of air mass types on mortality in 2 ways: one independent of temperature effects, i.e. the effects of all other meteorological variables combined in the air mass type were assessed, and the other was including the temperature effects.

We examine the associations between air mass types and mortality in Athens, Greece for the period 1987-1991, using an automated air mass classification scheme, similar to the one used by Kalkstein et al (1991), developed using surface level data by Kassomenos et al (2003). This system was produced using surface meteorological data collected between 1954-1999 in the area of Athens. These data were classified in 8 and 6 weather types for winter and summer respectively using Principal Component and Cluster Analysis. Prior to the final adoption of the weather types they examined in terms of their physical interprentation. This classification system differs from the one employed in Kassomenos et al (2001) in the procedures followed and the number of resulting synoptic categories. In the classification system of Kassomenos et al (2001), described in detail in Kassomenos et al (1998,) the 12-y daily weather maps (1983-1995) at 850 and 700 hPa levels were attributed manually to 8 a priori defined weather types by two independent observers. It is therefore interesting to see the associations of the synoptic categories, resulting from this more "objective" process, with mortality in Athens and compare them with previous results derived with a different type of synoptic classification.

Data and Methods

Athens is situated in a small peninsula located in the southeastern edge of the Greek mainland (central Greece). It covers about 450 Km^2 and has about 4,000,000 inhabitants. The built up area is mainly located in a basin, surrounded by tall mountains from three sides and open to the sea from the south. There are small openings connecting the Metropolitan area of Athens with the rest of Greek mainland to the north, northwest and northeast of the basin. In Athens, more than 2,000,000 cars are registered while industrial activities are mainly located in the west and southwest of the basin (Katsoulis and Kassomenos 2004).

The climate of the area is Mediterranean with hot, dry summers and moderately wet, mild winters. The mean daily temperature for winter is 10.2oC and the daily minimum temperature drops below 0oC only for a few days every year. In summer, the mean daily air temperature is 26.2oC, and the average daily maximum temperature is higher than 31.0oC. Solar radiation income is strong with daily values of the order of 22 MJ/m2 in summer and 8 MJ/m2 in winter (Katsoulis and Kassomenos 2004).

For the extraction of the air mass types we used daily values of 11 meteorological parameters recorded in the National Observatory of Athens (NOA) at the surface for the period 1954-1999. These parameters are: mean, maximum and minimum air temperature (T_{mean}, T_{max}, T_{min}), diurnal temperature range (T_{range}), total solar radiation (SR), mean relative humidity (RH), mean water vapor pressure (e), mean atmospheric pressure (P), arithmetic mean wind speed (WS) and mean wind velocity components of W-E and S-N directions (u and v respectively) (Kassomenos et al. 2003).

The number of daily non-accidental deaths, for the period January 1st 1987 to December 30th 1991 (a total of 1826 days) was recorded from the Athens Town Registry and the registries of all towns contiguous to Athens (19 town registries) (Touloumi et al 1994). In July 1987, in Athens, there was a 9-day heat wave characterized by maximum daily temperatures greater than 35°C (>40°C on 6 days). The total number of daily deaths increased by more than 100% during this month. Since this period is a climatic outlier, we did our analyses both including it and excluding it from the time series.

Enhanced concentrations of particulates are associated with health effects (Katsouyanni et al 2001; Pope and Kalkstein, 1996; Samet et al., 1998). Ambient particles in Athens were measured during the study period by the method of black smoke (BS), a photometric index assessed on the basis of black particles with aerodynamic diameter < 4.5 micrometers. The air pollution measurements (daily values of BS for the time period 1987-1991) were provided by the Monitoring Network operated by the Ministry of Environment, Planning and Public Works (Ministry of Environment, 1989). BS is measured by the method of the Organization for Economic Cooperation and Development (WHO, 1997). In order, for the pollution time series to be more representative, we used the average daily measurements of three fixed sites (Patision, Aristotelous, Piraeus) for BS (24 hour level in $\mu g/m^3$). These stations cover the study area and are representative of the population exposure (Touloumi et al., 1994). During this period, BS exceeded the World Health Organization 1997 air quality guideline (125 $\mu g/m^3$) on 42% of the days, in the center of Athens (Patision) where the highest levels were observed. Missing values in each station were completed as described by Katsouyanni et al (1996).

Weather effects were accounted for using an air mass classification, originally developed in Kassomenos et al (2003). P-mode principal components analysis, using varimax rotation, was used to reduce the number of variables of the original meteorological data and in a second stage the non-hierarchical k-means clustering analysis, which allows the rearrangement of the observations after they have been classified into a group, gave an optimized final classification. The air mass classification was applied separately for two sub-periods of the year. The first includes the days from 16 October to 15 April (8090 days consisting the cold period) and the second includes the days from 16 April to 15 October (8283 days consisting the warm period). This splitting is considered necessary, because of the different general and local atmospheric circulation regimes, characterizing the two seasons. The classification revealed 8 weather types for the cold period and 6 for the warm period of the year. The basic characteristics of each air mass type by season are briefly described in Tables 1 and 2 respectively. More details on the methods and data used may be found in Kassomenos et al (2003).

For the analyses investigating the effects of air mass types on mortality, we applied Generalized Additive Models (GAM), extending Poisson regression to model the non-linear effects of the covariates; we used a LOESS smoother to control for seasonal patterns and long term trends and allowed for overdispersion (Schwartz et al., 1996). All analyses were done in S-Plus, using stringent convergence criteria, as proposed by Dominici et al (2002).

We tested various smoothing parameters to remove the basic seasonality from the data. To choose among these, diagnostic tools including partial autocorrelation plots and plots of residuals over time were used to determine the smoothing parameter (i.e. the fraction of the data used for smoothing). We had decided in advance that the smoothing window should not be below 2 months in order to avoid eliminating short-term patterns, which may actually be due to the exposure under study (Kassomenos et al., 2001). After seasonal and long-term trends were controlled for, temperature was incorporated into the model. Smoothed functions of the same day and of lags up to 2 days or averaged over 1 to 3 days of daily mean temperature were investigated.

The inclusion of lagged temperature variables and the choice of smoothing parameters were done by minimizing Akaike's information criterion (Fujikoshi and Satoh, 1997). Then we added dummy variables to the model to control for day of the week. We included dummy variables for the air mass types. Finally, we included BS as a linear term, average of lags 0 and 1, in the model to adjust for air pollution potential confounding effects.

Tables 1 and 2 present the basic characteristics and the frequency of occurrence of air mass types over the study period, for the cold and warm period of the year respectively. For winter the most frequent air mass type was 7W (high atmospheric pressure-high diurnal temperature range- weak northern winds), while for summer these were 3S (low wind speed- high temperature range) and 4S (strong northern winds- low pressure and humidity). It can be seen that there is a seasonal variation in mortality and black smoke levels. Thus the mean daily number of deaths in the cold period is 39.8 whilst it is 34.1 for the warm period. Black smoke concentrations in the cold period exceed those in the warm by more than 20μg/m^3. Within the cold period, the daily number of deaths was increased during the weather type categories 7W, 4W (high humidity- SW flow – cloudiness) and 2W (strong and dry N-NW flow- cloudiness), while for summer during 3S and 4S.

Table 3 shows the relative risks for daily mortality for each air mass type, by season, adjusting for black smoke, temperature, long term and seasonal trends and day of the week, excluding the data for the July 1987 period. The air mass type with the smallest observed daily number of deaths (as seen in Tables 1 and 2) was chosen as a reference category for each of the periods: 5W (weak SW flow-high radiation levels- low relative humidity- high temperature range) for the cold and 2S (strong NE wind- low temperature and humidity) for the warm period. The highest risk for mortality for the cold period is observed during days with 4W (9% increase in the daily number of deaths with 95% CI: 3-14%). No other estimated relative risk is statistically significant for the day an air mass is observed (ie for lag 0). For lag 1, again the highest relative risk is for type 4W, but it does not reach the nominal level of statistical significance. No air mass type has an elevated relative risk for lag 2. For the warm period, the highest relative risk for mortality is observed during days with 6S (SW winds- high temperature and humidity) (7% increase in the daily number of deaths for lag 0 with 95% confidence interval (CI): 2-13%; 5% for lag1 , 95% CI 0-11% ; and 5% for lag 2, 95% CI 0-10%). Type 1S (weak SW flow during the day- warm and humid air masses) also has higher risks for mortality which are statistically significant at lags 0 and 1 (6% increase 95% CI 1-12% and 7% with 95% CI 1-13% in the daily number of deaths respectively). Relative risks estimated from models without adjustment for black smoke followed an identical pattern and were in some instances slightly higher (results not shown).

In Table 3 the effects of air mass types shown are adjusted for temperature, so the temperature effect within each type is estimated separately. Table 4 shows the relative risks for daily mortality for each air mass type, by season, adjusting for black smoke, long term and seasonal trends and day of the week, but not adjusting for temperature. For the cold season, the relative risks for mortality associated with all air mass types except 2W remain unchanged. 4W air mass type still presents the higher relative risk for mortality (8% increase in the daily number of deaths for lag 0 with 95% confidence interval (CI): 3-14%). For type 2W there is now an elevated risk, which is statistically significant for lag 0. The type 2W is associated with the lowest winter temperatures and extensive cloudiness (see Table 1) and this excess mortality is due to the cold temperature effect. When the temperature effect is accounted for, the other meteorological characteristics of this air mass type are not associated with additional excess mortality. For the warm season, the relative risks associated with the two air mass types which have the coolest temperatures (1S and 6S, see Table 2) is reduced as it now reflects the protective effect of cool summer temperatures on mortality, which were estimated separately when temperature was adjusted for. On the contrary, the risks associated with the warmest types (3S and 4S, see Table 2), are increased.

The analysis was done including the July 1987 period, which was characterized by unusually high temperatures. Adjusting for temperature, the relative risks estimated for mortality in the warm period, remained practically the same and the pattern of statistical significance remained identical. During the 1987 heat wave the air mass types observed were 3S (5 days) and 4S (4 days).

In all models, positive relative risks for mortality were associated with exposures to black smoke. Specifically, an increase of 10μg/m^3 was associated with about a 0.5% increase in the daily number of deaths.

Discussion

In this study we observed associations of daily air mass types with the daily number of deaths in Athens, Greece, an area with typical Mediterranean climate. We also adjusted for confounding effects of air pollution using ambient particles concentrations. Temperature effects on mortality are well established.

For the cold period of the year, the lowest mortality days are those with the 5W air mass type, characterized by dry conditions, local circulation cells, and relatively high radiation levels. The temperature is rather high for the winter and these meteorological conditions form pleasant conditions over Athens and are associated with decreased mortality. The most unfavorable air mass type during the cold period is 4W. Mortality during these days is elevated by almost 10% compared to category 5W. This air mass type is combined with high humidity levels, relatively strong southerly flow over Athens and extensive cloudiness. Another unfavorable air mass type is 6W, characterized by a relatively high temperature range. The humidity is very high, combined with almost stagnant conditions over Athens. Since the wind speed is very low, from southern directions, the air masses transported over Athens are coming from the Aegean Sea and consequently are humid enhancing the unpleasant conditions over Athens. The days characterized by air mass type 2W, also have significant elevated mortality. Air mass type 2W is characterized by extensive cloudiness and dry strong NW flow. It is further characterized by the lowest minimum temperature. These conditions are known for the formation of unpleasant conditions for sensitive groups of population (McGregor, 1999, McGregor and Kassomenos 2005). It is observed that the effects of the air mass types on mortality appear mainly on the same day (lag 0).

For the warm period of the year the lowest mortality days are those characterized by 2S which was used as the baseline air mass type to which all other were compared. This air mass type induces strong northeasterly flow, small water vapor pressure and relative humidity. The temperature range is the lowest. This type of flow contributes significantly to the ventilation of the atmosphere over Athens and is associated with decreased mortality. Categories 3S, 4S and 5S do not differ from 2S to a statistically significant degree, when the temperature effect is estimated separately. However, when the effect of temperature in included in the estimation, the warmest air mass types 3S and 4S are also associated with increased mortality. The most unfavorable air mass type for the warm season is 6S. The airflow is weak from SW directions during the daytime and is associated with the establishment of local circulations over Athens (e.g sea breezes). Sea breezes bring humid and relatively warm air masses over Athens. The meteorological characteristics of 6S lead to intense thermal discomfort conditions. Similar results were found for type 1S. This air mass type is characterized by relatively weak SW flow. The air masses over Athens are warm and humid and it seems to contribute to the establishment of unpleasant weather conditions. It should be noted that the effects of air mass type on mortality in the warm period appear on the same day (lag 0) and also persist on the next day and even 2 days later (lags 1 and 2).

The adjustment for temperature is an advantage of our analyses because it gives an estimate of the effect on mortality of the other –not studied so far- meteorological variables combined. The estimates including temperature, which are also provided, confirm the reported results (Curriero et al 2000) of the cold and heat associated effects on increasing mortality.

The comparison of crude (unadjusted) and adjusted daily number of deaths by air mass type shows that the contrast of about 10% is preserved during the cold period and is slightly lowered during the warm period when black smoke levels, seasonal patterns and day of the week are taken into account. For the cold season, types 5W and 3W have the lowest crude mortality followed by 6W and 8W and this rank is preserved after adjustment. However, category 7W has the highest crude daily number of deaths, whilst it has a low one after adjusting, presumably because it is the category with the highest black smoke levels and its elevated crude mortality is due to elevated black smoke. For the warm season, the lowest crude daily number of deaths is observed when categories 2S and 5S prevail, followed by all the other categories. When adjusting for black smoke levels, seasonal patterns, day of the week and temperature the highest adjusted mortality is observed in types 6S and 1S. From the comparison of the results of the different models presented, it is inferred that the high mortality during days with air mass types 3S and 4S is due to the high temperatures characterizing these types.

The air mass type classification used in the present paper is different from a previously reported one (Kassomenos et al 2001) which used manual categorization with a priori defined air mass types. The present classification is based on the meteorological data and produces air mass types which are based on the actual observations. Thus it is possible that these latter types are more specific to the local situation and may reflect better the associated health effects. A cross-classification of the two categorizations shows that there is no one to one correspondence of the derived types of air masses, however there is some overlap. A comparison of the results shows that the classification of Kassomenos et al (2001) also indicated that SW flow and zonal flow combined at the isobaric levels of 850 and 700 hPas, resulting in local circulations on the surface, are associated with enhanced relative risk for mortality in Athens but it failed to detect associations between strong NW flow and mortality. Moreover the southerly and southeasterly flow is not detected by the 'subjective' method. Both

Comparing the present findings with those of similar classifications in the USA (Kalkstein, 1991) and Europe (McGregor, 1999) it is seen that in all situations increased mortality is associated with warm and humid air masses.

In our analyses, we adjusted also for a measure of particulate matter pollution, black smoke. The results confirm the independence of the effects of weather and air pollution on mortality. This implies that for each synoptic category for which an effect on mortality is found, this is independent of the corresponding air pollution levels. The results are consistent with those reported in the literature (Pope and Kalkstein 1996, Samet et al 1998).

We also found that the positive relative risks for mortality associated with exposures to particles in Athens are similar for both seasons and independent of air mass type and temperature effects. The size of the estimated black smoke effect is consistent with the findings of Katsouyanni et al (1997) who reported an increase of 0.6% in the daily number of deaths combined with a change of 10μgr/m^3 in BS levels.

Conclusions

From the analysis presented above the following main conclusions could be drawn:

- High relative risk for mortality was detected during the cold period of the year when the area of Athens is affected by air masses associated with SW flow (characterized by high humidity, relatively strong southerly wind and cloudiness), followed by days characterized by stagnant, high humidity, high temperature range conditions.
- During the warm period again days with air masses characterized by SW flow (with humid and warm conditions) have the highest mortality rates.
- The effects of the air mass types on mortality (excluding the temperature effects) are observed mainly on the same day during the cold period but persist on the next day during the warm period.
- The effects of air mass types and black smoke levels on mortality are independent.
- In conclusion, this work provides evidence that objective air mass classification schemes could act as a useful tool for studying the weather-health associations in Athens. Given the high predictability of the air mass types (2-3 days before with very high accuracy) a well developed air mass type classification could be a valuable tool for the authorities to predict future unhealthy conditions for humans, and therefore the impact on public health.

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References

1. Curriero, F.C, K.S. Heiner, J.M. Samet, S.L. Zeger, L. Strug and J. A. Patz (2000) Extremely hot/cold temperatures and mortality in 11 cities of theeastern USA. American Journal of Epidemiology 155**:** 80-87.
2. Dominici, F., A. McDermott S.L. Zeger and J.M. Samet (2002) On the Use of Generalized Additive Models in Time Series of Air Pollution and Health American Journal of Epidemiology 156**:** 193-203.
3. Fujikoshi, Y. and K. Satoh (1997) Modified AIC and Cp in multivariate linear regression. Biometrica 84**:** 707-716.
4. Garcia R, L. Prieto, J. Diaz, MT del Teso (2002) Synoptic conditions leading to extremely high temperatures in Madrid. Annales Geophysicae 20: 237-245.
5. Garcia R, J. Diaz, R.M. Trigo, E. Hernandez (2005) Extreme summer temperatures in Iberia:health impacts and associated synoptic conditions. Annales Geophysicae 23: 239-251.
6. Guest, C.S., K. Wilson, A.J. Woodward, K. Hennesy, L.S. Kalkstein, C. Skinner and A.J. McMichael (1999) Climate and mortality in Australia:a retrospective study, 1979-1990, and predicted impacts in five major cities in 2030. Climate Research 13: 1-15.
7. Handley, B.A. and A. Webster (1995) Some factors affecting the airborne survival of bacteria outdoors. J. Appl. Bacteriol. 79**:** 368-78.
8. Jendritzki, G. and U. Sievers (1989) Human biometeorological approaches with respect to human planning. Driscoll D, Box EO eds. Proceedings of the Xth Congress of the International Society of Biometeorology. West Lafayette, USA. The Hague, SPB Academic Publishing 25-39.

9. Kalkstein, L.S. and M. Davis (1989) Weather and Mortality: an evaluation of demographic and inter-regional responses in the United States, Annals of Association of American Geographers 79: 44-64.
10. Kalkstein, L.S (1991) A new approach to evaluate the impact of climate on human mortality. Environ. Health. Perspect 96**:** 145-150.
11. Kalkstein L.S, Nichols MC, Barthel CD, Greene JS, (1996) A new spatial synoptic classification: application to air-mass analysis. International Journal of Climatology 16: 983-1104.
12. Katsoulis B and Kassomenos P, (2004) Assessment of the air-quality over Urban areas by means of biometeorological indices. The case of Athens, Greece. Environmental Technology, 25:1293-1304.
13. Kassomenos, P.A., A. Gryparis, E. Samoli, K. Katsougianni, S. Lykoudis and H. Flocas (2001) Atmospheric Circulation types and daily mortality in Athens, Greece. Environ. Health. Perspect 109**:** 591-596.
14. Kassomenos, P.A., O. Sindosi and C. Lolis (2003) Seasonal cycles of the synoptic conditions occurring over southern Greece. A 50-years study. Climate Research 24**:** 33-46.
15. Kassomenos P., H.A. Flocas, S. Lykoudis, M. Petrakis, (1998) Analysis of mesoscale patterns in relation to synoptic conditions over an urban Mediterranean Basin. Theoretical and Applied Climatology 59: 215-229.
16. Katsouyanni, K., J. Schwartz, C. Spix, G. Touloumi, D. Zmirou, A. Zanobetti, B. Wojtyniak, J.M.Vonk, A. Tobias, A. Ponka, S. Medina, L. Bacharova and H.R. Anderson (1996) Short-term effects of air pollution on health: a European approach using epidemiologic time-series data: the APHEA protocol. JECH, 50**:** S12-S18.
17. Katsouyanni, K, G. Touloumi, C. Spix, J. Schwartz, F. Balducci, S. Medina, G. Rossi, B. Wojtyniak, J. Sunyer, L. Bacharova, J.P. Schouten, A. Ponka and H.R. Anderson (1997) Short-term effects of ambient sulfur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. BMJ 314**:**1658-1663.
18. Katsouyanni K, Touloumi G, Samoli E, Gryparis A, Le Tertre A, Monopolis Y, Rossi G, Zmirou D, Ballester F, Boumghar A, Anderson HR, Wojtyniak B, Paldy A, Braunstein R, Pekkanen J, Schindler Ch, Schwartz J. Confounding and effect modification in the short-term effects of ambient particles on total mortality: results from 29 European cities within the APHEA2 project. Epidemiology 2001, 12: 521-31.
19. Kilbourne, E.M (1986) Illness due to thermal extremes. In: Last JM, Ed., Maxcy-Rosenau public health and preventive medicine: 12th ed. New York: Appleton-Century-Crofts. 703-714.
20. Kljakovic, M. and C. Salmond (1998) A model of the relationship between consultation behaviour for asthma in a general practice and weather. Climate Research 10**:**109-113.
21. Kunst, A.E., C.W.N. Looman and J. P. Mackenbach (1993) Outdoor air temperature and mortality in the Netherlands: a time-series analysis. Am J Epidemiol 137**:**331-41.
22. McGregor, G.R (1999) Winter ischaemic heart disease deaths in Birmingham, United Kingdom:a synoptic climatological analysis. Climate Research 13**:** 17-31.
23. Glenn McGregor and Kassomenos P (2005). Exploring winter mortality variability using back trajectory composite analysis. Proceedings of the 15th AMS conference on Applied Climatology, Savannah, USA, 20-24 June, 2005.
24. Ministry of the Environment, Planning and Public works (1989) Program for air pollution control. Athens: Technical Report.
25. Pope, C.A. and L.S. Kalkstein (1996) Synoptic weather modeling and estimates of the exposure-response relationship between daily mortality and particulate air pollution. Environmental Health Perspectives, 104**:** 414-420.

26. Rooney, C., A.J. McMichael, R.S. Kovats and M. Coleman (1998) Excess mortality in England and Wales and in Greater London during the 1995 heat wave. J Epidemiol Comm Health 52**:** 482-486.
27. Saez, M., J. Sunyer, J. Castellsague, C. Murillo and J.M. Anto (1995) Relationship between weather temperature and mortality: a time series analysis approach in Barcelona. International Journal of Epidemiology 24**:** 576-582.
28. Samet, J., S. Zeger, J. Kelsall, J. Xu and L. Kalkstein (1998) Does weather confound or modify the association of particulate air pollution with mortality? Env. Res 77**:** 9-19.
29. Sheridan SC (2002) The redevelopment of a weather type classification scheme for North America. International Journal of Climatology, 22: 51-68.
30. Schwartz, J., C. Spix, G. Touloumi, L. Bacharova, T. Barumamdzadeh, A. Le Tertre, T. Piekarksi, A. Ponce de Leon, G. Rossi, M. Saez and J.P. Schouten (1996) Methodological issues in studies of air pollution and daily counts of deaths or hospital admissions. J Epidemiol Comm Health 50**:** S3-S11.
31. Steadman, R.C (1984) A universal scale of apparent temperature. Journal of Climate and Applied Meteorology 23**:** 1674-1687.
32. Touloumi, G., K. Katsouyanni and D. Trichopoulos (1994) Short-Term Effects of Air Pollution on Daily Mortality in Athens: A Time-Series Analysis. Int J Epidemiol 23**:** 957-967.
33. WHO (1987) Air Quality guidelines for Europe.

Table 1. Air mass type frequency and characteristics for the cold period of the year.

Abbre-viation	Short description of the meteorological situation over Athens	Mean Air Temperature (^oC)	Mean Water Vapor pressure (mmHg)	Number of days (%)	Daily number of deaths	Black smoke mean (µg/m3)
1W	Weak easterly flow. High humidity, extensive cloudiness and low radiation levels.	12.2	11.5	110 (12.3)	39.7	99.8
2W	Relatively strong and dry N-NW flow. Extensive cloudiness.	7.5	7.4	98 (11.0)	41.0	75.9
3W	Strong and relatively dry NE flow.	10.2	8.6	108 (12.1)	38.0	54.2
4W	High humidity levels, SW flow and extensive cloudiness.	12.9	11.4	82 (9.2)	41.2	92.8
5W	Weak southwesterly flow. Local circulation cells, relatively high radiation levels. The relative humidity is low and the diurnal temperature range is high.	14.1	10.3	102 (11.5)	37.8	88.8
6W	S-SE flow. Warm and humid air masses, relatively high temperature range.	16.1	14.2	119 (13.4)	38.9	119.7
7W	The atmospheric pressure is the highest, the diurnal temperature range is also high and the winds are weak from northern directions.	10.0	9.0	157 (17.6)	41.4	122.3
8W	A weak pressure gradient over Aegean. The air temperature, the diurnal temperature range and solar radiation are high.	12.5	9.3	115 (12.9)	39.0	98.0

Table 2. Air mass type frequency and characteristics for the warm period of the year (excluding the "heat-wave" period of July 21-30, 1987)

Abbreviation	Short description of the meteorological situation over Athens	Mean Air Temperature (°C)	Mean water vapor pressure (mmHg)	Number of days (%)	Daily number of deaths	Black smoke mean (μg/m3)
1. 1S	Relatively weak SW flow during all the day. The air masses are warm and humid. The total radiation is at low levels.	20.8	16.1	127 (14.4)	34.5	71.8
2S	The wind is strong and blows from NE, the solar radiation and air temperature and humidity are relatively low.	21.0	13.3	81 (9.2)	31.8	54.0
3S	Wind speed is relatively low and its direction is not well defined at the surface. High temperature range.	26.9	18.4	180 (20.4)	35.3	80.4
4S	Strong northerly wind flow. Water vapor pressure and relative humidity are generally low.	26.8	15.8	177 (20.0)	35.0	60.4
5S	The wind is light without constant direction, the total radiation is low.	22.1	16.0	158 (17.9)	32.3	88.8
6S	Local circulations having a SW direction during daytime. Air masses are humid and relatively warm.	19.3	13.0	160 (18.1)	34.7	69.1

Table 3. Relative risks (95% confidence interval-CI) for total daily mortality, for each air mass type by season, for lag 0, lag 1 and lag 2 (adjusting for BS, temperature, seasonal patterns, day of the week)

Air mass type	**Cold period**			**Air mass type**	**Warm period**		
	Lag 0	Lag 1	Lag 2		Lag 0	Lag 1	Lag 2
5W	Reference category			2S	Reference category		
1W	1.03 (0.98,1.08)	1.01 (0.97,1.06)	1.00 (0.95,1.05)	1S	1.06 (1.01,1.12)	1.07 (1.01,1.13)	1.04 (0.99,1.09)
2W	1.03 (0.98,1.08)	0.96 (0.91,1.01)	0.92 (0.87,0.97)	3S	1.02 (0.97,1.08)	1.01 (0.95,1.06)	0.98 (0.92,1.03)
3W	0.99 (0.94,1.04)	0.96 (0.92,1.01)	0.95 (0.91,1.00)	4S	1.01 (0.95,1.07)	1.01 (0.95,1.06)	0.96 (0.91,1.02)
4W	1.09 (1.03,1.14)	1.04 (0.99,1.09)	0.98 (0.93,1.03)	5S	1.00 (0.95,1.05)	1.01 (0.96,1.07)	1.01 (0.96,1.06)
6W	1.04 (0.99,1.09)	1.03 (0.99,1.08)	1.02 (0.97,1.07)	6S	1.07 (1.02,1.13)	1.05 (1.00,1.11)	1.05 (1.00,1.10)
7W	1.00 (0.96,1.05)	1.00 (0.95,1.05)	1.01 (0.96,1.06)				
8W	1.00 (0.95,1.04)	1.00 (0.96,1.05)	1.01 (0.97,1.06)				

Table 4. Relative risks (95% confidence interval-CI) for total daily mortality, for each air mass type by season, for lag 0, lag 1 and lag 2 (adjusting for BS, seasonal patterns, day of the week)

Air mass type	**Cold period**			**Air mass type**	**Warm period**		
	Lag 0	Lag 1	Lag 2		Lag 0	Lag 1	Lag 2
5W	Reference category			2S	Reference category		
1W	1.04 (0.99,1.09)	1.02 (0.98,1.07)	1.01 (0.97,1.06)	1S	1.04 (0.98,1.10)	1.04 (0.98,1.10)	1.01 (0.95,1.07)
2W	1.07 (1.02,1.12)	1.03 (0.98,1.08)	1.01 (0.96,1.06)	3S	1.07 (1.01,1.12)	1.04 (0.98,1.10)	1.02 (0.97,1.08)
3W	1.00 (0.96,1.05)	1.00 (0.96,1.05)	1.01 (0.96,1.06)	4S	1.07 (1.02,1.13)	1.07 (1.01,1.12)	1.03 (0.98,1.08)
4W	1.08 (1.03,1.14)	1.04 (0.99,1.09)	0.99 (0.95,1.05)	5S	0.98 (0.92,1.03)	0.99 (0.93,1.05)	0.98 (0.93,1.04)
6W	1.02 (0.97,1.07)	1.01 (0.96,1.05)	0.99 (0.94,1.04)	6S	1.05 (1.00,1.11)	1.02 (0.97,1.08)	1.02 (0.97,1.08)
7W	1.03 (0.99,1.08)	1.04 (0.99,1.08)	1.05 (1.00,1.10)				
8W	1.02 (0.97,1.06)	1.03 (0.98,1.08)	1.04 (0.99,1.09)				

4. The effect of apparent temperature on mortality in summer

See attached pdf file

5. The effect of apparent temperature on mortality in winter

Effects of Cold Weather on Mortality: Results from 15 European Cities within the PHEWE Project

Prepared by A. Analitis & K. Katsouyanni & Phewe co-authors

Mortality is known to be associated with meteorological conditions and to display a seasonal pattern, with excess mortality during the winter as well as during very hot days in the summer (Kilbourne 1986, Kalkstein & Greene 1997). In recent years, the effects of meteorological factors on health have attracted renewed interest due to the observed and predicted climate change expected to result in a general rise in temperature but also in abnormal climatic extremes. The short-term effects of meteorological variables (mainly of temperature) have been studied in various locations. A J shaped association with mortality has been observed with increased mortality at cold and hot temperatures and a minimum mortality observed at various points according to the latitude (Kunst et al 1993; Touloumi et al 1994). In the U.S. various multi-city studies on short-term effects of weather on mortality have been reported recently (Braga et al 2002; Curriero et al 2002). In Europe the Euro-winter project reported results from the time period between 1988 and 1992 (The Eurowinter Group, 1997) and a more recent multi-country project used monthly data to estimate excess winter mortality in 14 European countries (Healy 2003). However, the different distribution of factors that affect weather related mortality (e.g. use of air conditioning or heating) can lead to major spatial and temporal differences in weather related health effects. The Assessment and Prevention of Acute Health Effects of Weather Conditions in Europe (PHEWE) project is a multi-city European project aiming to assess the short-term cold and heat related mortality and morbidity in 15 European cities with more than 30 million inhabitants using data for 5 to 11 years for each city within 1990-2000. The extent of the data base and the geographical diversity allows the exploration of issues of heterogeneity and adaptation. We report here the cold related effects on cause-specific mortality.

Data

The PHEWE database includes data from 15 European cities covering almost every geographical region of the continent and representing about 30 million European citizens. Athens, Barcelona, Budapest, Dublin, Helsinki, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia and Zurich provided daily mortality, meteorological and air pollution data within years 1990-2001. More details on the data are provided in Michelozzi et al (2006, protocol paper).

The causes of death considered are: all natural causes (ICD-9: 1-799), cardiovascular (ICD-9: 390-459), cerebrovascular (ICD9: 430-438) and respiratory diseases (ICD-9: 460-519) for all ages and by age group (0-14,15-64,65-74, 75+). Cerebrovascular mortality data were not available in three cities (Athens, Paris and Zurich) and the age group 0-14 in two cities (Athens, Barcelona). The mean daily number of deaths by cause and age group are presented in Table 1.

In the PHEWE database there is information concerning the 3 hourly levels of: air temperature, dew point temperature, wind speed, wind direction, sea level pressure, total cloud cover, solar radiation, precipitation, visibility. In this application we use apparent temperature as exposure variable, adjusting for wind speed and barometric pressure. Maximum apparent temperature is a discomfort index based on air and dew point temperatures. It is defined as the maximum daily value of the three-hourly apparent temperature values, calculated using the following formula:

$$AT = -2.653 + 0.994*T + 0.0153*(DT)^2$$

where AT is apparent temperature, T is the air temperature in °C and DT is the dew point temperature in °C.

For Barcelona three-hourly data were not available and mean apparent temperature was used.

The air pollution part of the database is an updated version of the APHEA database (Katsouyanni et al 2001) and includes daily concentration measurements of the following pollutants: SO_2 (24-hour), an index of 24-hour ambient particles concentrations, TSP or Black Smoke or PM10 as available, NO_2 (1 hour, 24-hours), O_3 (1 hour, 8-hours), CO (8-hour). SO2 and ozone in the winter have generally low concentrations, CO was available only in 11 cities and the particle indicators were not uniformly comparable, so NO2 was chosen to adjust for air pollution. NO2 is considered a good traffic pollution indicator and in the PHEWE cities traffic is the major pollution source. The maximum 1-hour value of NO_2 was selected as the air pollution index in the main analysis. Median values and 10th and 90th percentile of the distribution of maximum apparent temperature and NO_2 1 hour are presented it Table 2.

Methods

In the PHEWE project, the investigation of the effects of apparent temperature on daily mortality was done separately for the cold (October to March) and the warm season (April to September). This design provides flexibility in the analysis as it reduces the complexity of the control for temporal confounding, avoiding the use of smooth functions when controlling for time trend. Also, it allows the use of different model structure per season.

The analysis was carried out in two stages. In the first stage individual city data were analysed and city-specific effect estimates were obtained which were then used in a second stage analysis to provide overall estimates and investigate heterogeneity.

Individual city data analysis

For the city-specific analysis we adopted the Generalized Estimating Equations (GEE) approach (Liang & Zieger) as an extension of Generalized Linear Models (GLM) for the analysis of longitudinal data. GEE model the marginal relationship between outcome variable and covariates, treating the correlation within subject as a nuisance. The observations between different subjects (clusters) are assumed to be independent while the observations of the same subject are correlated. GEE require the specification of a “working” correlation matrix, defining the structure within subject. For a large number of clusters the robust (empirical) estimator of variance has the property of being a consistent estimator of the covariance matrix even if the “working” correlation matrix is mis-specified.

In this study, for each city we have an outcome variable and several covariates observed at different days. We assumed a Poisson distribution on the outcome variable. Further, it was assumed that the observations within each cold season (October to March) are correlated, while observations in different cold seasons are independent. So, for example, the winter 1992-93, the winter 1993-94 etc were considered independent. (A similar approach was previously suggested by Schwartz & Dokcery (1992) for the evaluation of short term effects of air pollution on health.) Since, in our case, the number of clusters (cold seasons) was small (equal to the number of years in the study period), the robust estimator of variance could be inefficient and the use of the model based variance estimator was favoured. A model based estimator requires a correct specification of the “working” correlation matrix. This was achieved by applying an exploratory analysis based on an approach similar to that described by Chiogna and Gaetan (2005). Dynamic regression models were combined with a genetic algorithm for the semi-automated selection of the best model over a large model space, covering different specifications of the correlation structure within cluster. This analysis suggested a first order autocorrelation structure to be appropriate.

A common model was specified for each city taking into account potential confounders: holidays (one dummy variable), day of the week (six dummy variables) and calendar month (five dummy variables), linear terms for barometric pressure, wind speed and an air pollution index (NO2 1 hour maximum, black smoke 24 hours average for Dublin as NO2 was not available) and linear and quadratic terms of time to pick up the potentially remaining long term trend. An indicator of influenza epidemics was also included in the model (not used for respiratory events). Previous results have shown a prolonged effect of cold temperature on heath so it was decided a-priori to use as indicator for the exposure variable the mean of the current day and the previous 15 days (lags 0 to 15).

Since the shape of the exposure-response curve between apparent temperature and log-mortality rate was unknown, the assumption of a linear association was not documented. Therefore the first step was to investigate the shape of the association between the exposure and outcome variables. A flexible parametric approach was used to model the exposure-response curve. We included in the GEE model the basis vector of a cubic regression spline of apparent temperature, obtained using mgcv library of R software (Wood 2001) after defining a city specific vector of equally spaced knots (one every 8 ºC). The exposure-response curve was estimated for the following outcomes: daily total natural number of deaths (0-14, 15-64, 65-74, >75 years of age), cardiovascular deaths (15-64, 65-74, >75 years of age), cerebrovascular (15-64, 65-74, >75 years of age) and respiratory deaths (15-64, 65-74, >75 years of age). In the majority of cities and outcomes the shape of the association is approximately linear with negative slopes indicating increased mortality at lower apparent temperature levels. Deviations from linearity but without a specific pattern appear in outcomes with small number of daily counts (cerebrovascular mortality, respiratory mortality <65 years of age). After identifying the linear relationship between maximum apparent temperature and mortality in the cold season, the city specific slope was estimated by introducing a linear term of exposure in the model.

The delayed effect (up to 30 days) of apparent temperature on mortality was investigated with distributed lag models. We applied 5th order, polynomial constrained, distributed lag models in order to obtain flexibility in modelling the lags distribution and avoid problems related to colinearity between lagged covariates (Almon 1965). Unconstrained distributed lag models that simultaneously included variables for same day and up to 5, 10, 15, 20, 25 and 30 days were used in order to obtain the cumulative effect of the exposure over five days, in each city.

Pooled analysis

A second stage analysis was performed to provide a quantitative summary of all individual city results. In order to reduce heterogeneity, we also pooled the results by grouping the cities according to predefined meteorological and geographical criteria. The Mediterranean cities group consists of Athens, Barcelona, Ljubljana, Milan, Rome, Turin and Valencia and the Continental and North Atlantic cities group, of Budapest, Dublin, Helsinki, London, Paris, Prague, Stockholm and Zurich.

Overall exposure-response curve was estimated using a GEE regression model with a cubic regression spline for maximum apparent temperature on the pooled dataset (all cities). The construction of the model was similar to the city-specific one, with the addition of city indicator variable as well as interaction terms with confounders. This fixed effects meta-analytical approach produces an overall descriptive exposure-response curve, without pooling the individual curves and thus avoiding problems related to the large variability of the exposure ranges among cities.

To combine slopes and sum the effect of apparent temperature on mortality for a more prolonged time of 30 days, unconstrained distributed lags models were used, with inverse variance weighted averages including a random variance component to incorporate heterogeneity (Laird…). In order to combine the city specific estimates of the coefficients from the distributed lag models we applied a multivariate random effects regression model described by Berkey et al (….new one).

Results

Table 1 shows the mean daily number of deaths in the 15 cities. The total natural number of death ranges from 7 (Ljubljana) to 179 (London). A large percentage of the deaths happen among those older than 75 years (50-68%), followed by deaths in the 65-74 years age group (14-29%), whilst the counts of deaths are very small in children. Cardiovascular mortality is about 40-50% of total whilst respiratory and cerebrovascular mortality generally represent less than 10% of the total mortality counts (an exception is London where respiratory deaths are 20% of the total).

In Table 2 the median, the 10th and 90th percentiles of apparent temperature and NO_2 concentrations in the 15 cities are shown. There is substantial variability in the median apparent temperature, which ranges from -1.2°C in Helsinki to 17.6°C in Valencia. The median concentrations of NO_2 also vary from 44.5 $\mu g/m^3$ in London to 148 $\mu g/m^3$ in Valencia.

Figures 1 – 4 show the combined exposure – response curves for total natural, cardiovascular, respiratory and cerebrovascular mortality. It can be seen that the curve can be adequately approximated by a linear model for all causes. The smaller counts represented by the respiratory & cerebrovascular series are reflected in the wider confidence intervals (zones?)

Figures 5-8 show the city specific and pooled estimated effects of apparent temperature on total natural, CVD, respiratory and cerebrovascular daily number of deaths. For total natural and CVD causes of death there is a statistically significant effect in all 3 age groups and there is a clear increase in the effect with increasing age. For respiratory and cerebrovascular mortality there is a statistically significant effect of similar magnitude in those 65-74 and >75 years old but the adverse effect of decreasing temperature is not nominally significant for those 15-64 years old for respiratory causes of death, whilst there is no effect for this age group on cerebrovascular mortality.

Table 3 shows the corresponding numbers for the pooled estimates shown in Figures 5-8 and additionally the estimated pooled effects for all ages and the effects of apparent temperature on total mortality in children. There is a statistically significant effect of apparent temperature on children mortality: once degree of decrease in temperature is associated with 1.15% increase in the daily number of deaths in the 0-14 years old age group.

Table 4 shows the estimated pooled effects of apparent temperature on the cause – specific mortality for all ages separately for the 7 Mediterranean and the 8 Central Northern European cities. It can be seen that the effects for total, CVD and cerebrovascular mortality are higher in Mediterranean cities but the inverse is true for respiratory causes of death. The heterogeneity between cities remains significant in most cases in the region-specific analysis.

Table 5 shows the cumulative effects for 30 days of decreased apparent temperature on cause specific daily deaths. It can be seen that the effect over 30 days is increased by about 30% for all age deaths and deaths among those >75 years old for all, CVD and cerebrovascular causes, whilst it triples for respiratory causes, indicating stronger prolonged effects. The cumulative effect is smaller in the younger age groups except for respiratory causes, where a pronounced prolonged effect is observed. Figure 9 shows the distributed lag curve for total mortality. It can be seen that there is an effect until about day 25 and no harvesting is observed. The same is seen for all other causes of death (results not shown).

Discussion

In the present paper we confirmed the results from previous work that temperature in the cold season is inversely associated with mortality. Specifically we found that the total natural daily number of deaths increases by 1.1% when the maximum apparent temperature decreases by 1°C. CV deaths increase by 1.4%, respiratory by 1.5% and cerebrovascular by about 1%. We have found that in warmer cities the cold temperature effect was higher. These results are consistent with previously reported results from the U.S. (Curriero et al 2002, Braga et al 2002) and from Europe (Eurowinter 1997, Healy 2003). One study done in the coldest setting in Siberia (Donaldson et al 1998) actually found no cold related mortality. For cause-specific mortality, the Eurowinter study found the effect of cold was larger in warmer countries for respiratory causes but this was not so pronounced for CVD and IHD. Braga et al observed stronger effects of cold weather on CVD compared to respiratory mortality especially in colder cities. Curriero et al grouped CVD and respiratory deaths together and observed similar effects to those on total mortality. Some studies focused on cardiac mortality as there is a stronger a-priori hypothesis that cold specifically affects the cardiovascular system. Several reports on mechanisms based on experiments have been presented. Thus Keatinge (1960,1961) studied the effects of cold exposure to the metabolic and vascular responses and also investigated acclimatization and its potential modifying role. In another study Keatinge et al (1984) showed that cold exposure increased platelet and red cell cents, blood viscosity and arterial pressure. In our study we observed effects of similar magnitude on deaths from respiratory and cardiovascular causes. However, when more prolonged effects were studied with distributed lag models, it appears that the respiratory effects are more persistent through time.

In our study we were able to investigate the effects by age groups. For total and CVD mortality the effects had an increasing gradient with age: they could be observed in the younger age groups but the effects were clearly larger in the elderly. Effects of apparent temperature on respiratory and cerebrovascular deaths were only observed on those older than 65 years. This observation is not entirely consistent with other reports. O' Neill et al 2003 found stronger cold related effects on mortality for those younger than 65 years and Curriero et al 2002 report a qualitatively similar relation between weather and mortality in the same age groups used in the present study. However, reports in Europe show that the elderly are more sensitive (Wilkinson et al 2001).

We observed significant heterogeneity in the effect estimates from specific cities. These may be due to differences in environmental, socioeconomic and behavioral patterns. The heterogeneity practically remained after dividing the cities in 2 groups according to geographical location, with the objective of having more homogeneous groups. In second stage models however, we identified various climatic effect modifiers which reduced the heterogeneity substantially or eliminated it. We identified as effect modifiers of the association between apparent temperature and mortality, the mean winter temperature over the study period (higher temperature was associated with larger cold effects) KKKKKK. These modifiers did not act uniformly for all causes of death. Thus…

Other studies have also attempted to investigate effect modification. Wilkinson et al 2002 studied potential effect modifiers of the cold related mortality in the elderly in Britain but was unable to identify others except female sex and pre-existing respiratory illness. In an ecological analysis comparing monthly mortality in 15 European counties, Healy (2003) identified several environmental and SES factors associated with the magnitude of effects. Thus higher mean temperatures and, to a lesser extent, higher humidity are associated with greater cold related mortality. Also countries with greater poverty, inequality and deprivation appear to have more excess winter mortality.

In the present work we have used apparent temperature as the weather index because this is now used by various public health agencies for prediction of discomfort conditions. Apparent temperature is calculated on the bases of temperature and humidity (or dew point) and is supposed to take into account the “discomfort” felt by the population from a combination of temperature and humidity conditions (reference – Paola please add). It is not clear which is the best indicator to use when assessing temperature effects. An alternative would be to use temperature and a measure of humidity separately. This latter gives more flexibility in estimating the separate temperature and humidity effects on the studied health index. Studies which have assessed these two separately show that humidity plays a small and inconsistent role in affecting mortality (Braya 2002). This issue deserves further investigation.

Table 1: Mean daily number of deaths by cause of death and age group for the cold season (October to March).

	Total natural					CVD				Respiratory				Cerebrovascular			
CITY	all ages	over 75 years	65 to 74 years	15 to 64 years	0 to 14 years	all ages	over 75 years	65 to 74 years	15 to 64 years	all ages	over 75 years	65 to 74 years	15 to 64 years	all ages	over 75 years	65 to 74 years	15 to 64 years
Athens	78	46	23	8		40	26	10	3	5	4	1	0				
Barcelona	43	27	9	7		17	13	3	1	5	4	1	0	5	4	1	0
Budapest	80	40	19	20	1	41	26	9	6	3	2	1	1	9	6	2	1
Dublin	14	8	3	3	0	6	4	2	1	2	1	1	0	1	1	0	0
Helsinki	18	11	4	4	0	9	6	2	1	2	1	0	0	3	2	0	0
Ljubljana	7	4	2	2	0	3	2	1	1	1	0	0	0	1	1	0	0
London	179	112	37	29	1	74	48	16	10	37	28	6	3	17	13	3	2
Milan	32	19	7	5	0	13	10	2	1	3	2	0	0	4	3	1	0
Paris	128	75	21	30	2	40	30	6	4	10	8	1	1				
Prague	39	21	10	7	0	23	15	5	3	2	1	0	0	6	5	1	1
Rome	62	36	14	11	0	27	19	5	3	4	3	1	0	6	4	1	1
Stockholm	31	21	6	4	0	15	12	2	1	3	2	0	0	3	3	1	0
Turin	23	14	5	4	0	10	7	2	1	2	1	0	0	3	3	1	0
Valencia	18	11	4	3	0	7	5	1	1	2	2	0	0	2	1	0	0
Zurich	14	9	2	2	0	6	5	1	1	1	1	0	0				

Table 2: Distribution of maximum apparent temperature, average of 16 days and NO_2 1 hour maximum, average of 2 days for the cold season (October to March).

City	Max. apparent temp.			NO_2 1 hour max.		
	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Athens	8.8	13.6	25.0	78.0	112.2	175.7
Barcelona	8.0	11.1	19.4	64.0	92.1	137.2
Budapest	-2.2	4.4	15.5	45.5	80.5	144.0
Dublin*	4.4	7.3	12.4	-	-	-
Helsinki	-5.2	-1.2	6.8	38.3	56.3	81.5
Ljubljana	-2.4	4.1	14.1	46.0	75.0	127.0
London	4.5	8.1	14.2	35.8	44.5	61.5
Milan	1.9	7.4	18.9	102.5	144.5	238.0
Paris	1.8	7.7	14.5	58.1	79.9	116.6
Prague	-3.5	2.6	11.2	38.1	55.9	86.4
Rome	9.1	12.4	22.3	71.2	94.3	131.6
Stockholm	-2.9	0.7	8.4	30.6	45.7	61.6
Turin	2.5	7.5	16.4	86.7	132.4	210.5
Valencia	13.3	17.6	25.8	108.7	148.1	197.6
Zurich	-1.5	5.0	12.9	43.8	61.2	95.2

* NO_2 was not available

Table 3: Percent increase (95% C.I.) in the daily number of deaths, for 1 ºC increase in the maximum apparent temperature (average of lags 0-15) in the cold season (October to March) by cause of death and age group in 15 European cities.

		all ages		over 75 years		65 to 74 years		15 to 64 years		0 to 14 years	
		% increase	95% C.I.	% increase	95% C.I.	% increase	95% C.I.	% increase	95% C.I.	% increase	95% C.I.
Total mortality	**Fixed p.e.**	-1.09*	(-1.18, -1.01)	-1.37*	(-1.48, -1.26)	-0.88*	(-1.04, -0.71)	-0.48	(-0.65, -0.32)	-1.15	(-1.97, -0.33)
	Random p.e.	-1.11	(-1.28, -0.94)	-1.36	(-1.56, -1.15)	-0.91	(-1.15, -0.66)	-0.52	(-0.76, -0.27)	-0.98	(-2.54, 0.61)
CVD mortality	**Fixed p.e.**	-1.39*	(-1.52, -1.27)	-1.51*	(-1.65, -1.36)	-1.18	(-1.44, -0.93)	-0.95	(-1.27, -0.63)		
	Random p.e.	-1.43	(-1.74, -1.11)	-1.53	(-1.79, -1.26)	-1.22	(-1.57, -0.88)	-0.99	(-1.35, -0.63)		
Respiratory mortality	**Fixed p.e.**	-1.76*	(-2.05, -1.47)	-1.75*	(-2.12, -1.39)	-1.79	(-2.42, -1.14)	-1.21*	(-2.03, -0.38)		
	Random p.e.	-1.48	(-2.05, -0.91)	-1.40	(-2.08, -0.70)	-1.79	(-2.46, -1.12)	-0.86	(-2.24, 0.54)		
Cerebrovascular mortality	**Fixed p.e.**	-0.97*	(-1.25,-0.69)	-1.06*	(-1.38,-0.73)	-1.29	(-1.91,-0.66)	-0.11	(-0.96, 0.75)		
	Random p.e.	-0.99	(-1.60,-0.38)	-1.24	(-2.15,-0.33)	-1.29	(-1.91,-0.66)	-0.11	(-0.96, 0.75)		

* significant heterogeneity

Table 4: Percent increase (95% C.I.) in the daily number of deaths for all ages in 7 Mediterranean and 8 North-Central cities, for 1 ºC increase in the maximum apparent temperature (average of lags 0-15) in the cold season (October to March) by cause of death.

		Mediterranean		North-Central	
		% increase	95% C.I.	% increase	95% C.I.
Total mortality	**Fixed p.e.**	-1.36*	(-1.53,-1.19)	-1.00*	(-1.10,-0.90)
	Random p.e.	-1.29	(-1.57,-1.00)	-0.98	(-1.16,-0.80)
CVD mortality	**Fixed p.e.**	-1.84*	(-2.10,-1.59)	-1.25*	(-1.39,-1.11)
	Random p.e.	-1.72	(-2.21,-1.22)	-1.22	(-1.45,-0.99)
Respiratory mortality	**Fixed p.e.**	-1.56*	(-2.16,-0.97)	-1.82	(-2.15,-1.49)
	Random p.e.	-1.21	(-2.55, 0.14)	-1.66	(-2.17,-1.16)
Cerebrovascular mortality	**Fixed p.e.**	-1.58*	(-2.20,-0.95)	-0.82	(-1.14,-0.51)
	Random p.e.	-1.49	(-2.65,-0.32)	-0.69	(-1.28,-0.10)

* significant heterogeneity

Table 5: Cumulative effect of apparent temperature on the daily number of deaths from 30-days polynomial distributed lags models. Percent increase (95% C.I.) in the daily number of deaths, for 1 ºC increase in maximum apparent temperature (average of lags 0-15) in the cold season (October to March) by cause of death and age group in 15 European cities.

		all ages		over 75 years		65 to 74 years		15 to 64 years		0 to 14 years	
		% increase	**95% C.I.**	**% increase**	**95% C.I.**	**% increase**	**95% C.I.**	**% increase**	**95% C.I.**	**% increase**	**95% C.I.**
Total mortality	**Fixed p.e.**	-1.39*	(-1.51,-1.27)	-1.83*	(-1.98,-1.67)	-1.09	(-1.32,-0.85)	-0.34*	(-0.58,-0.10)	-0.96	(-2.20, 0.30)
	Random p.e.	-1.42	(-1.63,-1.21)	-1.81	(-2.09,-1.53)	-1.09	(-1.35,-0.83)	-0.51	(-1.02, 0.00)	-0.80	(-2.61, 1.05)
CVD mortality	**Fixed p.e.**	-1.82*	(-1.99,-1.64)	-2.01*	(-2.22,-1.81)	-1.67	(-2.03,-1.31)	-0.93	(-1.40,-0.45)	-	-
	Random p.e.	-1.86	(-2.19,-1.53)	-2.01	(-2.42,-1.61)	-1.71	(-2.20,-1.22)	-0.93	(-1.40,-0.45)	-	-
Respiratory mortality	**Fixed p.e.**	-4.74*	(-5.17,-4.31)	-4.72*	(-5.25,-4.18)	-4.70	(-5.61,-3.79)	-3.92*	(-5.09,-2.74)	-	-
	Random p.e.	-4.21	(-5.17,-3.24)	-4.20	(-5.20,-3.18)	-4.70	(-5.61,-3.79)	-3.22	(-5.05,-1.35)	-	-
Cerebrovascular mortality	**Fixed p.e.**	-1.37*	(-1.62,-1.12)	-1.71*	(-2.05,-1.37)	-1.23	(-1.74,-0.72)	-0.47	(-0.98, 0.03)	-	-
	Random p.e.	-1.23	(-1.85,-0.61)	-1.59	(-2.67,-0.51)	-1.22	(-2.54, 0.12)	-0.08	(-1.15, 1.01)	-	-

* significant heterogeneity

6. Short term effect of apparent temperature on hospital admissions during summer: results of the European PHEWE project

Introduction

Several studies have assessed the relationship between outdoor temperature and health outcomes during the warm season. Climate change models indicate that the frequency and intensity of heat wave events are expected increase in the future. To date, time series studies on the effect of hot temperatures have largely used mortality as the outcome measure; whereas the analysis of the effect of hot temperature on non-fatal outcomes, such as hospital admissions, is to date limited.

Results of studies in both European and U.S. cities have shown an effect of increasing temperature on total mortality, with a stronger effect on cardiovascular and respiratory causes, and a higher vulnerability of the elderly. Moreover, previous results indicate a large heterogeneity in the effect due to the local meteorological conditions and population characteristics. Cardiovascular, respiratory and cerebrovascular diseases were the most frequent underlying causes of death during heat waves (1, 2, 3, 4, 5, 6, 7, 8), since heat produces stress on the cardiovascular and respiratory systems, especially among persons with limited adaptive responses. Keatinge *et al.* (9) have documented some physiological changes that promote arterial thrombosis following moderately severe exposure to hot weather; after heat esposure, blood viscosity and plasma cholesterol levels increased, as a consequence of the reduction of plasma volume due to a loss of salt and water from the body (9). Moreover, heat stress causes a release of platelets into the circulation whose deposition on arterial walls was the early stage of arterial thrombosis. A sudden fall in arterial pressure may precipitate cerebral as well as coronary thrombosis, that is a possible explanation to the increase of mortality for cerebral and cardiovascular disease observed after episodes of extreme heat.

Studies on hospital admissions may clarify if heat waves are also associated to increases in non-fatal illness, allowing to identify indicators of the effect of heat on morbidity, moreover they may help to obtain indications on the mechanisms that underlie the association between outdoor air temperature and mortality.

Few studies have quantified the effect of heat on hospital admissions (2, 10, 11, 5, 12, 13, 14, 15, 16). A study on 12 U.S. cities (15) showed an increase in admissions for heart diseases in response to hot weather. According to the limited published literature, the effect of heat on hospital admission seems to be lower than the effect observed on mortality. A study which analysed the effect of high temperatures on emergency hospital admissions in London reported a small, or no impact, of heat on admissions for several causes including cardiovascular diseases (14).

The project “Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe” (PHEWE) is a collaborative effort to investigate the short-term health effect of weather conditions across Europe using a standardized time series approach. This multi-city study allows to evaluate the health effects of temperature both during hot and cold season in a wide variability of climatic conditions A multi-centre study has the advantages of comparing city-specific results using the same methodological approach, giving the possibility to investigate pattern across cities, and to explore factors related to the variability of the effect observed.

In the PHEWE project, the health end-points were total mortality, selected cause specific mortality, and hospital admissions for cardiovascular, cerebrovascular and respiratory causes; details are described elsewhere (*Chapter 2*). In this article a summary of the results of the effect of temperature during the summer season on hospital admissions in 12 European cities are presented. Results of the effect of temperature on hospital admissions during cold season, and results of the effect on mortality are presented elsewhere *(Chapter 4,5, Chapter 7).*

Methods

Study areas and populations

For 12 cities, Barcelona, Budapest, Dublin, Ljubljana, London, Milan, Paris, Rome, Stockholm, Turin, Valencia and Zurich, out of the 15 cities participants the PHEWE project were considered for the hospital admissions analysis on the basis of data availability. These cities include a population of about 25 million people and are heterogeneous by demographic and socio-economic structures, and by climates and air pollution levels. More details on the datasets are provided in Chapter 2.

Hospital admission data

Hospital admissions data were provided by routine registers and referred to the resident population only, except for Dublin where data also included non residents. For most cities, quality control of the data was carried out by local researchers and included checking for completeness of diagnosis and validity. For Barcelona, London, Milan, Paris, Rome and Stockholm data were previously collected within the second APHEA (Air Pollution on Health: European Approach) project (17, 18) and were updated. For the remaining cities data were collected for the first time and a minimum of 3 years was considered within the period 1990-2001. Time series of daily counts of admissions were constructed, for all ages combined and for specific age groups (0-14 yrs, 15-64 yrs, 65-74 yrs, 75+ yrs), for the following causes:

- Cardiovascular causes: International Classification of Diseases, 9th revision (ICD-9), 390-459
- Cerebrovascular causes: ICD-9, 430-438
- Respiratory diseases: ICD-9, 460-519
- Influenza: ICD-9, 487

Data for cerebrovascular causes was not available in Paris while in Zurich both cerebrovascular and respiratory data were not provided. Each cause was extracted by considering only the main discharge diagnosis. Furthermore, only hospital admission for acute conditions were collected for all cities. Acute admissions was available in Barcelona, Budapest, Dublin, Ljubljana, London, Stockholm (from 1997), Turin and Valencia. For the other cities where admissions for acute conditions could not be directly derived, a common procedure was adopted. The selection criteria implied to exclude transfers from other hospitals, to focus on the diagnoses reported only for the first service in which the patients were admitted, and to exclude the highly elective conditions (day hospital stay, rehabilitation, surgery, traumas, deliveries, psychiatric and dermatological conditions).

Meteorological data

The dataset comprised of three-hourly meteorological variables including air temperature (T_{air}, °C), dew point temperature (T_{dewpt}, °C), relative humidity (%), wind speed (m/s), wind direction (degree), sea level pressure (hPa), total cloud cover (octas), solar radiation (MJ/m^2), precipitation (mm), visibility (m) (17). In the present study, maximum apparent temperature (T_{appmax}) was used as the exposure variable apparent temperature, an index of thermal discomfort based on air temperature and dew point temperature using the following formula (19, 20).

$$T_{app} = -2.653 + 0.994(T_{air}) + 0.0153(T_{dewpt})^2$$

The choice of maximum apparent temperature as the exposure variable for the time series analysis was driven by the fact that it comprises air and dew point temperature in a single parameter. The simplified formula for this indicator was considered the most suitable one on the basis of data availability and quality. In Barcelona, where the three-hourly meteorological data were not available, the mean apparent temperature was used.

Air pollution data

Since air pollution levels are linked to atmospheric conditions, there is the potential for an effect modification and/or confounding of air pollution on the relationship between temperature and mortality, although the magnitude of the effect is still unclear.

The air pollution database comprised of the following pollutants: PM10, TSP or Black Smoke, SO_2 (24-hour), NO_2 (1 hour, 24-hour), O_3 (1 hour, 8-hour), and CO (8-hour). Further details on the data collection and datasets are provided in Chapter 2. The maximum 1-hour daily value of NO_2 was used as pollutant variable to include in the model in all cities, except Dublin and Ljubljana where the daily average of Black Smoke and SO_2 were used respectively. NO_2 was selected as an indicator of air pollution levels on the basis of a series of considerations; firstly it is a good traffic pollution indicator as well as a valid proxy of the overall pollutant levels in an urban area, and secondly for the completeness of the data series in most cities.

Statistical analysis

In the PHEWE project the analysis of the effect of apparent temperature on hospital admissions was performed separately for the warm (April-September) and the cold season (October-March); this design provides flexibility in the analysis allowing the use of different model structure for season. In this paper the analysis was carried out for the summer period to investigate the effect of maximum apparent temperature on daily hospital admissions. The statistical analysis followed two stages. In the first stage, data from each city were analyzed to estimate the city-specific effects using a common model, defined on the basis of a sensitive analysis. In the second stage city-specific results were combined to obtain pooled estimates and to investigate heterogeneity.

City-specific analysis

The city-specific analyses were based on the Generalized Estimating Equations (GEE) models (21). According to this approach, we modelled the marginal relationship between daily hospital admission counts and maximum apparent temperature, treating the dependence of daily observations within each summer as a nuisance parameter. Since hospital admissions are often highly correlated over time, we assumed that observations between days of different summer periods were independent and observations within each summer were correlated. As required by the GEE approach, the correlation structure within observations was specified on the basis of an exploratory analysis (22) and a first order autoregressive term within year was included in the model (23).

In the common model considered for each city, a Poisson distribution with a logarithmic link function was fitted on daily counts for hospital admissions (outcome variable), including different covariates as potential confounders. Potential confounders considered in the analysis were: holiday, day of the week and calendar month (included as dummy variables); linear terms for barometric pressure (lag 0-3), wind speed, linear and quadratic terms of time to pick up the long-term trend (24, 25, 26) and an air pollution variable (lag 0-1). For all cities, the maximum 1-hour daily value of NO_2 was used as an indicator for air pollution levels, except Dublin and Ljubljana where the daily average of Black Smoke and SO_2 were used respectively. Furthermore, to control for population reduction during the summer periods, a moving average value of total admission counts (ICD-9: 0-800) was included in the model as an offset variable.

As exposure variable it was decided to consider the delayed effect of maximum apparent temperature (lag 0-3), chosen on the basis of results from transfer functions exploratory analysis and in agreement with other results presented in time series studies (15, 27, 28,).

Since the shape of relationship between maximum apparent temperature and hospital admissions is not known, the exposure-response curve was modelled through a flexible parametric approach including penalized cubic regression splines for the temperature variable. Temperature splines were created considering the whole range of maximum apparent temperature, specifying a vector of interior knots placed at equally-spaced intervals for each city (one knot every 8 °C) using the 'mgcv' library available for the R software Version 2.1.0 (29).

Finally, we investigated the effect of extremely high temperatures. In each city, the 90th annual percentile of the maximum apparent temperature was identified and above this value the relation between hospital admissions and maximum apparent temperature was considered linear. To estimate the effect of extreme temperatures, a dummy variable with value of 1 for days with maximum apparent temperature grater than the 90th percentile was added to the model. The estimated effect was then expressed as percent change in daily hospital admissions for 1°C increase in maximum apparent temperature above this value.

Pooled analysis

In the second stage of the analysis, results from each city were combined to summarize estimates of all cities. To reduce the heterogeneity among the city-specific estimates, results were pooled after classifying cities in two groups identified *a priori* on the basis of meteorological and geographical criteria. The two groups were defined as Mediterranean cities (Barcelona, Ljubljana, Milan, Rome, Turin and Valencia) and Northern-Continental cities (Budapest, Dublin, London, Paris, Stockholm and Zurich).

In order to describe the overall exposure-response curves, a GEE regression model with a cubic regression spline for maximum apparent temperature was specified on the pooled dataset containing information from all cities. The model was the same as the one used in the first stage analysis, and a city indicator variable and interaction terms between confounders and city indicator were added. This approach allows to obtain an overall exposure-response curve that accounts for the large variability of the range in the exposure variable among cities. The analysis were performed separately for all cities and for the two city groups.

Finally, in order to obtain the overall estimates of the effect of the temperature on the hospital admissions, a meta-analytical approach was applied on the results obtained from each city. In this case, fixed effects and random effects models were run to derive the pooled estimates of the effect of maximum apparent temperature (lag 0-3) on the daily hospital admissions. Furthermore, the effect of extreme temperatures was investigated according to the meta-analytical approach, and in both cases the percent change in daily hospital admissions for 1°C increase in maximum apparent temperature was estimated. Again the analysis were performed separately for all cities and for the two city groups.

Results

Table 1 shows the median, 10th and 90th percentiles of temperature (air, dew point and maximum apparent temperature) and air pollution (maximum 1-hour NO_2 concentrations) variables and the study period in the 12 cities during summer. Results show a variability among the cities considered, with median apparent temperatures ranging from 15.0°C in Stockholm to 30.7°C in Valencia. The 90th percentile in maximum apparent temperature is highest in Valencia, Milan and Rome (36.7°C, 34.2°C and 34.1°C respectively) and lowest in Dublin and Stockholm (20.4°C and 23.6°C respectively) The median concentrations of NO_2 range from 7.0 µg/m3 in Dublin to 137.1 µg/m3 in Milan.

Table 2 shows the population size and the mean number of daily hospital admissions for cardiovascular, cerebrovascular and respiratory disease in the 12 cities during summer. Heterogeneity among population size and hospital admissions can be observed. London and Paris have over 6 million inhabitants, while Ljubljana has just over 250 thousand. It is interesting to note that the percentage of elderly in the population changes greatly among cities, with Barcelona having over 10% of the population in the 65-74 and 75+ ages groups respectively, while London, Paris and Dublin have under 14% of the population aged 65 and over. For all the causes considered, the highest daily mean number of admissions, in the 75+ age group, is recorded in London, while Ljubljana registers the lowest. London, Budapest and Rome register the highest number of cardiovascular admissions, ranging from 68-50 mean daily admissions. London and Rome have the largest number of cerebrovascular admissions, (15 and 14 admissions in the 75+ age respectively), while the other cities range from 8 in Milan to 1 in Ljubljana. Respiratory disease again are highest in London (33 daily admissions in the 75+ age group) while in the other cities range from 11 in Paris and Rome to 1 in Ljubljana.

Figure 1-3 illustrate the city-specific and pooled estimates of the association between cardiovascular, cerebrovascular and respiratory hospital admissions and T_{appmax}. Cardiovascular and cerebrovascular causes appear to be weakly associated with an increase in T_{appmax}, while respiratory causes show a positive and significant association for the pooled all ages estimates and 75+ age group. City-specific results show no effect of high temperatures was observed on cardiovascular and cerebrovascular causes for all ages considered. Considering all age groups an effect of temperature on respiratory admissions was observed only in Stockholm, Milan and London. Analysis by age groups gave a better insight with a positive association between high temperatures and respiratory admissions in a larger group of cities: Stockholm (65-74, 75+), London (15-64; 65-74; 75+), Rome and Valencia for the very old (75+), in Milan for the young (0-14) and very old (75+) and Turin only in the 15-64 age group. Overall, the effects tend to be greatest and statistically significant in the 75+ years age group. City-specific estimates illustrate a degree of heterogeneity in the association for all the three outcomes between and T_{appmax}.

Figure 4 shows the combined exposure-response curves for cardiovascular, respiratory and cerebrovascular hospital admissions in all cities, Mediterranean and continental/northern cities for the 75+ age group. Respiratory admission curves have a j-shape when considering all cities and the Mediterranean group, suggesting a positive correlation between temperature and respiratory admissions; as maximum apparent temperature increase the number of admission also increases. For the Continental/northern cities the trend for maximum apparent temperature and respiratory admissions also seems to be positive but with a less clear trend. No clear trend can be observed for cardiovascular and cerebrovascular admissions. The smaller counts in cerebrovascular counts are reflected by the wider confidence interval bands.

Table 3 illustrates the pooled estimates of the association between maximum apparent temperature and hospital admissions for cardiovascular, cerebrovascular and respiratory causes in the 12 cities. No effect of high temperatures was observed on cardiovascular and cerebrovascular causes for all age groups considered, in all cities as well as in the Mediterranean and Continental/Northern cities.

A significant effect was observed for respiratory disease when considering all cities and Mediterranean cities, for all ages and the 75+ age group. A significant effect of maximum apparent temperature on respiratory admissions was also seen in the 75+ age group in the Continental and Northern cities.

Discussion

The PHEWE project was the first study to systematically analyse the effect of temperature on hospital admissions in European cities. The present paper on the effect during the summer season shows no association of high temperatures with hospital admissions for cardiovascular and cerebrovascular causes in old age groups in all the cities considered. Although there is heterogeneity of the dose-response curves, hot temperature was inversely associated with hospital admissions for cardiovascular and cerebrovascular causes in all the cities. An effect of hot temperature was found only on hospital admissions for respiratory causes especially, in the over 75 age group, and only in some cities. Results regarding hospital admissions for cardiovascular and cerebrovascular causes are not consistent with mortality studies that report a positive association between temperature and cardiovascular deaths during summer and during heat wave episodes (31).

Only few studies until now have analysed the effect of high temperatures on hospital admissions (5,10,13,14,15, 16, 31, 32).

In Europe, only two studies analysed the effect of heat on hospital admissions. In London Kovats et al. 2004 reported no effect of heat on cardiovascular admissions, and a recent study in Florence showed no effect of hot temperatures on myocardial infarction among the elderly and a small effect only among men younger than 65 years (16).

Studies from the U.S. showed different results reporting a positive association of high temperature and hospital admissions for cardiovascular causes both in episode analyses (5,10) and analysing long time series through a time series approach (13, 15); these studies found a positive association of high temperatures and hospital admissions for all cardiovascular and cerebrovascular diseases and for specific diseases (acute myocardial infarction, coronary atheriosclerosis, pulmonary heart disease and congestive heart failure). Moreover the study on hospital admissions for heart disease in 12 U.S. cities showed a linear association between high temperatures and hospital admissions without threshold, for cardiovascular diseases and myocardial infarction admissions among elderly, and a similar effect was observed in all cities (15).

The PHEWE study shows a small significant effect of high apparent temperature only on respiratory admissions and only among the elderly (75+ age group), while for the younger age groups the effect was absent or not significant. The London study (14) even if with a lower effect than that observed on mortality, also reported an increase in respiratory admissions in response to high temperatures.

Episode studies on heat waves or extreme temperatures, have reported an increase in several European cities deaths due to cardiovascular, cerebrovascular and respiratory diseases, but results from this study show that hospital admissions for the same causes don’t to be affected by heat. The inconsistency of mortality and hospital admissions results may be explained by the adverse effect of heat on people suffering from chronic cardiovascular and respiratory disease; heat may exacerbate their health conditions and cause a rapid death often before receiving medical treatment or admission to hospital. This hypothesis is confirmed by previous observations of a greater increase in out-of-hospital deaths with respect to in -hospital deaths during heat waves (30). These results may also reflect the different analytical procedure employed and intent in the coding death certificates and hospital admissions since the first one aim to identify the pathologies most responsible for initiating the sequence of events leading to death, whereas hospital admission codes reflect major clinical conditions treated in the hospital. Furthermore, in the case of multiple diagnoses regulations for the definition of reimbursement may bias the choice of primary diagnosis coding criteria.

In conclusion, our results showed that high temperatures do not have an impact on hospital admissions for cardiovascular and cerebrovascular diseases while a small impact on admissions for respiratory causes. The same results have been observed in all cities, and this seems to reflect a true effect of heat on health that seems to produce an increase in deaths for cardiovascular causes but not an increase in non-fatal illnesses.

Our results may have important public health implications, and preventive interventions should be focused on the surveillance of susceptible subgroups (ageing people and those suffering from chronic diseases) staying at home at high risk of dying during periods of high temperatures.

References

1. Schuman S.H. Patterns of Urban Heat-Wave Deaths and Implications for Prevention: Data from New York and St. Louis During July, 1966. Environmental Research 1972; 5:59-75.
2. Ellis F.P., Nelson F. Mortality in the Elderly in a Heat Wave in New York City, August 1975. Environmental Research 1978; 15:504-512.
3. Ellis F.P., Princé H.P., Lovatt G., Whittington R.M. Mortality and Morbidity in Birmingham during the 1976 Heatwave. Quarterly Journal of Medicine 1980; New Series XLIX:(193)1-8.
4. Rooney C., McMichael A.J., Kovats R.S., Coleman M.P. Excess mortality in England and Wales, and in Greater London, during the 1995 heatwave. J Epidemiol Community Health 1998; 52:482-486.
5. Semenza J.C., McCullough J.E., Flanders W.D., McGeehin M.A., Lumpkin J.R. Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med 1999; 16:(4)359-60.
6. Huynen M, Martens P, Schram D et al. The Impact of Heat Waves and Cold Spells on Mortality Rates in the Dutch Population. Environ Health Perspect 2001; 109:463-470.
7. Kyselý J. Mortality and displaced mortality during heat waves in the Czech Republic. Int J Biometeorol 2004; 49:91-97.
8. Michelozzi P, de' Donato F, Bisanti L, Russo A, Cadum E, DeMaria M, et al. The impact of the summer 2003 heat waves on mortality in four Italian cities. Euro Surveill 2005; 10:161-165.
9. Keatinge W.R., Coleshaw S, Easton J, Cotter F, Mattock M, Chelliah R. Increased Platelet and Red Cell Counts, Blood Viscosity, and Plasma Cholesterol Levels during Heat Stress, and Mortality from Coronary and Cerebral Thrombosis. American Journal of Medicine 1986; 81:795-800.
10. Jones TS, Liang AP, Kilbourne EM, Griffin MR, Patriarca PA, Wassilak SG et al. Morbidity and mortality associated with the July 1980 heat wave in St Louis and Kansas City, Mo. JAMA 1982; 247:(24)3327-3331
11. Danet S.., Richard F., Montaye M., Beauchant S., Lemaire B., Graux C., et al. Unhealthy Effects of Atmospheric Temperature and Pressure on the Occurrence of Myocardial Infarction and Coronary Deaths: A 10-Year Survey: The Lille-World Health Organizatin MONICA Project(Monitoring Trends and Determinants in Cardiovascular Disease). Circulation 1999; 100:e1-e7
12. Dematte J.E., O' Mara K., Buescher J., Whitney C.G., Forsythe S., McNamee T., et al. Near-Fatal Heat Stroke during the 1995 Heat Wave in Chicago. Annals of Internal Medicine 1998; 129:(3)173-181.
13. Koken P.J.M., Piver W.T., Ye F., Elixhauser A., Olsen L.M., Portier C.J. Temperature, Air Pollution, and Hospitalization for Cardiovascular Diseases among Elderly People in Denver. Environ Health Perspect 2003; 111:(10)1312-1317.
14. Kovats S.R., Hajat S., Wilkinson. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in greater London, UK. Occupational Journal of Environmental Medicine 2004; 61; 893-898.
15. Schwartz J, Samet J, Patz J. Hospital Admissions for Heart Disease: The Effects of Temperature and Humidity. Epidemiology 2004; 15:(6)755-61.
16. Morabito M., Modesti P.A., Cecchi L., Crisci A., Orlandini S., Maracchi G., et al. Relationships between weather and myocardial infarction: A biometeorological approach. International Journal of Cardiology 2005; 105:288-293.
17. Atkinson RW, Anderson HR, Sunyer J, et al. Acute effects of particulate air pollution on respiratory admissions. Results from APHEA 2 Project. *Am J Crit Care Med* 2001; 164: 1860-1866.

18. Le Tertre A, Medina S, Samoli E, *et al*. Short-term effects of particulate air pollution on cardiovascular diseases in eight European cities. *J Epidemiol Community Health* 2002; 56: 773-779.
19. Kalkstein LS, Valimont KM. An evaluation of summer discomfort in the United States using a relative climatological index. *Bull Am Meteorolog Soc* 1986;67:842-8.
20. O'Neill M.S., Zanobetti A, Schwartz J. Modifiers of the Temperature and Mortality Association in Seven US Cities. Am J Epidemiol 2003; 157:(12)1074-1082.
21. Liang K-Y, Zeger SL. Longitudinal analysis using generalized linear models. *Biometrika* 1986; 73: 13-22
22. Chiogna M., Gaetan C., Transfer function modelling strategy for combining evidence on air pollution and daily mortality. In Proceedings of SCO2003, Treviso 4-6 september 2003, 140-145.
23. Schwartz J, Dockery DW. Increased mortality in Philadelphia associated with daily air pollution concentrations. Am Rev Respir Dis 1992;145(3):600-4.
24. Biggeri et al. 2004a, Biggeri A, Baccini M, Chiogna M, Accetta G, Atkinson R, Analitis A, Medina S, Paldy A, Sunyer J. 2004a. The PHEWE project – The methodological approach used to evaluate the short-term health effects of weather conditions. *Epidemiology* 15:S103.
25. Biggeri et al. 2004b, Biggeri A, Baccini M, Lertxundi A, Michelozzi P, Katsouyanni K, Bisanti L, Cadum E, Tiittanen P. 2004b. Short Term Effects of Temperature and Humidity on Mortality in European Cities: results from the PHEWE Project. *Epidemiology* 15:S101.
26. Biggeri et al. 2005 Biggeri A, Baccini M, Michelozzi P, Kirchmayer U, Analitis A, Katsouyanni K, Bisanti L, Cadum E, Tiittanen P, Medina S, Paldy A. 2005. Short term effects of apparent temperature on mortality in European cities: results from the PHEWE Project. *Epidemiology* 16:S140.
27. Kunst A, Looman C, Mackenbach J. Outdoor Air Temperature and Mortality in the Netherlands: A Time-Series Analysis. Am J Epidemiol 1993; 137:(3)331-341.
28. Ballester F, Corella D, Perez-Hoyos S, Saez M et al. Mortality as a Function of Temperature. A Study in Valencia, Spain, 1991-1993. Int J Epidemiol 1997; 26:(3)551-561.
29. *The R Foundation for Statistical Computing*. 2004. Version 2.1.0 (2005-04-19), http://cran.r-project.org.
30. Michelozzi P., de' Donato F., Accetta G., Forastiere F., D'Ovidio M., Perucci C.A. Impact of Heat Waves on Mortality - Rome, Italy, June-August 2003. MMWR 2004; 53:369-371.
31. Basu R., Samet J. Relation between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence. Epidemiologic Reviews 2002; 24:(2)190-202.
32. Johnson H., Kovats R.S., McGregor G., Stedman J., Gibbs M., Walton H. The impact of the 2003 heat wave on daily mortality in England and Wales and the use of rapid weekly mortality estimates. Euro Surveill 2005; 10:(7); 168-71.

Tables and Figures

Table 1. Study period and summary statistics of daily mean air temperature (T_{air}, °C), daily mean dew point temperature (T_{dewpt}, °C), daily maximum apparent temperature (T_{appmax}, °C) and the maximum 1 hour daily value of NO_2 (μg/m^3) in 12 European cities within the PHEWE project during summer (April-September), 1990-2001.

City	Study period	Percentile of mean T_{air}[§] (°C)			Percentile of mean T_{dewpt}[§] (°C)			Percentile of T_{appmax}[§°] (°C)			Percentile of NO_2[*] (□g/m^3)		
		10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
Barcelona	1994-1997	15.9	22.6	27.4	9.0	15.7	20.6	14.8	23.9	31.0	61.7	94.1	142.9
Budapest	1997-2000	12.0	18.6	23.9	4.0	10.9	15.6	13.3	22.3	29.9	35.0	59.0	82.0
Dublin	1994-2001	7.7	12.8	16.4	4.7	9.9	13.6	8.6	15.0	20.4	4.0	7.0	14.0
Ljubljana	1997-1999	9.7	16.8	21.4	4.8	12.0	16.2	11.5	20.8	28.2	3.0	10.0	40.0
London	1992-2000	9.5	15.4	20.1	4.0	9.8	13.7	10.8	18.1	25.3	31.5	44.0	66.0
Milan	1990-1999	12.9	20.5	26.0	7.2	14.9	20.1	15.6	25.9	34.1	102.0	137.1	192.0
Paris	1991-1995	9.8	16.4	22.0	5.0	11.5	16.3	11.0	19.9	28.6	48.5	79.4	125.8
Rome	1998-2000	14.3	21.3	25.9	10.2	15.7	19.9	17.4	27.4	34.2	89.7	116.6	145.8
Stockholm	1990-2000	5.2	13.5	19.1	-0.6	8.0	13.7	6.3	15.7	23.6	23.3	42.3	65.7
Turin	1995-1999	12.5	18.9	24.0	6.8	14.1	19.4	14.8	23.8	31.7	70.7	101.0	140.7
Valencia	1996-2000	16.2	23.3	26.8	14.4	20.6	24.4	20.5	30.7	36.7	84.0	122.6	170.3
Zurich	1990-1996	8.7	15.4	21.4	3.2	10.2	15.3	9.9	19.1	28.3	46.6	69.6	100.5

[§] Three-hourly meteorological data from the nearest airport weather station
[°] Mean apparent temperature in Barcelona
[*] Daily average of Black Smoke (g/m^3) and SO_2 (g/m^3) in Dublin and Ljubljana respectively

Table 2. Population size and daily mean number of hospital admissions (HA) for cardiovascular, cerebrovascular, and respiratory causes by age group in 12 European cities within the PHEWE project during summer (April-September), 1990-2001.

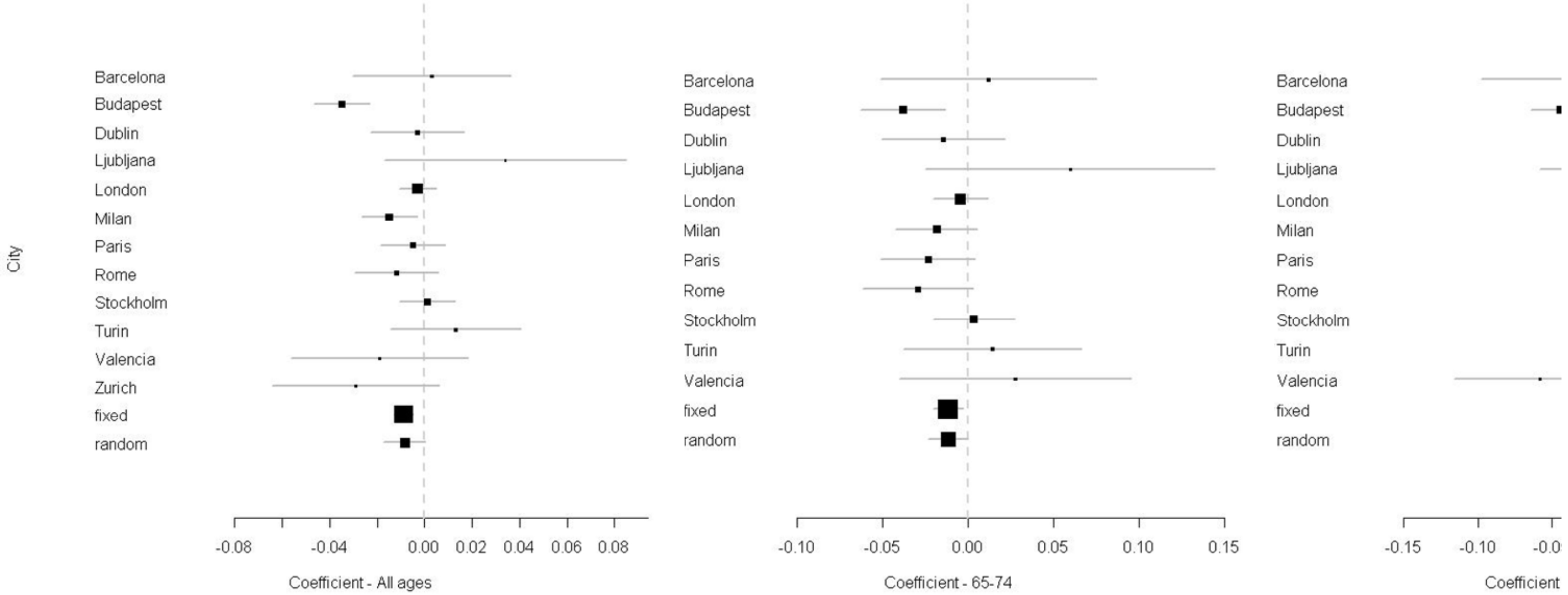
City	Population size*			Cardiovascular causes (daily number of HA)			Cerebrovascular causes (daily number of HA)			Respiratory causes (daily number of HA)		
	all ages (n)	65-74 yrs (%)	75+ yrs (%)	all ages	65-74 yrs^	75+ yrs	all ages	65-74 yrs^	75+ yrs	all ages	65-74 yrs^	75+ yrs
Barcelona	1,512,971	11.8	10.1	22	7	9	5	2	2	16	4	6
Budapest	1,797,222	9.4	7.3	111	30	50	15	4	6	26	4	5
Dublin	481,854	7.8	5.3	26	7	9	5	1	2	23	3	5
Ljubljana	263,290	9.3	5.9	11	3	3	2	0	1	7	1	1
London	6,796,900	7.0	6.8	164	42	68	28	7	15	125	18	33
Milan	1,304,942	12.1	9.5	71	19	25	14	4	8	26	4	6
Paris	6,161,923	7.1	6.1	127	31	29	n.a.	n.a	n.a.	59	8	11
Rome	2,812,573	10.9	8.2	120	34	50	25	6	14	43	8	11
Stockholm	1,173,183	6.9	8.5	48	12	25	10	3	6	18	4	6
Turin	901,010	12.3	9.2	25	7	11	7	2	4	10	2	3
Valencia	739,004	9.9	7.6	12	4	5	3	1	1	9	2	3
Zurich	990,000	n.a.	n.a.	8	5	n.a.	n.a.	1	n.a.	n.a.	1	n.a.

* 1996 population in Dublin; 1999 population in Paris; 2000 population in Barcelona, Budapest, Ljubljana, Rome, Stockholm, Turin and Valencia; 2001 population in London and Milan

^ Daily number of hospital admissions for the 65+ age group in Zurich

n.a.: not available

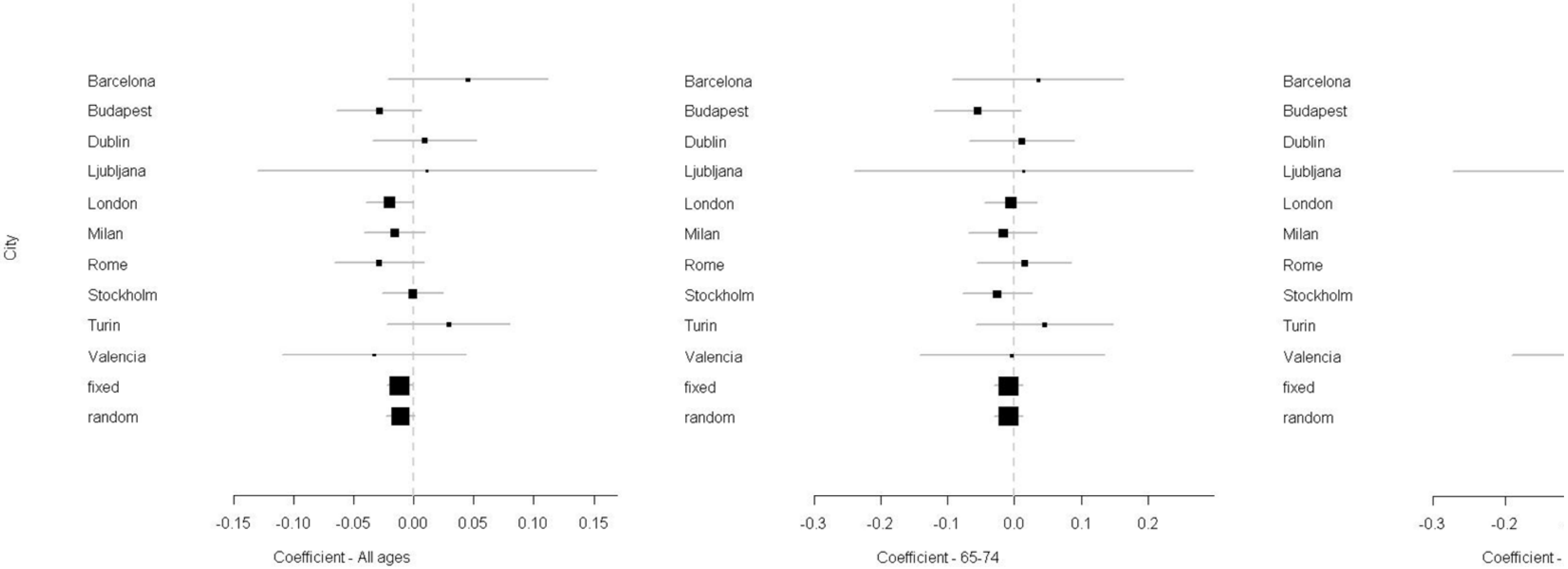
Figure 1. City-specific and pooled^ estimates (regression coefficients* and 95% confidence intervals) of association between daily hospital admissions for cardiovascular causes and maximum apparent temperature (T_{appmax}, °C) (lag 0-3) by age group (all age, 65-74 yrs and 75+ yrs) in 12 European cities within the PHEWE project during summer (April-September), 1990-2001.



^ Results from fixed and random effects meta-analysis

* Coefficients expressed as number of daily admissions for an increase of 1°C over 90th seasonal percentile of T_{appmax} (30.8 °C in Barcelona, 28.9 °C in Budapest, 19.7 °C in Dublin, 27.3 °C in Ljubljana, 24.6 °C in London, 33.8 °C in Milan, 27.8 °C in Paris, 34.5 °C in Rome, 22.8 °C in Stockholm, 31.2 °C in Turin, 36.4 °C in Valencia, 27.3 °C in Zurich)

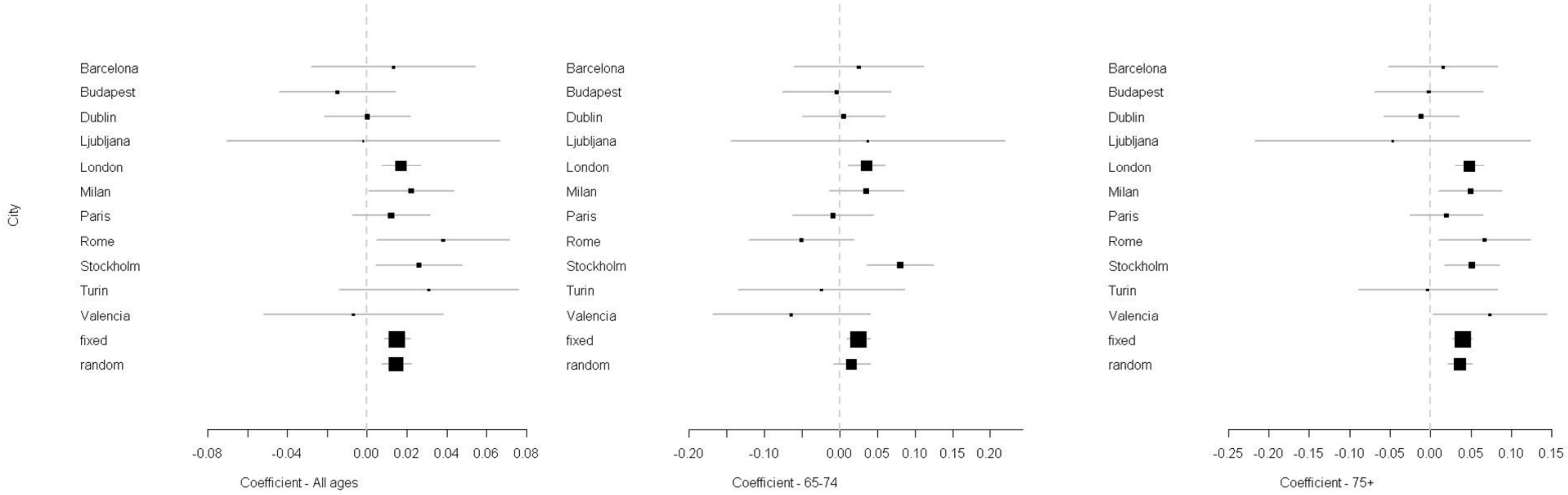
Figure 2. City-specific and pooled^ estimates (regression coefficients* and 95% confidence intervals) of association between daily hospital admissions for cerebrovascular causes and maximum apparent temperature (T_{appmax}, °C) (lag 0-3) by age group (all age, 65-74 yrs and 75+ yrs) in 12 European cities within the PHEWE project during summer (April-September), 1990-2001.



^ Results from fixed and random effects meta-analysis

* Coefficients expressed as number of daily admissions for an increase of 1°C over 90th seasonal percentile of T_{appmax} (30.8 °C in Barcelona, 28.9 °C in Budapest, 19.7 °C in Dublin, 27.3 °C in Ljubljana, 24.6 °C in London, 33.8 °C in Milan, 27.8 °C in Paris, 34.5 °C in Rome, 22.8 °C in Stockholm, 31.2 °C in Turin, 36.4 °C in Valencia, 27.3 °C in Zurich)

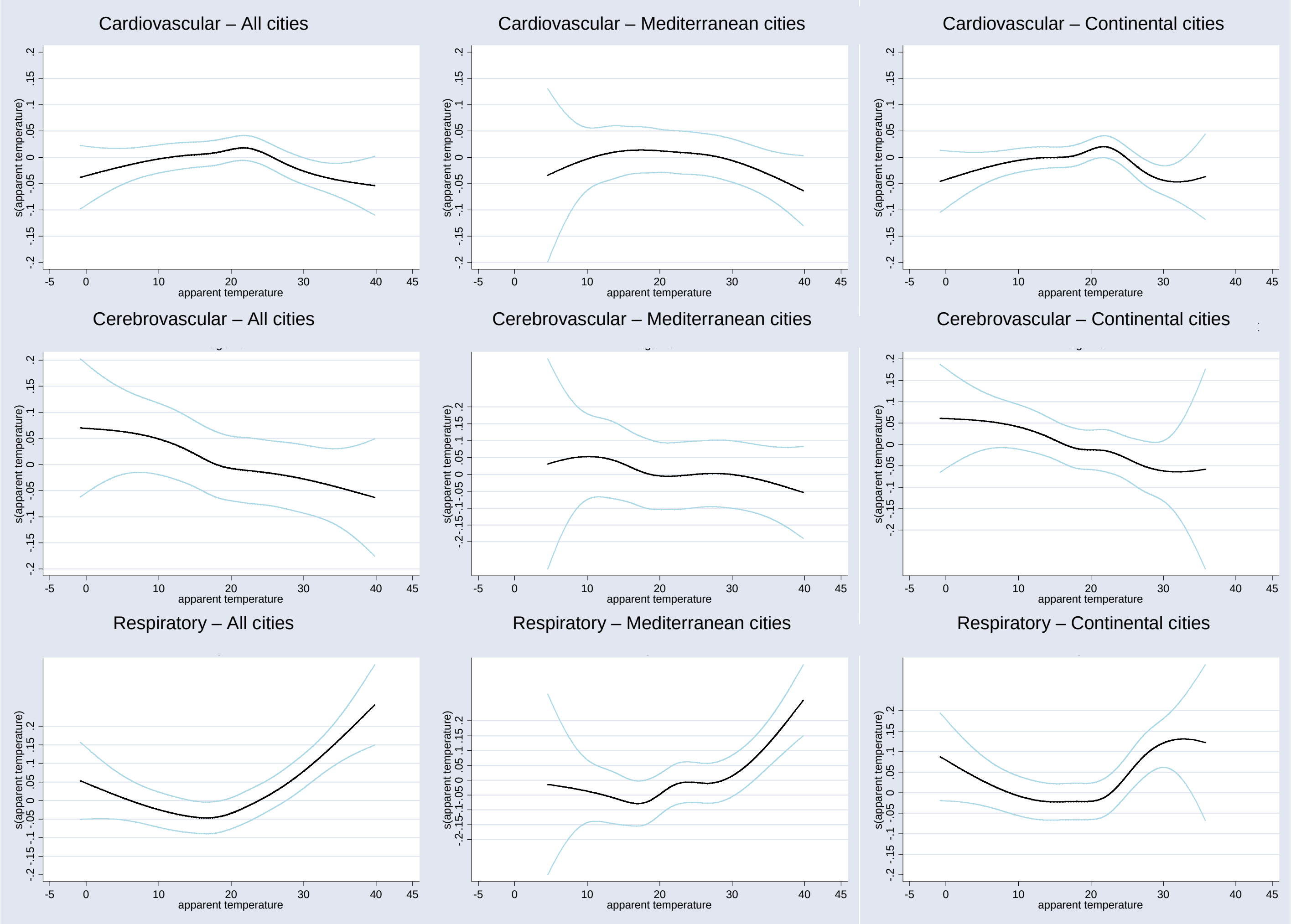
Figure 3. City-specific and pooled^ estimates (regression coefficients* and 95% confidence intervals) of association between daily hospital admissions for respiratory causes and maximum apparent temperature (T_{appmax}, °C) (lag 0-3) by age group (all age, 65-74 yrs and 75+ yrs) in 12 European cities within the PHEWE project during summer (April-September), 1990-2001.



^ Results from fixed and random effects meta-analysis

- Coefficients expressed as number of daily admissions for an increase of 1°C over 90th seasonal percentile of T_{appmax} (30.8 °C in Barcelona, 28.9 °C in Budapest, 19.7 °C in Dublin, 27.3 °C in Ljubljana, 24.6 °C in London, 33.8 °C in Milan, 27.8 °C in Paris, 34.5 °C in Rome, 22.8 °C in Stockholm, 31.2 °C in Turin, 36.4 °C in Valencia, 27.3 °C in Zurich)

Figure 4. The pooled exposure-response curves of maximum apparent temperature (T_{appmax}, °C) (lag 0-3) and daily hospital admissions for cardiovascular, cerebrovascular and respiratory causes in the 75+ yrs age group in all cities, Mediterranean° and Continental/Northern°° cities within the PHEWE project during summer (April-September), 1990-2001



° Mediterranean cities: Barcelona, Ljubljana, Milan, Rome, Turin and Valencia
°° Continental/Northern cities: Budapest, Dublin, London, Paris, Stockholm and Zurich

Table 3. Pooled[^] estimates of the association between maximum apparent temperature (T_{appmax}, °C) (lag 0-3) and daily hospital admissions (HA) for cardiovascular, cerebrovascular and respiratory causes by age group in all cities, Mediterranean and Continental/Northern cities within the PHEWE project during summer (April-September), 1990-2001.

	All cities		**Mediterranean cities[°]**		**Continental/Northern cities[°°]**	
	% change (95%CI) in daily HA for 1°C increase in T_{appmax}		**% change (95%CI) in daily HA for 1°C increase in T_{appmax}**		**% change (95%CI) in daily HA for 1°C increase in T_{appmax}**	
	Fixed effects	**Random effects**	**Fixed effects**	**Random effects**	**Fixed effects**	**Random effects**
Cardiovascular causes						
all ages	-0.9 (-1.3; -0.5)	-0.8 (-1.7; 0.0)	-0.9 (-1.8; -0.1)	-0.6 (-1.8; 0.5)	-0.9 (-1.4; -0.4)	-1.1 (-2.4; 0.2)
65-74	-1.2 (-2.1; -0.3)	-1.2 (-2.3; 0.0)	-1.0 (-2.7; 0.6)	-0.5 (-2.7; 1.7)	-1.2 (-2.3; -0.2)	-1.4 (-2.9; 0.1)
75+ years	-1.1 (-1.8; -0.4)	-1.2 (-2.3; -0.1)	-1.1 (-2.5; 0.3)	-1.1 (-2.5; 0.3)	-1.1 (-2.0; -0.3)	-1.2 (-2.8; 0.5)
Cerebrovascular causes						
all ages	-1.2 (-2.3; -0.1)	-1.1 (-2.3; 0.0)	-0.9 (-2.7; 0.8)	-0.7 (-3.0; 1.6)	-1.3 (-2.7; 0.0)	-1.3 (-2.7; 0.1)
65-74	-1.0 (-3.1; 1.1)	-1.0 (-3.1; 1.1)	0.4 (-3.1; 4.0)	0.4 (-3.1; 4.0)	-1.7 (-4.3; 0.9)	-1.7 (-4.3; 0.9)
75+ years	-1.5 (-3.0; -0.1)	-1.5 (-3.0; -0.1)	-1.9 (-4.2; 0.5)	-1.9 (-4.2; 0.5)	-1.3 (-3.1; 0.5)	-1.3 (-3.1; 0.6)
Respiratory causes						
all ages	1.5 (0.8; 2.1)	1.5 (0.7; 2.2)	2.1 (0.6; 3.6)	2.1 (0.6; 3.6)	1.3 (0.6; 2.1)	1.1 (0.0; 2.2)
65-74	2.5 (0.9; 4.2)	1.5 (-0.9; 4.1)	0.0 (-3.1; 3.4)	-0.3 (-4.1; 3.6)	3.3 (1.4; 5.1)	2.7 (-0.4; 6.0)
75+ years	4.1 (2.7; 5.3)	3.7 (2.1; 5.3)	4.5 (1.9; 7.3)	4.5 (1.9; 7.3)	3.9 (2.4; 5.3)	2.9 (0.5; 5.4)

[^] Results from fixed and random effects meta-analysis

[*] Percentage change for 1°C increase over the 90th annual percentile of T_{appmax} (30.8 °C in Barcelona, 28.9 °C in Budapest, 19.7 °C in Dublin, 27.3 °C in Ljubljana, 24.6 °C in London, 33.8 °C in Milan, 27.8 °C in Paris, 34.5 °C in Rome, 22.8 °C in Stockholm, 31.2 °C in Turin, 36.4 °C in Valencia, 27.3 °C in Zurich)

[°] Mediterranean cities: Barcelona, Ljubljana, Milan, Rome, Turin and Valencia

[°°] Continental/Northern cities: Budapest, Dublin, London, Paris, Stockholm and Zurich

7. Short term effect of apparent temperature on hospital admissions during winter: results of the European PHEWE project

INTRDUCTION

Cold temperatures have been related to increases in mortality during winter in a number of time series studies both in Europe (Rossi et al. 1999, Huynen *et al*. 2001, Keatinge and Donaldson 2001, Wilkinson et al. 2004, Carder et al. 2005, Diaz et al. 2005), in the United States (O'Neill et al. 2003), and in other countries (El-Zein et al. 2004, O'Neill et al. 2005). These studies have documented a geographical variability in the impact of cold on mortality but comparisons have to be made cautiously as the exposure indicator and the statistical methods employed differ considerably. The few multi-city studies available, allowing for unbiased comparison thanks to standardization of protocols between study centers, and showed a greater effect of low temperatures in populations residing in warmer than in colder regions of Europe (Eurowinter Group 1997) and of the U.S. (Braga et al. 2001, Curriero et al. 2002). The underlying mechanisms by which cold exposure can lead to heterogeneous responses in different populations are still not completely understood. Possible explanations consist in a different population's ability to cope with extremely low temperatures attributable, for example, to differences in home heating, clothing and in level of physical activity outdoors (The Eurowinter Group 1997), as well as, in a diverse demographic and socio-economic structure that makes a specific population more susceptible to the effect of cold.

Direct effects of cold, such as hypothermia, are rarely the cause of winter deaths, at least in developed countries, and the greatest part of cold-related mortality is due to cardiovascular and respiratory diseases, especially in the elderly who have beginning stage arterial disease and limited thermoregulatory responses (Keatinge 2002). Effects on morbidity usually anticipate death as suggested by the biological mechanisms underlying cold-related illnesses (Näyhä 2002). However, the influence of cold on outcomes other than mortality has received little investigation and are somewhat in contrast. Time series studies performed in France (Danet et al. 1999), Italy (Morabito et al. 2005) and Greece (Panagiotakos et al. 2004) have documented cold-related increases in hospital admissions for myocardial infarction or coronary disease in subjects older than 65 years. On the contrary, a large multi-city study from the U.S. found a linear relation between temperature and heart disease admissions in the elderly with the lowest admission rates recorded during cold weather (Schwartz et al. 2004). Considering the limited and conflicting evidence available, the specific contribution of cold temperatures on hospital admissions needs to be thoroughly examined. Moreover, no study to date has systematically examined the effect of cold on both mortality and morbidity outcomes. This could be of interest to address the question how well the health services are able to respond to cold weather. Studies carried out during heat waves (Jones et al. 1982, Whitman et al. 1997, Semenza et a. 1999, Kovats et al. 2004) suggest that burden on hospital admissions does not reflect the magnitude of that on mortality, supporting the hypothesis that many heat related deaths occur before coming to medical attention. Similar studies carried out during cold weather are needed. This knowledge gap could only be filled in by studies with enough power to test the hypothesis of interest but also including different areas to ensure results can be generalised. This can be the case of multi-centres studies with standardized protocols and procedures between study areas. Such studies could also be important to establish international collaborations between experts in several disciplines like health care and meteorology that may support institutions in defining usable public health programmes for preventing cold-related impacts on health.

The three-year EU funded multi-cities project PHEWE (Assessment and prevention of acute health effects of weather conditions in Europe) was planned with the primary aim to evaluate the acute health effects of weather during the warm and the cold season through a time series approach. Both mortality and hospital admissions for cardiovascular, cerebrovascular, and respiratory causes were the outcomes considered. The objectives and the design of the PHEWE study have already been described elsewhere (*chapter 2*). Results from city specific and pooled analyses of the relationship between meteorological variables and daily number of hospital admissions for the winter season will be discussed in this paper.

Methods

Study areas and populations

Twelve cities (Barcelona, Budapest, Dublin, Ljubljana, London, Milan, Paris, Rome, Stockholm, Turin, Valencia and Zurich) were considered for the hospital admissions analysis on the basis of data availability. These cities include a population of about 25 million people and are heterogeneous by demographic and socio-economic structures, and by climates and air pollution levels. More details on the datasets are provided in *chapter 2*.

Hospital admission data

Hospital admissions data were provided by routine registers and referred to the resident population only, except for Dublin where data also included non residents. For most cities, quality control of the data was carried out by local researchers and included checking for completeness of diagnosis and validity. For Barcelona, London, Milan, Paris, Rome and Stockholm data were previously collected within the second APHEA (Air Pollution on Health: European Approach) project (Atkinson et al. 2001, Le Tertre et al. 2002) and were updated. For the remaining cities data were collected for the first time and a minimum of 3 years was considered within the period 1990-2001. Time series of daily counts of admissions were constructed, for all ages combined and for specific age groups (0-14 yrs, 15-64 yrs, 65-74 yrs, 75+ yrs), for the following causes:

- Cardiovascular causes: International Classification of Diseases, 9th revision (ICD-9), 390-459
- Cerebrovascular causes: ICD-9, 430-438
- Respiratory diseases: ICD-9, 460-519
- Influenza: ICD-9, 487

Data for cerebrovascular causes was not available in Paris, while in Zurich both cerebrovascular and respiratory data were not provided. Each cause was extracted by considering only the main discharge diagnosis. Furthermore, only hospital admission for acute conditions were collected for all cities. Acute admissions was available in Barcelona, Budapest, Dublin, Ljubljana, London, Stockholm (from 1997), Turin and Valencia. For the other cities where admissions for acute conditions could not be directly derived, a common procedure was adopted. The selection criteria implied to exclude transfers from other hospitals, to focus on the diagnoses reported only for the first service in which the patients were admitted, and to exclude the highly elective conditions (day hospital stay, rehabilitation, surgery, traumas, deliveries, psychiatric and dermatological conditions).

Meteorological data

The dataset comprised of three-hourly meteorological varaibles including air temperature (T_{air}, °C), dew point temperature (T_{dewpt}, °C), relative humidity (%), wind speed (m/s), wind direction (degree), sea level pressure (hPa), total cloud cover (octas), solar radiation (MJ/m^2), precipitation (mm), visibility (m) (*chapter 2*). In the present study, maximum apparent temperature (T_{appmax}) was used as the exposure variable apparent temperature, an index of thermal discomfort based on air temperature and dew point temperature using the following formula (Kalkstein and Valimont, 1986; O'Neill et al. 2003).

$$T_{app} = -2.653 + 0.994(T_{air}) + 0.0153(T_{dewpt})^2$$

The choice of maximum apparent temperature as the exposure variable for the time series analysis was driven by the fact that it comprises air and dew point temperature in a single parameter. The simplified formula for this indicator was considered the most suitable one on the basis of data availability and quality. In Barcelona, where the three-hourly meteorological data were not available, the mean apparent temperature was used.

Air pollution data

Since air pollution levels are linked to atmospheric conditions, there is the potential for an effect modification and/or confounding of air pollution on the relationship between temperature and mortality, although the magnitude of the effect is still unclear.

The air pollution database comprised of the following pollutants: PM10, TSP or Black Smoke, SO_2 (24-hour), NO_2 (1 hour, 24-hour), O_3 (1 hour, 8-hour), and CO (8-hour). Further details on the data collection and datasets are provided in *chapter 2*. The maximum 1-hour daily value of NO_2 was used as pollutant variable to include in the model in all cities, except Dublin and Ljubljana where the daily average of Black Smoke and SO_2 were used respectively. NO_2 was selected as an indicator of air pollution levels on the basis of a series of considerations; firstly it is a good traffic pollution indicator as well as a valid proxy of the overall pollutant levels in an urban area, and secondly for the completeness of the data series in most cities.

Statistical analysis

Daily hospital admissions counts were collected in each city and sent to partner 1 in which the analysis was centralised. The time series used in the analysis were chosen based on the datasets available that differed between cities (Table 1). The present analysis was carried out for the winter period (October-March) to investigate the effect of maximum apparent temperature on daily hospital admissions. The statistical analysis followed two stages according to a jointly decided methodology defined by the Working Group Epidemiology and Statistics. In the first stage, data from each city were analyzed to estimate the city-specific effects. A common model, defined on the basis of a sensitive analysis was used for each city. In the second stage city-specific results were combined to obtain pooled estimates and to investigate heterogeneity.

City-specific analysis

The city-specific analyses were based on the Generalized Estimating Equations (GEE) models (Liang and Zeger 1986). According to this approach, we modelled the marginal relationship between daily hospital admission counts and maximum apparent temperature, treating the dependence of daily observations within each winter as a nuisance parameter. Since hospital admissions are often highly correlated over time, we assumed that observations between days of different summer periods were independent and observations within each winter were correlated. As required by the GEE approach, the correlation structure within observations was specified on the basis of an exploratory analysis (Chiogna and Gaetan 2003) and a first order autoregressive term within year was included in the model (Schwartz and Dockery 1992).

In the common model considered for each city, a Poisson distribution with a logarithmic link function was fitted on daily counts for hospital admissions (outcome variable), including different covariates as potential confounders. Potential confounders considered in the analysis were: holiday, day of the week and calendar month (included as dummy variables); linear terms for barometric pressure (lag 0-3), wind speed, linear and quadratic terms of time pick up the long-term trend (Biggeri et al. 2004a, Biggeri et al. 2004b, Biggeri et al. 2005) and an air pollution variable (lag 0-1). For all cities, the maximum 1-hour daily value of NO_2 was used as an indicator for air pollution levels, except Dublin and Ljubljana where the daily average of Black Smoke and SO_2 were used respectively. Furthermore, an indicator of influenza epidemics was also included, but it was not included in the analysis for respiratory causes. Considering that the analysis is only for the winter period, seasonality is accounted for and will not be regarded as confounder in the analysis. However it is important to consider that there is heterogeneity in the length of the season and that the climatic characteristics vary among the 12 cities (for details see *chapter 2*).

As exposure variable it was decided to considered the delayed effect of maximum apparent temperature (lag 0-15), chosen on the basis of results from transfer functions exploratory analysis and in agreement with other time series studies' results (Kunst et al. 1993, Ballester et al. 1997, Schwartz et al. 2004). Sensitivity analyses using the minimum apparent temperature were performed and consistent results were obtained. Since the shape of relationship between maximum apparent temperature and hospital admissions is not well known, the exposure-response curve was modelled using a flexible parametric approach including penalized cubic regression splines for the temperature variable. Temperature splines were created considering the whole range of maximum apparent temperature, specifying a vector of interior knots placed at equally-spaced intervals for each city (one knot every 8 °C) using the 'mgcv' library available for the R software Version 2.1.0 (The R Foundation 2004).

Pooled analysis

In the second stage of the analysis, results from each city were combined to summarize estimates of all cities. To reduce the heterogeneity among the city-specific estimates, results were pooled after classifying cities in two groups identified *a priori* on the basis of meteorological and geographical criteria. The two groups were defined as Mediterranean cities (Barcelona, Ljubljana, Milan, Rome, Turin and Valencia) and Northern-Continental cities (Budapest, Dublin, London, Paris, Stockholm and Zurich).

In order to describe the overall exposure-response curves, a GEE regression model with a cubic regression spline for maximum apparent temperature was specified on the pooled dataset containing information from all cities. The model was the same as the one used in the first stage analysis, and a city indicator variable and interaction terms between confounders and city indicator were added. This approach allows to obtain an overall exposure-response curve that accounts for the large variability of the range in the exposure variable among cities. The analysis were performed separately for all cities and for the two city groups.

Finally, to obtain the overall estimates of the effect of temperature on hospital admissions, a meta-analysis approach was applied on the results obtained from each city. In this case, fixed effects and random effects models were run to derive the pooled estimates of the effect of maximum apparent temperature (lag 0-15) on the daily hospital admissions. The estimated effect was then expressed as the percent change in daily hospital admissions for 1°C increase in maximum apparent temperature. Again the analysis were performed separately for all cities and for the two city groups.

Preliminary analysis showed a weak associations for the younger age groups (0-14 years and 15-64 years age groups), hence it was decided to present results only for the following age groups: all ages, 65-74 years and 75+ years.

Results

Table 1 shows the study periods and summarizes the distribution of mean air temperature, mean dew point temperature, T_{appmax} and NO_2 for the 12 cities included in the present analysis. The median of the daily mean air temperature ranged from 1.4°C in Stockholm and 13.5 °C in Barcelona, with the greatest variability observed in Ljubljana and Budapest (range between the 90th and the 10th percentile equal to 14.6 °C and 14.5 °C respectively) and the lowest in Dublin (range between the 90th and the 10th percentile equal to 9.2 °C). The mean dew point temperature has a similar distribution with the minimum in Stockholm (median equal to 0.8 °C) and the maximum in Valencia (median equal to 12.7 °C), with the greatest variability in Budapest, Ljubljana and the Italian cities (range between the 90th and the 10th percentile about 14 °C) and the lowest in Valencia (range between the 90th and the 10th percentile equal to 8.2 °C). Similarly, T_{appmax} ranged from 0.8°C in Stockholm and 17.2°C in Valencia, with the greatest variability in Ljubljana range between the 90th and the 10th percentile equal to 17 °C) and the lowest in Dublin (range between the 90th and the 10th percentile equal to 10.6 °C. The median concentrations of NO2 also vary, from 150.3 μg/m^3 in Valencia to 28.0 μg/m^3 in Ljubljana.

In Table 2 is given a description of population size and daily number of hospital admissions for cardiovascular, cerebrovascular and respiratory causes by age group in the 12 cities. The number of city residents ranged from about 6.8 million in London to just over 250,000 in Ljubljana, with the greatest proportion of persons in the 75+ years age group in Barcelona (10.1%), Milan (9.5%) and Turin (9.2%) and the lowest in Dublin (5.3%) and Ljubljana (5.9%). With regards to the hospital admissions, there is some variability among cities; with the highest mean number of admissions recorded in London for both cardiovascular (171 admissions) and respiratory (179 admissions) causes, and the lowest in Zurich for cardiovascular causes (9.1 admissions) and Ljubljana for respiratory causes (8 admissions). Overall, the greatest mean number of daily admission for all the three causes considered was recorded in the 75+ years age group.

Figure 1 to 3 illustrate the city-specific and pooled estimates of the association between cardiovascular, cerebrovascular and respiratory hospital admissions and T_{appmax}. Overall, cardiovascular causes appear to be weakly associated with a decrease in T_{appmax} only for the 65-74 and 75+ years age groups. In most cities cardiovascular admissions tend to increase in presence of low temperatures although a significant effect can only be observed in Barcelona (all ages and 75+ age group), Budapest (all age groups considered) and London (all ages and 75+ age group). Pooled admissions for cerebrovascular causes were not associated with a decrease in temperature; city-specific results show an increase in admission counts with decreasing temperature in most cities, but significant associations only in Barcelona (75+ age group) and Budapest (all ages and 75+ age group). A significant effect of decreasing temperatures was observed in the pooled analysis on respiratory admissions in all age groups considered. Significant coefficients were observed in all age groups considered in Budapest, Dublin, London, Paris, Rome, Stockholm and Valencia. While for Barcelona and Milan only for total and the 75+ age group. It's worth noting a certain degree of heterogeneity between city-specific estimates for all the three outcomes.

The pooled exposure-response curves of maximum apparent temperature and daily hospital admissions in the 75+ years age group in all cities, Mediterranean and Continental/Northern cities are depicted in Figure 4. When considering all cities together, the relation between T_{appmax} and hospital admissions assumes a linear relation with admission rates rising progressively as temperature decreases for all the three outcomes, although it appears to be stronger for respiratory causes. In the analysis carried out on Mediterranean and Continental/Northern cities separately, the strongest associations are visible for the second group of cities, especially for respiratory causes. The wider confidence intervals observed for cerebrovascular causes reflect the smaller admission counts.

Table 3 shows pooled estimates of the association between maximum apparent temperature and daily hospital admissions by age group in all cities, Mediterranean and Continental/Northern cities. Significant increases in hospital admission counts for a decrease in 1°C in T_{appmax} are visible for cardiovascular causes in the 65-74 and 75+ years age groups in all cities and only in the 75+ age group in Continental/Northern cities. Overall, no effect of low temperature was found for cerebrovascular admissions in all three groups of cities. With regards to respiratory admissions, significant association between admissions rates and a decrease in T_{appmax} is observed for all the age groups considered even if higher in the 75+ years age group in all cities as well as in Continental/Northern cities, with a high degree of heterogeneity. In Mediterranean cities the only significant association was found in the 75+ age group.

Discussion

The present study carried out within the PHEWE project provides evidence of a small increase in daily hospital admission counts for cardiovascular and cerebrovascular causes while an higher significant effect was observed for respiratory causes. When comparing with findings for cold-related mortality within the same cities in the PHEWE project (see *chapter 4*) it can be observed that the effect seen on cardiovascular mortality is higher than the impact on admissions. Respiratory admissions on the contrary show a similar effect to that already observed for mortality (see *chapter 4*). The effect on respiratory admissions are stronger in the 65-74 years and 75+ years age groups with a 1.8% and 2.5% increase in daily counts for 1 °C decrease in maximum apparent temperature, respectively. This findings are also in agreement with results found in the Eurowinter study (Eurowinter Group, 1997) involving people aged 50-74 years in various European regions (Finland, Baden-Württemberg, Netherlands, London, Athens, northern Italy and Palermo) where a significant effect of cold temperatures on respiratory mortality but not on cardiovascular mortality was observed.

The twelve cities included in the present study cover a wide range of climatic conditions. To reduce such a heterogeneity pooled analyses were run after grouping cities on the basis of meteorological and geographical criteria into Mediterranean and Continental/Northern cities. When considering pooled results for the two groups of cities, the larger effects of cold temperatures on cardiovascular (75+ age group only) and respiratory admissions were observed in Continental/Northern cities. Such a geographical heterogeneity is in contrast with findings on cold-related mortality within the PHEWE project that show a cold effect on mortality (both all and specific causes) greater in Mediterranean than in Continental/Northern cities (see *chapter 4*). Other authors have also found results contrasting with the present study, with greater effect of low temperatures in populations residing in warm regions suggesting that in these areas populations are usually less adapted to cold weather. The Eurowinter study (Eurowinter Group, 1997) estimated an increase in total mortality for a 1 °C fall in temperature below 18 °C highest in warmer than in colder countries (from 2.2% in Athens, Greece to 0.27% in south Finland). Curriero *et al*. (2002) in 11 cities in the eastern United States found an highest cold impact on warmest cities (increase in mortality from 0.1% below 21.4°C in Baltimore, Maryland to 0.5% below 27.2°C in Miami, Florida, at lag 0). However, comparisons with other studies on winter exposure should be made with caution as different methodologies are employed and no other studies present pooled estimates of the effect.

References

1. Atkinson RW, Anderson HR, Sunyer J, et al. Acute effects of particulate air pollution on respiratory admissions. Results from APHEA 2 Project. *Am J Crit Care Med* 2001; 164: 1860-1866.
2. Ballester F, Corella D, Perez-Hoyos S, Saez M, Hervas A. Mortality as a function of temperature. A study in Valencia, Spain, 1991-1993. *Int J Epidemiol* 1997; 26(3): 551-561.
3. Biggeri A, Baccini M, Chiogna M, Accetta G, Atkinson R, Analitis A, Medina S, Paldy A, Sunyer J. 2004a. The PHEWE project – The methodological approach used to evaluate the short-term health effects of weather conditions. *Epidemiology* 15:S103.
4. Biggeri A, Baccini M, Lertxundi A, Michelozzi P, Katsouyanni K, Bisanti L, Cadum E, Tiittanen P. 2004b. Short Term Effects of Temperature and Humidity on Mortality in European Cities: results from the PHEWE Project. *Epidemiology* 15:S101.
5. Biggeri A, Baccini M, Michelozzi P, Kirchmayer U, Analitis A, Katsouyanni K, Bisanti L, Cadum E, Tiittanen P, Medina S, Paldy A. 2005. Short term effects of apparent temperature on mortality in European cities: results from the PHEWE Project. *Epidemiology* 16:S140.
6. Braga A.L.F., Zanobetti A, Schwartz J. The Effect of Weather on Respiratory and Cardiovascular Deaths in 12 U.S. Cities. Environ Health Perspect 2002; 110:(9)859-863.
7. Carder M., McNamee R., Beverland I., Elton R., Cohen G.R., Boyd J., et al. The lagged effect of cold temperature and wind chill on cardiorespiratory mortality in Scotland. Occup Environ Med 2005; 62:702-710.
8. Chiogna M., Gaetan C., Transfer function modelling strategy for combining evidence on air pollution and daily mortality. In Proceedings of SCO2003, Treviso 4-6 september 2003, 140-145.
9. Curriero F, Heiner K, Samet J et al. Temperature and Mortality in 11Cities of the Eastern United States. Am J Epidemiol 2002; 155:(1)80-87.
10. Danet S.., Richard F., Montaye M., Beauchant S., Lemaire B., Graux C., et al. Unhealthy Effects of Atmospheric Temperature and Pressure on the Occurrence of Myocardial Infarction and Coronary Deaths: A 10-Year Survey: The Lille-World Health Organizatin MONICA Project(Monitoring Trends and Determinants in Cardiovascular Disease). Circulation 1999; 100:e1-e7
11. Diaz J, Garcia R., Lopez C., Linares C., Tobias A., Prieto L. Mortality impact of extreme winter temperatures. Int J Biometeorol 2005; 49:179-183.
12. El - Zein A., Tewtel - Salem M., Nehme G. A time-series analysis of mortality and air temperature in Greater Beirut. Science of the Total Environment 2004; 330:71-80.
13. Eurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, repiratory disease, and all casues in warm and cold regions of Europe. Lancet 1997; 349:1341-1346.
14. Huynen M, Martens P, Schram D et al. The Impact of Heat Waves and Cold Spells on Mortality Rates in the Dutch Population. Environ Health Perspect 2001; 109:463-470.
15. Jones TS, Liang AP, Kilbourne EM, Griffin MR, Patriarca PA, Wassilak SG et al. Morbidity and mortality associated with the July 1980 heat wave in St Louis and Kansas City, Mo. JAMA 1982; 247:(24)3327-31.
16. Kalkstein LS, Valimont KM. An evaluation of summer discomfort in the United States using a relative climatological index. *Bull Am Meteorolog Soc* 1986;67:842-8.
17. Katsouyanni K, Schwartz J, Spix C, *et al.* Short term effects of air pollution on health: a European approach using epidemiologic time series data: the APHEA protocol. *J Epidemiol Comm Health* 1996; 50(Suppl 1): S12-S18.

18. Katsouyanni K, Zmirou D, Spix C, *et al*. Short-term effects of air pollution on health: a European approach using epidemiological time-series data. *Eur Respir J* 1995; 8: 1030-1038.
19. Keatinge W, Donaldson G. Mortality Related to Cold and Air Pollution in London after Allowance for Effects of Associated Weather Patterns. Environ Res 2001; Section A:(86)209-216.
20. Keatinge W.R. Winter mortality and its causes. International Journal of Circumpolar Health 2002; 61:292-299.
21. Kovats S.R., Hajat S., Wilkinson. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in greater London, UK. Occup Environ Med 2004; 61; 893-898
22. Kunst A, Looman C, Mackenbach J. Outdoor air Temperature and mortality in the Netherlands: a time-series analysis. *Am J Epidemiol* 1993; 137(3): 331-341.
23. Le Tertre A, Medina S, Samoli E, *et al*. Short-term effects of particulate air pollution on cardiovascular diseases in eight European cities. *J Epidemiol Community Health* 2002; 56: 773-779.
24. Liang K-Y, Zeger SL. Longitudinal analysis using generalized linear models. *Biometrika* 1986; 73: 13-22.
25. Michelozzi P, Kirchmayer U, Katsouyanni K, *et al*. Assessment and prevention of acute health effects of weather conditions in Europe. The PHEWE project: background, objectives, design. (*submitted*)
26. Michelozzi P, Kirchmayer U, Katsouyanni K, *et al.* Assessment and prevention of acute health effects of weather conditions in Europe. The PHEWE project: background, objectives, design. (submitted)
27. Morabito M., Modesti P.A., Cecchi L., Crisci A., Orlandini S., Maracchi G., et al. Relationships between weather and myocardial infarction: A biometeorological approach. International Journal of Cardiology 2005; 105:288-293.
28. Näyhä S. Cold and the risk of cardiovascular diseases. International Journal of Circumpolar Health 2002; 61 :(4)373-80.
29. O'Neill M.S., Hajat S., Zanobetti A, Ramirez-Aguilar M., Schwartz J. Impact of control for air pollution and respiratory epidemics on the estimated associations of temperature and daily mortality. Int J Biometeorol 2005; 50:(2)121-9.
30. O'Neill M.S., Zanobetti A, Schwartz J. Modifiers of the Temperature and Mortality Association in Seven US Cities. Am J Epidemiol 2003; 157:(12)1074-1082.
31. O'Neill MS, Zanobetti A, Schwartz J. Modifiers of the temperature and mortality association in seven US cities. *Am J Epidemiol* 2003;157:1074-1082.
32. Panagiotakos D.B., Chrysohoou C., Pitsavos C., Panagiotis N., Anadiotis A., Tentolouris C., et al. Climatological variations in daily hospital admissions for acute coronary syndromes. International Journal of Cardiology 2004; 94:229-233.
33. Rossi G., Vigotti M.A., Zanobetti A., Repetto F., Gianelle V., Schwartz J. Air Pollution and Cause-Specific Mortality in Milan, Italy, 1980-1989. Archives of Environmental Health 1999; 54:(3)158-164.
34. Schwartz J, Dockery DW. Increased mortality in Philadelphia associated with daily air pollution concentrations. Am Rev Respir Dis 1992;145(3):600-4.
35. Schwartz J, Samet J, Patz J. Hospital Admissions for Heart Disease: The Effects of Temperature and Humidity. Epidemiology 2004; 15:(6)755-61.
36. Schwartz J, Samet J, Patz J. Hospital admissions for heart disease: the effects of temperature and humidity. *Epidemiology* 2004; 15(6): 755-61.

37. Schwartz J. The distributed lag between air pollution and daily deaths. *Epidemiology* 2000; 11(3): 320-326.
38. Semenza J.C., McCullough J.E., Flanders W.D., McGeehin M.A., Lumpkin J.R. Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med 1999; 16:(4)359-60.
39. *The R Foundation for Statistical Computing*. 2004. Version 2.1.0 (2005-04-19), http://cran.r-project.org.
40. Whitman S, Good G, Donoghue DR, Benbow N, Shou W, Mou S. Mortality in Chicago Attributed to the July 1995 Heat Wave. Am J Public Health 1997; 87:(9)1515-1518.
41. Wilkinson P, Pattenden S, Armstrong B, Fletcher A, Kovats S, Mangtani P, et al. Vulnerability to winter mortality in elderly people in Britain: population based study. BMJ 2004; 329:647.
42. Wyzga RE. Effect of air pollution upon mortality. Consideration of distributed lag models: quantifying mortality displacement. *Biostatistics* 2000; 1: 279-292.
43. Zanobetti A, Wand MP, Schwatrz J, Ryan LM. Geberalized additive distributed lag models: quantifying mortality displacement. *Biostatistics* 2000; 1: 279-292.

Table 1. Study period and summary statistics of daily mean air temperature (T_{air}, °C), daily mean dew point temperature (T_{dewpt}, °C), daily maximum apparent temperature (T_{appmax}, °C) and the maximum 1 hour daily value of NO_2 (μg/m^3) in 12 European cities within the PHEWE project during winter (October-March), 1990-2001.

City	Study period	Percentile of mean T_{air}§ (°C)			Percentile of mean T_{dewpt}§ (°C)			Percentile of T_{appmax}§° (°C)			Percentile of NO_2* (μg/m^3)		
		10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
Barcelona	1994-1997	9.5	13.5	19.5	3.3	8.3	14.6	7.0	12.1	19.8	64.7	91.0	133.0
Budapest	1997-2000	-2.8	4.0	11.7	-6.6	-0.2	7.7	-3.2	4.8	13.6	33.0	67.0	96.0
Dublin	1994-2001	2.4	6.8	11.6	0.3	4.8	9.6	2.3	7.4	12.9	4.0	10.0	23.0
Ljubljana	1997-1999	-4.3	2.2	10.3	-6.7	-0.3	7.8	-3.7	3.6	13.8	10.0	28.0	68.0
London	1992-2000	2.7	7.7	12.1	-0.7	4.1	9.4	2.6	8.4	13.9	33.5	44.0	62.5
Milan	1990-1999	1.0	6.7	14.1	-2.9	3.3	11.3	1.0	7.8	18.0	98.0	143.8	247.2
Paris	1991-1995	0.6	7.2	12.7	-1.8	4.6	10.1	0.4	7.8	14.5	53.1	77.1	116.8
Rome	1998-2000	5.1	9.7	16.6	0.6	7.0	15.0	7.3	12.6	21.5	90.9	116.1	149.0
Stockholm	1990-2000	-4.7	1.4	7.6	-7.6	-0.8	5.4	-4.7	0.8	8.0	26.8	45.3	66.1
Turin	1995-1999	1.0	5.9	13.1	-4.4	1.2	9.8	1.5	7.6	17.1	79.3	123.7	195.2
Valencia	1996-2000	8.9	13.1	18.8	9.0	12.7	17.2	11.6	17.2	25.3	105.2	150.3	209.7
Zurich	1990-1996	-2.4	4.0	10.3	-5.6	1.0	7.3	-3.0	4.5	13.0	42.1	61.6	96.3

§ Three-hourly meteorological data from the nearest airport weather station

° Mean apparent temperature in Barcelona

* Daily average of Black Smoke (g/m^3) and SO_2 (g/m^3) in Dublin and Ljubljana respectively

Table 2. Population size and daily mean number of hospital admissions (HA) for cardiovascular, cerebrovascular, and respiratory causes by age group in 12 European cities within the PHEWE project during winter (October-March), 1990-2001.

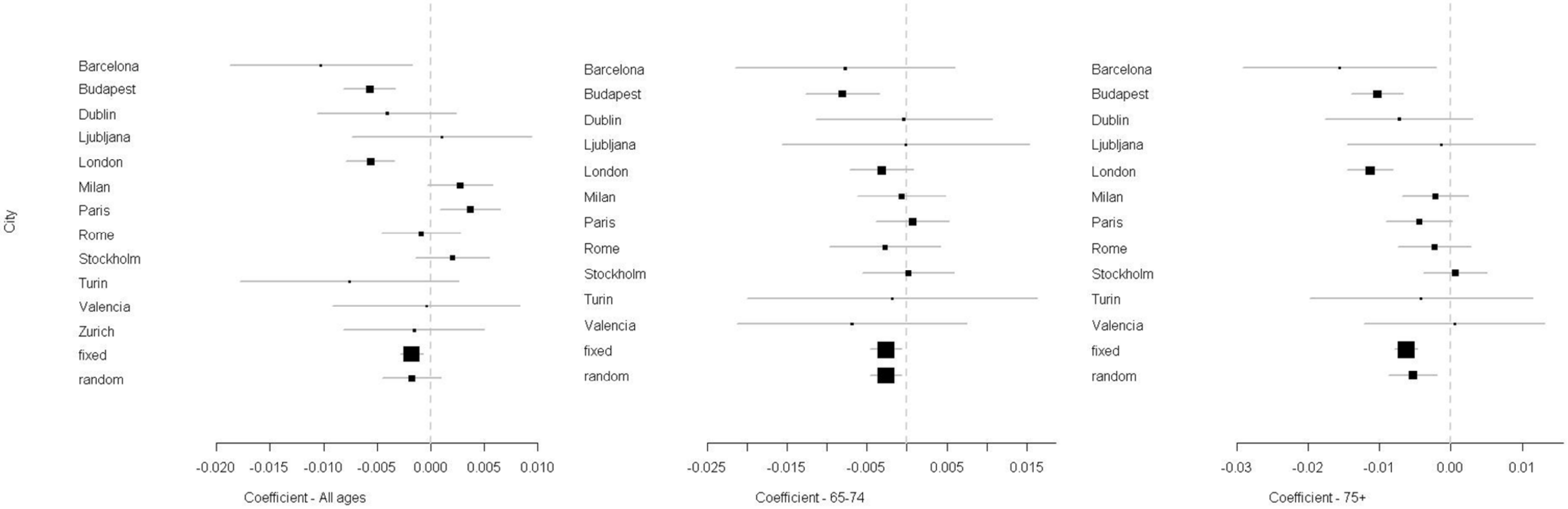
City	Population size*			Cardiovascular causes (daily number of HA)			Cerebrovascular causes (daily number of HA)			Respiratory causes (daily number of HA)		
	all ages (n)	65-74 yrs (%)	75+ yrs (%)	all ages	65-74 yrs^	75+ yrs	all ages	65-74 yrs^	75+ yrs	all ages	65-74 yrs^	75+ yrs
Barcelona	1,512,971	11.8	10.1	26	8	11	6	2	3	24	5	8
Budapest	1,797,222	9.4	7.3	119	32	54	15	4	6	37	5	7
Dublin	481,854	7.8	5.3	27	8	10	6	2	3	30	5	6
Ljubljana	263,290	9.3	5.9	12	4	4	2	1	1	8	1	1
London	6,796,900	7.0	6.8	171	43	73	30	7	16	179	24	50
Milan	1,304,942	12.1	9.5	82	21	29	15	4	8	34	5	9
Paris	6,161,923	7.1	6.1	147	37	34	n.a.	n.a.	n.a.	85	10	16
Rome	2,812,573	10.9	8.2	134	38	56	27	7	15	63	12	18
Stockholm	1,173,183	6.9	8.5	51	13	26	11	3	6	24	5	8
Turin	901,010	12.3	9.2	29	8	13	8	2	5	16	3	4
Valencia	739,004	9.9	7.6	14	4	6	3	1	2	14	3	5
Zurich	990,000	n.a.	n.a.	9	6	n.a.	n.a.	1	n.a.	n.a.	1	n.a.

* 1996 population in Dublin; 1999 population in Paris; 2000 population in Barcelona, Budapest, Ljubljana, Rome, Stockholm, Turin and Valencia; 2001 population in London and Milan

^ Daily number of hospital admissions for the 65+ age group in Zurich

n.a.: not available

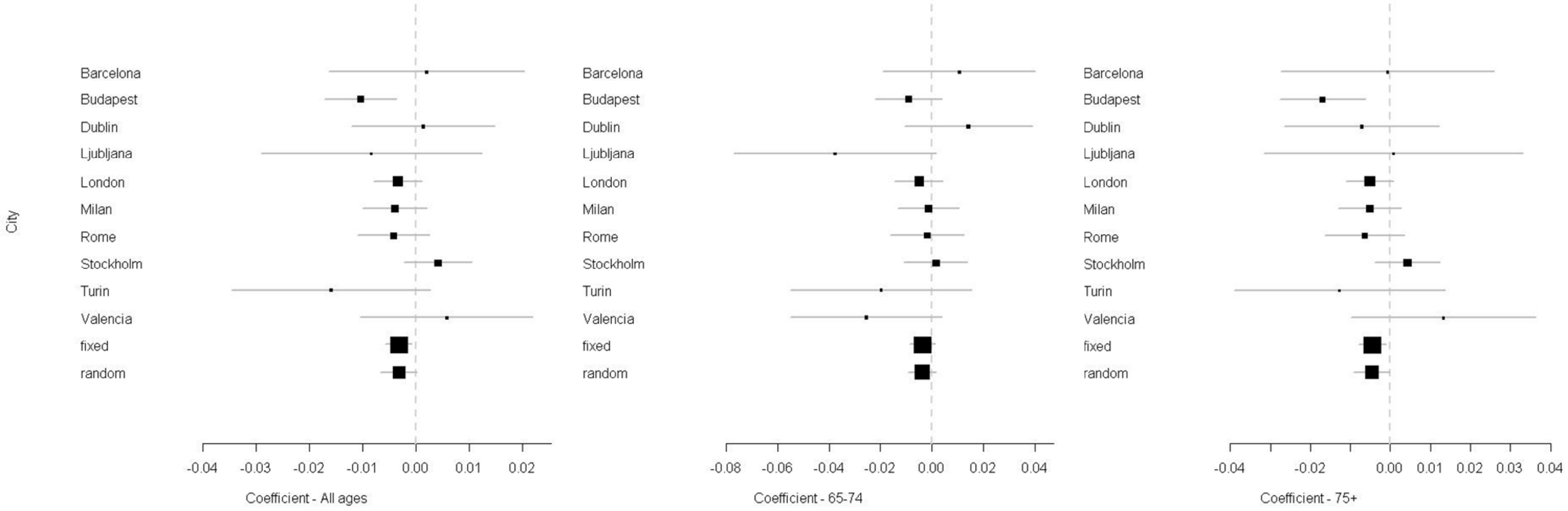
Figure 1. City-specific and pooled^ estimates (regression coefficients* and 95% confidence intervals) of association between daily hospital admissions for cardiovascular causes and maximum apparent temperature (T_{appmax}, °C) (lag 0-15) by age group (all age, 65-74 yrs and 75+ yrs) in 12 European cities within the PHEWE project during winter (October-March), 1990-2001.



^ Results from fixed and random effects meta-analysis

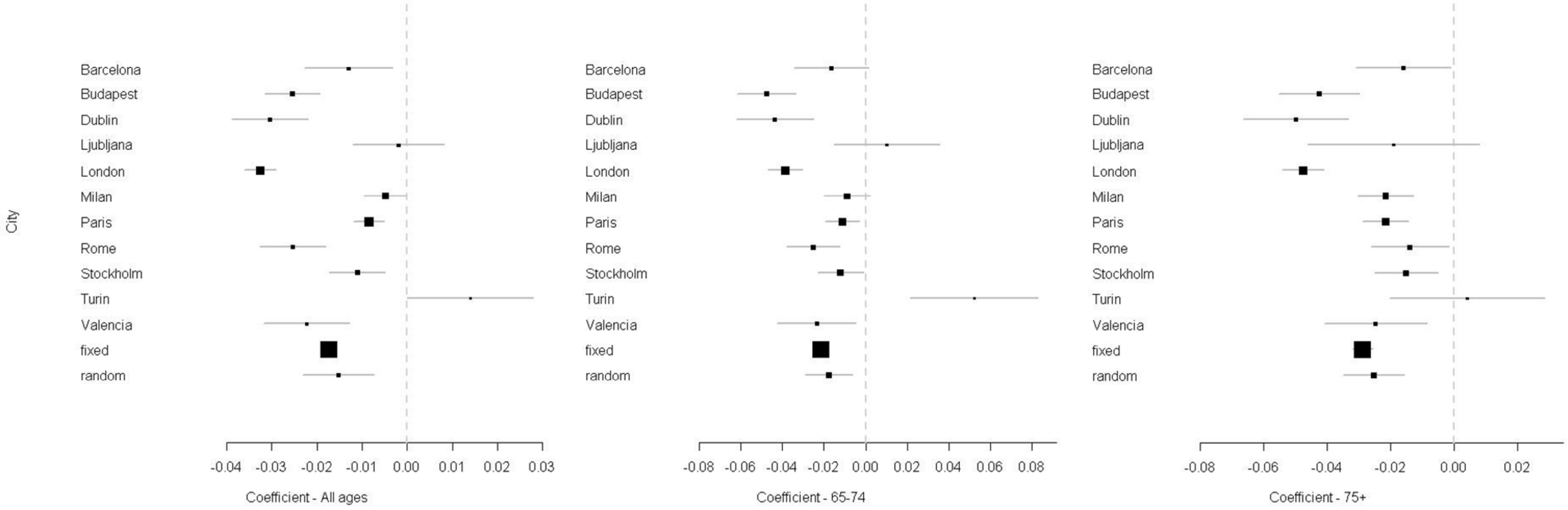
* Coefficients expressed as number of daily admissions for an increase of 1°C of Tappmax

Figure 2. City-specific and pooled^ estimates (regression coefficients* and 95% confidence intervals) of association between daily hospital admissions for cerebrovascular causes and maximum apparent temperature (Tappmax, °C) (lag 0-15) by age group (all age, 65-74 yrs and 75+ yrs) in 12 European cities within the PHEWE project during winter (October-March), 1990-2001.



^ Results from fixed and random effects meta-analysis
* Coefficients expressed as number of daily admissions for an increase of 1°C of Tappmax

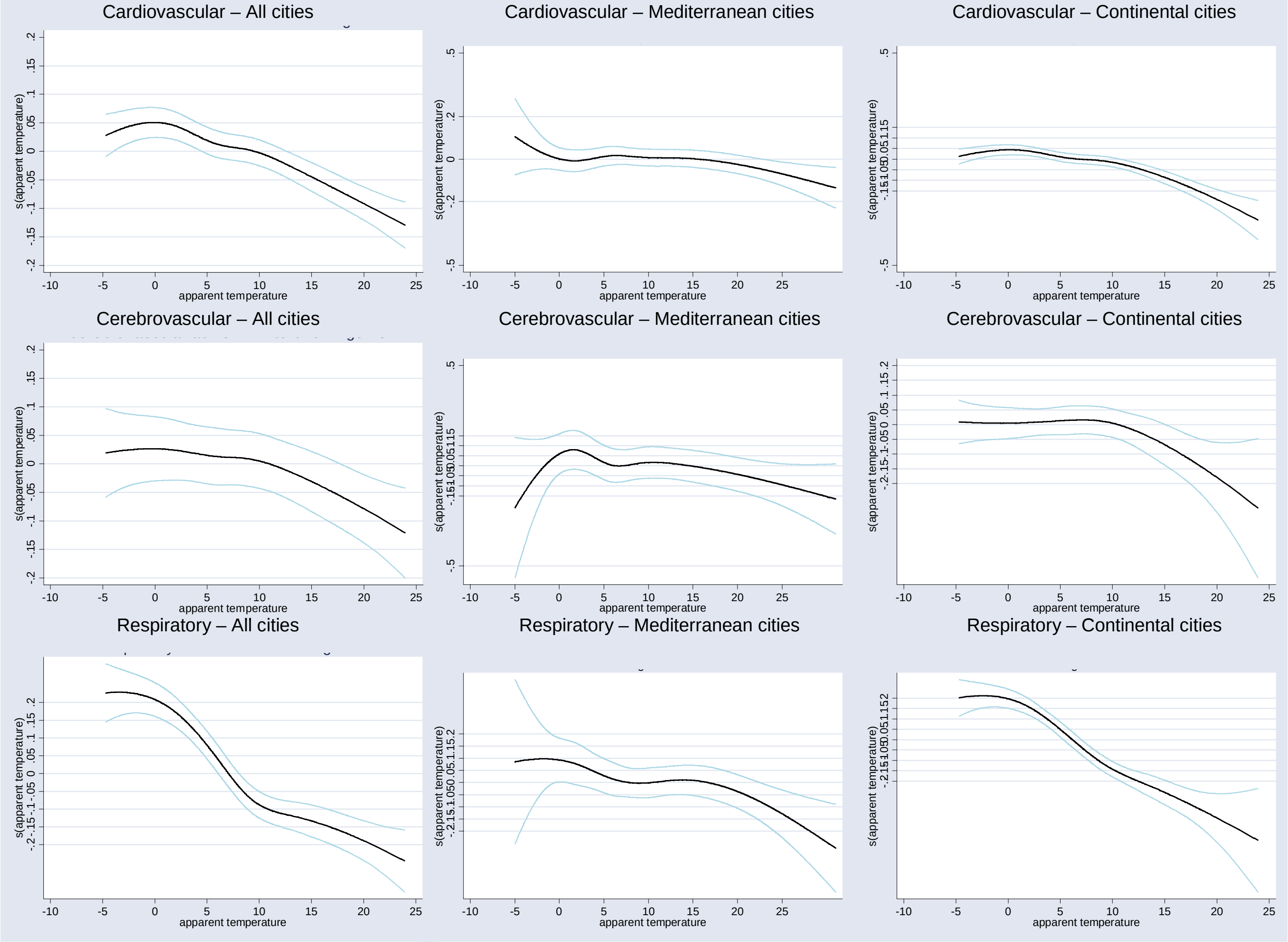
Figure 3. City-specific and pooled^ estimates (regression coefficients* and 95% confidence intervals) of association between daily hospital admissions for respiratory causes and maximum apparent temperature (Tappmax, °C) (lag 0-15) by age group (all age, 65-74 yrs and 75+ yrs) in 12 European cities within the PHEWE project during winter (October-March), 1990-2001.



^ Results from fixed and random effects meta-analysis

* Coefficients expressed as number of daily admissions for an increase of 1°C of Tappmax

Figure 4. The pooled exposure-response curves of maximum apparent temperature (Tappmax, °C) (lag 0-15) and daily hospital admissions for cardiovascular, cerebrovascular and respiratory causes in the 75+ yrs age group in all cities, Mediterranean° and Continental/Northern°° cities within the PHEWE project during winter (October-March), 1990-2001.



° Mediterranean cities: Barcelona, Ljubljana, Milan, Rome, Turin and Valencia

°° Continental/Northern cities: Budapest, Dublin, London, Paris, Stockholm and Zurich

Table 3. Pooled^ estimates of the association between maximum apparent temperature (Tappmax, °C) (lag 0-15) and daily hospital admissions (HA) for cardiovascular, cerebrovascular and respiratory causes by age group in all cities, Mediterranean and Continental/Northern cities within the PHEWE project during winter (October-March), 1990-2001.

	All cities		**Mediterranean cities°**		**Continental/Northern cities°°**	
	% change (95%CI) in daily HA for 1°C increase in T_{appmax}		**% change (95%CI) in daily HA for 1°C increase in T_{appmax}**		**% change (95%CI) in daily HA for 1°C increase in T_{appmax}**	
	Fixed effects	**Random effects**	**Fixed effects**	**Random effects**	**Fixed effects**	**Random effects**
Cardiovascular causes						
all ages	-0.2 (-0.3; -0.1)	-0.2 (-0.4; 0.1)	0.0 (-0.2; 0.2)	-0.1 (-0.5; 0.2)	-0.2 (-0.4; -0.1)	-0.2 (-0.6; 0.2)
65-74	-0.3 (-0.5; -0.1)	-0.3 (-0.5; -0.1)	-0.2 (-0.6; 0.1)	-0.2 (-0.6; 0.1)	-0.3 (-0.5; -0.1)	-0.3 (-0.6; 0.1)
75+ years	-0.6 (-0.8; -0.5)	-0.5 (-0.9; -0.2)	-0.3 (-0.6; 0.0)	-0.3 (-0.6; 0.0)	-0.8 (-1.0; -0.6)	-0.7 (-1.1; -0.2)
Cerebrovascular causes						
all ages	-0.3 (-0.6; -0.1)	-0.3 (-0.7; 0.0)	-0.4 (-0.8; 0.0)	-0.4 (-0.8; 0.0)	-0.3 (-0.6; 0.0)	-0.3 (-0.9; 0.4)
65-74	-0.4 (-0.9; 0.1)	-0.4 (-0.9; 0.2)	-0.5 (-1.3; 0.3)	-0.7 (-1.7; 0.4)	-0.3 (-0.9; 0.3)	-0.3 (-1.0; 0.4)
75+ years	-0.5 (-0.8; -0.1)	-0.5 (-0.9; 0.0)	-0.4 (-1.0; 0.1)	-0.4 (-1.0; 0.1)	-0.5 (-0.9; 0.0)	-0.6 (-1.4; 0.3)
Respiratory causes						
all ages	-1.7 (-1.9; -1.6)	-1.5 (-2.3; -0.7)	-1.0 (-1.3; -0.7)	-1.0 (-2.0; 0.0)	-2.1 (-2.3; -1.9)	-2.2 (-3.2; -1.0)
65-74	-2.1 (-2.5; -1.8)	-1.8 (-2.9; -0.6)	-1.2 (-1.9; -0.5)	-0.6 (-2.2; 1.1)	-2.6 (-3.1; -2.1)	-3.0 (-4.4; -1.4)
75+ years	-2.9 (-3.1; -2.6)	-2.5 (-3.4; -1.6)	-1.8 (-2.4; -1.2)	-1.8 (-2.4; -1.2)	-3.3 (-3.7; -3.0)	-3.4 (-4.8; -2.0)

^ Results from fixed and random effects meta-analysis

° Mediterranean cities: Barcelona, Ljubljana, Milan, Rome, Turin and Valencia

°° Continental/Northern cities: Budapest, Dublin, London, Paris, Stockholm and Zurich

8. Effects of apparent temperature on mortality: Investigation of potential confounding by air pollution and possible interaction between air pollutants and temperature in the PHEWE project

Objectives

In this WP we assess the potential confounding by all available pollutants on the temperature – mortality effect and investigate the possibility for interactive effects of temperature and pollution on mortality.

Data

Within PHEWE we have data from 15 cities which include: exposure to meteorological variables, air pollution, and health outcomes.

In this analysis, we used the maximum 3-hourly apparent temperature as the exposure variable for each day.

The available pollutants include: NO_2 (1 hour), ozone (8 hours), particles (PM_{10}, black smoke BS), CO (8 hours), SO_2 (24 hours). In Table 1 the levels and availability of each pollutant for each city is shown.

The health outcomes concerning mortality are: total natural (ICD-9 code : 0-799), cardiovascular (ICD-9 code: 390-459), respiratory (ICD-9 code: 460-519), cerebrovascular (ICD-9 code: 430-438). The health outcomes also included hospital admission data, but since the temperature effects on these outcomes are not clear, we will only analyze mortality outcomes.

Methods

Control of confounding of air pollution in the estimated temperature-mortality effects:

The modeling strategy in PHEWE (details may be found in previous chapters), was based on seasonal analysis (i.e. separate analysis for the warm - April to September - and for the cold - October to March - season) using GEE modeling. In the core analysis, to control for the confounding effects of pollution, we used NO_2, average of lags 0 and 1 as air pollution indicator, when attempting to estimate the apparent temperature - mortality association. Air pollution concentrations co-vary (within season), so any pollutant represents to some considerable extent the variability of the other pollutants within each season. We chose to use as a first adjustment NO_2 concentrations because NO_2 was the pollutant available in all cities and with more complete series.

For the investigation of confounding by all available pollutants, models with and without adjustment for the pollutant were applied and their results compared. Because each pollutant was available for a different number of cities, we ran models with and without each specific pollutant for the same set of cities. If there was confounding at lags 0-1, we investigated further using the same lags for air pollutants as the ones used for temperature.

The results were assessed both at city by city level and as combined estimates.

Interaction between temperature and pollution effect:

There are indications in the literature about possible interactive effects of high temperature and air pollution. However, the data are sparse and most results are based on limited series (i.e. one city). Furthermore, the questions have been addressed with various different methodologies and it is difficult to review the results in a formal way. The PHEWE data base offers a unique opportunity to investigate this issue using an extensive data base and a standardized protocol for the analysis.

We investigated possible interaction by season (i.e. separately for the cold and warm period), for all cities and for the groups of cities which have been established (i.e. Mediterranean, Central - Northern).

For the cold period we have so far observed a linear relationship of apparent temperature and mortality. The same is true for the relationship of pollutants and mortality for those pollutants for which we have found statistically significant associations. Therefore, to investigate possible interaction we will include the interaction terms between each pollutant and apparent temperature.

For the warm period, the association between apparent temperature is not linear. It follows a well reported J shape, with no association until a certain level of temperature and a steep rise in mortality after a certain point. So the estimation of this association involves two parameters: estimation of the turning point and of the slope of the curve above the turning point. In principle, the investigation of the temperature-pollution interaction should assess the effects on both parameters.

We propose to start holding the turning point unchanged and investigating the interaction of apparent temperature and the pollutants (in single pollutant models). The slope above the turning point has so far been considered linear. The first step will be to assess one interaction term of temperature and pollutant in a linear association above the turning point. A second step will involve creating two turning points: the first one as described above and the second one at the 90th percentile of apparent temperature. In this latter model we will estimate 2 slopes, which may or may not differ statistically significantly; the slope during days with highest 10% of temperature may be steeper. We will introduce 2 interactions terms to estimate the possible temperature-pollutant synergy at different temperature levels. The hypothesis behind the second approach is that there is a possibility that pollution and temperature interact at certain temperature levels and not in others.

We will also investigate the role that pollution may play in changing the estimated turning point. This will be done in second stage analyses with the turning point of temperature as dependent variable and the average air pollutant concentrations (NO_2, particles, ozone) alternatively as independent variables.

Results

In Tables 2 to 9, the results of the investigation for the confounding effects by air pollutants are shown for total natural, cardiovascular, respiratory and cerebrovascular mortality, separately for the cold and warm season.

For the cold season (Tables 2, 4, 6, 8) the observed confounding is indeed minimal. In all cases, except when adjusting for SO_2 and ozone in cerebrovascular disease mortality, the change in the effect estimates is less than 10% after adjustment by the air pollutant. In all cases, the change after inclusion of the air pollutant variable in the model is to obtain a smaller effect estimate.

For the warm season (Tables 3, 5, 7, 9) again the confounding effect of pollutants on the size of the apparent temperature effect estimate is small (<10% in all cases, except when including PM_{10} in the fixed effects model for cerebrovascular disease mortality. The size of the effect estimate of apparent temperature when adjusting for an air pollution variable generally decreases, except for a few specific models concerning effects on cerebrovascular disease (Table 9).

In Tables 10 to 17, the results of the investigation for the possible interactive effects of apparent temperature with each pollutant alternatively on cause-specific mortality are shown. The interactive effects are investigated above the estimated threshold of effects which are given from a different WP.

For the winter season (Tables 10, 12, 14, 16), the parameters for the interaction variables are not statistically significant with a few exceptions. One exception is the interactive effect of NO_2 and apparent temperature on total natural mortality, which is significant only when the fixed effects model is applied and becomes totally insignificant in the random effects model (Table 10). Also, the interactive effect of CO and apparent temperature on total mortality is significant and a smaller effect of apparent temperature is observed when the pollutant level in a city is higher (Table 10). Further, the interactive effect of apparent temperature and PM_{10} on respiratory mortality is significant and the effect of apparent temperature is smaller when the PM10 levels in a city are higher (Table 14). Finally, the interactive effect of apparent temperature and SO_2 on cerebrovascular disease is significant when the fixed effects model is applied. The effect of apparent temperature is higher when the pollutant is higher (Table 16).

For the summer season, more significant interactive effects are observed. Thus, for the effects of apparent temperature on total natural mortality, there is a significant but small interactive effect with CO and a larger interactive effect with ozone (Table 11). In cities where the ozone levels are higher, the effects of apparent temperature are higher. Specifically, for a city with ozone level at the 25th percentile of the ozone distribution over all cities, the increase in mortality associated with an increase of 1°C above the threshold level is 1.66%, whilst in a city with ozone at the 75th percentile, the increase in mortality is 2.10%. However, the significance of the interactive effect does not reach the nominal level when the random effects model is applied (preserving the same pattern). For cardiovascular disease mortality, there is a significant interaction of apparent temperature with black smoke levels both with fixed and random effects models (Table 13). The increase in mortality associated with 1°C increase in apparent temperature, is 3.06% in a city with low black smoke (at the 25th percentile) whilst it is 2.47% in a city with high black smoke (75th percentile). There is no interaction of the effects of apparent temperature with any pollutant when respiratory and cerebrovascular mortality is analyzed (Tables 15 and 17).

As mentioned above, these interactive effects are investigated for all temperatures above the turning point (threshold) of the temperature- mortality association, as estimated from previous WPs. We intend to investigate whether there is interaction of temperature and the pollutants available for the warmest 10% of the days in each city and also to investigate a possible effect of the pollutants on the estimate of the threshold per se.

Table 1A. Descriptive statistics for the levels and availability of air pollutants in 15 cities. Winter (October – March)

City	NO_2 (µg/m^3)			SO_2 (µg/m^3)			PM_{10} (µg/m^3)			BS (µg/m^3)			CO (mg/m^3 – 8h)			Ozone (µg/m^3-8h)		
	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile
Athens	90	111	146	38	55	81	34	42	53	47	70	105	5	7	9	35	44	58
Barcelona	75	89	109	_	_	_	38	50	63	33	42	56	1	2	2	21	31	44
Budapest	61	81	109	35	41	52	_	_	_	_	_	_	2	3	5	29	43	59
Dublin	_	_	_	14	19	26	_	_	_	7	11	18	_	_	_	_	_	_
Helsinki	44	56	69	3	5	10	14	19	28	_	_	_	1	1	2	36	47	58
Ljubljana	56	74	96	20	33	55	_	_	_	14	22	38	1	2	3	6	16	36
London	39	44	51	4	8	14	18	23	31	7	11	18	1	1	1	5	11	17
Milano	115	144	185	22	35	59	_	_	_	_	_	_	5	7	15	6	11	22
Paris	66	80	95	13	20	32	16	24	36	15	25	39	_	_	_	7	14	27
Prague	44	56	70	14	29	61	27	43	67	_	_	_	_	_	_	_	_	_
Rome	80	95	113	3	6	9	33	44	61	_	_	_	3	4	6	24	45	70
Stockholm	35	45	56	3	5	7	9	12	18	_	_	_	1	1	2	39	51	60
Torino	100	128	168	18	28	47	_	_	_	_	_	_	_	_	_	8	19	46
Valencia	123	147	174	14	19	26	_	_	_	34	46	60	3	3	4	19	29	40
Zurich	51	62	76	10	15	23	_	_	_	_	_	_	1	1	2	8	25	44

Table 1B. Descriptive statistics for the levels and availability of air pollutants in 15 cities. Summer

City	NO_2 (µg/m^3)			SO_2 (µg/m^3)			PM_{10} (µg/m^3)			BS (µg/m^3)			CO (mg/m^3 – 8h)			O_3 (µg/m^3-8h)		
	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile	25th percentile	median	75th percentile
Athens	104	126	162	28	39	52	33	39	46	40	58	81	4	5	6	73	89	105
Barcelona	71	88	108	_	_	_	36	45	55	25	32	39	1	1	1	51	63	76
Budapest	57	78	120	28	34	38	_	_	_	_	_	_	2	2	4	65	82	101
Dublin	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Helsinki	48	61	75	2	3	6	16	22	31	_	_	_	1	1	1	49	61	74
Ljubljana	57	72	87	9	17	28	19	28	39	6	8	12	1	1	1	44	66	88
London	37	45	54	3	5	8	19	24	31	6	8	12	1	1	1	14	20	27
Milano	116	137	164	4	8	13	_	_	_	_	_	_	3	4	6	46	75	106
Paris	65	81	101	7	10	15	16	21	30	11	16	23	_	_	_	34	50	70
Prague	40	55	74	7	13	27	22	35	56	_	_	_	_	_	_	_	_	_
Rome	86	100	116	2	3	5	37	48	61	_	_	_	2	3	3	96	115	139
Stockholm	31	42	54	2	2	4	10	13	18	_	_	_	1	1	1	57	70	81
Torino	89	109	132	6	10	15	_	_	_	_	_	_	_	_	_	78	104	131
Valencia	104	124	150	7	10	14	_	_	_	24	31	39	2	2	3	45	53	62
Zurich	57	70	85	4	6	9	_	_	_	_	_	_	1	1	1	58	80	105

Table 2. Effects of apparent temperature on total mortality all ages during the cold season (October – March) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1° C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	14	Fixed	-1.08* (-1.17, -1.00)	-1.08* (-1.17, -1.00)
		Random	-1.08 (-1.25, -0.92)	-1.08 (-1.26, -0.91)
PM_{10}	8	Fixed	-1.14* (-1.25, -1.03)	-1.12* (-1.23, -1.00)
		Random	-1.18 (-1.40, -0.95)	-1.17 (-1.40, -0.94)
BS	7	Fixed	-1.27* (-1.39, -1.15)	-1.23* (-1.35, -1.10)
		Random	-1.36 (-1.56, -1.16)	-1.35 (-1.57, -1.12)
SO_2	14	Fixed	-1.05* (-1.14, -0.96)	-0.96* (-1.06, -0.86)
		Random	-1.05 (-1.19, -0.90)	-0.97 (-1.11, -0.82)
CO	11	Fixed	-1.13* (-1.25, -1.02)	-1.12* (-1.23, -1.00)
		Random	-1.18 (-1.38, -0.98)	-1.17 (-1.36, -0.97)
Ozone	13	Fixed	-1.11* (-1.21, -1.02)	-1.10* (-1.20, -1.00)
		Random	-1.14 (-1.31, -0.97)	-1.14 (-1.32, -0.96)

* significant heterogeneity

Table 3. Effects of apparent temperature on total mortality all ages during the warm season (April – September) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	14	Fixed	2.71* (2.52, 2.89)	2.55* (2.37, 2.74)
		Random	3.22 (1.97, 4.49)	3.04 (1.85, 4.24)
PM_{10}	8	Fixed	2.48* (2.24, 2.72)	2.31* (2.06, 2.56)
		Random	3.19 (1.54, 4.86)	2.90 (1.36, 4.46)
BS	6	Fixed	2.39* (2.13, 2.64)	2.28* (2.02, 2.53)
		Random	2.54 (1.02, 4.07)	2.46 (0.99, 3.95)
SO_2	13	Fixed	2.72* (2.52, 2.93)	2.68* (2.47, 2.88)
		Random	3.06 (1.97, 4.16)	3.01 (1.95, 4.09)
CO	11	Fixed	2.47* (2.23, 2.71)	2.43* (2.20, 2.67)
		Random	3.11 (1.83, 4.40)	3.09 (1.81, 4.40)
Ozone	13	Fixed	2.79* (2.60, 2.99)	2.62* (2.42, 2.82)
		Random	3.31 (1.97, 4.68)	3.13 (1.85, 4.42)

* significant heterogeneity

Table 4. Effects of apparent temperature on cardiovascular diseases mortality all ages during the cold season (October – March) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	14	Fixed	-1.38* (-1.50, -1.26)	-1.38* (-1.50, -1.25)
		Random	-1.39 (-1.64, -1.13)	-1.39 (-1.65, -1.12)
PM_{10}	8	Fixed	-1.45* (-1.61, -1.28)	-1.43* (-1.59, -1.27)
		Random	-1.51 (-1.79, -1.23)	-1.50 (-1.78, -1.22)
BS	7	Fixed	-1.58 (-1.76, -1.39)	-1.53* (-1.71, -1.34)
		Random	-1.65 (-1.93, -1.36)	-1.61 (-1.91, -1.30)
SO_2	14	Fixed	-1.30* (-1.43, -1.17)	-1.18* (-1.32, -1.04)
		Random	-1.30 (-1.52, -1.08)	-1.19 (-1.41, -0.97)
CO	11	Fixed	-1.36* (-1.52, -1.21)	-1.35* (-1.50, -1.19)
		Random	-1.40 (-1.69, -1.12)	-1.39 (-1.68, -1.10)
Ozone	13	Fixed	-1.36* (-1.50, -1.22)	-1.32* (-1.46, -1.18)
		Random	-1.37 (-1.62, -1.11)	-1.35 (-1.67, -1.02)

* significant heterogeneity

Table 5. Effects of apparent temperature on cardiovascular diseases mortality all ages during the warm season (April – September) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	14	Fixed	2.95* (2.67, 3.24)	2.83* (2.54, 3.11)
		Random	3.32 (1.73, 4.94)	3.17 (1.61, 4.74)
PM_{10}	8	Fixed	2.50* (2.12, 2.88)	2.36* (1.97, 2.76)
		Random	3.32 (0.78, 5.93)	3.22 (0.68, 5.83)
BS	6	Fixed	2.42* (2.00, 2.85)	2.35* (1.92, 2.78)
		Random	2.56 (1.03, 4.11)	2.49 (0.99, 4.01)
SO_2	13	Fixed	2.90* (2.58, 3.21)	2.87* (2.55, 3.18)
		Random	3.22 (1.62, 4.84)	3.20 (1.61, 4.82)
CO	11	Fixed	2.87* (2.51, 3.24)	2.83* (2.47, 3.20)
		Random	3.37 (1.51, 5.26)	3.38 (1.49, 5.30)
Ozone	13	Fixed	2.86* (2.53, 3.18)	2.67* (2.34, 3.01)
		Random	3.28 (1.71, 4.88)	3.15 (1.62, 4.70)

* significant heterogeneity

Table 6. Effects of apparent temperature on respiratory diseases all ages during the cold season (October – March) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	14	Fixed	-1.78* (-2.07, -1.48)	-1.77* (-2.06, -1.47)
		Random	-1.49 (-2.09, -0.88)	-1.47 (-2.08, -0.86)
PM_{10}	8	Fixed	-1.86 (-2.22, -1.50)	-1.81 (-2.18, -1.44)
		Random	-1.75 (-2.38, -1.12)	-1.73 (-2.34, -1.12)
BS	7	Fixed	-2.18 (-2.55, -1.81)	-2.10* (-2.47, -1.71)
		Random	-2.16 (-2.81, -1.51)	-2.06 (-2.79, -1.33)
SO_2	14	Fixed	-1.71 (2.02, -1.40)	-1.64 (-1.97, -1.31)
		Random	-1.51 (-1.99, -1.01)	-1.48 (-1.96, -1.00)
CO	11	Fixed	-1.98 (-2.35, -1.61)	-1.96 (-2.34, -1.59)
		Random	-1.84 (-2.36, -1.32)	-1.82 (-2.34, -1.30)
Ozone	13	Fixed	-1.93 (-2.24, -1.61)	-1.93 (-2.24, -1.61)
		Random	-1.86 (-2.28, -1.43)	-1.86 (-2.28, -1.43)

* significant heterogeneity

Table 7. Effects of apparent temperature on respiratory diseases mortality all ages during the warm season (April – September) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	14	Fixed	5.96* (5.25, 6.67)	5.58* (4.86, 6.30)
		Random	7.72 (4.95, 10.57)	7.31 (4.63, 10.05)
PM_{10}	8	Fixed	4.85* (3.98, 5.73)	4.64* (3.74, 5.55)
		Random	5.54 (3.39, 7.74)	5.06 (3.09, 7.06)
BS	6	Fixed	4.51* (3.65, 5.38)	4.34* (3.47, 5.21)
		Random	4.80 (2.31, 7.35)	4.70 (2.14, 7.34)
SO_2	13	Fixed	5.96* (5.16, 6.76)	5.92* (5.12, 6.73)
		Random	6.63 (4.79, 8.51)	6.55 (4.77, 8.36)
CO	11	Fixed	5.37* (4.50, 6.25)	5.28* (4.41, 6.16)
		Random	6.59 (4.39, 8.83)	6.42 (4.31, 8.58)
Ozone	13	Fixed	5.57* (4.82, 6.33)	5.12* (4.33, 5.92)
		Random	6.70 (4.91, 8.52)	6.23 (4.49, 8.00)

* significant heterogeneity

Table 8. Effects of apparent temperature on cerebrovascular diseases mortality all ages during the cold season (October – March) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	11	Fixed	-0.99* (-1.27, -0.71)	-0.96* (-1.24, -0.68)
		Random	-0.98 (-1.68, -0.27)	-0.94 (-1.61, -0.27)
PM_{10}	6	Fixed	-0.89 (-1.30, -0.47)	-0.80 (-1.22, -0.37)
		Random	-0.82 (-1.42, -0.22)	-0.75 (-1.40, -0.10)
BS	4	Fixed	-1.23 (-1.78, -0.68)	-1.15 (-1.70, -0.59)
		Random	-1.08 (-2.22, 0.08)	-1.07 (-2.30, 0.18)
SO_2	11	Fixed	-0.84 (-1.13, -0.54)	-0.69 (-1.00, -0.38)
		Random	-0.78 (-1.20, -0.36)	-0.66 (-1.16, -0.15)
CO	8	Fixed	-0.83* (-1.15, -0.51)	-0.82* (-1.14, -0.49)
		Random	-0.70 (-1.35, -0.05)	-0.70 (-1.33, -0.07)
Ozone	10	Fixed	-0.80* (-1.13, -0.47)	-0.70* (-1.04, -0.37)
		Random	-0.67 (-1.29, -0.04)	-0.57 (-1.21, 0.08)

* significant heterogeneity

Table 9. Effects of apparent temperature on cerebrovascular diseases mortality all ages during the warm season (April – September) with and without adjustment for NO_2, SO_2, CO, PM_{10} and BS. Results are given in percent increase in the daily number of deaths (95% Confidence Intervals) associated with 1^o C increase in apparent temperature.

Pollutant	No of cities	Model	Without adjustment	With adjustment
NO_2	11	Fixed	3.95* (3.30, 4.61)	3.80* (3.15, 4.46)
		Random	3.93 (1.30, 6.63)	3.82 (1.31, 6.39)
PM_{10}	6	Fixed	3.05 (2.01, 4.10)	2.60* (1.54, 3.67)
		Random	3.71 (1.49, 5.98)	3.88 (0.79, 7.07)
BS	3	Fixed	2.75 (1.36, 4.15)	2.72 (1.33, 4.13)
		Random	2.71 (1.19, 4.26)	2.72 (1.33, 4.13)
SO_2	10	Fixed	3.65* (2.95, 4.35)	3.60* (2.90, 4.31)
		Random	3.81 (1.74, 5.91)	3.78 (1.74, 5.86)
CO	8	Fixed	3.91* (3.11, 4.72)	4.00* (3.19, 4.81)
		Random	4.31 (2.12, 6.55)	4.42 (2.13, 6.76)
Ozone	10	Fixed	3.81* (3.02, 4.60)	3.49* (2.67, 4.31)
		Random	3.92 (1.93, 5.95)	3.61 (1.52, 5.74)

* significant heterogeneity

Table 10: Percent increase (95% C.I.) in the total daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the cold season (October to March).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	14	Fixed**	-1.10* (-1.20,-1.01)	-1.07* (-1.16,-0.99)
		Random	-1.09 (-1.26,-0.92)	-1.09 (-1.26,-0.91)
PM_{10}	8	Fixed	-1.17* (-1.30,-1.05)	-1.10* (-1.21,-0.99)
		Random	-1.23 (-1.50,-0.95)	-1.14 (-1.36,-0.93)
BS	7	Fixed	-1.25* (-1.39,-1.11)	-1.21* (-1.34,-1.09)
		Random	-1.35 (-1.58,-1.13)	-1.33 (-1.56,-1.11)
SO_2	14	Fixed	-0.95* (-1.05,-0.85)	-0.97 (-1.07,-0.86)
		Random	-0.96 (-1.10,-0.81)	-0.97 (-1.11,-0.83)
CO	11	Fixed	-1.17* (-1.29,-1.06)	-1.07* (-1.18,-0.95)
		Random**	-1.22 (-1.43,-1.01)	-1.10 (-1.28,-0.92)
Ozone	13	Fixed	-1.09* (-1.20,-0.99)	-1.11* (-1.21,-1.00)
		Random	-1.13 (-1.32,-0.94)	-1.15 (-1.35,-0.95)

* significant heterogeneity
** significant interaction

Table 11: Percent increase (95% C.I.) in the total daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the warm season (April to September).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	14	Fixed	2.33* (2.09,2.57)	2.54* (2.35,2.73)
		Random	2.80 (1.60,4.01)	3.14 (1.80,4.49)
PM_{10}	8	Fixed	2.32* (1.98,2.67)	2.31* (2.05,2.57)
		Random	3.00 (0.97,5.07)	2.86 (1.18,4.56)
BS	6	Fixed	2.21* (1.89,2.54)	2.29* (2.04,2.55)
		Random	2.73 (0.88,4.61)	2.44 (0.88,4.02)
SO_2	13	Fixed	2.72* (2.48,2.96)	2.64* (2.40,2.88)
		Random	2.95 (1.95,3.96)	3.11 (1.96,4.27)
CO	11	Fixed**	2.34* (2.06,2.63)	2.43* (2.17,2.68)
		Random	3.01 (1.68,4.37)	3.18 (1.70,4.69)
Ozone	13	Fixed**	1.66* (1.35,1.98)	2.10* (1.86,2.33)
		Random	2.44 (1.26,3.63)	2.74 (1.63,3.87)

* significant heterogeneity
** significant interaction

Table 12: Percent increase (95% C.I.) in the cardiovascular daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the cold season (October to March).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	14	Fixed	-1.40* (-1.53,-1.26)	-1.37* (-1.50,-1.25)
		Random	-1.38 (-1.71,-1.05)	-1.39 (-1.65,-1.12)
PM_{10}	8	Fixed	-1.52* (-1.70,-1.34)	-1.41* (-1.58,-1.25)
		Random	-1.63 (-2.13,-1.14)	-1.47 (-1.73,-1.21)
BS	7	Fixed	-1.59 (-1.79,-1.38)	-1.50* (-1.69,-1.31)
		Random	-1.64 (-1.92,-1.36)	-1.57 (-1.89,-1.25)
SO_2	14	Fixed	-1.18* (-1.33,-1.04)	-1.18 (-1.33,-1.04)
		Random	-1.18 (-1.42,-0.94)	-1.20 (-1.40,-1.00)
CO	11	Fixed	-1.39* (-1.55,-1.23)	-1.30* (-1.46,-1.14)
		Random	-1.42 (-1.81,-1.03)	-1.35 (-1.61,-1.08)
Ozone	13	Fixed	-1.27* (-1.42,-1.11)	-1.35* (-1.50,-1.20)
		Random	-1.31 (-1.57,-1.04)	-1.37 (-1.75,-0.99)

* significant heterogeneity

Table 13: Percent increase (95% C.I.) in the cardiovascular daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the warm season (April to September).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	14	Fixed	2.63* (2.26,3.00)	2.89* (2.59,3.19)
		Random	2.99 (1.42,4.58)	3.32 (1.62,5.05)
PM_{10}	8	Fixed	2.58* (2.02,3.13)	2.45* (2.04,2.86)
		Random	3.82 (1.29,6.41)	3.38 (0.90,5.92)
BS	6	Fixed**	2.57* (2.02,3.12)	2.35* (1.91,2.78)
		Random**	3.06 (0.95,5.22)	2.47 (0.82,4.15)
SO_2	13	Fixed	2.96* (2.59,3.33)	2.89* (2.52,3.26)
		Random	3.12 (1.67,4.59)	3.45 (1.78,5.14)
CO	11	Fixed	2.78* (2.34,3.22)	2.82* (2.44,3.21)
		Random	3.46 (1.50,5.47)	3.22 (1.32,5.17)
Ozone	13	Fixed	2.12* (1.60,2.64)	2.55* (2.17,2.93)
		Random	3.12 (1.19,5.07)	3.13 (1.50,4.78)

* significant heterogeneity
** significant interaction

Table 14: Percent increase (95% C.I.) in the respiratory daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the cold season (October to March).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	14	Fixed	-1.77* (-2.08,-1.45)	-1.76* (-2.06,-1.46)
		Random	-1.45 (-2.09,-0.81)	-1.47 (-2.10,-0.83)
PM_{10}	8	Fixed**	-2.09 (-2.49,-1.68)	-1.76 (-2.13,-1.38)
		Random**	-2.05 (-2.59,-1.50)	-1.63 (-2.30,-0.95)
BS	7	Fixed	-2.13* (-2.54,-1.71)	-2.05 (-2.43,-1.66)
		Random	-2.06 (-2.89,-1.22)	-2.07 (-2.74,-1.39)
SO_2	14	Fixed	-1.64 (-1.99,-1.29)	-1.63 (-1.97,-1.28)
		Random	-1.59 (-2.03,-1.15)	-1.41 (-1.95,-0.86)
CO	11	Fixed	-2.06* (-2.45,-1.66)	-1.92 (-2.31,-1.53)
		Random	-1.81 (-2.45,-1.15)	-1.86 (-2.31,-1.42)
Ozone	13	Fixed	-1.93 (-2.28,-1.58)	-1.93* (-2.28,-1.57)
		Random	-1.93 (-2.29,-1.55)	-1.89 (-2.42,-1.35)

* significant heterogeneity
** significant interaction

Table 15: Percent increase (95% C.I.) in the respiratory daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the warm season (April to September).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	14	Fixed	5.51* (4.58,6.45)	5.40* (4.65,6.15)
		Random	6.82 (4.05,9.66)	7.06 (4.53,9.66)
PM_{10}	8	Fixed	4.55 (3.27,5.84)	4.42* (3.45,5.41)
		Random	4.70 (2.30,7.15)	4.74 (2.64,6.89)
BS	6	Fixed	3.93* (2.81,5.05)	4.36* (3.49,5.25)
		Random	4.71 (1.94,7.56)	4.60 (1.88,7.40)
SO_2	13	Fixed	6.29* (5.35,7.25)	5.30* (4.36,6.24)
		Random	6.60 (4.97,8.26)	6.20 (4.08,8.36)
CO	11	Fixed	4.87* (3.80,5.95)	5.38* (4.45,6.31)
		Random	5.65 (3.74,7.59)	6.96 (4.48,9.50)
Ozone	13	Fixed	3.80 (2.62,4.98)	4.46* (3.56,5.38)
		Random	4.34 (2.24,6.49)	5.76 (3.69,7.86)

* significant heterogeneity

Table 16: Percent increase (95% C.I.) in the cerebrovascular daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the cold season (October to March).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	11	Fixed	-0.93* (-1.23,-0.63)	-1.00* (-1.28,-0.71)
		Random	-0.94 (-1.65,-0.22)	-0.97 (-1.63,-0.31)
PM_{10}	6	Fixed	-0.81 (-1.28,-0.33)	-0.82 (-1.25,-0.39)
		Random	-0.73 (-1.50,0.05)	-0.79 (-1.34,-0.23)
BS	4	Fixed	-1.26 (-1.87,-0.64)	-1.06 (-1.63,-0.49)
		Random	-1.29 (-2.50,-0.07)	-0.82 (-2.09,0.46)
SO_2	11	Fixed**	-0.63* (-0.96,-0.31)	-0.75 (-1.08,-0.42)
		Random	-0.62 (-1.27,0.03)	-0.73 (-1.15,-0.30)
CO	8	Fixed	-0.82* (-1.16,-0.48)	-0.81 (-1.15,-0.48)
		Random	-0.71 (-1.41,-0.00)	-0.75 (-1.20,-0.29)
Ozone	10	Fixed	-0.59* (-0.97,-0.22)	-0.75 (-1.11,-0.39)
		Random	-0.45 (-1.26,0.36)	-0.66 (-1.23,-0.08)

* significant heterogeneity
** significant interaction

Table 17: Percent increase (95% C.I.) in the cerebrovascular daily number of deaths, all ages, for 1 ºC increase in the maximum apparent temperature at the 25th and 75th percentile of the city-specific distribution of each pollutant, in the warm season (April to September).

Pollutant	No of cities	Model	25th percentile	75th percentile
NO_2	11	Fixed	3.40* (2.56,4.25)	3.95* (3.26,4.64)
		Random	3.54 (1.37,5.76)	4.05 (1.11,7.08)
PM_{10}	6	Fixed	2.50* (0.90,4.13)	2.62* (1.45,3.79)
		Random	4.68 (-0.39,10.01)	4.15 (0.57,7.86)
BS	3	Fixed	2.72 (1.02,4.45)	2.67 (1.21,4.15)
		Random	2.72 (1.02,4.45)	2.59 (0.58,4.63)
SO_2	10	Fixed	3.61* (2.79,4.44)	3.38 (2.57,4.19)
		Random	3.61 (1.57,5.68)	3.52 (1.71,5.37)
CO	8	Fixed	3.97* (2.97,4.98)	3.84* (2.98,4.71)
		Random	4.67 (2.33,7.06)	3.74 (1.96,5.54)
Ozone	10	Fixed	3.59* (2.24,4.95)	3.76* (2.83,4.71)
		Random	4.97 (1.04,9.05)	3.87 (1.25,6.56)

* significant heterogeneity

9. The Development of Heat Stress Watch Warning Systems (WWS) for Five European Cities

The overall aim of the WWS work package is to develop heat stress watch warning systems (WWS) for 5 European cities that can be applied in the mitigation of heat related death and illness. The related objectives are therefore:

1. To construct statistical algorithms that will form the scientific basis of the WWS for the prediction of heat related death and illness in the target cities. Algorithms will describe the relationship between stratified/unstratified daily mortality (morbidity) and a range of standard and derived (rate of change and antecedent) daily meteorological and human energy balance-based heat stress index variables.
2. To design a set of generic and city specific mitigation measures for the reduction of heat stress related mortality and morbidity as an integral part of a WWS for each city.
3. To formulate protocols for implementing a WWS
4. To install and undertake a ghost trial of the WWS for each target city and thus an evaluation of the potential effectiveness of the WWS and associated mitigation measures.

Materials

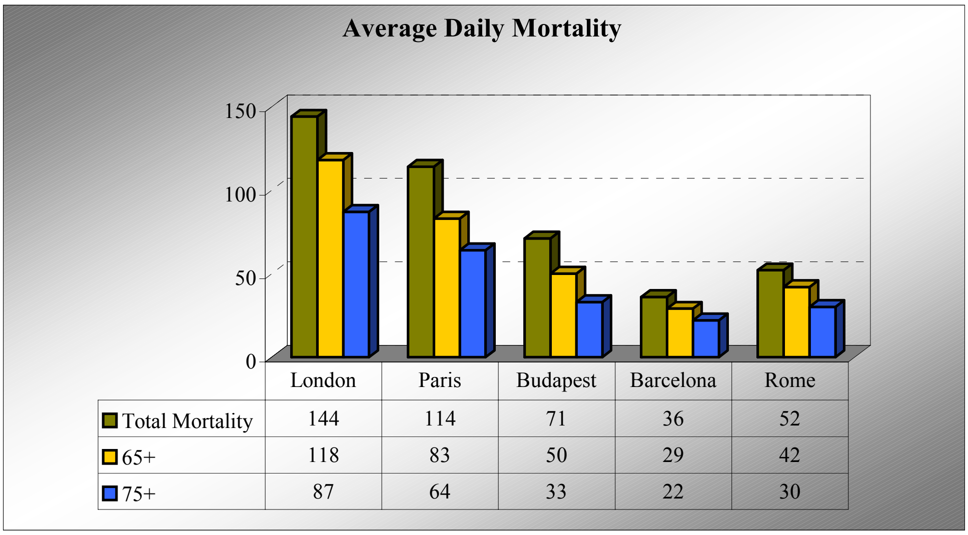
In order to develop an experimental HHWWS mortality, meteorological and forecast data were required as described below.

Mortality data

Daily data on total mortality, mortality older than 64 (65+) and older than 74 (75+) ("all causes") were available for following periods and locations:

London	01/01/1992 until 31/12/2000
Paris	01/01/1991 until 31/12/1998
Budapest	01/01/1992 until 31/12/2001
Barcelona	01/01/1991 until 31/12/2000
Rome	01/01/1992 until 31/12/2001

The average of the daily mortality for each target city are displayed in figure 1.



	London	Paris	Budapest	Barcelona	Rome
🟩 Total Mortality	144	114	71	36	52
🟨 65+	118	83	50	29	42
🟦 75+	87	64	33	22	30

Figure 1 Average daily mortality London, Paris, Budapest, Barcelona, and Rome

Mortality time series, which demonstrated a statistically temporal trend, were de-trended. This correction was achieved by linear regression modelling with time as the independent variable. Regression model residuals were added to the mean mortality for the study period to create a de-trended time series (McGregor et al. 2004).

Meteorological data

Weather data on air temperature, dew point temperature, air pressure, total cloud cover, wind speed and direction, measured 4 times daily (0, 6, 12 and 18 UTC), were available for London, Rome, Budapest and Paris. For Barcelona only the mean daily temperature, the minimum daily temperature and the mean dew point temperature were available as well air pressure, wind speed and direction at 0 and 18 UTC. The periods for the time series were:

London	01/01/1990 until 31/12/2000
Paris	01/01/1990 until 31/12/1999
Budapest	01/01/1992 until 31/12/2001
Barcelona	01/01/1992 until 31/12/2000
Rome	01/01/1992 until 31/12/2000

In addition apparent temperature, a heat index to identify heat-stress days, was calculated. The AT combines air temperature and humidity into a single variable. This value takes into account human physiology and is based on the synergistic effects of high temperature and humidity and their ability to stress the body's thermal regulatory systems (Steadman 1984, Smoyer et al. 2000).

The apparent temperature (T_{app}) was calculated from the following equation:

$$T_{app} = -2.719 + 0.994\ T_{air} + 0.016(T_{dew})^2$$

where T_{air} = air temperature and T_{dew} = dew point temperature is (Smoyer et al. 2000).

Forecast data

For each city we obtain the subsequent daily forecast data (0,6,12 and 18 UTC) from the German Meteorological Service (DWD):

TT = air temperature (°C)
TD = dew point temperature (°C)
DD = wind direction (degrees – multiply by 10)
FF = wind speed (knots)
N = total cloud cover (octas)
PT = perceived temperature (°C)

Methods

The first objective of this project was to identify the historical relationships between heat-related mortality and weather for the five European cities. In this connection we chose four different climatological modelling procedures to determine the best means of relating variations in summer weather to the mortality data. These included:

- a perceived temperature approach, which evaluates the energy budget of the body
- the conditional probability, which gives the probability of a certain mortality level to a specified air and dew point temperature
- a statistical model for "Weather-Related" Mortality
- a synoptic climatological approach, which places each day within an air mass type and decides the impact of the total weather situation on the individual

The period for which analyses were conducted was from 1 June until 31 August for each year.

Perceived temperature

A first indication to observe if a day causes thermal stress is the perceived temperature; a term, which was developed from the German Meteorological Service (DWD). This temperature compares the actual existing outside conditions with the temperature that would prevail in a standard environment in order to experience an identical feeling of warmth, comfort, or cold (Table 1) (WMO 2000). Value of perceived temperature were supplied by the DWD.

Table 1 Perceived temperature, thermal sensation, and thermal stress (Koppe et al. 2004)

Perceived temperature (°C)	Thermal Sensation	Thermal Stress
≤ -39	Very cold	Extreme
-26 to -39	Cold	Strong
-13 to -26	Chilly	Moderate
0 to -13	Slightly chilly	Slight
0 to +20	Comfortable	None
+20 to +26	Slightly warm	Slight
+26 to +32	Warm	Moderate
+32 to +38	Hot	Strong
≥ +38	Very hot	Extreme

Conditional Probability

A further possibility to estimate a link between heat-related mortality and weather is by using conditional probability. It is the probability of a certain excess mortality level being attained given the occurrence of a specified air and dew point temperature. For this we used the air and dew point temperature as well the daily mortality excess for total mortality, mortality older than 64 and older than 74. The meteorological variables were classified in five equal percentile classes; the mortality excesses were divided into a number of classes (depend of the city size).

By dint of the combination of the two temperature percentiles it was possible to classify a day as cold or hot as well dry or humid (maximal 25 categories were possible). We used the 0 and 12 UTC data to calculate the probability expect for Barcelona. For this city we determined merely the daily mean probability.

The results for each city are presented below.

London

Remarkable is the high probability of a severe mortality day occurring, compared to the other temperature combinations, given the event of very hot nights and dry conditions (air temperature between 17.6 and 24.4ºC and dew point temperature between 10.9 and 12.3ºC at 0 UTC = 52.9% excess total mortality ≥ 20). During the day hot and humid conditions seem to have the strongest effect on the total mortality (air temperature between 23.5 and 32.5ºC and dew point temperature between 14 and 19.4ºC at 12 UTC = 44.4% excess mortality ≥ 10). The same is apparent for each investigated age group.

Paris

A high probability is reached especially on hot days (air temperature over 19ºC at midnight and over 26ºC at 12 UTC). For the 80-100 percentile air temperature the excess (total mortality) features a conditional probability mostly over 50% during the night and around 45% during day. The two elderly age groups showed a similar behaviour pattern to that observed for all-age mortality.

Budapest

The severe effect for total mortality is obvious on the 80-100 percentile of the air temperature (20.7-26.8ºC at 0UTC and 29.4-36.7ºC at 12UTC). To that is added a high humidity effect: 80-100 percentile for air and dew point temperature evince around 50% excess mortality ≥ 10. The excess mortality of elderly population has in addition a high probability on hot and dry days.

Barcelona

A high probability of high excess mortality occurs mainly on hot days with a mean daily temperature greater than 25ºC. The age group mortality over 64 years seems in addition more sensitive on humid days (excess around 30%).

Rome

The 80-100 percentile of the air temperature (≥ 23.2 at 0UTC and ≥ 31.6 at midday) evinces a high conditional probability for the excess total mortality ≥ 10. During the night dry conditions seem to have a strong effect on severe mortality; meanwhile during day humid conditions are more important. The results are similar for the two elderly age groups.

Statistical model for "Weather-Related" Mortality

The first step of the analysis was to find different algorithms in a special temperature band for each city: a stepwise multiple regression procedure was performed on all summer days to determine which environmental factors contribute most to high mortality. A number of meteorological factors were used as independent variables within the regression analysis (Table 2).

Table 2 Independent variables used in regression analysis

London	Paris	Budapest	Barcelona	Rome
Air temperature (0,6,12,18 UTC)	Air temperature (0,6,12,18 UTC)	Air temperature (0,6,12,18 UTC)	Air temperature (mean, minimum)	Air temperature (0,6,12,18 UTC)
Dew point temperature (0,6,12,18 UTC)	Dew point temperature (0,6,12,18 UTC)	Dew point temperature (0,6,12,18 UTC)	Dew point temperature (mean, minimum)	Dew point temperature (0,6,12,18 UTC)
Wind speed (0,6,12,18 UTC)	Wind speed (0,6,12,18 UTC)	Wind speed (0,6,12,18 UTC)	Wind speed (0,18 UTC)	Wind speed (0,6,12,18 UTC)
Total cloud cover (0,6,12,18 UTC)	Total cloud cover (0,6,12,18 UTC)	Total cloud cover (0,6,12,18 UTC)	Total cloud cover (0,18 UTC)	Total cloud cover (0,6,12,18 UTC)
Sea level pressure (0,6,12,18 UTC)	Sea level pressure (0,6,12,18 UTC)	Sea level pressure (0,6,12,18 UTC)	Sea level pressure (0,18 UTC)	Sea level pressure (0,6,12,18 UTC)
Apparent temperature (0,6,12,18 UTC)	Apparent temperature (0,6,12,18 UTC)	Apparent temperature (0,6,12,18 UTC)	Apparent temperature (0,18 UTC)	Apparent temperature (0,6,12,18 UTC)

A sudden large decrease in air temperature is not always associated with an immediate change in mortality rate. There is often a lag between the mortality response and a given weather even (Kalkstein et al. 1989). One, two, and three days prior to the day of the deaths were also analysed to find out if a lag time exists between the weather event and the associated mortality. Heat event were described by using the temperature sum over 2 to 8 days.

Using multiple stepwise regression analysis we defined algorithms for each temperature range. The temperature used as the independent variable was different for each city; so the air temperature at 6 UTC had the strongest historical weather-mortality relationship in London and Barcelona, in Paris the air temperature at 0 UTC, in Budapest the dew point temperature at 18 UTC and in Rome the apparent temperature at midnight (Table 3). The choice of temperature was determined by the R Square of the multiple regression analysis.

On the basis of the algorithms and the forecast data it is feasible to calculate prediction mortality and excess for each day.

Table 3 Statistical Significant Models for Mortality in Summer (TT6 = air temperature at 6 UTC, TT0 = air temperature at 0 UTC, TD18 = dew point temperature at 18 UTC, TA0 = apparent temperature at 0 UTC)

London		Paris		Budapest		Barcelona		Rome	
Range	R^2	Range	R^2	Range	R^2	Range	R^2	Range	R^2
TT6 < 10.8	0.50	10.7 < TT0	0.55	TD18 < 6.1	0.43	15.1 < TT6	0.21	TA0 < 17.5	0.54
12.4 < TT6 ≥ 10.8	0.43	12.8 < TT0 ≥ 10.7	0.33	8.1 < TD18 ≥ 6.1	0.32	17.9 < TT6 ≥ 15.1	0.29	20.4 < TA0 ≥ 17.5	0.32
14.5 < TT6 ≥ 12.4	0.23	14.4 < TT0 ≥ 12.8	0.23	9.5 < TD18 ≥ 8.1	0.14	20.9 < TT6 ≥ 17.9	0.11	20.4 < TA0 ≥ 22	0.46
15.8 < TT6 ≥ 14.5	0.32	15.3 < TT0 ≥ 14.4	0.27	11.2 < TD18 ≥ 9.5	0.24	TT6 ≥ 20.9	0.21	22 < TA0 ≥ 24.5	0.30
16.6 < TT6 ≥ 15.8	0.26	16.3 < TT0 ≥ 15.3	0.46	13.1 < TD18 ≥ 11.2	0.2			24.5 < TA0 ≥ 26.5	0.29
TT6 ≥ 16.6	0.53	17.2 < TT0 ≥ 16.3	0.25	14.7 < TD18 ≥ 13.1	0.29			TA0 ≥26.5	0.50
		19.5 < TT0 ≥ 17.2	0.26	16.7< TD18 ≥ 14.7	0.49				
		TT0 ≥ 19.5	0.50	TD18 ≥ 16.7	0.52				

Air-mass classification

A further statistical method was the creation of an air mass-based climatological index to categorize days, based on its meteorological character, into groups that are relatively homogeneous. Seven available weather elements were included for London, Paris, Budapest and Rome: air temperature, dew point temperature, total cloud cover, sea level pressure, wind speed and wind components u and v at 12 UTC.

The identification of air mass types was based on the daily meteorological data in conjunction with principal components analysis (PCA) followed by cluster analysis (CA). The result of the application of these two techniques is a temporal synoptic index (TSI) from which a daily calendar of air mass types may be constructed (McGregor 1999). To identify the different types the mean meteorological conditions of all days in each air mass group are assessed (Sheridan et al. 1998).

Relationship between air mass categories and mortality

Not all days within an offensive air mass (one which is on average associated with high mortality) possess elevated mortality. For the experimental mortality predictions as part of the HHWWS we chose only those types of air masses, which evince a high excess mean mortality. Once these had been identified multiple stepwise regression analysis was used to explore the nature of the linkage between a range of independent meteorological variables and the dependent mortality variable for those air mass types. Algorithms were developed for total mortality, those 65 and over, those 75 and over. These were subsequently used with weather forecast data supplied by the DWD to make experimental mortality predictions.

Air mass London

Application of a P mode PCA (Yarnal 1993) resulted in 3 principal components being identified. These accounted for 69 % of the original data variance. Clustering of principal component scores resulted in 8 major air mass types being identified. The main meteorological characteristics of the air mass types are summarised in figure 2 and table 4.

Table 4 Air mass types

no.	Air mass		Features
1	Transition	TR	mainly southwest wind, humid condition, low pressure, cloudy, moderately wind speed - at midday increase the wind speed, warm conditions during the night
2	Moist moderate	MM	generally west or northwest wind, low wind speed, chill and humid, cloudy (special at midday)
3	Moist polar	MP	principally west or northwest wind, low wind speed, cold and humid, cloudy (special at midday)
4	Dry moderate	DM	high pressure, mainly north or northeast wind, night = cold & day = warm conditions, very dry, low cloud cover, low wind speed
5			low pressure, mostly south or southwest wind, humid conditions, very high wind speed (maximum at 12 UTC)
6	Dry tropical	DT	wind direction is not unitary at 0 and 6UTC, west wind at 12 and south wind at 18 UTC (not distinct), hot, high pressure, dry conditions on midday and afternoon, low wind speed
7	Moist tropical	MT	high humidity, warm temperature (particularly in the night) , low wind speed, cloudy, south or west wind (but it is not so distinct), low pressure
8	Dry tropical+	DT+	hot and very dry conditions, mainly east wind at 00UTC and southeast wind at 12 and 18 UTC, low cloud cover, high pressure

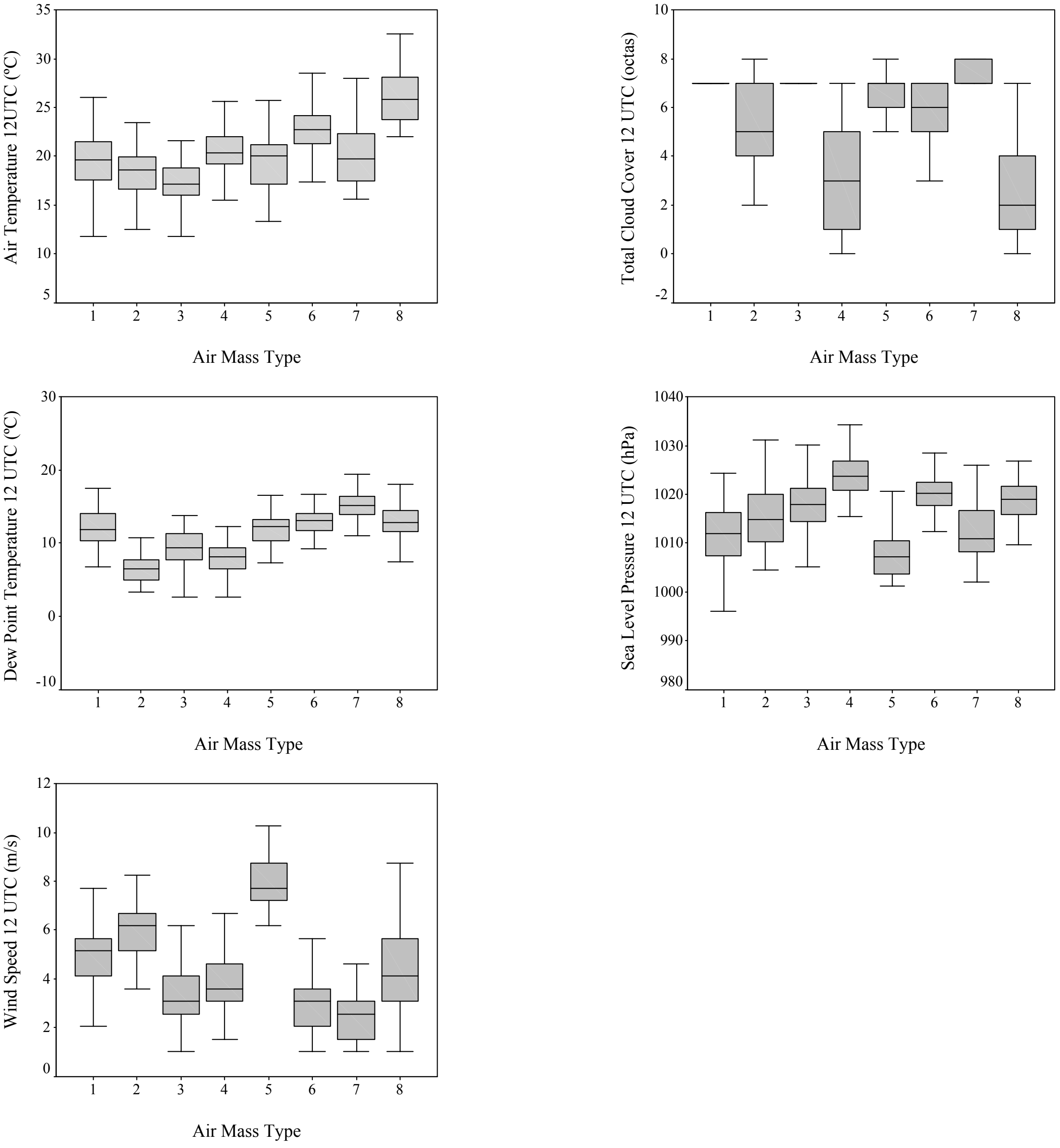


Figure 2 Meteorological characteristics of air mass types at 12 UTC

Figure 3 describes the mean mortality (total mortality, mortality over 64 years and mortality over 74 years) by air mass for London for the summertime, defined as 1 June to 31 August, over the period 1992-2000. Especially air mass type 8 has a mean mortality with is statistically significantly higher than the other 7 air masses, with an additional 9 deaths per day (total mortality). Besides air mass types 6 and 7 feature a higher mortality than the mean.

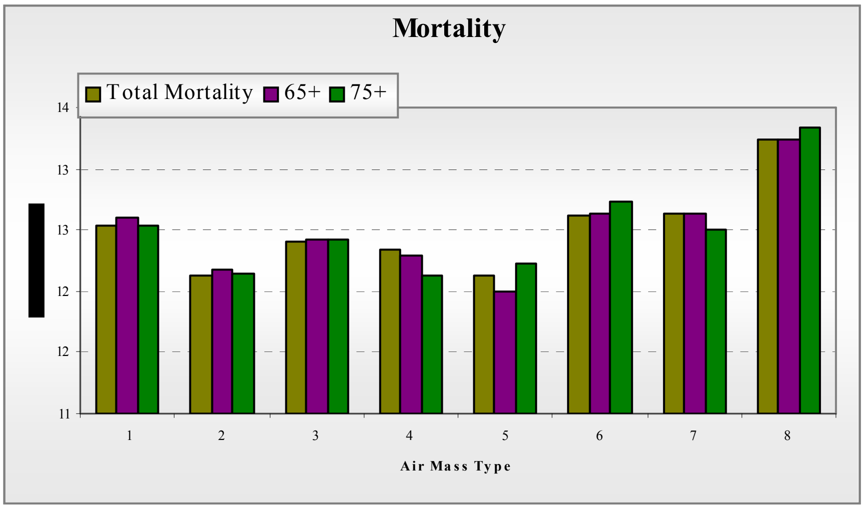


Figure 3: Mortality by air mass types

DT, MT and DT+ comprise approximately 31 % of all summer days in London. DT+ contains the highest temperature of any air mass, and the least cloud cover. This air mass type can qualify as a subgroup from DT, which has as well hot and dry conditions. MT, while lower in afternoon temperature, has the highest dew point of any air mass. Characteristically for these 3 air masses is a very high overnight temperature.

Typically, the air masses, which enclose the highest mean daily mortality also, contain the highest daily standard deviation of mortality as well. This indicates that, although some DT, MT, and DT+ days have very high mortality totals, sometimes over 50 deaths above the mean, other days within these air masses have very little excess mortality.

Daily mortality data was regressed against a range (air mass types) of meteorological variables, as described in Table 5. Stepwise multiple regression analysis results revealed a significant relationship between daily mortality. Altogether the relationship is very weak by the first five air mass types. Air mass types DT, MT and DT+ have a positive excess mortality and the R Square is with over 42% (total mortality) for a prediction useable.

Table 5 Daily mortality statistics by air mass type and R Square

Cluster	Frequency	Percent	Total Mortality			65+			75+		
			Excess	Range	R Square	Excess	Range	R Square	Excess	Range	R Square
1	156	22.4	0.4	66	0.07	0.3	61	0.1	-0.4	44	0.07
2	44	6.3	-4.3	48	0.19	-3.6	44	0.17	-3.1	44	0.32
3	155	22.3	-1.2	82	0.27	-1.4	77	0.31	-1.2	74	0.26
4	98	14.1	-1.8	78	0.34	-2.7	65	0.23	-3.2	60	0.34
5	23	3.3	-4.4	52	0.63	-5.4	50	0.7	-2.5	46	0.44
6	70	10.1	1.3	71	0.42	0.6	74	0.41	0.9	65	0.42
7	62	8.9	1.5	65	0.60	0.7	59	0.45	-0.6	50	0.47
8	87	12.5	8.5	82	0.59	6.3	72	0.68	5.1	56	0.49

Conditional probabilities by air mass type are displayed in Table 6. Notable is the high probability of a severe mortality day (excess mortality ≥ 6) occurring, compared to the other air mass types, given the occurrence of 6, 7, and 8 for total mortality. Especially air mass type 8 features with over 55% a high probability. Conditional probabilities for the age groups 65+ and 75+ don't evince such a high relationship as for total mortality. The air mass type 8 is the most sensitive for these age groups: probabilities (mortality excess ≥ 6) are over 46%.

Table 6 Conditional probability by air mass type – (a) total mortality, (b) mortality older than 64 and (c) mortality older than 74

(a)

		Conditional probability (in %): total mortality							
		1	2	3	4	5	6	7	8
Excess	-20.1	6.1	8.7	7.5	7.7	13.8	7	4.6	1.1
	-20 to -10.1	15.2	17.4	15.7	20.2	20.7	14.1	16.9	11.4
	-10 to -6.1	9.7	6.5	10.7	8.7	10.3	9.9	10.8	6.8
	-6 to -2.1	9.1	15.2	18.9	13.5	10.3	11.3	9.2	8
	-2 to -0.1	8.5	8.7	4.4	5.8	6.9	5.6	1.5	3.4
	0 to 1.9	8.5	13	2.5	7.7		4.2	4.6	6.8
	2 to 5.9	11.5	23.9	5.7	4.8	3.4	7	10.8	6.8
	6 to 9.9	7.9	4.3	13.2	14.4	20.7	16.9	15.4	19.3
	10 to 19.9	15.8	2.2	15.1	9.6	13.8	18.3	16.9	11.4
	20+	7.9		6.3	7.7		5.6	9.2	25

(b)

		Conditional probability (in %): 65+							
		1	2	3	4	5	6	7	8
Excess	-20.1	4.2	6.5	5	8.7	13.8	5.6	4.6	
	-20 to -10.1	15.2	21.7	17.6	15.4	17.2	9.9	13.8	12.5
	-10 to -6.1	6.7	4.3	10.7	13.5	17.2	15.5	6.2	6.8
	-6 to -2.1	12.1	6.5	18.2	11.5	10.3	15.5	23.1	6.8
	-2 to -0.1	9.1	21.7	5.7	8.7	6.9	8.5	6.2	9.1
	0 to 1.9	12.1	4.3	6.9	8.7		4.2	1.5	3.4
	2 to 5.9	10.9	19.6	8.2	12.5	13.8	14.1	12.3	12.5
	6 to 9.9	10.3	10.9	9.4	7.7	10.3	2.8	12.3	11.4
	10 to 19.9	14.5	4.3	15.7	8.7	10.3	16.9	13.8	23.9
	20+	4.8		2.5	4.8		7	6.2	13.6

(c)

		Conditional probability (in %): 75+							
		1	2	3	4	5	6	7	8
Excess	-20.1	1.2	6.5	2.5	8.7	6.9	2.8	1.5	
	-20 to -10.1	15.2	15.2	18.2	19.2	20.7	11.3	13.8	8
	-10 to -6.1	11.5	15.2	11.3	13.5	13.8	11.3	12.3	10.2
	-6 to -2.1	15.2	13	12.6	14.4	10.3	12.7	18.5	5.7
	-2 to -0.1	9.1	8.7	12.6	6.7	13.8	7	6.2	11.4
	0 to 1.9	9.1	6.5	6.9	6.7		14.1	9.2	6.8
	2 to 5.9	15.2	15.2	13.8	9.6	13.8	12.7	13.8	11.4
	6 to 9.9	7.9	13	9.4	9.6	3.4	12.7	9.2	17
	10 to 19.9	13.3	6.5	9.4	6.7	13.8	9.9	13.8	18.2
	20+	2.4		3.1	4.8	3.4	5.6	1.5	11.4

Air Mass Paris

Seven air mass types were identified for Paris. The main meteorological characteristics of the air mass type are summarised in table 7 and figure 4.

Table 7 Air mass types

No.	Air mass		Features
1	Moist tropical	MT	low pressure, cloudy, warm conditions (quite hot in the night), quite high wind speed, quite humid, southwest wind after midday
2	Moist polar+	MP+	northwest or west wind, cloudy, cold conditions, humid, quite high wind speed
3			southwest or west wind, high cloud cover, low pressure, mean temperature, very humid (especially during the day), high wind speed
4	Moist moderate	MM	cloudy, warm (particularly during the day), low wind speed
5	Moist polar	MP	high pressure, cold (particularly during the night)
6	Transition	TR	dry (especially during the day), high pressure, during night: cold conditions, during day: warm conditions, low cloud cover
7	Dry tropical	DT	very dry and hot (particularly during the day), low wind speed, northeast wind (particularly during the night), low cloud cover

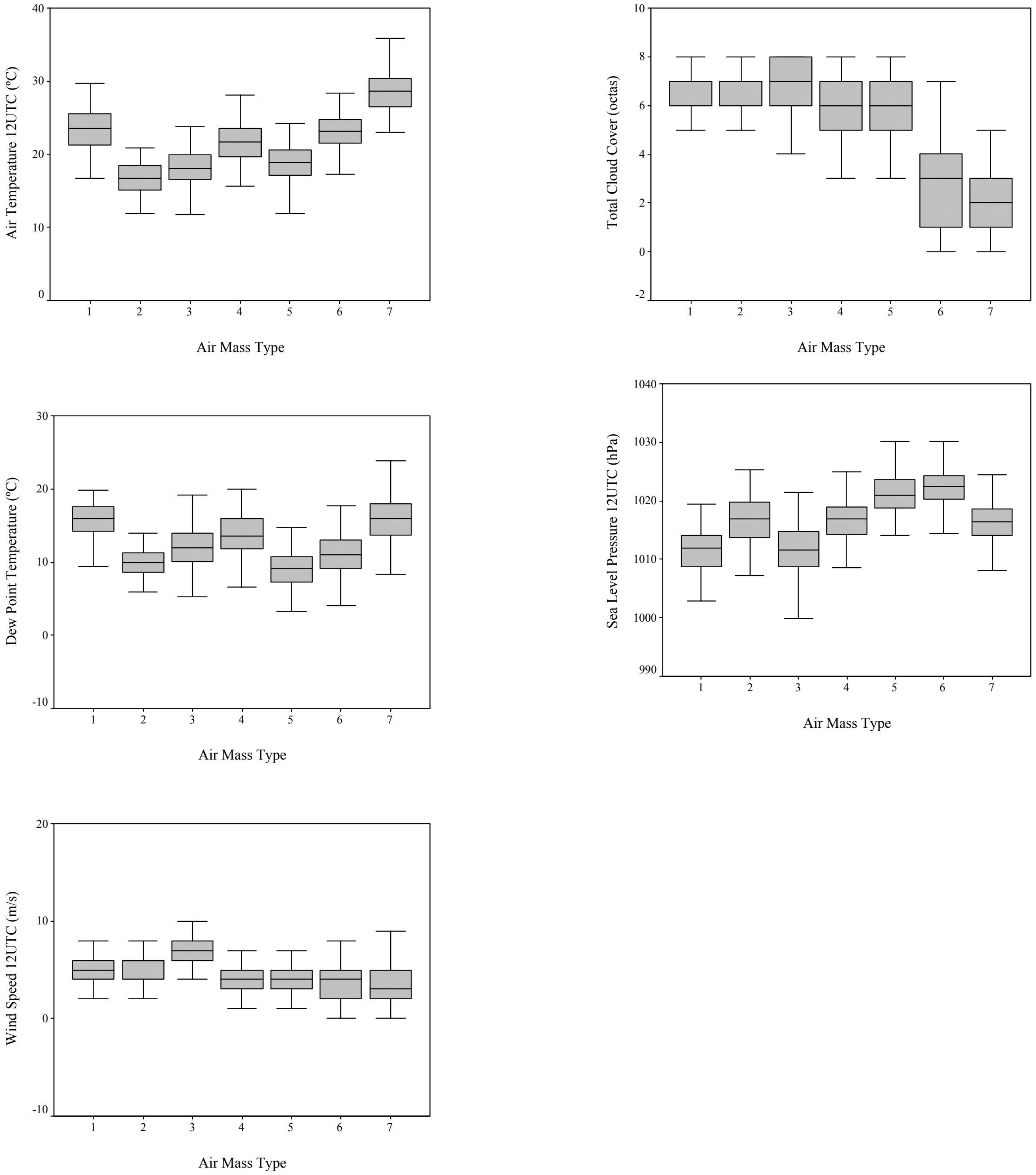


Figure 4 Meteorological characteristics of air mass types at 12 UTC - Paris

The mean mortality (total mortality, mortality over 64 years and mortality over 74 years) by air mass for the summertime are shown in figure 5. Air mass 1 and 7 feature a high mean mortality with in addition 4 to 10 deaths per day (total mortality). Around 30 % of all summer days are accounted for by these air mass types.

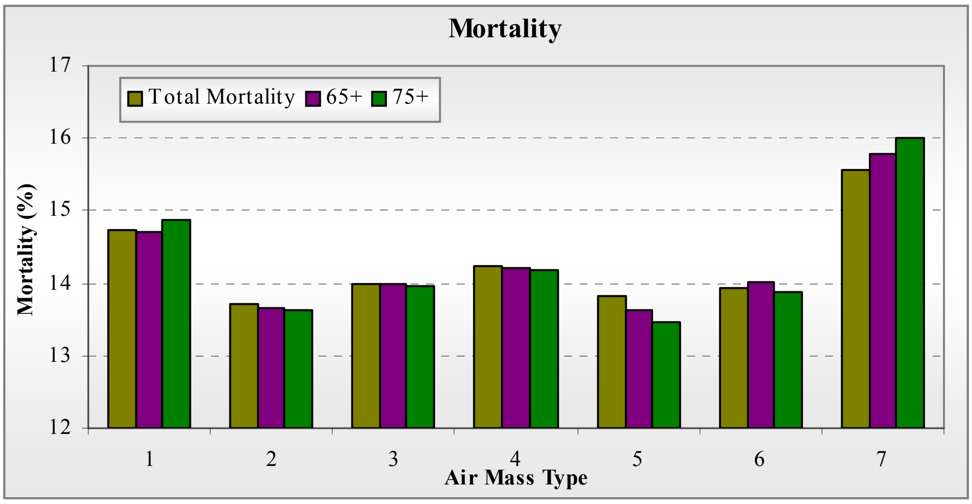


Figure 5: Mortality by air mass types

By means of multiple stepwise regression analyses between daily mortality data and range of meteorological variables (air mass types) we could find 2 air mass types, which evince a positive excess mortality (Table 8). In particular air mass type 7 shows with an excess average from 9.6 a severe mortality day.

Table 8 Daily mortality statistics by air mass type and R Square

Cluster	Frequency	Percent	Total Mortality			65+			75+		
			Excess	Range	R Square	Excess	Range	R Square	Excess	Range	R Square
1	73	10.1	3.1	73	0.31	2	54	0.44	2.2	45	0.49
2	51	7	-4.9	51	0.57	-4.1	36	0.36	-3.3	33	0.62
3	107	14.8	-2.9	68	0.23	-2.1	59	0.22	-1.8	41	0.21
4	170	23.4	-0.9	56	0.17	-0.9	50	0.25	-0.8	46	0.22
5	94	13	-4.1	62	-	-4.2	50	-	-4	36	-
6	104	14.3	-3.2	61	0.20	-2	50	0.21	-2.2	44	0.23
7	126	17.4	9.6	81	0.52	8.1	65	0.49	7.2	58	0.43

Figures 6 should give a summery about the connection between air mass types and excess mortality for each investigates age group

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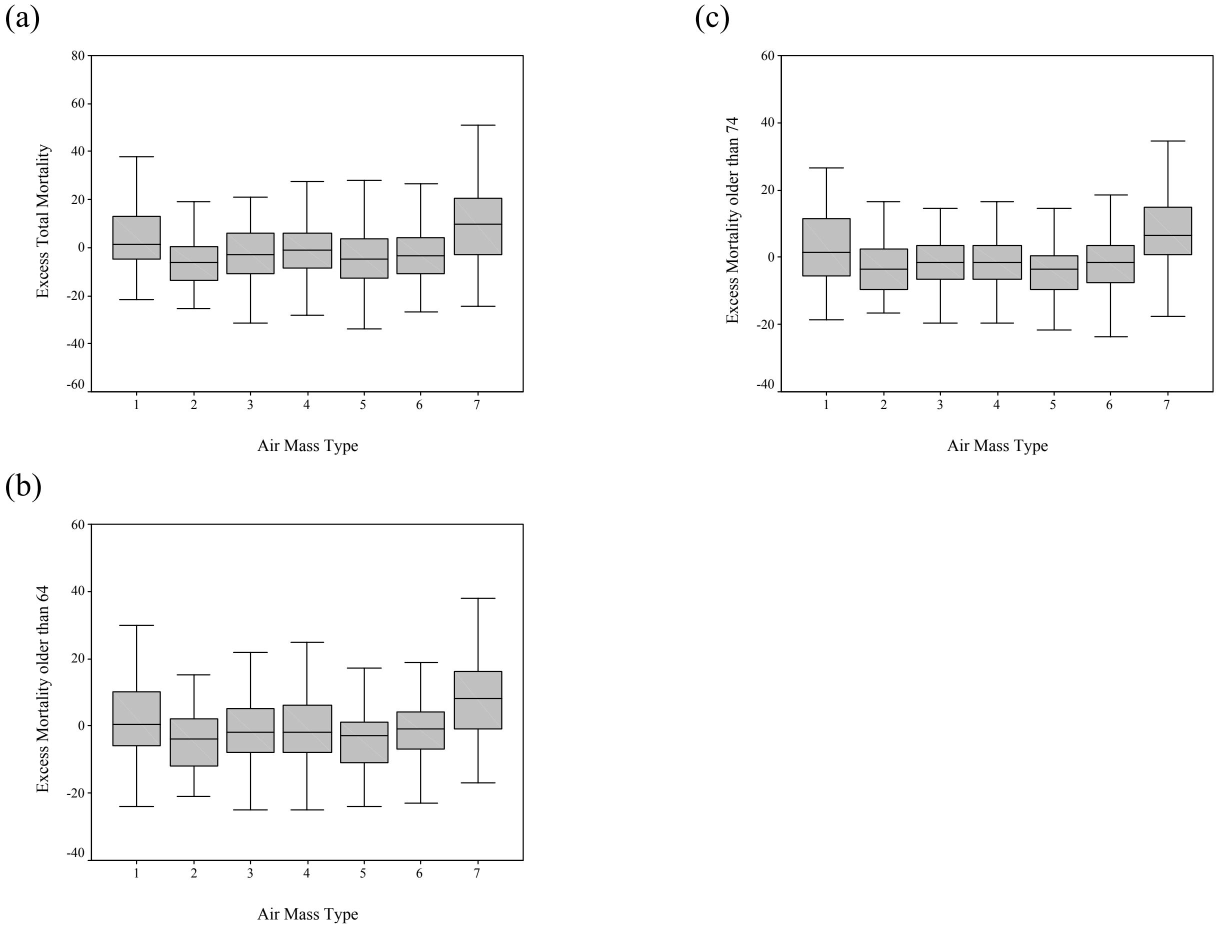


Figure 6 (a) Excess total mortality, (b) older than 64 and (c) older than 74 and air mass types - Paris

Table 9 describes the conditional probabilities by air mass type for total mortality (a), mortality over 64 years (b) and mortality over 74 years (c). A high probability is evident particularly on hot days (air mass type 1 and 7). The probability of excess total mortality ≥ 10 on hot and dry days is approximately 48 %; days with hot and humid conditions feature a value around 28%. The two elderly age groups showed a similar alleviated behaviour pattern to that observed for all-age mortality.

Table 9 Conditional probability by air mass type – (a) total mortality, (b) mortality older than 64 and (c) mortality older than 74

(a)

		Conditional probability (in %): total mortality						
		1	2	3	4	5	6	7
Excess	-20.1	2.7	3.8	10.1	5.3	7.4	5.7	1.6
	-20 to -10.1	14.9	32.1	16.5	17.5	21.3	22.9	12.6
	-10 to -6.1	5.4	15.1	11	12.9	12.8	6.7	5.5
	-6 to -2.1	10.8	13.2	13.8	11.7	20.2	16.2	6.3
	-2 to -0.1	12.2	7.5	5.5	4.7	4.3	6.7	2.4
	0 to 1.9	4.1	5.7	5.5	8.2	4.3	9.5	2.4
	2 to 5.9	16.2	11.3	13.8	15.2	10.6	12.4	8.7
	6 to 9.9	5.4	1.9	9.2	5.3	8.5	8.6	12.6
	10 to 19.9	13.5	7.5	11.9	13.5	7.4	9.5	22
	20+	14.9	1.9	2.8	5.8	3.2	1.9	26

(b)

		Conditional probability (in %): 65+						
		1	2	3	4	5	6	7
Excess	-21	4.1	1.9	3.7	2.3	4.3	3.8	
	-20 to -11	13.5	26.4	16.5	14.6	22.3	13.3	7.9
	-10 to -7	5.4	9.4	10.1	13.5	11.7	11.4	4.7
	-6 to -3	12.2	18.9	18.3	15.8	16	16.2	9.4
	-2 to -1	8.1	7.5	7.3	8.2	13.8	12.4	3.9
	0 to 1	9.5	9.4	8.3	8.8	7.4	7.6	7.1
	2 to 5	12.2	9.4	13.8	10.5	10.6	14.3	11.8
	6 to 9	9.5	7.5	11.9	11.7	6.4	12.4	10.2
	10 to 19	13.5	9.4	8.3	10.5	6.4	8.6	28.3
	20+	12.2		1.8	4.1	1.1		16.5

(c)

		Conditional probability (in %): 75+						
		1	2	3	4	5	6	7
Excess	-21			0.9			2.9	
	-20 to -11	17.6	24.5	18.3	12.3	22.3	13.3	4.7
	-10 to -7	5.4	15.1	6.4	16.4	11.7	12.4	10.2
	-6 to -3	12.2	18.9	22	18.1	25.5	20	4.7
	-2 to -1	8.1	13.2	16.5	11.7	8.5	12.4	4.7
	0 to 1	9.5	1.9	6.4	7	11.7	6.7	5.5
	2 to 5	12.2	11.3	10.1	14	9.6	18.1	19.7
	6 to 9	6.8	9.4	9.2	9.9	6.4	6.7	11.8
	10 to 19	23	5.7	10.1	7.6	3.2	7.6	26
	20+	5.4			2.9			12.6

Air Mass Budapest

7 air masses were revealed for Budapest as described in Table 10 and Figure 7. The distribution of excess mortality by air mass is presented in Figure 11 and along with condition probability of high excess mortality by air mass type in Table 12.

Table 10 Air mass types

No.	Air mass		Features
1	Dry tropical	DT	warm and dry conditions (in particular during the day), low wind speed, low cloud cover, quite high pressure
2	Transition	TR	humid, cloudy, low pressure,
3	Moist polar	MP	cold and very humid, cloudy
4			cold conditions (very cold during the day), high humidity, very high wind speed, cloudy, low pressure, northwest wind
5	Moist tropical	DT	warm conditions (especially from morning until midday), quite humid, in the afternoon high wind speed, low pressure, southeast wind
6	Dry polar	DP	cold and dry, high wind speed, high pressure, northwest wind
7	Dry moderate	DM	quite cold conditions (particularly in the night) and very dry, low wind speed, low cloud cover, high pressure

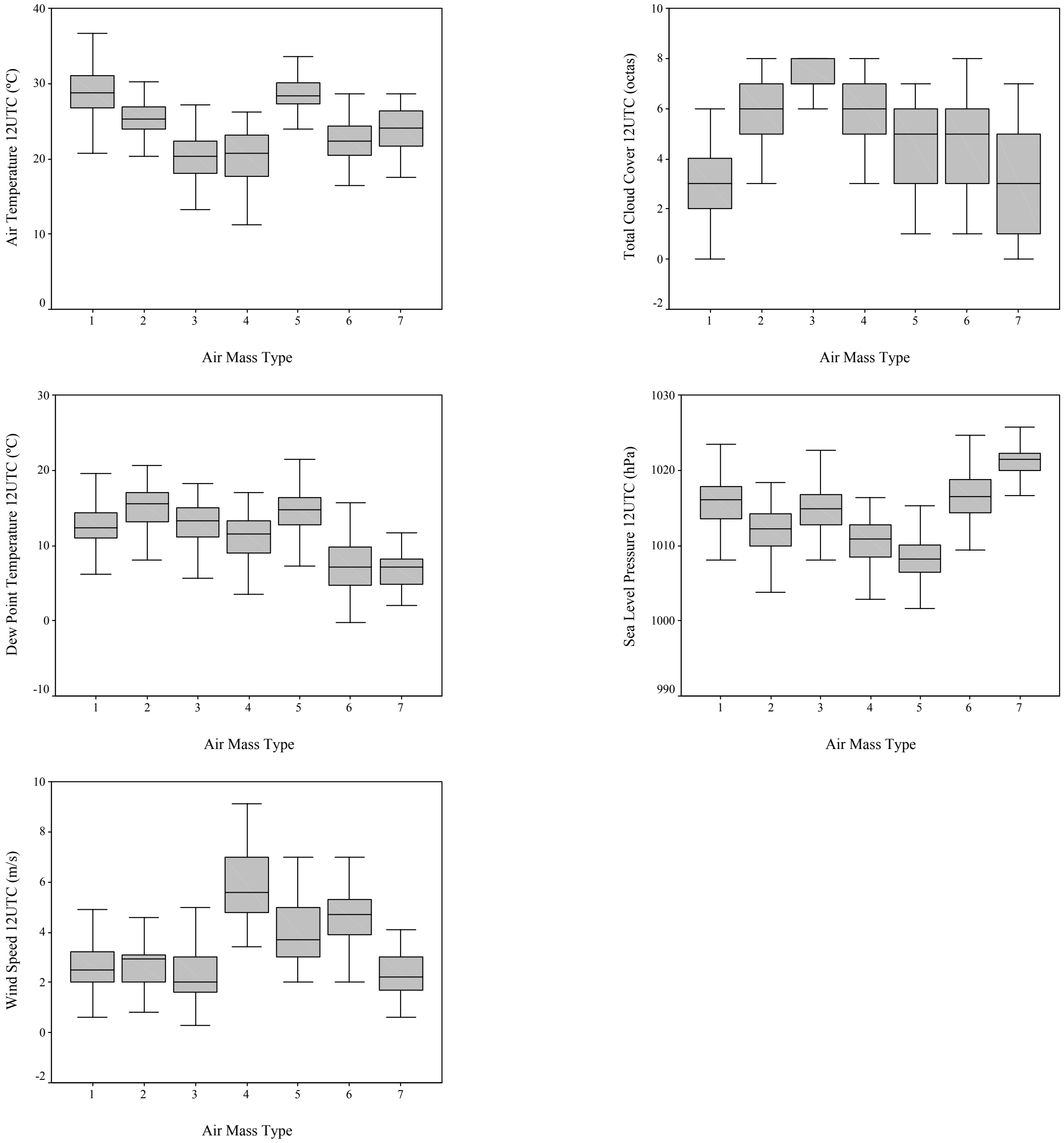
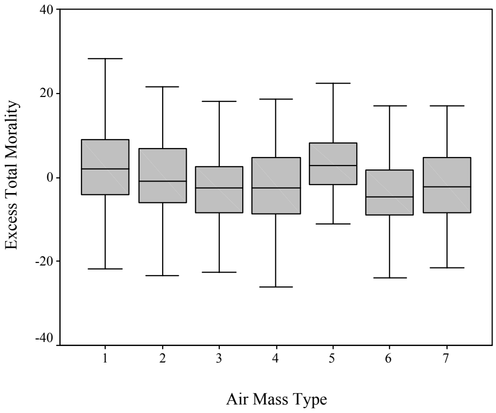
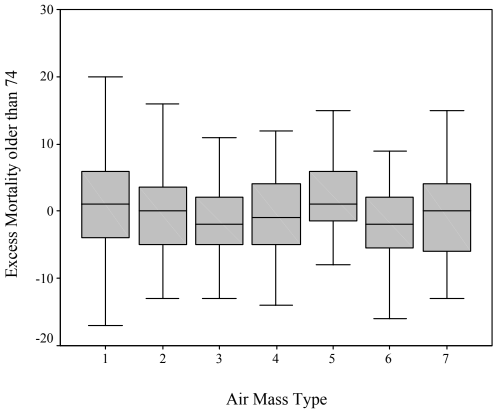


Figure 7 Meteorological characteristics of air mass types at 12 UTC - Budapest

Table 11 Daily mortality statistics by air mass type and R Square

Cluster	Frequency	Percent	Total Mortality			65+			75+		
			Excess	Range	R Square	Excess	Range	R Square	Excess	Range	R Square
1	350	40.2	3.2	64	0.30	2.1	55	0.30	1.7	45	0.28
2	102	11.7	-0.3	45	09	-1	37	0.21	0	30	0.16
3	128	14.7	-2.9	43	0.13	-2.4	38	0.15	-1.4	32	0.23
4	77	8.8	-1.9	45	0.13	-1.9	35	0.24	-0.7	32	0.21
5	51	5.9	3.9	56	0.38	3.9	35	0.21	2.3	27	0.51
6	111	12.7	-3.6	41	0.21	-3	30	0.27	-1.8	32	0.18
7	52	6	-1.4	50	0.11	-1.1	36	0.33	-0.3	28	0.56





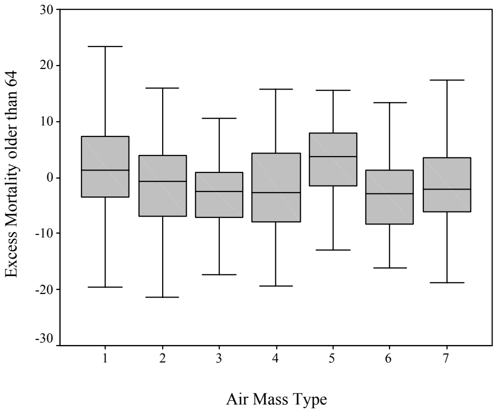


Table 12 Conditional probability by air mass type – (a) total mortality, (b) mortality older than 64 and (c) mortality older than 74

(a)

		Conditional probability (in %): total mortality						
		1	2	3	4	5	6	7
Excess	-10.1	9	13.9	23.3	16.5	3.6	21.8	11.1
	-10 to -6.1	9	11.1	11.3	19	7.1	18.5	25.9
	-6 to -2.1	14.1	20.4	17.3	16.5	14.3	18.5	13
	-2 to -0.1	8.2	9.3	9.8	3.8	10.7	10.1	5.6
	0 to 1.9	9.5	6.5	12.8	8.9	10.7	8.4	9.3
	2 to 5.9	15.8	10.2	12	13.9	19.6	9.2	11.1
	6 to 9.9	12.2	16.7	3.8	11.4	12.5	6.7	14.8
	10+	22.3	12	9.8	10.1	21.4	6.7	9.3

(b)

		Conditional probability (in %): 65+						
		1	2	3	4	5	6	7
Excess	-10.1	9	10.2	16.5	12.7	1.8	17.6	7.4
	-10 to -6.1	9.5	17.6	14.3	20.3	5.4	16	16.7
	-6 to -2.1	14.4	17.6	23.3	20.3	16.1	22.7	25.9
	-2 to -0.1	9.2	9.3	14.3	6.3	10.7	11.8	14.8
	0 to 1.9	12.8	13.9	7.5	5.1	5.4	10.1	5.6
	2 to 5.9	16.3	10.2	9.8	19	19.6	10.9	13
	6 to 9.9	11.7	10.2	10.5	10.1	21.4	7.6	9.3
	10+	17.1	11.1	3.8	6.3	19.6	3.4	7.4

(c)

		Conditional probability (in %): 75+						
		1	2	3	4	5	6	7
Excess	-11	2.7	4.6	3.8	7.6		4.2	1.9
	-10 to -7	10.1	8.3	13.5	12.7	3.6	16	20.4
	-6 to -3	16.8	25.9	30.8	22.8	16.1	26.1	16.7
	-2 to -1	9	10.2	11.3	8.9	10.7	10.9	9.3
	0 to 1	13	10.2	11.3	10.1	23.2	14.3	14.8
	2 to 5	22	23.1	16.5	19	19.6	20.2	16.7
	6 to 9	13.3	7.4	9.8	13.9	17.9	7.6	11.1
	10+	13	10.2	3	5.1	8.9	0.8	9.3

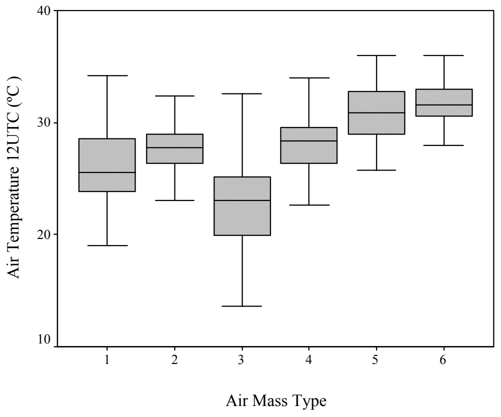
Air Mass Barcelona

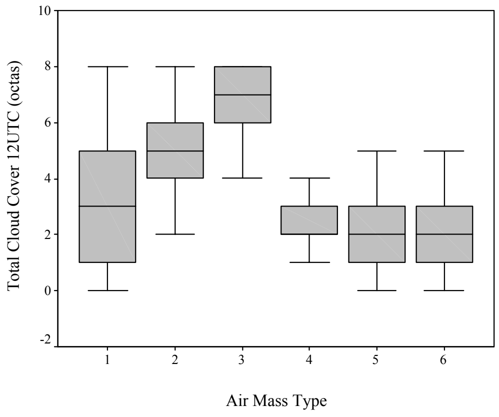
For Barcelona no ‘offensive’ air mass types were found therefore iar masses were not used in the HHWWS for Barcelona.

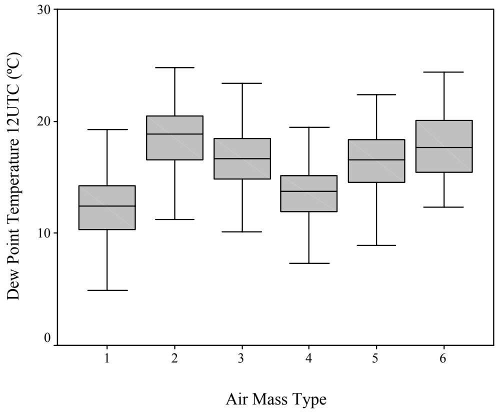
Air Mass Rome

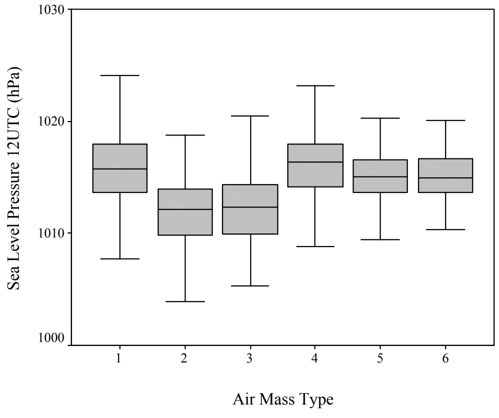
The main air mass types for Rome are shown below. High excess mortality was found to be associated with dry tropical air masses.

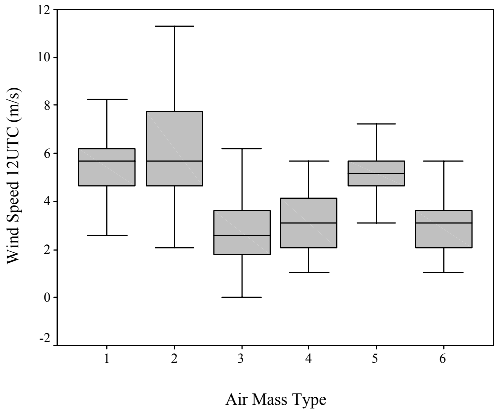
No.	Air mass		Features
1	Dry polar	DP	cold, in the afternoon quite dry, low wind speed, low cloud cover, high pressure
2	Moist moderate	MM	warm during the night, quite cold during the day, high humidity during the day, high wind speed, cloudy, low pressure,
3	Moist polar	MP	very cold and humid (particularly in the afternoon), low wind speed, high cloud cover, low pressure
4	Dry moderate	DM	chilly, during the day dry and during the night humid, low wind speed, low cloud cover, high pressure
5	Dry tropical	DT	warm - especially during midday, quite dry, low wind speed, low cloud cover
6	Dry tropical+	DT+	hot and quite dry during the day, low wind speed, low cloud cover



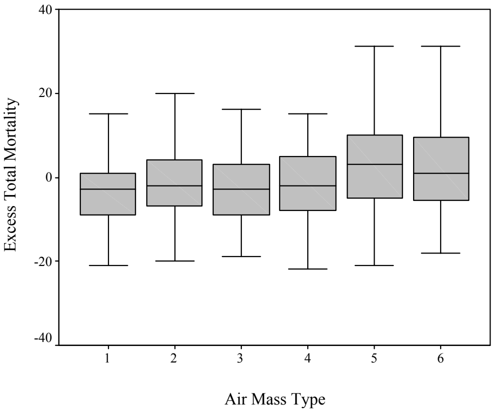


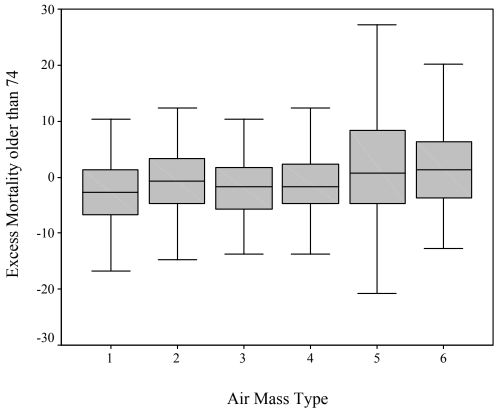






			Total Mortality			65+			75+		
Cluster	Frequency	Percent	Excess	Range	R Square	Excess	Range	R Square	Excess	Range	R Square
1	139	18.9	-3	73	0.16	-2.9	60	0.18	-2.5	48	0.37
2	137	18.6	-0.8	61	0.30	-0.4	56	0.31	-0.2	44	0.27
3	53	7.2	-2.8	35	0.18	-2.9	32	0.38	-2.3	32	0.42
4	123	16.7	-1.8	48	0.24	-1.6	44	0.30	-1.5	35	0.25
5	165	22.4	3.5	72	0.27	3.1	66	0.40	2.7	57	0.26
6	119	16.2	3	53	0.52	2.7	51	0.54	2.2	38	0.53





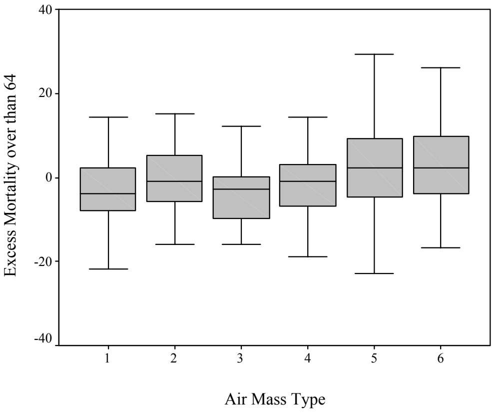


Table 13 Conditional probability by air mass type – (a) total mortality, (b) mortality older than 64 and (c) mortality older than 74

(a)

		Conditional probability (in %) - total mortality					
		1	2	3	4	5	6
Excess	-11	18.2	15.3	20.6	18.3	9.6	13.4
	-10 to -7	14.9	12.9	12.7	12.2	12.4	9.4
	-6 to -3	20.1	17.1	17.5	16.8	11.8	10.2
	-2 to -1	13	11.2	11.1	6.9	6.2	9.4
	0 to 1	9.7	4.7	7.9	9.2	7.9	7.9
	2 to 5	11.7	17.6	9.5	14.5	11.2	15
	6 to 9	4.5	10.6	9.5	14.5	12.4	9.4
	10+	7.8	10.6	11.1	7.6	28.7	25.2

(b)

		Conditional probability (in %) - 65+					
		1	2	3	4	5	6
Excess	-11	14.9	12.4	15.9	11.5	8.4	12.6
	-10 to -7	18.2	12.4	17.5	14.5	10.7	7.9
	-6 to -3	23.4	20	17.5	19.8	15.7	12.6
	-2 to -1	11	8.2	19	9.2	9	7.1
	0 to 1	6.5	9.4	7.9	11.5	5.6	7.1
	2 to 5	14.3	15.9	7.9	19.8	14.6	20.5
	6 to 9	7.1	10	7.9	8.4	12.4	7.1
	10+	4.5	11.8	6.3	5.3	23.6	25.2

(c)

		Conditional probability (in %) - 75+					
		1	2	3	4	5	6
Excess	-11	7.8	6.5	9.5	8.4	5.6	4.7
	-10 to -7	22.1	12.9	12.7	9.9	10.1	11
	-6 to -3	25.3	18.2	27	26.7	17.4	15.7
	-2 to -1	10.4	14.7	15.9	13	12.9	8.7
	0 to 1	12.3	12.4	9.5	14.5	5.6	11
	2 to 5	13	18.8	19	17.6	14.6	21.3
	6 to 9	6.5	9.4	1.6	6.1	11.8	10.2
	10+	2.6	7.1	4.8	3.8	21.9	17.3

The Protocol and Mechanics of the HHWWS

The information from the aforementioned analyses was used as described above to create a number of experimental mortality prediction models which formed the basis of the HHWWS. The HHWWS protocol is presented in the figure on the last page of this report. Basically weather forecast data from the DWD were used as input into the various mortality prediction algorithms. From the algorithms an estimate of the excess mortality was calculated every 6 hours as new weather forecast was issued. The receipt of weather forecast from the DWD, calculation of the mortality estimate and subsequent display of this was all performed on a PHEWE HHWWS password protect web site. Below the basic structure of the site is described as well as simple instructions for moving through the web site.

For an evaluation of the HHWWS in practice the reader is referred to the report complied by Dr A Paldi for the Budapest HHWWS.

Guidance for Use of HHWWS Web Pages

Click on the City of interest on the left hand side of the PHEWE Info Page. This will take you to the individual city page.

PHEWE: Assesment and Prevention of acute Health Effects of Weather conditions in Europe

PHEWE Info page

Website now active for the 2005 summer period.

Individual City Page (example London given below)

A number of buttons are displayed as follows

Forecast Data: the 6 hourly forecast received from the German Weather Service up to 48 hours ahead for a number of meteorological variables.

PT Data: Comfort levels according to the Perceived Temperature Index (see PT Data Page)

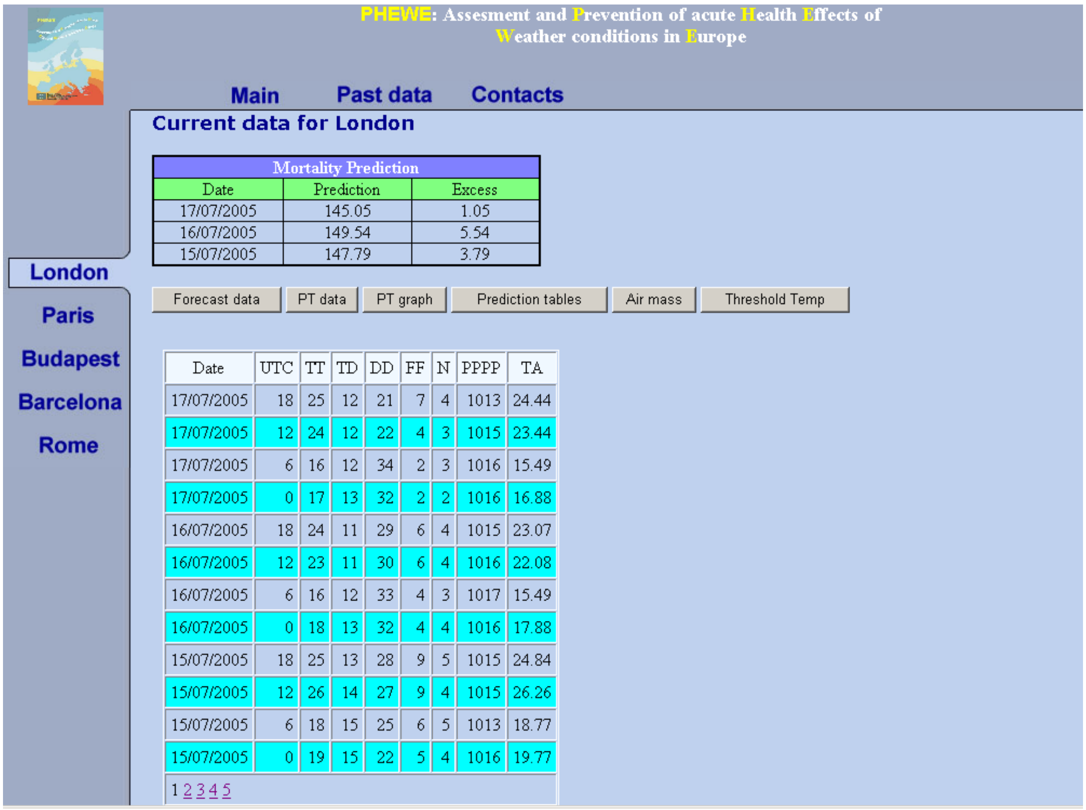
PT Graph: A plot of the PT Index over the last few days

Prediction Tables: Conditional Probability of mortality exceeding a given level for a combination of dry bulb and dew point temperature combinations (See Prediciton Tables Page)

Air Mass: Mortaity prediction associated with the occurrence of a predicted air mass. Only predictions for air masses that are climatologically associated (that is over the long term) with higher than normal mortality are given (See Air Mass Page)

Threshold Temperature: Mortality predictions when the forecast temperature exceeds a given threshold (See Threshold Page)

Forecast Page



Current data for London

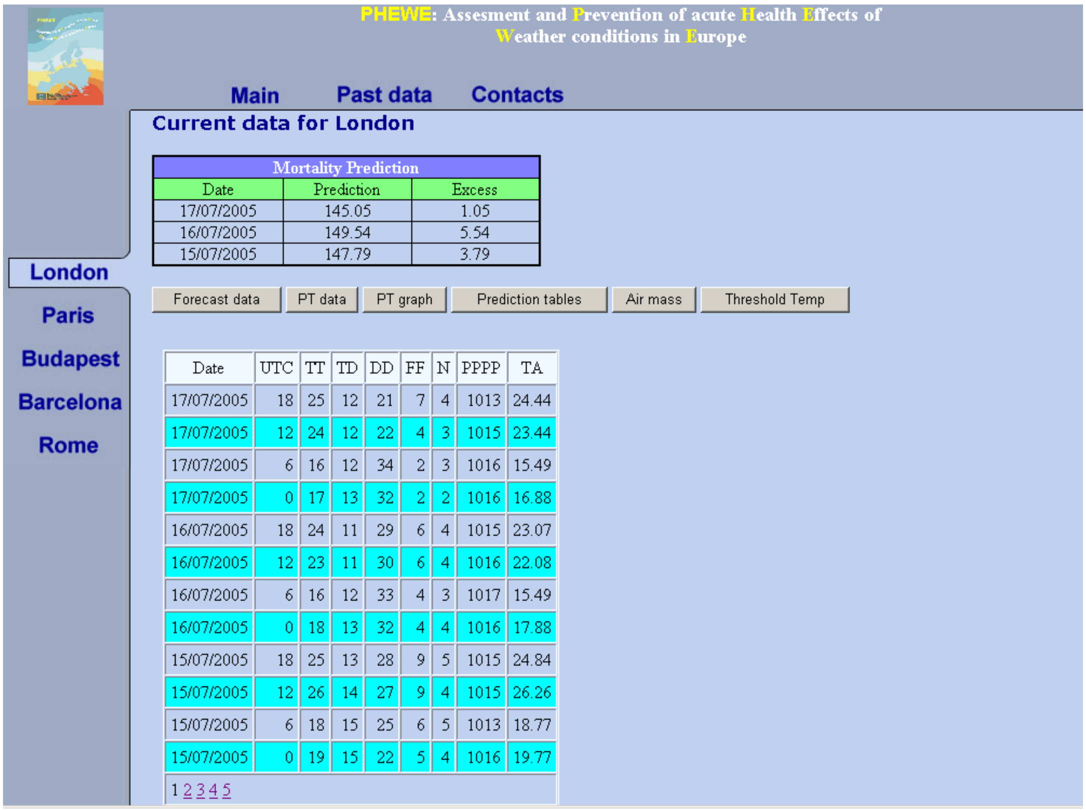
Mortality Prediction		
Date	Prediction	Excess
17/07/2005	145.05	1.05
16/07/2005	149.54	5.54
15/07/2005	147.79	3.79

Date	UTC	TT	TD	DD	FF	N	PPPP	TA
17/07/2005	18	25	12	21	7	4	1013	24.44
17/07/2005	12	24	12	22	4	3	1015	23.44
17/07/2005	6	16	12	34	2	3	1016	15.49
17/07/2005	0	17	13	32	2	2	1016	16.88
16/07/2005	18	24	11	29	6	4	1015	23.07
16/07/2005	12	23	11	30	6	4	1016	22.08
16/07/2005	6	16	12	33	4	3	1017	15.49
16/07/2005	0	18	13	32	4	4	1016	17.88
15/07/2005	18	25	13	28	9	5	1015	24.84
15/07/2005	12	26	14	27	9	4	1015	26.26
15/07/2005	6	18	15	25	6	5	1013	18.77
15/07/2005	0	19	15	22	5	4	1016	19.77
1 2 3 4 5								

Explanation of Forecast Data Page

Mortality Predictions: Multiple stepwise regression analysis has been used to develop mortality prediction algorithms that describe the relationship between daily mortality and weather. The output from the prediction algorithms is **predicted** and **excess** mortality. Predicted in the total mortality while excess is the number of deaths above the long-term average for the given day of the year.

The mortality predictions are based on statistical algorithms for different temperature bands. For example for a particular city there may be different algorithms for describing weather mortality relationships for the following temperature ranges at 1200hrs; 18-21°C, 21-23°C, 23-26°C and so on. If the forecast temperature at 1200hrs is 24°C then a statistical model for the 23-26oC range, is run that describes weather mortality relationships for that range of temperatures.



PHEWE: Assesment and Prevention of acute Health Effects of Weather conditions in Europe

Current data for London

Mortality Prediction		
Date	Prediction	Excess
17/07/2005	145.05	1.05
16/07/2005	149.54	5.54
15/07/2005	147.79	3.79

Date	UTC	TT	TD	DD	FF	N	PPPP	TA
17/07/2005	18	25	12	21	7	4	1013	24.44
17/07/2005	12	24	12	22	4	3	1015	23.44
17/07/2005	6	16	12	34	2	3	1016	15.49
17/07/2005	0	17	13	32	2	2	1016	16.88
16/07/2005	18	24	11	29	6	4	1015	23.07
16/07/2005	12	23	11	30	6	4	1016	22.08
16/07/2005	6	16	12	33	4	3	1017	15.49
16/07/2005	0	18	13	32	4	4	1016	17.88
15/07/2005	18	25	13	28	9	5	1015	24.84
15/07/2005	12	26	14	27	9	4	1015	26.26
15/07/2005	6	18	15	25	6	5	1013	18.77
15/07/2005	0	19	15	22	5	4	1016	19.77

German Meteorological Service (DWD) 3-day forecast variables

UTC = coordinated universal time
TT = air temperature (°C)
TD = dew point temperature (°C)
DD = wind direction (degrees – multiply by 10)
FF = wind speed (knots)
N = total cloud cover (octas)
PPPP = sea level pressure (hPa)
TA = apparent temperature (°C)
Excess = difference between predicted mortality and the mean of the historical data set

Explanation of PT Data Page

Date	UTC	PT	Thermal Sensation	Thermal Stress
17/07/2005	18	24.5	Slightly Warm	Slight
17/07/2005	12	28.8	Warm	Moderate
17/07/2005	6	17.6	Comfortable	None
17/07/2005	0	12	Comfortable	None
16/07/2005	18	23.4	Slightly Warm	Slight
16/07/2005	12	26	Warm	Moderate
16/07/2005	6	15	Comfortable	None
16/07/2005	0	12	Comfortable	None
15/07/2005	18	23.9	Slightly Warm	Slight
15/07/2005	12	28.9	Warm	Moderate

Perceived temperature (PT) in ºC

The perceived temperature is an indicator of daily thermal stress. This temperature compares the existing outside conditions with the temperature that would prevail in a standard environment in order to experience an identical feeling of warmth, comfort, or cold (WMO 2002).

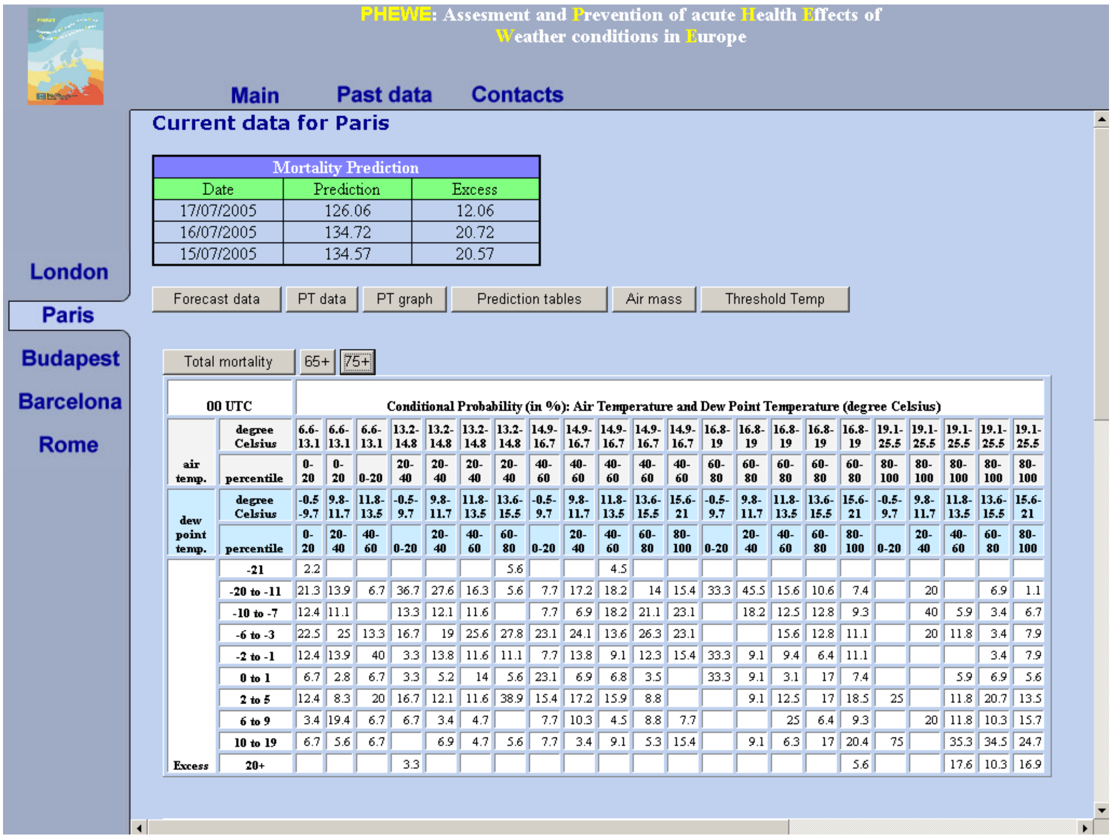
Table 1: Perceived temperature, thermal sensation, and thermal stress (Koppe et al. 2004)

Perceived temperature (°C)	Thermal Sensation	Thermal Stress
≤ -39	Very cold	Extreme
-26 to -39	Cold	Strong
-13 to -26	Chilly	Moderate
0 to -13	Slightly chilly	Slight
0 to +20	Comfortable	None
+20 to +26	Slightly warm	Slight
+26 to +32	Warm	Moderate
+32 to +38	Hot	Strong
≥ +38	Very hot	Extreme

References

1. World Meteorological Organization (eds.), 2002: Guide on the application of new technology and research to public weather services. WMO/TD No. 1102, Geneva.
2. Koppe C., Jendritzky G. and Pfaff G., 2004: Die Auswirkungen der Hitzewelle 2003 auf die Gesundheit. In Deutscher Wetterdienst: Klimastatusbericht 2003. Offenbach, 152-162.

Explanation of Prediction Tables Page



Current data for Paris

Mortality Prediction		
Date	Prediction	Excess
17/07/2005	126.06	12.06
16/07/2005	134.72	20.72
15/07/2005	134.57	20.57

00 UTC		Conditional Probability (in %): Air Temperature and Dew Point Temperature (degree Celsius)																					
air temp.	degree Celsius	6.6-13.1	6.6-13.1	6.6-13.1	13.2-14.8	13.2-14.8	13.2-14.8	13.2-14.8	14.9-16.7	14.9-16.7	14.9-16.7	14.9-16.7	14.9-16.7	16.8-19	16.8-19	16.8-19	16.8-19	16.8-19	19.1-25.5	19.1-25.5	19.1-25.5	19.1-25.5	19.1-25.5
	percentile	0-20	0-20	0-20	20-40	20-40	20-40	20-40	40-60	40-60	40-60	40-60	40-60	60-80	60-80	60-80	60-80	60-80	80-100	80-100	80-100	80-100	80-100
dew point temp.	degree Celsius	-0.5-9.7	9.8-11.7	11.8-13.5	-0.5-9.7	9.8-11.7	11.8-13.5	13.6-15.5	-0.5-9.7	9.8-11.7	11.8-13.5	13.6-15.5	15.6-21	-0.5-9.7	9.8-11.7	11.8-13.5	13.6-15.5	15.6-21	-0.5-9.7	9.8-11.7	11.8-13.5	13.6-15.5	15.6-21
	percentile	0-20	20-40	40-60	0-20	20-40	40-60	60-80	0-20	20-40	40-60	60-80	80-100	0-20	20-40	40-60	60-80	80-100	0-20	20-40	40-60	60-80	80-100
	-21	2.2						5.6			4.5												
	-20 to -11	21.3	13.9	6.7	36.7	27.6	16.3	5.6	7.7	17.2	18.2	14	15.4	33.3	45.5	15.6	10.6	7.4		20		6.9	1.1
	-10 to -7	12.4	11.1		13.3	12.1	11.6		7.7	6.9	18.2	21.1	23.1		18.2	12.5	12.8	9.3		40	5.9	3.4	6.7
	-6 to -3	22.5	25	13.3	16.7	19	25.6	27.8	23.1	24.1	13.6	26.3	23.1			15.6	12.8	11.1		20	11.8	3.4	7.9
	-2 to -1	12.4	13.9	40	3.3	13.8	11.6	11.1	7.7	13.8	9.1	12.3	15.4	33.3	9.1	9.4	6.4	11.1				3.4	7.9
	0 to 1	6.7	2.8	6.7	3.3	5.2	14	5.6	23.1	6.9	6.8	3.5		33.3	9.1	3.1	17	7.4			5.9	6.9	5.6
	2 to 5	12.4	8.3	20	16.7	12.1	11.6	38.9	15.4	17.2	15.9	8.8			9.1	12.5	17	18.5	25		11.8	20.7	13.5
	6 to 9	3.4	19.4	6.7	6.7	3.4	4.7		7.7	10.3	4.5	8.8	7.7			25	6.4	9.3		20	11.8	10.3	15.7
	10 to 19	6.7	5.6	6.7		6.9	4.7	5.6	7.7	3.4	9.1	5.3	15.4		9.1	6.3	17	20.4	75		35.3	34.5	24.7
Excess	20+				3.3													5.6			17.6	10.3	16.9

As well as displaying predictions from the forecast page of total and excess mortality this page displays the conditional probability of a given excess mortality (total, 65+ and 75+) level being attained given a range of air and dew point temperatures. An excess of 0 is equal to the long term mean mortality. Air and dew point temperatures are classified into five percentile groups and through the combination of these two measures it is possible to classify a day as cold or transition or hot as well as dry or transition or humid.

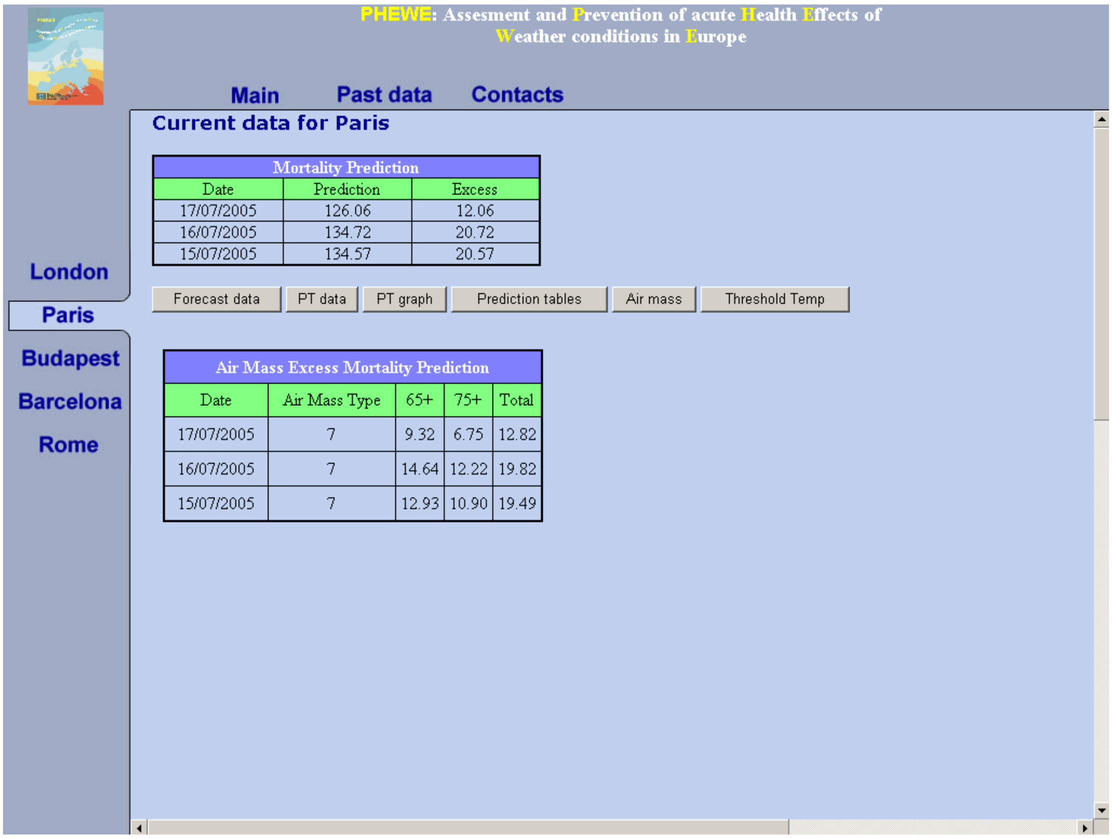
Example

If the forecast for London at 12:00 UTC is TT = 23ºC = 80-100 percentile;
TD = 11ºC = 40-60 percentile

The conditional probability for excess total mortality is as follows:

17.6 % excess mortality between –20 and -10.1
11.8% excess mortality between –6 and –2.1
5.9 % excess mortality between 6 and 9.9
11.8 % excess mortality between 11.8 and 19.9
52.9 % excess mortality more than 20

Explanation of Air Mass Page



PHEWE: Assesment and Prevention of acute Health Effects of Weather conditions in Europe

Current data for Paris

Mortality Prediction		
Date	Prediction	Excess
17/07/2005	126.06	12.06
16/07/2005	134.72	20.72
15/07/2005	134.57	20.57

Air Mass Excess Mortality Prediction				
Date	Air Mass Type	65+	75+	Total
17/07/2005	7	9.32	6.75	12.82
16/07/2005	7	14.64	12.22	19.82
15/07/2005	7	12.93	10.90	19.49

Air-mass classification

An air mass-based climatological index is created to categorize days based on their meteorological character into groups that are relatively homogeneous. The identification of air mass types is based on the daily meteorological data in conjunction with principal components analysis (PCA) followed by cluster analysis (CA). The result of the application of these two techniques is a temporal synoptic index (TSI) from which a daily calendar of air mass types may be constructed (McGregor 1999). To identify the different types the mean meteorological conditions of all days in each air mass group are assessed (Sheridan et al. 1998). Not all days within a specific air mass possess elevated mortality. Predictions are made for only those air masses that normally have higher than normal mortality associated with them. Air masses likely to increase mortality are labelled ‘offensive’. Multiple stepwise regression analysis is used to explore the nature of the linkage between a range of independent meteorological variables and the dependent mortality variable for each offensive air mass type. Algorithms are therefore developed for total mortality (Total), mortality of ages older than 64 (65+), and 74 (75+) for each offensive air mass type. Forecast data are used to determine which air mass will occur over the following 48 hours. If an offensive air mass is predicted then the mortality prediction algorithm for that air mass is run to give a prediction of total. 65+ and 75+ mortality.

The air masses are labelled by number in the table on the air mass page. The translation of the numbers in terms of an air mass name is given below. If a prediction is not given this means that the weather forecast data is indicating that an offensive will not occur over the nest 48 hours. In most cases predictions are made for dry tropical, dry tropical + and moist tropical air masses as these on average have higher than normal mortality associated with their occurrence.

Air Masses by City

London

No.	Air mass	
1	Transition	TR
2	Moist moderate	MM
3	Moist polar	MP
4	Dry moderate	DM
5		
6	Dry tropical	DT
7	Moist tropical	MT
8	Dry tropical+	DT+

Pairs

No.	Air mass	
1	Moist tropical	MT
2	Moist polar+	MP+
3		
4	Moist moderate	MM
5	Moist polar	MP
6	Transition	TR
7	Dry tropical	DT

Budapest

No.	Air mass	
1	Dry tropical	DT
2	Transition	TR
3	Moist polar	MP
4		
5	Moist tropical	DT
6	Dry polar	DP
7	Dry moderate	DM

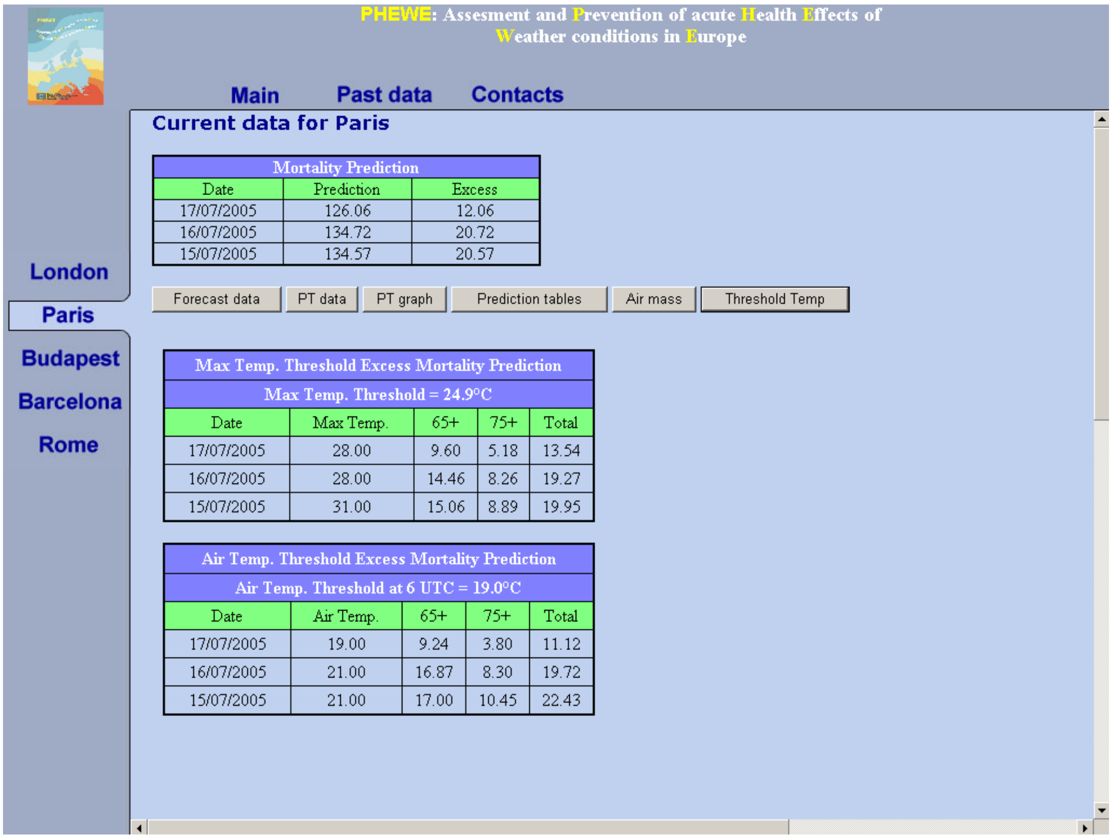
Rome

No.	Air mass	
1	Dry polar	DP
2	Moist moderate	MM
3	Moist polar	MP
4	Dry moderate	DM
5	Dry tropical	DT
6	Dry tropical+	DT+

References

1. McGregor G.R., 1999: Winter ischaemic heart disease deaths in Birmingham, United Kingdom: a synoptic climatological analysis. Climate Research, 13, 17-31.
2. Sheridan S.C. and Kalkstein, L.S., 1998: Heat Watch-Warning Systems in Urban Areas. Resource Review, 10, 375-383.

Explanation of Threshold Page



Current data for Paris

Mortality Prediction		
Date	Prediction	Excess
17/07/2005	126.06	12.06
16/07/2005	134.72	20.72
15/07/2005	134.57	20.57

Max Temp. Threshold Excess Mortality Prediction

Max Temp. Threshold = 24.9°C

Date	Max Temp.	65+	75+	Total
17/07/2005	28.00	9.60	5.18	13.54
16/07/2005	28.00	14.46	8.26	19.27
15/07/2005	31.00	15.06	8.89	19.95

Air Temp. Threshold Excess Mortality Prediction

Air Temp. Threshold at 6 UTC = 19.0°C

Date	Air Temp.	65+	75+	Total
17/07/2005	19.00	9.24	3.80	11.12
16/07/2005	21.00	16.87	8.30	19.72
15/07/2005	21.00	17.00	10.45	22.43

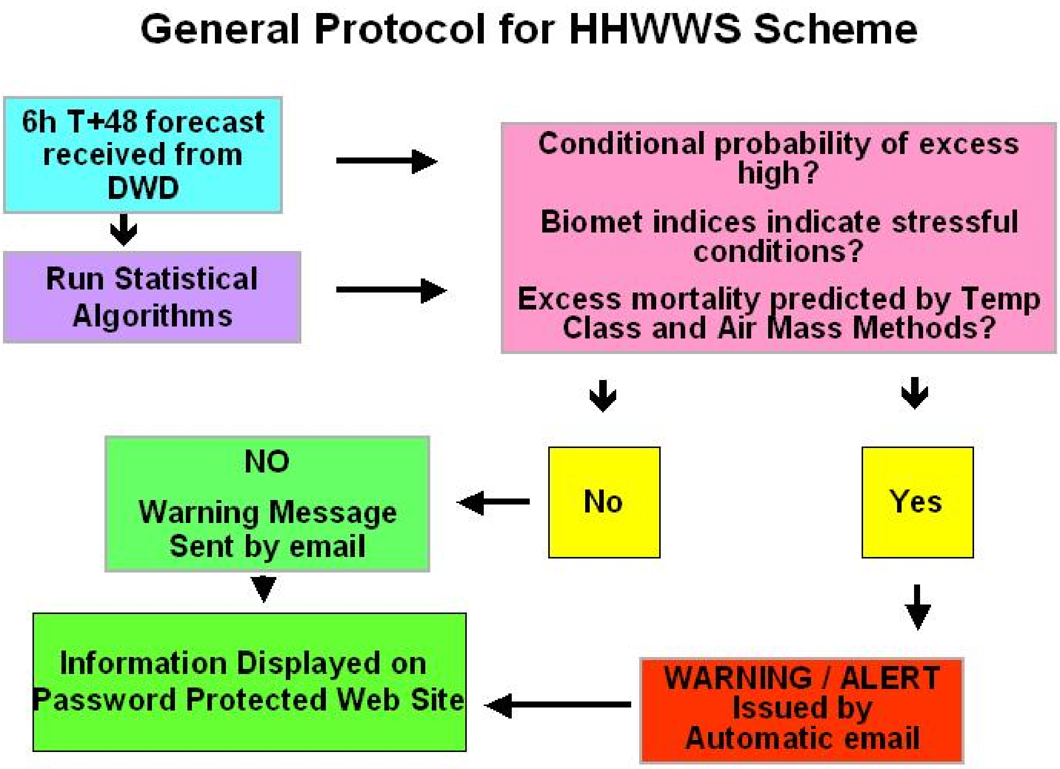
Threshold temperature

A threshold temperature is a temperature beyond which the rate of mortality shows a sharp increase. Two threshold temperature predictions are given.

The first threshold temperature is based of daily maximum temperature for the 6 month period (April until September). The temperature threshold is that identified by the PHEWE *Epi Stats Group* for each of the HHWWS cities. For example for Paris the Tmax threshold is 24.9°C.

The second threshold temperature is based on the air temperatures at 0:00 (Budapest), 6:00 (Paris, Rome) or 12:00 (London) and is calculated for the months June, July, and August. These thresholds were determined in the following way using the methodology of Kalkstein and Davis (1989). For a given temperature (e.g. 22˚C air temperature at 6:00) the mean mortality is computed for all days above and all days below that temperature. Afterwards the variance is calculated for these two groups and the sum of the variances (total sum of squares = TSS) are computed. The procedure is iterated for half-degree increments (22.0˚C, 22.5˚C…) producing an array of TSS values. The temperature with the smallest TSS is chosen as the threshold temperature, since this represents the point where between-group variances are maximized and within-group variances are minimized.

For both the thresholds multiple stepwise regression analysis is used to develop prediction algorithms for the subset of days with temperatures greater than the given threshold. Prediction algothims are developed for total, 65+ and 75+ mortality. If the forecast temperature for a given time is exceeds the temperature threshold then the mortality prediction algorithm is run In the above case a prediction has been made for Paris because the forecast temperature for 0600hrs exceeds the threshold temperature of 19°C.



References

1. Kalkstein L.S. and Davis R.E. (1989): Weather and human mortality: an evaluation of demographic and interregional responses in the United States. Annals of the Association of American Geographers, 79, 44-64.
2. Koppe C., Jendritzky G. and Pfaff G. (2004): Die Auswirkungen der Hitzewelle 2003 auf die Gesundheit. In Deutscher Wetterdienst: Klimastatusbericht 2003. Offenbach, 152-162.
3. McGregor G.R. (1999): Winter ischaemic heart disease deaths in Birmingham, United Kingdom: a synoptic climatological analysis. Climate Research, 13, 17-31.
4. McGregor G.R., Watkin H.A. and Cox M. (2004): Relationships between the seasonality of temperature and ischaemic heart disease mortality: implications for climate based health forecasting. Climate Research, 25, 253-263.
5. Sheridan S.C. and Kalkstein, L.S. (1998): Heat Watch-Warning Systems in Urban Areas. Resource Review, 10, 375-383.
6. Smoyer, K.E., Rainham, D.G.C and Hewko, J.N. (2000): Heat-stress-related mortality in five cities in Southern Ontario: 1980-1996. International Journal of Biometeorology, 44, 190-197.
7. Steadman, R.G. (1984): A Universal Scale of Apparent Temperature. Journal of Climate and Applied Meteorology, 23, 1674-1687.
8. World Meteorological Organization (2002): Guide on the application of new technology and research to public weather services. Geneva.
9. Yarnal B. (1993): Synoptic climatology in environmental analysis. London.

10. The pilot implementation of the HHWWS in Budapest

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[4]Capital Institute of National Ambulance Service
[5]National Meteorological Service

Summary

More and more scientific evidence supports the health impact of heat waves, which can be decreased by a heat health watch warning system. A HWWS was elaborated in Budapest within the program “PHEWE” (“Prevention of acute health effects of weather conditions in Europe, EU/QLK-CT-2001-00152SZ). In this article the experiences of the HWWS in Budapest are described.

Material and methods

In the article the information flow of the heat alarm is described, as well as the prediction of mortality and weather are compared with the registered values by regression. The Measures taken during the heat waves are demonstrated and the effectiveness of communication was assessed by a telephone survey containing 10 questions of 2500 people in the five biggest cities.

Results

In 2004 the Budapest partners (FJNCPH-NIEH, National Meteorological Service, Capital Institute of the National Service of Public Health, Capital Institute of National Ambulance Service) established HWWS, being in operation from 1st June till 30th August in 2004-2005. The system used the heat health forecast of university Birmingham. In the 1st year FJNCPH-NIEH forwarded the warning to the Capital Institute of Ambulance service. In case of a heatwave (PT>33,0 oC at 12.00 UTC and an excess mortality >15%) for 3 or more consecutive days its PR referent announced the heat wave alarm for the general public via mass media.

In 2005 a three level warning plan was elaborated: In 2005, one heat-wave occurred in Budapest: 27-31.07. **The warning was announced by the chief medical officer based on the initiative of the FJNCPH-NIEH**. The public health service warned the general public, the municipality of Budapest respectively the health care system and guidelines were elaborated for them. Several communication tools were used: interviews, leaflets, TV advertisement spot.

The analysis of predictions and recorded data of the year 2004 showed good correlation, so the forecast system can be used in the future as well. The evaluation of the effectiveness of the system could not be analysed, because of the limited number of heat waves in Budapest.

Evaluation of the questionnaire survey was divided into four parts. **1) Awareness of heat**: Generally people could mention one harmful impact but people aging 30-59y could say more than two impacts. Most of them mentioned hypertension (27%), heatstroke 11%) skin problems (31%), cardiovascular diseases in 22%. Half of the interviewees considered support for elderly of high importance. **2) Preventions**: 4/5 of the people took preventive steps but only 1/5 of them could tell exactly how: drinking liquid (20%), sit in shade (17%), in a room with air-conditioning (16%). **3) Communication plan**: 25% of the interviewees, mostly between 45-59 years, saw any advertisement. Most of them in the television (78%), daily newspapers (57%), street boards (41%). **4) HHWWS**: Large number of interviewees (59%) heard about the announcement of “heat-alarm” and found the guidance informative (42%) and suitable (39%). 2/5 of them would like to know more about heat-wave by the following communication tools: television (92%), radio (76%), regional newspaper (67%).

The effect of age sex, profession and place of residence on the answers to the questions was studied in regression models. 7 It is interesting to mention that people with vocational school (OR: 0,646, CI: 0,521-0,800) and high school qualification (OR: 0,681, CI: 0,558-0,830) answered significantly more often to hear about that The Medical Chief Officer announced the 2nd level of heat warning 27-31 July, 2005. However, the results showed that people have limited knowledge about the impact of heat and the ways of prevention.

Conclusion

The HWWS should be further elaborated and implemented in Budapest. The 3rd level of alert needs a legal support. Measures should also be completed. Public awareness should be increased by using different communication tools.

Introduction

There is a consensus of the majority of the world's scientists that the era of global warming has started. According to international literature data the mean surface temperature of the Earth increased from 13,87 °C to 14,52 °C. In 1950 1612 million ton of carbon was released to the atmosphere, in the year 2003 this amount was 6999 million ton. Discussions concentrate on the question whether global warming is only a natural phenomenon or a consequence of anthropogenic effects. It is possible that both factors play a role, they provoke the effect mutually. The increase of frequency and number of extreme weather situations is a consequence of global warming, which can alter the global as well as local climate.

There are numerous harmful financial consequences of unfavourable meteorological and environmental events, the annual fluctuations are considerable. The information is not entire, but it is probable that the total sum of losses, necessary prevention and remediation is about 150-180 billion HUF, almost 1% of the Hungarian GDP (*1*).

The changes in the climate of the Earth influence the ecosystems, their species as well as human health. Several effects can be beneficial, like a decrease of winter mortality in consequence of milder winters in countries of moderate climate zone, but as a whole climate change has a harmful effect on human health. (*2*).

Climate change has an impact on human organism, not only on chronically ill persons and elderly people, but also on health individuals, while extreme heat causes a vulnerable health state. In Hungary, research activity aimed at the impact of heat waves, at the characteristics of pollination of allergic plants, at vector borne diseases like tick-borne encephalitis and Lyme disease, as well as at skin cancers due to UVB radiation (*11*).

The extreme heat events caused the death of many people in Europe in 2003. The losses were the highest in France between 4th and 12th of August, the excess mortality was 14802 cases (*3*). In Italy more than 3000 excess deaths were registered during this period (*4*).

According to literature data heat alarms play an important role in the prevention of health impact of climate change (*5,6,7,8*). The first "heat alarm plan" was elaborated in Lisbon in 1981 when 63 people died in the capital on 15th of June and the excess mortality was 1906 cases in the country due to the daily maximum of 43 °C. In 1995, due to the heat wave heat alarm plan was also elaborated in Philadelphia in the United States of America (*9*).

The studies related to the health impact of climate change started in 2000 in Hungary within the frames of the National Environmental Health Action Program (*11*). The effect of weather variables on mortality was studied using the data of Budapest, capital of Hungary for the period of 1970-2000. A heat health watch warning system (HWWS) was elaborated in the capital within the program "PHEWE" ("Prevention of acute health effects of weather conditions in Europe, EU/QLK-CT-2001-00152SZ). In this article we would like to present the experiences of the HWWS.

Material and methods

The HWWS was elaborated by the study group of the University of Birmingham within the PHEWE project by using the mortality and meteorological data of Budapest for the years 1992-2000, as well as the weather forecast data produced by the Hungarian Meteorological Service. The HWWS forecast data were available for the Hungarian group on the internet. In the year of 2004 and 2005, from 1st of June till 30th of August the forecast data were updated every morning till 9.00 o'clock am. The forecast was issued for 3 days, indicating the weather conditions and the predicted excess deaths. The issue of the different levels of heat alarm was considered on this basis. The flow of information containing the warnings of the health care system and the general population was elaborated on the basis of the experiences of the year 2005. The National Institute of Environmental Health triggered a communication campaign on health impact and adaptation methods. Several communication tools were used for raising the awareness of heat-wave, like distribution of leaflets in GP rooms, pharmacies. As for mass media, a 20-second video clip advertisement was broadcasted on the National Geographic Channel in August 2005, and leading health experts gave interviews about heat-related illness.
The HWWS is evaluated by comparing the forecasted weather and registered weather variables and the forecasted mortality versus registered daily mortality as well as the daily emergency ambulance calls in 2004. The data sources are: forecasted data: http://www.phewe.bham.ac.uk/Default.aspx. Mortality data were gained from the Central Statistical Office, Hungary, and emergency ambulance data from the Budapest Directorate of the National Ambulance Service.

In order to assess the efficiency of heat health warnings and information campaign, in November, 2005 a telephone survey was carried out in the five biggest towns in Hungary. Sample size: 2500 over 18 years having a dwelling with telephone. The questionnaire contained 10 questions aimed to assess the knowledge and awareness of people about heat, adaptation methods and heat-alert system. Chi square test and logistic regression models were used for the statistical analysis carried out by SPSS 10.1 program

Q 1., The summer was very hot in 2005. Do you know the harmful effects of heat? (open question)

- strong perspire
- tiredness
- sunstroke
- heatstroke
- problems with hypertension
- others

0 – do not know, X – do not responds

Q 3., If yes, how do you usually protect yourself against heat? (maximum 3 answers, open questions)

- drink more liquid
- wear a hat
- wear a sunglasses
- use sun cream
- spend time in an air conditioned place
- others

0 – do not know, X – do no respond

Q 6., If yes, what medium did you see that advertisement through?

	6a. *mentioned spontainously*	**6b. 2-heard/saw the advertisement 3-did not hear/see 0-do not know, X-do not respond**
1. Television	*1*	2 - 3 - 0 - X
2. Radio	*1*	2 - 3 - 0 - X
3. National newspaper	*1*	2 - 3 - 0 - X
4. Regional newspaper	*1*	2 - 3 - 0 - X
5. Internet	*1*	2 - 3 - 0 - X
6. Street boards	*1*	2 - 3 - 0 - X
7. Leaflet	*1*	2 - 3 - 0 - X
8. Others_________________	*1*	2 - 3 - 0 - X

Q 8., How do you agree with that the information spread related to heat was….

1 – completely agree
2 – yes
3 – no
4 – no, et al
0 – do not know, X – do no respond

- informative
- nice
- help in the protection against heat
- suitable

The following questions were analysed with only *logistic regression*:

Q 2., Do you usually protect yourself against heat?

1 – Yes
2 – No (Jump to the question 4)
0 – do not know
X – do not respond

Q 7., The Medical Chief Officer announced the 2nd level of heat warning 27-31 July, 2005. did you hear about it?

1 – yes
2 – no
0 – do not know, X – do no respond

Q 9., Would you like to know more about the harmful effects of heat wave?

1 – yes
2 – no
0 – do not know, X – do no respond

The Capital Institute of the, National Service of Public Health collected the emergency hospital admission data potentially due to heat related morbidity (injuries, myocardial infarction, stroke, deliveries, exsiccation, psychiatric disorders) and mortality in the hospitals for the period of heat alarm: 28.-31.07. 2005 and for 30.06.-24.07. of the same year. The frequency of hospital admissions during the heat-wave were compared to that of non heat wave periods.

Results

Heat Health Watch Warning System

Threshold levels of heat alarm

In the year of 2004 the study group of the University of Birmingham issued the warning when perceived temperature was forecasted higher than 33 ºC at 12.00 UTC and an excess mortality was forecasted above 15%. This threshold was met too often and at the same time the daily mean temperature was lower than 26,6 ºC, which was the 98% of summer daily mean temperature (11).
During 2004 summer there was one heat-wave in Budapest meeting these criteria from 19th July to 22nd July

Therefore the threshold value for issuing the warning message by the University of Birmingham was modified according to the previous findings of the Hungarian study group.
A three level heat alarm system was elaborated. As for the system used the temperature measurements of the meteorological station in the outskirt, the effect of heat island was taken into consideration and lower threshold of mean temperature was defined:
The **first level** “internal warning” for internal use is announced if the daily mean temperature is above 25 ºC and the predicted excess mortality is 15% for one day.

The **second level** “preparedness” for the public is announced if the daily mean temperature is above 25 ºC for 3 consecutive days or the daily mean temperature reaches 27 ºC for a day, at least - which is equal to 30% predicted excess mortality.

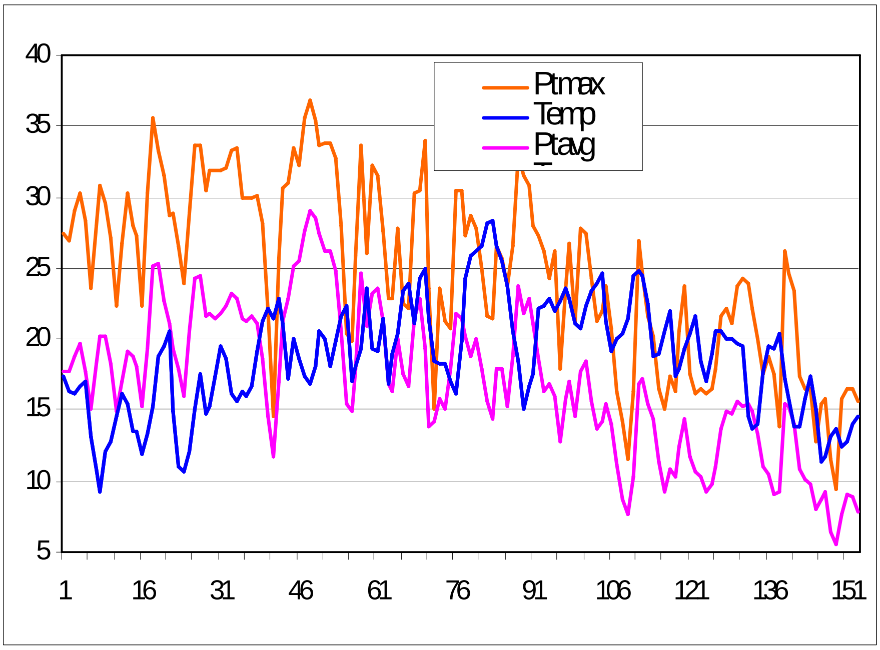
The **third level** “alert” is announced when the daily mean temperature exceeds 27 ºC (30% excess mortality). This situation meets the criteria of “extreme weather condition” stated in the governmental order on catastrophe situations (179/1999 (XII.10)).

Evaluation of the forecasts of 2004

In 2004 there was one heat wave in Budapest, from 19th to 23rd of July. We represent the results of the assessment of predicted mortality and temperature values with registered values for the whole summer period of 2004, and for the heat wave period as well.

The following figures represent the daily mean temperature registered in Budapest, summer 2004, and the perceived temperature forecast data: **Ptmax, Pt average** according to University of Birmingham

Figure 1: Daily mean TEMP and Ptmax, Pt average forecast (according to University of Birmingham) for Budapest, 2004



The statistical evaluation showed a good correlation between predicted temperature and registered temperature

Summary table

Regression statistics	
r value	0,472044128
R Square	0,222825659
Corrected R Square	0,217678809
Standard error	4,959544256
Observations	153

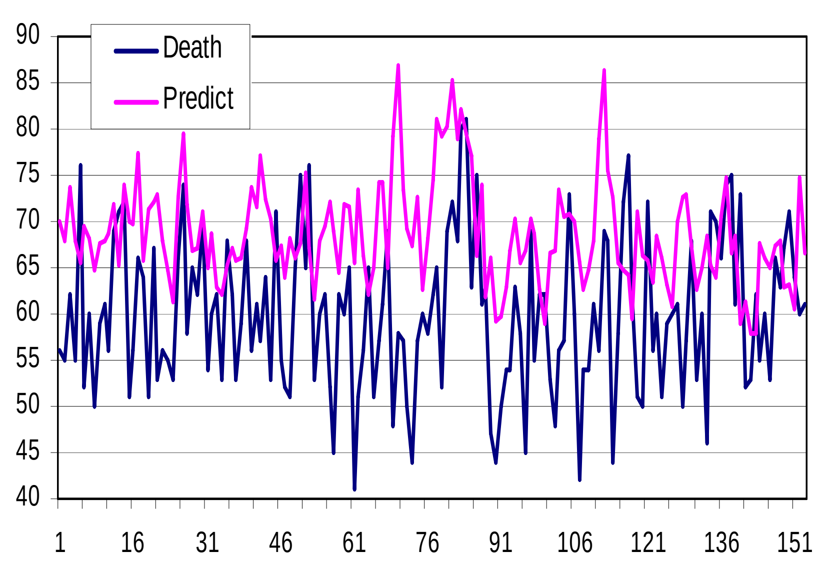
ANALYSIS of VARIANCE

	df	*SS*	*MS*	*F*	*Significance of F*
Regression	1	1064,896092	1064,896	43,2936	7,28611E-10
Residual	151	3714,158964	24,59708		
Total	152	4779,055056			

	Coefficients	*Standard error*	*t value*	*p-value*	*Low 95%*	*High 95%*	*Low 95%*	*High 95%*
Constant	56,1051975	1,956077841	28,6825	5,43E-63	52,24037903	59,97002	52,24038	59,97002
Temp	0,673628122	0,102378406	6,579787	7,29E-10	0,471348875	0,875907	0,471349	0,875907

Figure shows the daily death counts and daily mean temperature for the summer period of 2004 (1st of June- 30th August)

Figure 2: Predicted death and registered death counts in Budapest, summer 2004



There was a significant correlation between the predicted and registered daily death counts.

Summary table

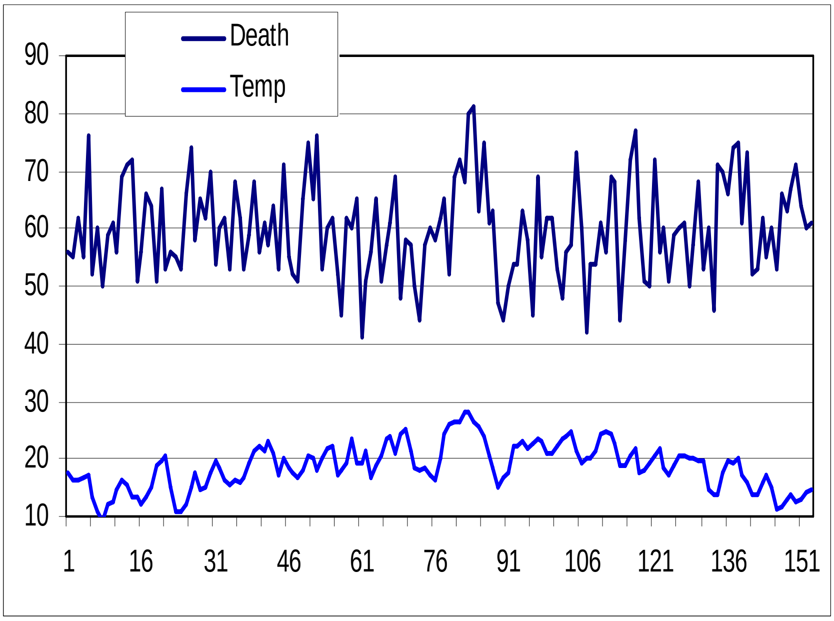
Regression statistics	
r value	0,185301736
R Square	0,034336733
Corrected R Square	0,027941612
Standard error	8,211423777
Observations	153

ANALYSYS of VARIANCE

	df	*SS*	*MS*	*F*	*Significance of F*
Regression	1	362,0321518	362,032152	5,369208	0,021839035
Residual	151	10181,54955	67,4274804		
Total	152	10543,5817			

	Coefficients	*Standard error*	*t value*	*p-value*	*Low 95%*	*High 95%*	*Low 95%*	*High 95%*
Constant	41,03843247	8,187516032	5,01231782	1,49E-06	24,86153885	57,21533	24,86154	57,21533
Predict	0,275234299	0,118781129	2,3171551	0,021839	0,040546552	0,509922	0,040547	0,509922

Figure 3: Daily death counts and daily mean temperature in summer in Budapest, 2004



Daily death counts and daily mean temperature showed a correlation on borderline significance.

Summary table

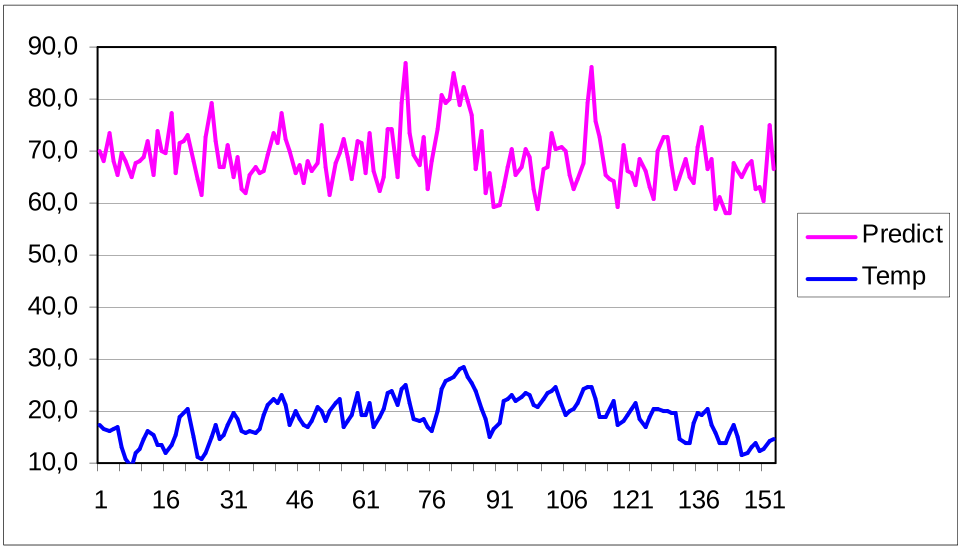
Regression statistics	
r value	0,137569566
R Square	0,018925386
Corrected R Square	0,012428203
Standard error	8,27668886
Observations	153

ANALYSIS of VARIANCE

	df	*SS*	*MS*	*F*	*Significance of F*
Regression	1	199,5413483	199,541348	2,91286	0,089931515
Residual	151	10344,04035	68,5035785		
Total	152	10543,5817			

	Coefficients	*Standard error*	*t value*	*p-value*	*Low 95%*	*High 95%*	*Low 95%*	*High 95%*
constant	54,49465803	3,264382136	16,6937129	4,12E-36	48,04489202	60,94442	48,04489	60,94442
Temp	0,291596995	0,170853241	1,70671035	0,089932	-0,045974828	0,629169	-0,045975	0,629169

Figure 4: Predicted death counts and registered temperature in Budapest, summer 2004



Predicted daily death counts and registered daily temperature showed a significant correlation for the summer period.

Summary table

Regression statistics	
r value	0,472044128
R Square	0,222825659
Corrected R Square	0,217678809
Standard error	4,959544256
Observations	153

ANALYSIS of VARIANCE

	df	*SS*	*MS*	*F*	*Significance of F*
Regression	1	1064,896092	1064,89609	43,2936	7,28611E-10
Residual	151	3714,158964	24,5970792		
Total	152	4779,055056			

	Coefficients	*Standard error*	*t value*	*p-value*	*Low 95%*	*High 95%*	*Low 95%*	*High 95%*
Constant	56,1051975	1,956077841	28,6824974	5,43E-63	52,24037903	59,97002	52,24038	59,97002
Temp	0,673628122	0,102378406	6,57978718	7,29E-10	0,471348875	0,875907	0,471349	0,875907

Figure 5: Predicted excess deaths, Pt average and registered mean during the heat wave in 2004, Budapest

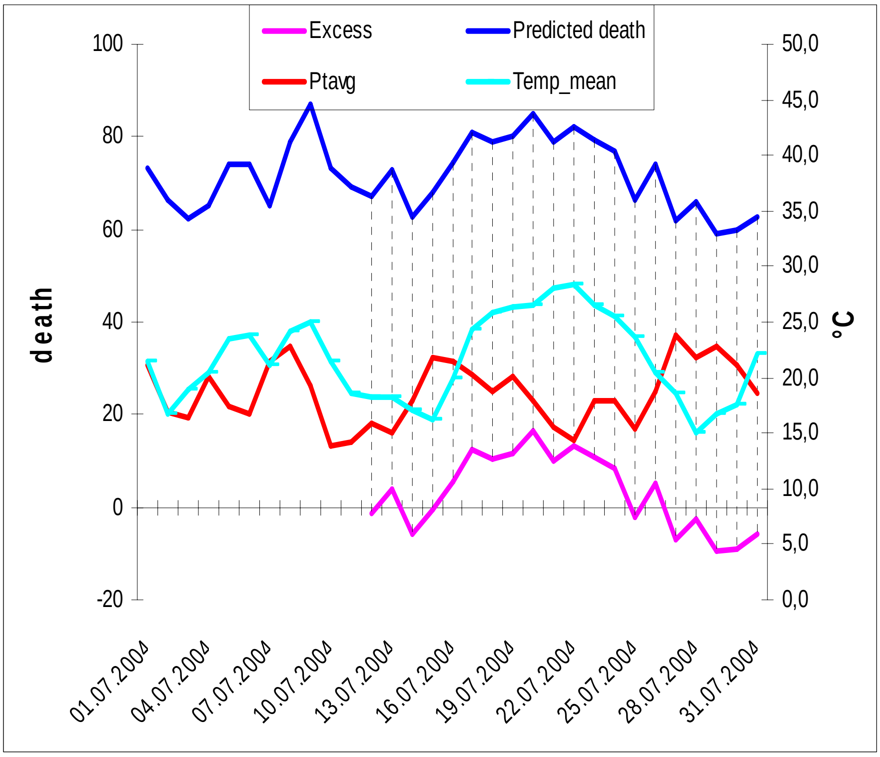
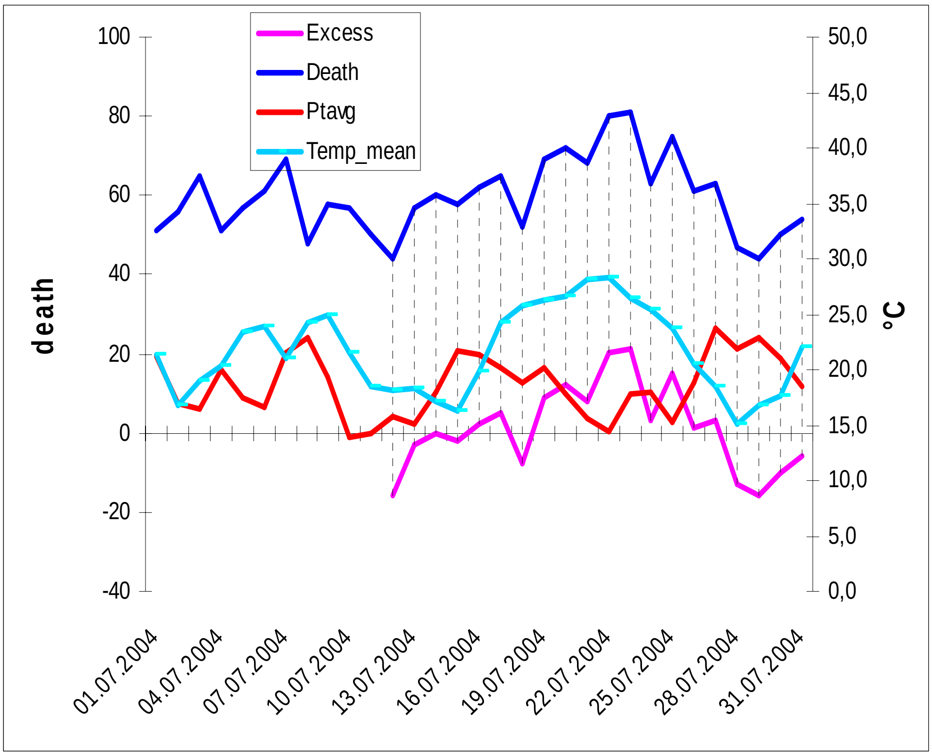
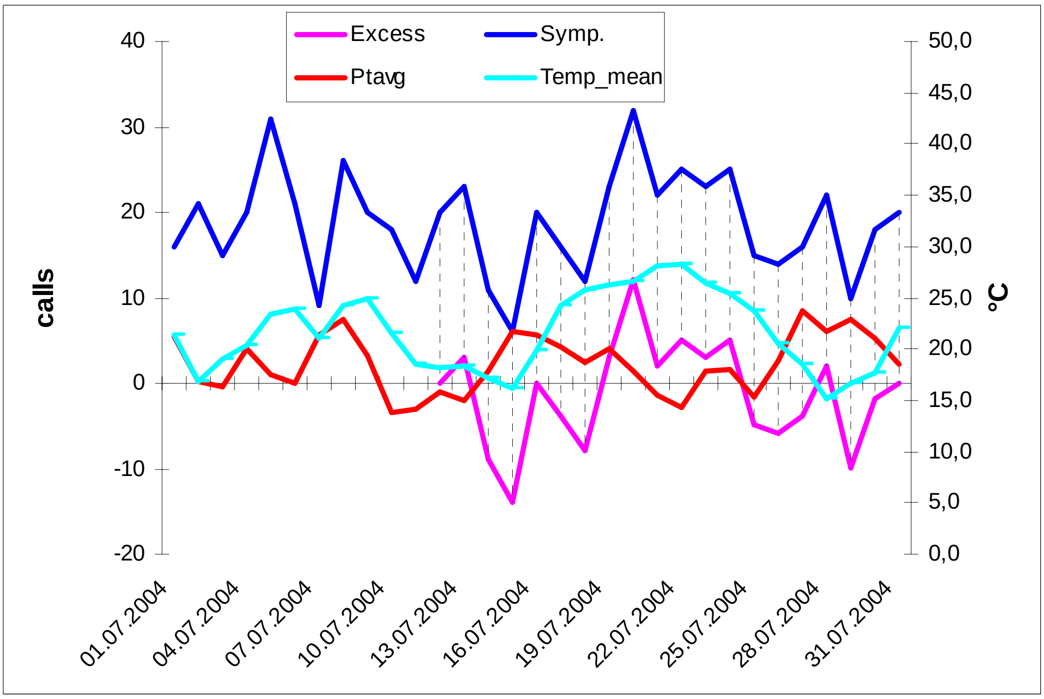


Figure 6: Registered daily excess deaths, Pt average and registered mean during the heat wave in 2004, Budapest



As it can be seen from the graphs, the registered mean temperature showed a better correlation with the predicted excess deaths as well as with registered excess deaths than predicted average perceived temperature.

Figure 7: Emergency ambulance calls due to ill defined symptoms (ICD 9: 780-799) -2004, July, Budapest



As it is seen form the graph, emergency calls due to ill defined symptoms better follow the registered daily mean temperature values than perceived temperature prediction.

Operation of HWWS

In 2004 – an experimental implementation

The Budapest partners of the WWS (FJNCPH_NIEH, National Meteorological Service, Capital Institute of the National Service of Public Health, Capital Institute of National Ambulance Service built up a network. The threshold levels of the warning system were defined on the basis of the results of analysis of studies of the Budapest mortality and meteorology database. When meeting the criteria of the alarm forecasted by the WWS, the FJNCPH-NIEH sent a warning message for the Capital Institute of Ambulance service. In case of a heat wave (PT>33,0 ^{o}C at 12.00 UTC and an excess mortality >15%) for 3 or more days the PR referent of the Ambulance service announced the heat wave alarm for the general public via mass media. When the (PT>33,0 ^{o}C at 12.00 UTC) was forecasted for 1 or 2 days, the information was forwarded to the Ambulance service as an internal information to ascertain the preparedness of the ambulance service.

During 2004 summer there was one heat wave in Budapest meeting these criteria from 19th July to 23rd July. During this event reports and interviews were given on the 5 leading TV channels, broadcasting services and in daily newspapers. On 24th of July the end of the alarm was also announced by the speaker of the Ambulance Service through mass media for the public.

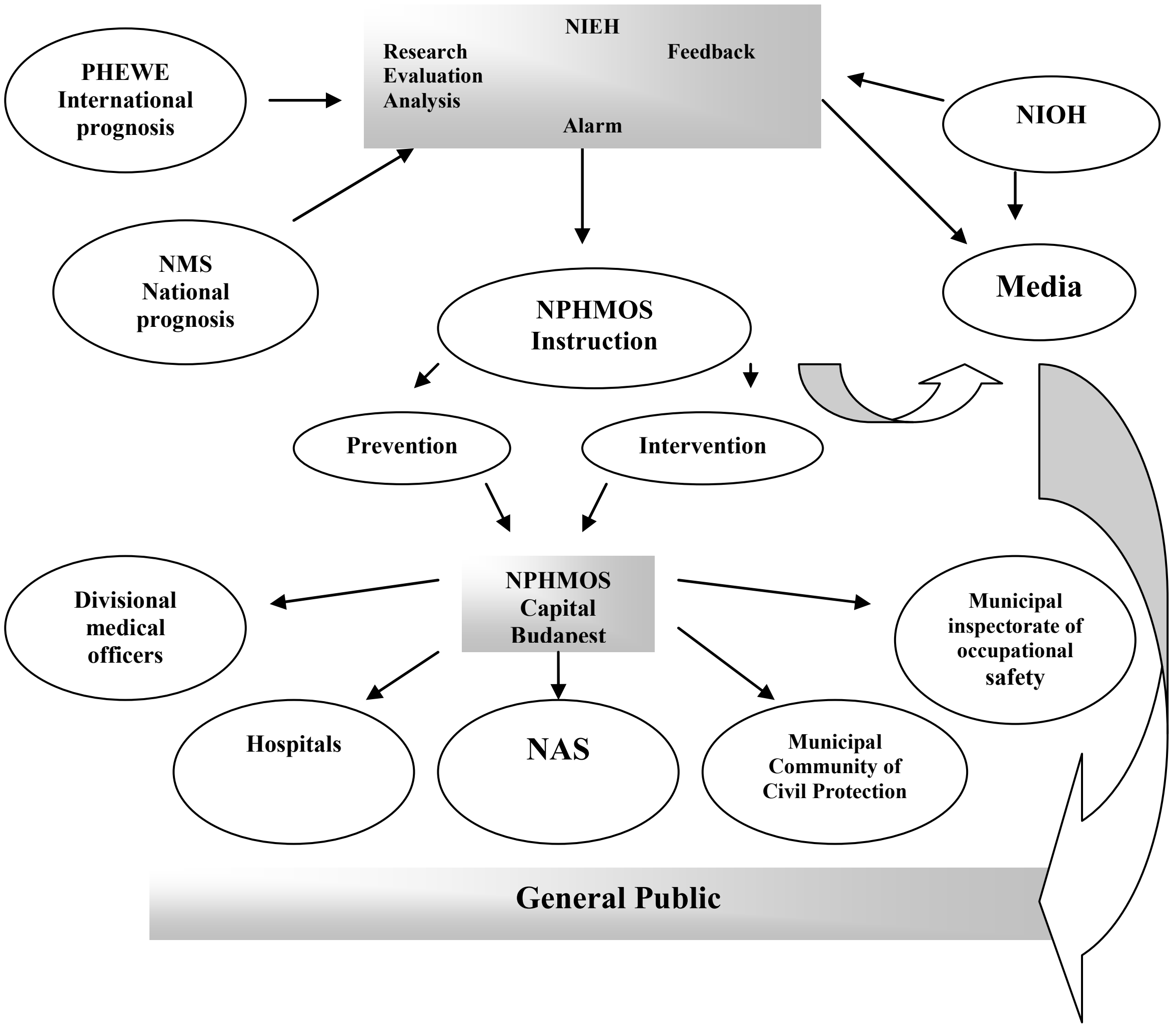
In 2005 – a modified HWWS

The study group of the University of Birmingham updated the HWWS website every day, beside this an automatic email message was sent to the National Institute of Environmental Health in case when daily mean temperature was forecasted above 25 ºC and the predicted excess mortality was 15% for one or more days. The ad hoc scientific group of the National Institute of Environmental Health and National Institute of Occupational Health evaluated the information and in case of the 2nd level of heat alarm, the Office of the Chief Medical Officer was informed. This situation occurred once during 2005 between 28-31 of July. On the basis of this information the chief medical officer ordered the second level of heat alarm, which contained alarming the health care system: hospitals and the ambulance service. The attention was drawn on the increase of emergency calls and hospital admission, and guidelines were given concerning the special problems of patient care during the heat wave. At the same time the general public was informed about the health impact of heat and the attention was called how to prevent the impact. The information flow is shown in Figure 1. The chief medical officer ordered the county institution of the public health service and the capital institute to inform the health care system about the health impact of heat wave. The Capital institute forwarded this information to the department of central inventory of hospital beds, to the division of public health and to the secretariat of the Committee of Civil Protection of the Municipality. The Secretariat forwarded the information to the concerned departments and to the Civil Protection Directorate of the Capital. The departments launched actions prepared beforehand. The Division of Health Care Management of Capital Institute of Public Health Service prepared guidelines for hospitalized patient treatment during heat waves.

Table 1: Guidelines for hospitalized patient treatment during heat waves prepared by the Division of Health Care Management of Capital Institute of Public Health Service

- More frequent measurement of body temperature. In case of high temperature cooling of the body by frequent washing of it or by covering the body surface with wet linen.
- Liquid supplementation “per os” or parenterally.
- More frequent changing of bed linen
- Keep track on the signs of fainting, loosing consciousness
- Keep track on the exanthemas of the skin due to heat and treat it timely
- Keep track on patients with chronic diseases (hypertension, diseases of the kidney, liver, diabetes etc.)
- Keep track on the changes of effect of several medicines due to the heat (eg beta blockers, antihistamines, antidepressants).
- Postpone the non acute operations in accordance with the patient’s decision.
- Control the concentration of electrolytes in diseases where increased loss of electrolytes display an elevated risk.
- Keeping the rules of “good practice” the treatment of special diseases should have a privilege.
- The working regime should be rationalised, optimal a resting time should be given to the personnel.
- Ventilation should be carried out in the morning hours, ventilators can be used and window shades should be put on early enough in the wards towards the South.
- Patients in a serious condition should be placed in rooms with air condition.
- Patients waiting for operation should be placed in rooms with air condition. Patients waiting for outpatient treatment should be placed in waiting rooms with air condition.
- The nursing personnel as well as the patients should be provided by sufficient amount of liquid. The cooling capacity should be increased.
- The technical personnel on duty should be enforced.

Figure 8: Information flow during heat alarm in Budapest, 2005



NMS - National Meteorological Services
NIEH – National Institute of Environmental Health
NPHMOS – National Public Health and Medical Officer Services
NAS – National Ambulance Service
NIWHOH – National Institute of Occupational Health

Te Office of the Chief Medical Officer issued the following set of guidelines parallel to the announcement of heat alarm

Table 2: Guidelines for the general population

- The extreme heat lasting for longer period has a health impact. It has an unfavourable effect on everybody, especially on people carrying out physical activity working either outdoor or indoor.
- Extreme heat can cause disorders of the cardiovascular system in elderly. If you have any health problems, please consult your GP immediately. Patients consuming medicines for heart diseases ask special advises from the doctors.
- Elderly people stay in cool places during hot days, avoid heavy physical activity. Take lukewarm shower several times a day.
- During the heat wave everybody should take care of the increased liquid consumption, which can be several times more of the usual consumption.
- Avoid being in the sun without a shade between 11 and 15 hours, while there is an elevated risk of sunstroke during these hours. Protect the body from the harmful UVB radiation of the sun by using sun crèmes. Wear cloths of light colour and natural material, broad rimmed hat to protect the eyes.
- Never leave small children or pets in closed cars.
- Outdoor sport activity should be restricted for the morning and evening hours.
- During heat waves employers should provide employees with protective liquid according to requests, at least once in half an hour this should be water of 14-16 ^{o}C or soft drinks of the same temperature and should ascertain breaks.

Special advertisements were produced for high risk groups: mothers with small children, youth and elderly. These advertisements were placed in consulting rooms of paediatricians and GPs, pharmacies and offices of the municipality.

Other tools of communication produced: Informative articles in different magazines, 15 sec advertisement spot: broadcasted 80 times in the National Geographic channel in August, 2005. The electronic version of the above mentioned information material was put on the website of the National Institute of Environmental Health (www.antsz.hu/oki.)

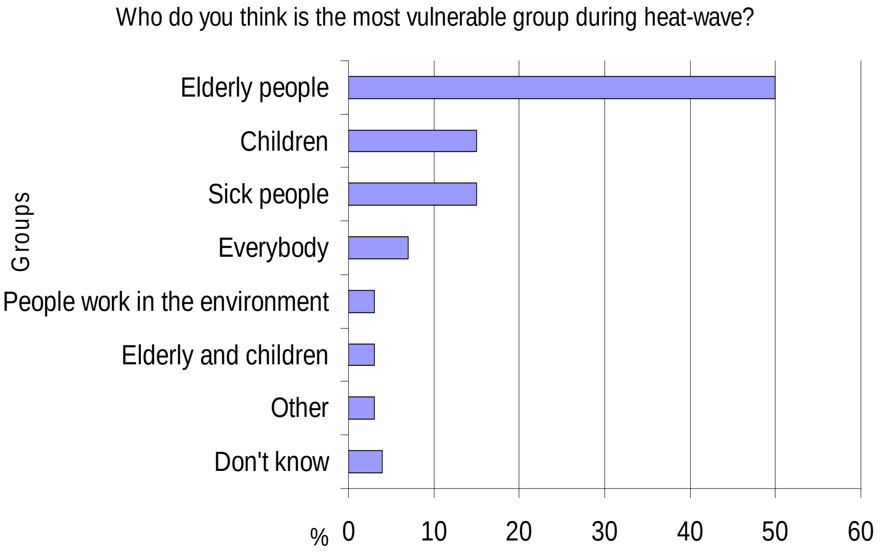
Experiences of the operation of HWWS in 2005.

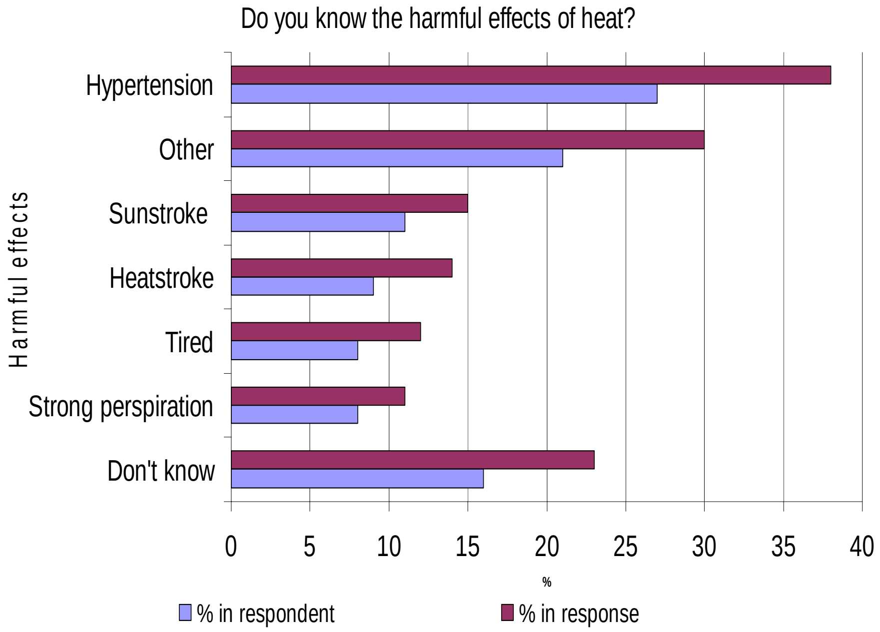
Evaluation of the effectiveness of the information activity

A **telephone-survey was carried out** in the five biggest towns in Hungary in November 2005. 2500 people over 18 years having a dwelling with telephone were interviewed. The questionnaire contained 10 questions aimed to assess the knowledge and awareness of the people about heat, adaptation methods and heat-alert system. The evaluation follows the four groups of questions.

1) *Awareness of heat*: Generally people could mention one harmful effect but people aging 30-59 y could say more than two impacts. Most of them mentioned hypertension (27%), heatstroke (11%) skin problems (31%) and cardiovascular diseases in 22%. Half of the interviewees considered support for elderly of high importance.

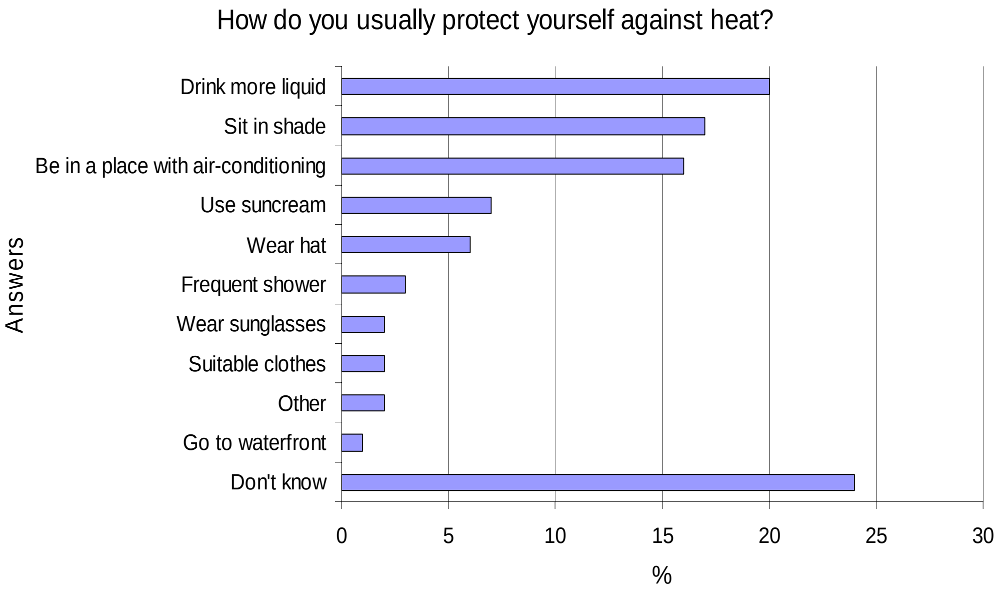
Awareness (*Figures 9-10*).





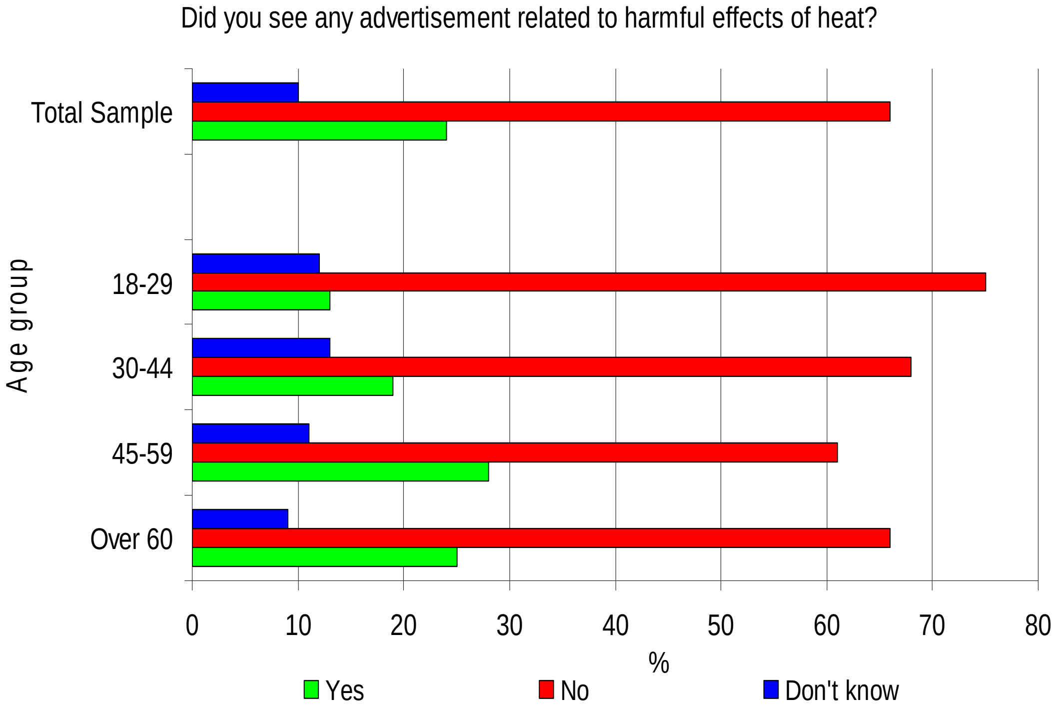
2) *Preventions*: 4/5 of the people took preventive steps but only 1/5 of them could tell exactly how: drinking liquid (20%), sit in shade (17%) or in a room with air-conditioning (16%).

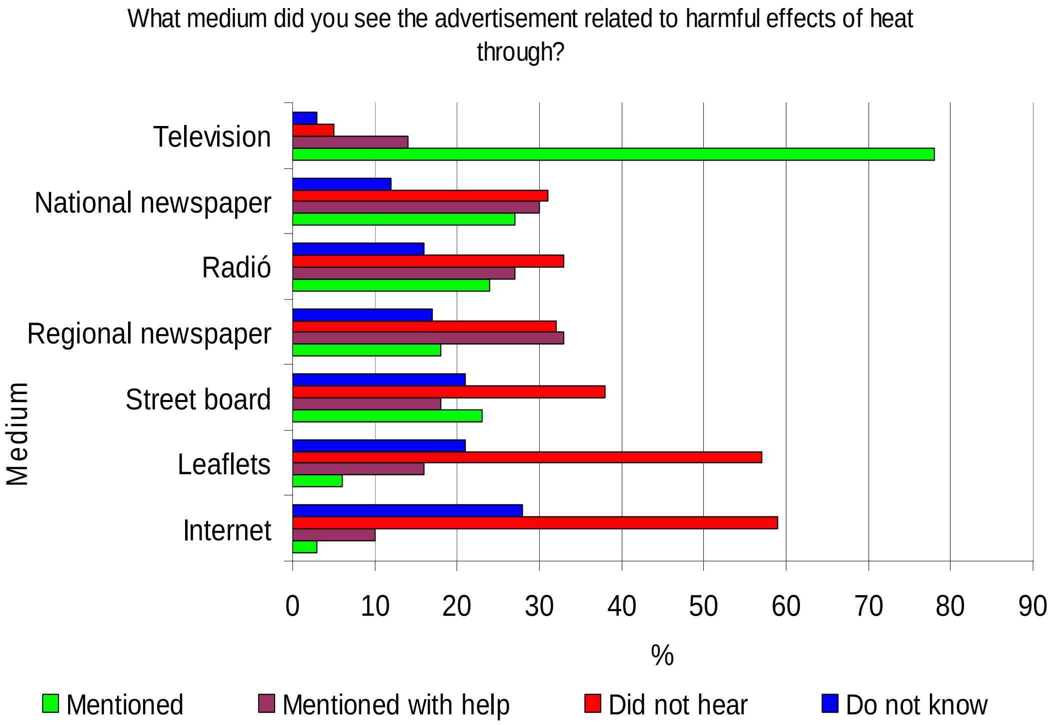
Prevention (*Figure 11*)



3) *Communication plan*: 25% of the interviewees, mostly between 45-59 years, saw any advertisement. Most of them have seen in the television (78%), daily newspapers (57%) and street boards (41%).

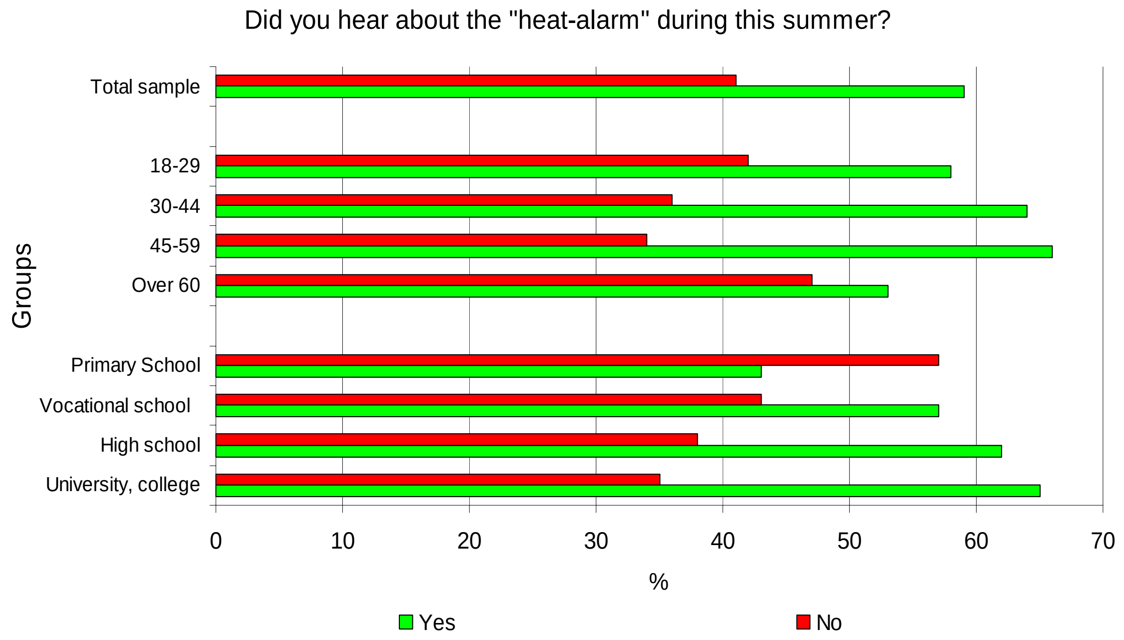
Communication plan (*Figures 12-13*)

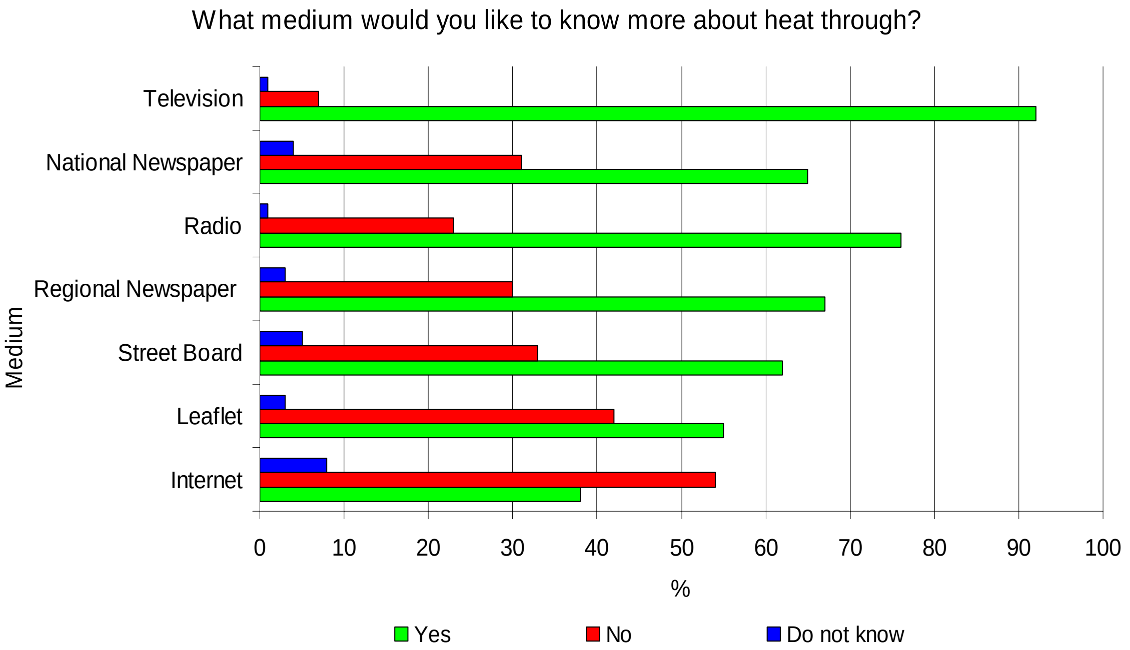


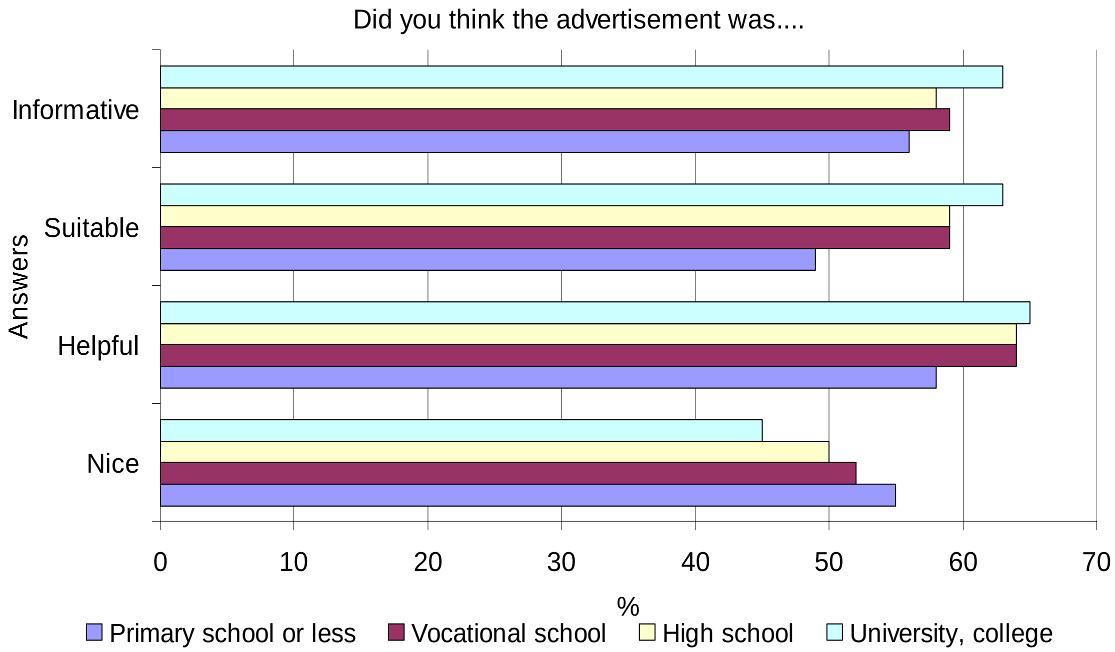


4) *HHWWS*: Large number of interviewees (59%) heard about the announcement of “heat-alarm” and found the guidance informative (42%) and suitable (39%). 2/5 of them would like to know more about heat-wave by the following communication tools: television (92%), radio (76%) and regional newspaper (67%).

HWWS (*Figs 14-16*)






Did you think the advertisement was....
Answers
Informative
Suitable
Helpful
Nice
0
10
20
30
40
50
60
70
%
Primary school or less
Vocational school
High school
University, college

Results of the statistical analysis

The differences in answers for the following questions were tested by statistical methods. We found significant relationship with Chi square test in case of the **question 1** *(Do you know the harmful effects of heat?).* Strong perspiration was significantly more often mentioned by the group of retired people compared to the group of "active workers" (OR: 0,671, CI: 0,516-0,873) and by the age group of 45-59 (OR: 0,644, CI: 0,496-0,837) compared to the younger.
In the logistic regression models we found significant relationship in one case: heatstroke was mentioned more often by the inactive workers (OR: 0,571, CI: 0,408-0,798). In case of other factors – age, sex, qualification – significant results were not found.
We also examined whether the answer to question 1 is influenced by the fact that the interviewers have seen any advertisement related to heat in 2005, but no significant association was detected.

We found significant association with Chi square test in case of **question 3** *(How do you usually protect yourself against heat?).* Retired people (OR: 0,671, CI: 0,516-0,873) compared to "other active workers", people living in Pécs (OR: 0,654, CI: 0,507-0,843) and interviewees at the age of 45-59 (OR: 0,644, CI: 0,496-0,837) compared to younger ones significantly more often mentioned "drinking more liquid" during heat. No significant differences were found concerning other factors – wearing hat and sunglasses, use sun cream and being in air-conditioned places.
In the regression model it was seen that "dependants" (homemakers) (OR: 0,332, CI: 0,160-0,689) compared to other active workers mentioned more often "drinking more liquid" during heat wave; "other inactive workers" significantly often mentioned that they "wear hat" (OR: 0,444, CI: 0,268-0,733) and "sun glasses" (OR: 0,232, CI: 0,108-0,499) during heat wave. Sex and qualification did m modified the results.
"Use of sun cream" was mentioned more often by the inactive workers (EH: 0,516, CI: 0,318-0,836), in the age group of 45-59 (OR: 0,584, CI: 0,424-0,803) and in the age group of over 60 (OR: 0,519, CI: 0,334-0,805).
Here, we also examined whether the answer to question 3 is influenced by the fact that the interviewees have seen any advertisement related to heat in 2005, but we did not find significant difference.

The answer to **question 6** (*What medium did you see that advertisement through?)* was not significantly modified by any factors.

Significant associations were found concerning the answer to **question 8** (How do you agree with that the information spread related to heat was informative, nice, help in the protection against heat, suitable). People living in Pécs (OR: 0,569, CI: 0,370-0,877) considered that the information did not give any help in case of protection against heat, at all.
People with high school qualification (OR: 0,522, CI: 0,336-0,813) found the information related to heat more beautiful than people with primary school.

People with vocation school *(OR: 0,646, CI: 0,521-0,800)* and high school qualification (OR: 0,681, CI: 0,558-0,830) answered significantly more often that they had heard that *The Medical Chief Officer announced the 2nd level of heat warning 27-31 July, 2005 (**question 7**).*

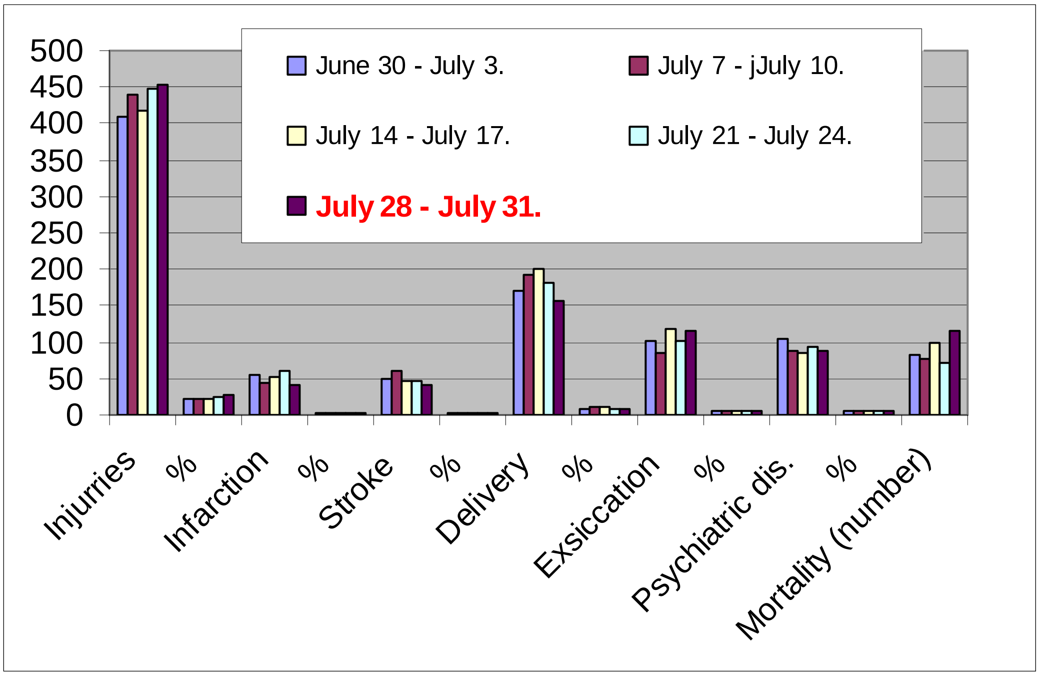
In case of question 9 (Would you like to know more about the harmful effects of heat wave?), men (OR: 0,673, CI: 0,567-0,800) answered that they would like to know more about it.

Evaluation of the emergency hospital admission data

The emergency hospital admission data of 13 hospitals in Budapest during the heat wave 28.-31.07 2005 and between 30.06.-24.07. 2005 were evaluated by descriptive method.

It can be stated that during the heat wave the frequency of admissions due to injuries and exsiccation. Concerning other diagnoses, there was no difference in the number of hospitalization. On the other hand mortality in the hospitals during the heat wave was by 30% higher compared to the average of the previous time period *Fig 17*)

Figure 17: Emergency hospital admission and mortality in the hospitals during the heat wave and in the previous weeks in Budapest, 2005.



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Discussion

The harmful health effects of weather condition were already known in the seventies, but no special attention was paid to them till the second half of the nineties. This is supported by the data given in table 3. In the late years several countries elaborated heat alarm system based on different threshold levels. For example heat alarm is launched in England (*16*) when the daily temperature reaches the threshold value (30 °C at daytime, 15 °C in the evening) on two consecutive days and t at night in between. In Paris (*17*) the heat alarm is launched when the daily minimum and maximum temperature exceeds the threshold value on three consecutive days. In Portugal (*18*), based on the ICARO index a heat wave is defined if daily mean temperature exceeds 32 °C on two days. In Italy (*19*), the thresholds for heat alert are city specific.

Heat alarm systems have three or four levels. Similarly to the Hungarian system, the Italian system has also three levels: warning, preparedness, alert. In England there are four levels: information, warning, heat wave and Emergency level. In Paris the system has also four levels: vigilance, pre-warning, warning, emergency. In Germany there are only two levels strong heat stress and extreme heat stress.

The HWWS is operated by the National Institute of Environmental Health and by the National Meteorological Service from 1st of June till 30th of August. In many countries the Meteorological Service is responsible for running the HWWS like in England and Germany. In Portugal, France and Italy the public health institutions are responsible for the system. The timeframe of the HWWS is different in the countries: In England from 1st of June till 15th September, in Germany from 1st of June till 30th September, in Portugal from 15th of May till 30th of September.

In the last 50 years, 2003 was the hottest in France with record day and night temperature. After the heat-wave period, they analyzed how the French media dealt with the public health from June to August in 2003. The text (newspaper and radio reports) analysis pinpointed to the absence of public health culture and “social exclusion” related to a breakdown of social cohesion.

For the future, more cooperation is needed between the media and public health professionals and a public health culture must be developed in France (*20*).

In Hungary we evaluated the effectiveness of the information given in 2005- The most popular communication tool was the television, 90% of the interviewees defined it. The least used media was the internet, but more than 30% chose this possibility.

The order of the second level of heat alarm which is mainly awareness raising of the risks of the heat both for the health care system and for the general population does not need legal basis. However, the 3rd level of the heat alarm meets the definition “extreme weather condition” of the governmental order 179/1999 (XII.10). 5th § 2nd section. In the future detailed legal regulation is necessary to define the responsibilities and tasks of the stakeholders.

There was a positive feedback from the health care units of Budapest concerning the HWWS. According to the opinions the HWWS

- was useful to during the heat waves
- the timely alert helped prepare the related wards of the hospital for the special tasks during the heat wave.
- there is a need to maintain the HWWS in the future.

According to the population survey the general population expressed a need for further information. The results showed that there is a lack of knowledge concerning the health impact of heat. More effective tools of communication should be elaborated in the future.

In consequence of global warming and its impact on human health prevention, mitigation and adaptation become more and more important. In Hungary the need to develop a National Climate Strategy is formulated in the New Governmental Program. The Climate-Health Prevention Strategy should be a part of it.

It should include the followings:

- The elements of climate-health network
- Further research on the possible related diseases and ways of their prevention
- Prevention should be prioritised besides patient care and rehabilitation
- Elaboration of tool for changing social consciousness

Heat wave	Mortality	Reference
Birmingham, UK 1976	Mortality increase by 10%, mainly 70-79 y old female and male population	Ellis et al (1980)
London, UK 1976	Mortality increase by 9,7%	Lye and Kamel (1977)
Portugal 1981	Excess mortality in Lisbon 63, in Portugal 1906	Garcia et al (1999)
Rome, Italy, 1983	Deaths due to heat stroke 56, excess mortality 35%	Todisco (1983)
Athens, Greece	Excess mortality >2000, heat related mortality 926, hospitalization 2690 people	Katsouyanni et al (1988)
London UK 1995	Excess mortality 619, mortality increased by 8,9%	Rooney et al (1998)

References

1. Láng I: A globális klímaváltozás: hazai hatások és válaszok, KvVM-MTA-„VAHAVA” projekt összefoglalás, 2006, Budapest, p: 5-6.,
2. Páldy A, Erdei E, Bobvos J. és tsai (2004): A klímaváltozás egészségi hatásai, Egészségtudomány, 48, 2-3: 220-236.
3. Hémon D, Jougla E. Surmortalité liée à la canicule d'août 2003- Rapport d'étape (1/3). Estimation de la surmortalité et principales caractéristiques epidemiologiques. Paris: Institut national de la santé et de la recherché médicale (INSERM); 25 September 2003. (http://www.sante.gouv.fr/htm/actu/surmort_canicule/avant_propos.pdf) [accessed 10 March 2004]
4. Centro Nazionale de Epidemiologia, Sorveglianza e Promozione della Salute, Ufficio di Statistica. Indagine Epidemiologica sulla Mortalità Estiva. Presentazione dei dati finali (Susanna Conti). Rome: Istituto Superiore di Sanità; 2003. (http://www.epicentro.iss.it/mortalita/presentazione%20mortalità%20estiva2.pdf)
5. J. Tan, Kalkstein, J.Huang et al (2004): An operational heat/health warning system in Shanghai, International Journal of Biometeorology, 48(3): 157-162
6. M. Pascal, K. Laaidi, M. Ledrans et al (2006): France's heat health watch warning system, International Journal of Biometeorology 50: 144-153.
7. K.L. Ebi, T.J. Teisberg, L.S. Kalkstein (2004): Heat watch warning systems save lives, American Meteorological Society: 1067-1073.
8. K. Smoyer-Tomic, D. Rainham et al (2001): Beating the heat: development and evaluation of a canadian hot weather health response plan, Environmental Health Perspectives, 109(12): 1241-1247
9. C. Koppe., S. Kovats., G. Jendritzky., B. Menne.: Heat-waves: risks and responses, Health and Global Environmental Change, series No.2., WHO, 2004
10. A. Paldy, J. Bobvos, A. Vamos, R.S. Kovats, S. Hajat : The Effects of Temperature and Heat Waves on Daily Mortality in Budapest 1970-2000: in Extreme weather events and public health responses ed. by W. Kirch, B. Menne, R. Bertollini:, p.:99-109 Springer Berlin, Heidelberg, New York 2005
11. Páldy A., Erdei E., Bobvos J. (2003): A klímaváltozás egészségi hatásai, AGRO Füzetek., 32: 62-77
12. S Kovats et al (2003) Heatwaves of August 2003 in Europe: provisional estimates of the impact on mortality (www.eurosurveillance.org)
13. Centro Nazionale de Epidemiologia, Sorveglianza e Promozione della Salute, Ufficio di Statistica. Indagine Epidemiologica sulla Mortalità Estiva. Presentazione dei dati finali (Susanna Conti). Rome: Istituto Superiore di Sanità; 2003 (http://www.epicentro.iss.it/mortalita/presentazione%20mortalità%20estiva2.pdf)
14. Páldy A, Bobvos J, Vámos A, Kishonti K: (2005) Többlethalálozás a nyári hőhullámok idején Budapesten 2001 és 2003 során, Egészségtudomány, 49:299-310
15. P. Michelozzi et al (2004): Impact of heat waves on mortality – Rome, Italy, June-August, 2003., MMWR: 53:369-371.
16. http://www.dh.gov.uk/assetRoot/04/13/52/97/04135297.pdf
17. Laadi K, Pascal M. et al (2004): Le Systéme francias d'alerte canicule et santé 2004 (SACS 2004) – un dispositif au Plan National Canicule, BEH no. 30-31 Numérő thématique: Plan National Cancicule, 134-136
18. Paixai, E: Behaviours of Portuguese population during the August 2003 heatwave. Paper given at the ICARO Conference, 7 May, 2004 Lisbon.

19. Michelozzi P, Nogueira P.J: A national system for the prevention of heat health effects in Italy. In WHO, Regional Office for Europe, Extreme weather and climate events and public health responses. Report on a WHO meeting in Bratislava, Slovakia 9-10, February 2004, Kopenhagen, Denmark, 2004
20. Boyer L., Robitail S., Debensason D et al (2005): Media and public health: example of heat wave during summer 2003., Rev Epidemiol Sante Publique, 53 (5): 525-34.

11. Heat prevention at national and city levels

Preparedness for heat-waves among cities in Europe

Tom Kosatsky, MD, MPH

Background

The WHO European Region has experienced an unprecedented rate of warming in the recent past. During the period 1976–1999, the mean daily maximum temperature in most areas during the summer months has increased by more than 0.3°C per decade (Koppe, 2004).

Increasing variability in the European climate has lead many experts to predict that extreme weather events including floods, heat waves, cold spells, and windstorms will become both more frequent and more severe (Navarra, 2004).

In the summer of 2003, heat waves struck large areas of Western Europe and caused many unanticipated deaths in several countries. According to provisional data provided by national authorities, there were more than 14,800 excess deaths in France alone (Kovats, 2004).

In recent years, preventing and responding to the effects on human health of extreme weather has become a public health action priority. Health Ministries have responded by invoking the three classic public health strategies: disease prevention; wellness promotion; and health protection (Detels and Breslow, 2002). As a fit population is better able to withstand heat and cold stress, and an informed population better able to adopt protective measures, wellness promotion also has a place in preparedness for extreme weather. Health protection measures such as the provision of air conditioning, clean water, and shelter for the homeless might be included in programmes to reduce the sanitary impacts of heat waves, floods, wind storms and cold spells.

Besides the classic strategies of prevention, promotion and protection, such integrative actions as vigilance (information gathering to signal early evidence of stress and/or impact on health) and resource coordination have been implicated in public health responses to extreme weather.

While each type of extreme weather event and each locale require a tailored response, public health is most effective where specific programmes form part of a well-developed network and approach. Thus, where a strong system of disease surveillance is already in place, public health authorities can more easily incorporate special measures to detect emerging health impacts related to new environmental stressors. Likewise, where the home care network is already active, it can more easily incorporate extraordinary measures to protect the most vulnerable during heat waves and floods.

One might argue that public health preparedness for extreme weather should be based on the assessment of vulnerabilities coupled with the mobilization of resources from within and outside the health sector. The assessment of vulnerabilities includes both environmental factors (examples: residential zones most liable to be flooded, urban areas where heat is trapped) and social and behavioural factors (examples: marginalized or non-autonomous populations, persons with low levels of immunity to infectious disease). Given the complexity of responses, resources must be mobilized, both from within and outside the health sector, to mitigate these vulnerabilities. In order that these resources truly strengthen population resilience in the domain of health (as opposed to other worthwhile objectives), public health authorities must both assume a coordinating role and act as primary advocates for health.

Public health authorities can be involved in both preparation for, and response to, extreme weather. Both mandates involve the building and activation of partnerships, with weather services, civil protection agencies, civic authorities, health service providers and voluntary agencies. Issues of responsibilities, leadership and coordination must be defined.

Finally, public health authorities can be involved in influencing those environmental stressors that contribute to global climate change and with it, extreme weather. Specifically, in promoting a healthier world, public health authorities can advocate for the great variety of measures which diminish vulnerabilities, an example at the global level being the reduction of greenhouse gas emissions, or, at the local level, reduction of the urban heat island, or limitation of residential encroachment on the flood plain.

The WHO Regional Office for Europe is working to place climate change higher on the global public health agenda. As a first step, there is a need to document policy frameworks, programmes and lead agencies in relation to actual public heath responses to extreme weather. The theoretical basis for public health intervention has been developed in two recent publications on heat waves:

- Methods of assessing human health vulnerability and public health adaptation to climate change (Kovats S, et al, 2003)\Heat waves: risks and responses (Koppe et al, 2003)

GOAL of the survey:

- Describe prevention activities related to population health during extreme weather events in 16 PHEWE cities;
- Initiate the development of best practices.

This has been part of the PHEWE project, and has followed a country analysis that was carried out under the cCASHh project.

Methodology

Three recent enquiries are particularly relevant. During the summer of 2002, the U.S. Centre for Disease Control (CDC) reviewed emergency response plans for 18 US City Health Departments (Bernard and McGeehin, 2004). Of the 18, six had no plan which encompassed a heat wave response, two included heat waves in an overall disaster response plan, and 10 had stand-alone heat wave plans. Of the latter 10, for seven, the plans were judged comprehensive, on the basis that: lead and participating agencies were identified; a consistent, standardized warning system was activated on the basis of weather forecasts; a communication plan was in place; the response plan targeted high risk groups; and mechanisms for information collection, evaluation, and revision were in place. While the CDC review covered the emergency response function, it excluded issues relating to the involvement of city health departments in the promotion of medium and long-term adaptation measures.

The WHO European Region's Division of Country Support conducted, during 2004, a survey of disaster preparedness in 12 (mainly Central and Eastern European and Central Asian) countries (G Rockenshaub, WHO European Region, personal communication). Among issues queried were the legal and administrative basis of disaster response and the nature of national disaster plans, including roles and responsibilities and chain of command; co-ordination of the national response, specific role of health authorities; training and monitoring and evaluation.

- Interpretation of responses is limited by contextual issues concerning the different histories and mandates of public health in the various European Region member states, and by difficulties in locating a single best respondent for the complex issue of preparedness for extreme weather.
- It does appear that most Health Ministries have become involved in the issue of response to extreme weather, that they participate in inter-Ministerial programmes, and that some have instituted strategies to identify and to rectify population vulnerabilities before such events occur.
- However, specific legislation referring to the health consequences of extreme weather is still the rarity in the European region, and Ministerial programmes designed to mitigate natural

disasters often do not include extreme weather events. Few Ministries cooperate formally with their national meteorological agencies.

- Fifteen (79%) Ministries responded that they had a plan for mobilization and response during emergencies. Eleven of these plans had sections devoted to earthquakes and 10 to chemical spills; fewer mentioned extreme weather events: floods (9), windstorms (3), heat waves (3), cold spells (1). Eight Ministries stated that their response plan had been revised within the last 5 years, of which 5 had been revised in 2003.
- Three (16%) Ministries had collaborative agreements with national weather services: agreements covered the transmission of weather information, the drafting of joint communiqués, and responsibilities for risk management. Nine (47%) Ministries had cooperative agreements with the national civil protection agency on extreme weather/natural disasters, and 4 (21%) with the national armed forces.
- Ten (53%) of the Ministries had programmes in place to monitor health during natural disasters, which in most cases included surveillance of medical visits, emergency services, hospitalisations, and recent deaths. However, in fewer than half of the 10 Ministries with health monitoring programs, were extreme weather events included.
- Other than national responsibilities in the area of extreme weather, in 16 (84%) countries there were also regional and in 18 cases (95%) also municipal mandates.

Methods

In June 2004, the WHO European Centre for Environment and Health (Rome) initiated a survey in the 16 PHEWE cities. This was distributed by e-mail and mail. It was addressed to directors of PHEWE city health departments in copy to the PHEWE co-ordinators; with several solicitation depending on the cities. In addition follow up interviews were hold where necessary. The content of the questionnaire included:

Our study questionnaire (Annex 1) was designed to cover the spectrum of powers and responses with respect to extreme weather events. It included, questions on: Last major flood, heat wave, cold spell, wind storm in each city and their effects on health (open-ended); Legislation empowering city to act; Lead agency for preparation and response; Role of health department; Existence of overall, and event-specific plans; Links with weather service, civil protection, national authorities; Activities planned for pre-and during-event and the Media interest. In order to assess the division of responsibilities within nations, we asked about whether regions and cities had mandates and programmes beyond those of their national Ministries. In order to validate and contextualize responses, we asked for written documentation of legal mandates and programme activities where available.

From the 9 cities that responded, the following were the responders: Director, city health department; PHEWE coordinator; National respondents to an earlier survey; Mayor; City emergency hot line.

Figure 1 shows in green those cities that responded extensively:

Problems encountered were the following: scarce interest; heat not perceived as a problem; language; Information provided was not validated and the high influence of the respondent (personnel interest, etc)

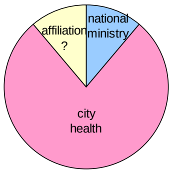
The questionnaire was pre-tested with colleagues at the WHO European Centre for Environment and Health and subsequently with French, Slovakian, and Canadian environmental public health authorities.

Respondents were identified by asking the Director of Public Health in the city. The questionnaire itself, written in English, German, and French. It included both open and closed questions, the answers to which were later coded based on response similarities. The transmittal letter was also sent to the WHO country liaison officers appointed to Central and Eastern European and Central Asian countries. (Annex 2)

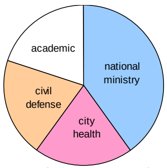
Completed survey forms were scanned for missing pages and questions left unanswered. When this occurred, we requested completion of the missing sections. Occasionally answers appeared inconsistent, as when a general question was answered “no”, but follow-up questions, contingent on the general question receiving a positive response, were answered anyway. Given that these responses may have been the result of an ambiguous question or of a situation where the respondent’s authority had particular legislation, programmes or activities, not considered when our questions were formulated, we accepted the responses as provided. Occasionally, inferences were required when a written response was received which did not fall into one of the suggested categories: these were coded as “uncertain”.

Results

As of 20 December 2004, 8of the 16PHEWE cities answered. 7 city responders came from the city government. As the questionnaire was filled in by different institutions, the secondary responders came from several sectors:



Primary respondent



Secondary respondent
(5)

Answers to the questions have been organized by city:

Does you city have the power to act during an emergency?

City	***Yes***	***No***
Athens	**X**	
Barcelona	**X**	
Budapest	**X**	
Crakow	**X**	
Helsinki	**X**	
London	**X**	
Lubljana	**X**	
Stockholm	**X**	
Zuerich	**X**	

Does emergency measures legislation mention specifically heatwaves

City	Yes	No
Athens	**X**	
Barcelona		X
Budapest	**X**	
Crakow		X
Helsinki		X
London		X
Lubljana	**X**	
Stockholm		X
Zuerich	**X – irrigation of fields**	

Does your city health department have a plan for mobilization during emergencies (for heat waves)?

City	Yes	No
Athens	**X general for all**	
Barcelona	**X**	
Budapest	**X**	
Crakow	**X**	
Helsinki		X
London		X – IT IS NATIONAL
Lubljana		X
Stockholm		X
Zuerich	**X**	

In what year has it been revised?

City	Yes	No
Athens	**2004**	
Barcelona	**CONSTANT**	
Budapest	**2004**	
Crakow	**2001**	
Helsinki	**2005**	
London	**2004**	
Lubljana	**-**	
Stockholm		
Zuerich	**EVERY YEAR**	

Is there a cooperative agreement between your city department and the weather service?

City	Yes	No
Athens	**X – transmission of information and forecasts as well as communication to public**	
Barcelona		X
Budapest	**X – transmission of information and forecasts as well as communication to public**	
Crakow	**X – transmission of information and forecasts as well as communication to public**	
Helsinki	**X – makes decisions in case of extreme weather events and is responsible for public communication**	
London		X
Lubljana		X
Stockholm		X
Zuerich	**X**	

Is there a cooperative agreement between your city department and the civil service?

City	Yes	No
Athens		X
Barcelona	**X**	
Budapest	**X**	
Crakow	**X**	
Helsinki	**X**	
London		X
Lubljana	**X**	
Stockholm		
Zuerich	**X**	

Is there a cooperative agreement between your city department and the armed forces?

City	Yes	No
Athens		X
Barcelona		X
Budapest	**-**	
Crakow	**X**	
Helsinki		
London		
Lubljana		
Stockholm		
Zuerich		

Does your City health department have a program to monitor population health in natural disasters?

City	Yes	No
Athens		X
Barcelona	**X**	
Budapest	**X**	
Crakow		X
Helsinki		X
London		X
Lubljana		X
Stockholm		X
Zuerich		X

If yes, does it include reports from funeral homes?

City	Yes	No
Athens		
Barcelona	**X**	
Budapest	**X**	
Crakow		
Helsinki		
London		
Stockholm		
Zuerich		

If yes, does it include surveillance from hospitals

City	Yes	No
Athens		
Barcelona	**X**	
Budapest	**X**	
Crakow		
Helsinki		
London		
Lubljana		
Stockholm		
Zuerich		

If yes, does it include emergency services and ambulance calls

City	Yes	No
Athens		
Barcelona		X
Budapest	**X**	
Crakow		
Helsinki		
London		
Lubljana		
Stockholm		
Zuerich		

If yes, does the surveillance program include heat waves

City	Yes	No
Athens		
Barcelona	**X**	
Budapest		X
Crakow		
Helsinki		
London		
Lubljana		
Stockholm		
Zuerich		

Has the media showed interest

City	Yes	No
Athens	++++	
Barcelona	+++	
Budapest	++++	
Crakow	++++	
Helsinki	+++	
London	++	
Lubljana	+++	
Stockholm	+++	
Zuerich	+	

In what year was your major heatwave

City	Yes	No
Athens	**1987**	
Barcelona	**2003**	
Budapest	**2003**	
Crakow	**-**	
Helsinki	**never**	
London	**-**	
Lubljana	**-**	
Stockholm	**-**	
Zuerich	**2003**	

What was the impact

City	Yes	No
Athens	**2000 DEATHS**	
Barcelona	**40% INCREASE IN MORTALITY**	
Budapest	**200 EXCESS DEATHS**	
Crakow	**-**	
Helsinki	**-**	
London	**-**	
Lubljana	**-**	
Stockholm	**-**	
Zuerich	**YES BUT NOT SPECIFIED**	

Does your city have a plan to prevent heatwaves

City	Yes	No
Athens	**X**	
Barcelona	**X**	
Budapest	**X**	
Crakow		X
Helsinki		X
London	**X SUGGESTED TO ASK SOMEBODY**	
Lubljana		X
Stockholm		X
Zuerich		X

What does it involve?

City	Yes	No
Athens	**CONFIDENTIAL PLAN: Assessment of people most susceptible; public education campaign; advice for health protection.**	
Barcelona	**Assessment of people most susceptible; public education campaigns; advice for health protection based on weather forecasts; advice for doctors.**	
Budapest	**Assessment of people most susceptible; public education campaigns; advice for health protection based on weather forecasts; advice for doctors.**	
Crakow		
Helsinki		
London		
Lubljana		
Stockholm		
Zuerich		

Discussion and Conclusion

Interpretation of responses is limited by the very few cities, that were analysed and by the little in depths analysis. The different histories and mandates of public health in the various cities, and by difficulties in locating a single best respondent for the complex issue of describing preparedness for heat-waves.

Language, culture, the division of powers between city, federal and state authorities, and the organisation of cities are complex, as shown by responses of London and Crakow:

> Other important points, are that for example that Crakow city does not have health competencies, but it is with the Sanitary inspection units.
>
> London has 32 departments, and it is actually greater London that is responsible, e.g. Thames protection

The issue of validity of responses goes beyond the question of rates of response. Typically, a variety of units and individuals within a city are involved in extreme weather preparedness and response. In some cities, an affiliated institute of public health assumes the functions. We attempted to give voice to the various actors involved by including different approached. In several cases, more than one individual contributed to the response. A more proactive approach would be to develop the survey on the basis of case studies, with the various actors implicated in extreme weather event preparedness interviewed both individually and in a group encounter.

Despite these obstacles, we submit that the current survey has added knowledge to an area where as yet little work has been done. Both the survey and the collection of legislation and programmes it has produced provide examples of the wide variety of public health responses

We found, in common with the Division of Country Support survey and the cCASH survey, that there is a wide variation in preparedness and response activities among cities and European Member States.

References:

1. Bernard SM, McGeehin MA. Municipal heat wave response plans. Am J Public Health. 2004 Sep;94(9):1520-2.
2. Detels R, Breslow R , Current scope and concerns in public health in Detels R, McEwen J, Beaglehole R, Tanaka H, *eds.,* Oxford Textbook of Public Health, Oxford, 2002.
3. Hajat S, Ebi K, Kovats S, Menne B, Edwards S, Haines A. The human health consequences of flooding in Europe and the implications for public health: a review of the evidence. App Environmental Science and Public Health 2003: 1 (1) 13-21.
4. Hassi J, Cold extremes and impacts on health, in Kirch W and Menne B Bertollini R, *eds.,* Extreme Weather Events and Public Health Responses. Springer, Heidelberg, 2005.
5. Koppe C, Kovats S, Jendritzky G, Menne B. Heat waves: risks and responses (2004) World Health Organization, Kopenhagen, Denmark.Kosatsky and Menne (2006) Public health responses to extreme weather events, in selected European countries. In: Climate change and adaptation strategies for human health. Eds. Menne and Ebi. Springer, Steinkopff, 360 pages. 2006
7. Kovats S, Wolf T, Menne B. Heatwave of August 2003 in Europe: provisional estimates of the impact on mortality. Eurosurveillance Weekly. 11 March 2004; 8(11). http://www.eurosurveillance.org/ew/2004/040311.asp
8. Lillibridge SR, Tornadoes, *in* Noji E, ed, The Public Health Consequences of Disasters. Oxford, 1997 pp 228-244.
9. Navarra A, The climate dilemma, in Kirch W and Menne B Bertollini R, *eds.,* Extreme Weather Events and Public Health Responses. Springer, Heidelberg, 2005.
10. Wilkinson P, Pattenden S, Armstrong B, Fletcher A, Kovats RS, Mangtani P, McMichael AJ. Vulnerability to winter mortality in elderly people in Britain: population based study. BMJ. 2004 Sep 18; 329(7467):647.

Appendix 1

Member States of the WHO European Region (survey respondents in bold)

EU Members

Austria
Belgium
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxemburg
Malta
Netherlands
Poland
Portugal
Slovak Republic
Slovenia
Spain
Sweden
United Kingdom

Newly Independent States

Armenia
Azerbijan
Belarus
Georgia
Kazakhstan
Kyrgyzstan
Republic of Moldova
Russia
Tajikistan
TurkmeNIStan
Ukraine

Uzbekistan

Other European Region Member States

Andorra
Albania
Bosnia and Herzegovinia
Bulgaria
Croatia
Former Yugoslav Republic of Macedonia
Iceland
Israel
Monaco
Norway
Romania
SanMarino
Serbia and Montenegro
Switzerland
Turkey

12. Summer excess deaths and YoLL

See attached pdf file

13. Heat Waves and Human Health.

See attached file

14. General discussion

Summer results

Effect of temperature on daily Mortality

The main results which emerge from the analysis of the effect of apparent temperature on daily mortality is that in summer a j-shaped relationship was observed in most cities. In the Mediterranean cities thresholds (temperature value above which an increase in temperature is associated to an increase in mortality) present high heterogeneity ranging from 21.5°C in Ljubljana to 32.7°C in Athens. The effect of heat was expressed in terms of percent variation in mortality associated to 1° C increase in apparent temperature above the city-specific threshold. The percent variation estimated ranges from 0.56% in Valencia to 5.54% in Athens. The effect of heat was immediate (picked up by lag 0-3 analysis).

The pooled estimates were produced for all cities, Mediterranean and Northern-Continental cities. The pooled threshold for the Mediterranean cities was 29.4°C, while for the northern-continental counties was 23.3°C. The percent variation in mortality was estimated for every 1°C increase in Tappmax above the common threshold. For total mortality significant overall percent variations was equal to 3.12 (95% CI: 0.60-5.72) and to 1.84 (95% CI: 0.06-3.64) respectively.

The percent variation in mortality was higher for respiratory and cardiovascular mortality. A statistically significant effect of high temperatures on cardiovascular mortality was seen when considering all age groups and in the 75+ age group in Mediterranean cities, while a significant effect in mortality by respiratory causes was observed for both Mediterranean and North Continental in all ages and the 75+ age group.

The impact of high temperatures differs within the summer season, in fact there was evidence that first episodes are the most dangerous as populations are not yet acclimatised.

An harvesting effect for total and cardiovascular mortality was observed, which was more evident in the Mediterranean cities.

Effect of temperature on daily Hospital admissions

Admissions for respiratory, cardiovascular and respiratory causes were analysed by age groups (0-14; 15-64; 65-74; 75+).

No effect of high temperatures was observed on cardiovascular and cerebrovascular causes for all ages considered. Considering all age groups an effect of temperature on respiratory admissions was observed only in Stockholm, Milan and London. Analysis by age groups gave a better insight with a positive association between high temperatures and respiratory admissions in a larger group of cities: Stockholm (65-74, 75+), London (15-64; 65-74; 75+), Rome and Valencia for the very old (75+), in Milan for the young (0-14) and very old (75+) and Turin only in the 15-64 age group.

Pooled analysis was carried out on extreme summer temperatures (>90th percentile during summer). For cardiovascular and cerebrovascular disease a negative significant coefficient was observed for all cities. For respiratory disease a positive coefficient was observed for all cities and northern-continental cities. Pooled analysis (Mediterranean and northern-Continental cities) for respiratory disease by age groups illustrated a significant positive effect of high temperatures for the 15-64 and 65-74 age groups was only observed in the northern-Continental cities, while for the 75+ age group a positive effect was estimated in all cities, Mediterranean and northern-Continental cities.

Attributable deaths: Years of Life lost

To estimate the impact of unusually high summer temperatures on the health of European urban populations a Years of life lost approach (YoLL) in which the loss of life expectancy over the city population is expressed as a function of summer weather.

Results of this analysis estimated less than 60 excess temperature-related deaths per 100,000, per year, between 1990-2000 in each city among subjects aged 15-64 and 65-74. While estimated 150-200 excess deaths per 100,000 per year for people aged 75+ in some cities, Paris, Barcelona, Athens, Budapest and Rome. These estimates are reduced by 35-60% when those displaced by less than 30 days are excluded (not those aged <75). In Paris, Budapest, Rome, Turin, and Barcelona appear to be particularly sensitive to the high temperature scenario.

Although an estimate, results presented are very useful as they present a good insight for health impact assessment of climate change scenarios.

Further analysis should consider life expectancy rates and the differences between age groups, as well as for the different susceptible subgroups. Infact, life expectancy is changing and mortality rates are declining but not in a homogeneous way. Estimates stratified by gender should also be included.

Air pollution: confounding and effect modification

Most studies in the literature assessing the confounding effect of air pollution in temperature-mortality outcomes show there is no or minimal confounding. Results from the PHEWE project show that in the warm season, the confounding effect of pollutants on the size of the apparent temperature effect estimate is small (<10% in all cases, except when including PM_{10} in the fixed effects model for cerebrovascular disease mortality. The size of the effect estimate of apparent temperature when adjusting for an air pollution variable generally decreases, except for a few specific models concerning effects on cerebrovascular disease.

For the summer season was observed a significant interactive of apparent temperature on total natural mortality with CO and a larger interactive effect with ozone. In cities where the ozone levels are higher, the effects of apparent temperature are higher. Specifically, for a city with ozone level at the 25th percentile of the ozone distribution over all cities, the increase in mortality associated with an increase of 1°C above the threshold level is 1.66%, whilst in a city with ozone at the 75th percentile, the increase in mortality is 2.10%. However, the significance of the interactive effect does not reach the nominal level when the random effects model is applied (preserving the same pattern). For cardiovascular disease mortality, there is a significant interaction of apparent temperature with black smoke levels both with fixed and random effects models. The increase in mortality associated with 1°C increase in apparent temperature, is 3.06% in a city with low black smoke (at the 25th percentile) whilst it is 2.47% in a city with high black smoke (75th percentile). There is no interaction of the effects of apparent temperature with any pollutant when respiratory and cerebrovascular mortality is analyzed.

Winter results

Effect of temperature on daily Mortality

A linear trend, with a negative slope, in the temperature mortality relationship was observed, suggesting mortality increasing as temperatures decline.

For total natural and CVD causes of death there was a statistically significant effect in all age group and in the oldest age groups (65-74 and >75 years). The results showed an increase in the effect with increasing age. For respiratory and cerebrovascular mortality there was a statistically significant effect of similar magnitude in those 65-74 and >75 years old but the adverse effect of decreasing temperature was not nominally significant for those 15-64 years old for respiratory causes of death, and there was no effect for this age group on cerebrovascular mortality.

City-specific analysis presented heterogeneous results and there is a difference between the Mediterranean and Northern-continental cities, with an higher effect for total CVD and cerebrovascular mortality in Mediterranean cities while an higher effect was observed in Northern-continental cities for respiratory causes of deaths.

The combined curves for total, cardiovascular, respiratory and cerebrovascular mortality also have a linear trend. The pooled analysis shows that for total and cardiovascular causes of death there is a statistically significant effect in all age groups considered and there is a clear increase in the effect with increasing age. For respiratory and cerebrovascular mortality there is a statistically significant effect of similar magnitude in the 65-74 and 75+ age groups. The 15-64 age groups shows a significant effect only for respiratory causes of death.

Distributed lags models showed the delayed effect of temperature on daily mortality. While unconstrained distributed lags models showed the cumulative effect of temperature on daily number of deaths up to 30 days for 5 day intervals. There is a delayed effect of low apparent temperature that goes up to 20 days.

Effect of winter temperature on daily Hospital admissions

Admissions for respiratory, cardiovascular and respiratory causes were analysed by age groups (0-14; 15-64; 65-74; 75+).

Cardiovascular causes showed a weak association with a decrease in T_{appmax} only for the 65-74 and 75+ years age groups. City-specific results for cardiovascular admissions showed a significant effect only in Barcelona (all ages and 75+ age group), Budapest (all age groups considered) and London (all ages and 75+ age group).

Cerebrovascular causes were not associated with a decrease in temperature in most cities; city-specific results showed a significant association only in Barcelona (75+ age group) and Budapest (all ages and 75+ age group).

A significant effect was observed on respiratory admissions in all age groups in Budapest, Dublin, London, Paris, Rome, Stockholm and Valencia. While for Barcelona and Milan only for total and the 75+ age group.

It’s worth noting a certain degree of heterogeneity between city-specific estimates for all the three outcomes.

The pooled exposure-response curves of maximum apparent temperature and daily hospital admissions in the 75+ years age group for all cities has a linear trend, with admission rates rising progressively as temperature decreases for all the three outcomes considered, although it appears to be stronger for respiratory causes.

Significant increases in hospital admission counts for a decrease in 1°C in T_{appmax} are visible for cardiovascular causes in the 65-74 and 75+ years age groups in all cities and only in the 75+ age group in Continental/Northern cities. Overall, no effect of low temperature was found for cerebrovascular admissions in all three groups of cities. With regards to respiratory admissions, a significant association with temperature was observed for all the age groups considered even if higher in the 75+ years age group in all cities as well as in Continental/Northern cities. In Mediterranean cities the only significant association was found in the 75+ age group.

Air pollution: confounding and effect modification

For the cold season the observed confounding effect of air pollution is indeed minimal. In all cases, except when adjusting for SO_2 and ozone in cerebrovascular disease mortality, the change in the effect estimates is less than 10% after adjustment by the air pollutant. In all cases, the change after inclusion of the air pollutant variable in the model is to obtain a smaller effect estimate.

The parameters for the interaction variables are not statistically significant with a few exceptions. One exception is the interactive effect of NO_2 and apparent temperature on total natural mortality, which is significant only when the fixed effects model is applied and becomes totally insignificant in the random effects model. Also, the interactive effect of CO and apparent temperature on total mortality is significant and a smaller effect of apparent temperature is observed when the pollutant level in a city is higher. Further, the interactive effect of apparent temperature and PM_{10} on respiratory mortality is significant and the effect of apparent temperature is smaller when the PM10 levels in a city are higher. Finally, the interactive effect of apparent temperature and SO_2 on cerebrovascular disease is significant when the fixed effects model is applied. The effect of apparent temperature is higher when the pollutant is higher.

Conclusions

The results of this project documented the effect of temperature on mortality both during the summer as well as the winter seasons in all the European cities included in the project, showing a large heterogeneity of the effect attributable to the differences in local climate and to the impact this has on local populations.

For the effect of hot temperatures thresholds were higher in the Mediterranean and lower in the Northern-Continental countries indicating that people residing in the latter are susceptible to lower values of apparent temperature. We found that the effect of heat was stronger in the very old (75+ age group) than earlier in life confirming a high vulnerability of elderly populations. In general, the highest effect of heat on mortality was observed for respiratory causes.

As shown by the distributed lag analysis, the effect of high apparent temperature appears to be immediate (5-6 days) both in Mediterranean and Northern-Continental cities. A certain evidence of mortality displacement was found in both groups but the displacement effect was more prolonged in Mediterranean cities.

One interesting result that emerged was that the effect of hot temperature on mortality was stronger earlier in the season, confirming previous observation that the impact of high temperatures differs within the summer season. From a physiological point of view, we can suppose that the human organism reacts better to latest heat due to acclimatization reasons. But this finding could be explained also by different composition of the population at risk over time, due to harvesting-like phenomena.

A relevant point to be addressed in the future concerns investigation of possible effect modifiers which explain heterogeneity in threshold and slope estimates. We can suppose that demographic and social-economic factors determine different proportion of susceptible subjects in the enrolled cities. Meteorological and geographical characteristics can explain part of the heterogeneity among cities, and could modify mechanisms intervening in the acclimatization process.

Concerning the effect of cold temperature during the winter months, our results documented that in European cities temperature is inversely associated with mortality, and the relationship appears to be linear. The effect of cold was observed on all causes of death, and was stronger on cardiovascular and respiratory causes.

Furthermore, in warmer cities the cold temperature effect was higher and these results are consistent with results previously reported in the U.S. (Curriero et al 2002, Braga et al 2002) and from Europe (Eurowinter 1997, Healy 2003).

In our study we observed effects of similar magnitude on deaths from respiratory and cardiovascular causes. However, when more prolonged effects were studied with distributed lag models, it appears that the respiratory effects are more persistent through time.

Results by age groups showed that for total and CVD mortality the effects had an age gradient; the effect increased progressively with age and was greatest in the elderly. Whereas the effects of apparent temperature on respiratory and cerebrovascular deaths were only observed on those older than 65 years.

As observed for the effect of heat, also for the effect of cold temperature on mortality we observed significant heterogeneity in the effect among cities. As already discussed for the summer effect, these may be due to differences in environmental, socioeconomic and behavioral patterns.

With respect to the effect of heat that is immediate, cold showed an effect on mortality up to two weeks. It is important to recall that cold temperatures are associated to the transmission of viruses, people are indoor more and enhance the spreading of viruses, and the biological mechanisms of transmission may justify the long lag effects observed.

The PHEWE project was the first study to systematically analyse the effect of temperature on hospital admissions in European cities. Results from the PHEWE project confirm previous results in Europe (S. Kovats et al. 2004; Morabito et al. 2005) that the impact of hot temperatures on hospital admissions are not consistent with the effect on mortality for cardiovascular and cerebrovascular causes during the warm season. Although a heterogeneity of the dose-response curves was observed, in all the cities hot temperatures were inversely associated with hospital admissions for cardiovascular and cerebrovascular causes.

An effect of heat was found only on hospital admissions for respiratory causes especially in the population over 75, and only in some cities.

Concerning the effect of cold temperatures on hospital admissions, the PHEWE project provides evidence of a small increase in daily hospital admission counts for cardiovascular and cerebrovascular causes, while a significant effects were observed for respiratory causes. The comparison of these findings with results on mortality showed that the effect on cardiovascular admissions was lower than the effect observed on mortality, whereas the effect on respiratory admissions was similar in magnitude. The effect of cold on respiratory admissions was higher among oldest age groups (people over 75).

The larger effects of cold temperatures on cardiovascular (75+ age group only) and respiratory admissions were observed in Continental/Northern cities. Such a geographical heterogeneity is in contrast with findings on cold-related mortality within the PHEWE project that show a cold effect on mortality (both all and specific causes) greater in Mediterranean than in Continental/Northern cities. However it may reflect differences in hospitalization among countries instead of differences in the diseases occurrence. A possible alternative explanation is that hospital admissions are of heterogeneous quality and probably not always a good indicator of morbidity.

In comparison to mortality data, hospital admissions data presents some problems which need to be considered, such as the seasonal fluctuations of specific disease, variation in the size of the susceptible population, cyclic variation in the supply of services (eg. Planned admissions have a higher variability than the unplanned ones). In the project the focus was on emergency admissions as these present less variability, however no differences in the results where observed among cities for which a code for emergency was available and the others.

The PHEWE project also included work packages on prevention. Pilot HHWWS warning systems were developed in Paris, Budapest, Rome, Barcelona and London. Mortality in the 65+ and 75+ was predicted using deterministic and conditional probabilistic models. The results showed that thresholds for warnings vary be region and the PHEWE project can provide guidance for local action. The models experimented became operational only in Budapest and in Rome. The indications from the PHEWE project for the future development of HHWWS are that it should be based on an efficient forecast and warning system, robust understanding of the temperature-mortality relationship and a series of effective response measure in terms of public health which include efficient infrastructures and prevention programs.

To have an overview of the prevention activities in action a survey on city preparedness was defined and a questionnaire was distributed to all the cities included in PHEWE. The aim of the survey was to describe prevention activities related to population health during extreme weather and environmental events in the 16 cities and develop guidelines on the various activities that can be put in practise during these events. Only nine cities responded to the questionnaire and results refer to these nine cities. The poor response can be attributable to a language barrier, difficulties in identifying the respondent/s and questions were too open ended. In terms of results this also made it difficult to validate the information, and who the respondent was influenced the outcome of the questionnaire.

In general the impact on hospital admissions hot temperature appears to be lower than the impact on mortality. Our conclusions are that, in European cities, hot temperatures seems to have an immediate effect on susceptible subgroups that died before getting to hospital. These results may be important to understand the physiological processes, and to focus preventive actions on susceptible subgroups, especially old and very old people living alone, to prevent fatal events allowing they come to medical's attention.

In the future other indicators than hospital admissions should be identified to document possible non-fatal outcome associated to high temperature exposures.

Concerning the public health aspects our results documented a large heterogeneity of the effect of temperature on mortality both during the warm and the cold season; these results may be due to heterogeneity in the exposures, in the social and demographic characteristics of the population, as well as the effectiveness of public health programs and the consequent adaptation processes of populations.

Considering global climate change scenarios, associated to an increase in the frequency and intensity of extreme weather events, the impact of heat on health will assume greater public health significance in the future. As a result, the constant monitoring of the temperature-mortality relationship and population vulnerability will be necessary to address and evaluate public health responses. Warning systems and prevention programmes, especially targeted at susceptible sub-groups, seems to represent an important resource for public health policies; the effectiveness of these systems needs to be evaluated at local level for improvements in the future.

15. Exploitation and dissemination of the results

The present project has provided new information on the short-term health effects of weather condition on the health of more than 30 Million European citizens from 16 cities, representing different climatic and socio-economic conditions. The association of weather on mortality has been investigated in all cities, whereas the effect on morbidity (in terms of hospital admissions) was studied in 12 cities, according to data availability. The project has been conducted using a multi-disciplinary approach, and experts from different disciplines (epidemiology, statistics, meteorology and public health) have taken over the leadership for the work performed in their specific field of interest, thus guaranteeing the maximum quality and at the same time sharing their knowledge with the rest of the group in order to provide a broader spectrum of the matter. The exploitation and dissemination of the results regard the scientific level as well as the public health level.

The following channels have been used for the exploitation and dissemination of the project findings:

Meetings*:*

- Two meetings were organised to which all project participants were invited: one at the beginning (March 2003), introducing the project objectives and work plan, and another one at the end (February 2006), in which the project results were presented and discussed.
- At the beginning of the third year the midterm review meeting was organised together with all partners responsible for the work. The preliminary results were discussed and revised by two external reviewers.
- A work-shop on the public health implications of the project and its findings was organised jointly with the final meeting in February 2006. Experts from the fields of Environmental Epidemiology and Public Health were invited for the discussion.
- The Steering Committee met four times (December 2002, February 2004, November 2004, and February 2006), in order to coordinate the scientific activities and share important decisions.
- **Three working groups (Epidemiology&Statistics, Meteorology, Public Health) were established during the first project meeting with the aim to support and supervise the work; these WGs met according to the specific needs of the scientist involved in the different parts of the project.**
- *Meetings for HHWWS pilot implementation: Issues regarding the pilot implementation of heat/health watch warning systems were presented and discussed at a local level in Budapest (June 2004), Paris (December 2003, February 2005), and Rome (March 2004)*

Presentations/Abstracts/Posters

- The PHEWE project was presented through poster and/or oral presentation in the following meetings: Environment-for-better-health conference March 2003, IEA conference 2003, AIRNET conference November 2003, EUPHA conference November 2003, ISEE conference 2005 (Abstracts published in Epidemiology: Volume 16(5) September 2005)., EC Workshop on “Global Environmental Change: Risks to Human Health?” June 2005,
- A symposium on the final project results was held at the International Conference on Environmental Epidemiology & Exposure in Paris on the 6th of September. The main results were presented to the scientific community and the abstracts were published in Epidemiology: Volume 15(4) November 2006

- The YoLL analysis was presented to the European Environment Agency in a meeting in Copenhagen on 26th September 2006

Websites:

- Information on the PHEWE project is available at http://www.epiroma.it/phewe
- Information on the HHWWS is available at www.phewe.bham.ac.uk (User = PHEWE; Password = pippin)

Scientific Publications:

A total of 11 scientific papers have been prepared during the final period of the project (chapters 2-12)

- The PHEWE study: background, objectives, design
- Analysis of the meteorological data and development of synoptic indices
- The effect of apparent temperature on mortality in winter
- The effect of apparent temperature on mortality in summer
- The effect of apparent temperature on hospital admissions in winter
- The effect of apparent temperature on hospital admissions in summer
- Confounding and effect modification: second stag analysis
- Development of HHWWS in PHEWE cities
- The pilot implementation of the HHWWS in Budapest
- Heat prevention at national and city levels
- Summer excess deaths and YoLL

Other publications are foreseen in the next months. Copies of publications will be sent to DG Research.

The results are of interest for international bodies dealing with the issue of Climate Change, e.g. the International Panel for Climate Change (IPCC), and will be useful in future decision making processes (e.g. EU climate policy response to the Kyoto protocol). On a national and local level, the efforts for the development of early heat warning systems, which have become a priority issue after the 2003 heat wave, can benefit from the PHEWE findings and experiences.

16. Policy related benefits

The potential health effects of a global warming is considered a serious problem for the 21st century in Europe but scanty data are available to predict the consequences of a wider temperature fluctuation, and the resulting increase in heat waves that several countries in the Union will face. PHEWE was the first pan-European epidemiological project to analyse the negative health effects of climate and to quantify the contribution of the single risk factors and their interaction with air pollution. The PHEWE project used a large-scale geographical approach, including areas with differing climatic conditions, which is crucial to address such a complex subject.

The findings of the PHEWE project, namely the detection of the effect of climate on health, its quantification and translation in YoLL, the role of air pollution, the development of early warning systems and the survey on current prevention strategies are milestones with regards to some of the environmental policy requests expressed in the last years:

Article 10/b of the Kyoto Protocol is requesting not only measures to mitigate climate change but also measures to facilitate adaptation to climate change. The Treaty of Amsterdam provides a legal basis for measures concerning environmental protection and human health with article 174.1 which recognises that Community policy must contribute to the pursuit of four environmental objectives, among these priorities is the protection of human health. Considering the potential impact of a changing climate and climatic hazards, an obvious response is to learn to live with it and to hedge against the risks of adverse climate impacts.

Therefore, evidence on the target population, the areas at highest risk, the quantification of the impact of heat on health and an inventory of existing policies are important elements for public health policies. The pilot implementation of heat/health watch warning systems, models to predict in advance and to alert city residents of potentially oppressive weather conditions that might negatively affect health, is an important step in the chain of prevention measures.

The project attempts to integrate the climate - health concern into associated policy areas, the policy area integration being a major feature of the modern EU policy direction, in particular, promoted under the umbrella of the Fifth Framework Programme for Research. The project specifically addresses the general objectives identified in Key Action 4, and in particular the objectives of point 4.1:

4.1.1 Analysis and quantification of the impact of environmental factors on human health: city-specific and pooled analysis, health impact assessment;

4.1.2 Assessment of the relative importance of, and the interactions between, factors impinging on health: confounding and effect modification of air pollution;

4.1.3 Development of an integrated approach to risk management taking into account environmental and public health aspects: development of heat/health watch warning systems

Furthermore, this project will, through its dissemination process and importance for the European policy agenda, promote the information of public health experts and also increase the request and attention from European Ministries of health. After the 2003 heat wave, the request for early warning systems has become a major topic of public health prevention strategies.

The PHEWE project was built on a multi-disciplinary collaboration: epidemiologists, statisticians, meteorologists, and public health experts exchanged their knowledge and achieved consensus through discussion. This co-operation between researchers from different disciplines is a good example for the combination of complementary expertise and resources available in Europe.

The establishment of a European data base of health, meteorological and air pollution data and the development of methodologies for the data analysis are important elements for future research. The know-how achieved in PHEWE has been or will be used in other European projects, funded within the 6th Framework Programme:

1. EuroHEAT (Improving public health responses to heat-waves in Europe): for a selection of the PHEWE cities, data were updated, including the 2003 heat wave, and the analysis will be performed following the PHEWE approach.
2. CIRCE (Climate Change and Impact Research: the Mediterranean Environment): the knowledge obtained in the present project, will be transferred to scientists in other areas and countries.

Economic benefits

The negative health effects of extreme weather events in Europe cause excess mortality and morbidity and consequently translate into direct costs, in terms of health care (hospital admissions, drug assumption, doctors consultation) and indirect costs in terms of work-absenteeism, loss of productive life and need of social support. Targeting the prevention measures at at-risk groups helps saving health care funds. Providing early warning systems and guide-lines for effective prevention to the population and health and social care providers can help to reduce the negative impact.

Moreover, the results coming out of the mortality and YoLL analyses may be useful for further research in the filed of cost-effectiveness of heat related prevention measures in Europe.

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