



Improving public health responses to extreme weather/heat-waves – EuroHEAT

Technical summary



ABSTRACT

EuroHEAT, a project co-funded by the European Commission Directorate-General for Health and Consumers, aimed to improve public health responses to weather extremes and to heat-waves in particular. Climate change is projected to lead to an increase in the frequency and intensity of extreme weather events, including heat-waves. In the European cities analysed in the EuroHEAT project, the estimated excess mortality ranged from 7.6% to 33.6% during heat-wave episodes. Long and intense heat-waves have the most severe health effects. There is growing evidence from EuroHEAT that the effects of heat-wave days on mortality are greater, particularly among the elderly, when levels of ozone or particulate matter are high. A wide range of chronic diseases and medical treatments, social isolation and some types of occupation increase the risk of heat stress in individuals. In European cities, the elderly suffer the greatest effects of heat-waves. Across Europe, housing and socioeconomic conditions showed varying influence on the impacts of heat on health. On the basis of the results generated by the EuroHEAT project, two tools for public health interventions were developed: the web-based climate information support tool and the guidance for heat-health action plans. This document summarizes the overall project results.

Keywords

CLIMATE – adverse effects
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Executive summary

In June 2004, at the Fourth Ministerial Conference on Environment and Health, European ministers of health and the environment recognized that “the climate is already changing and that the intensity and frequency of extreme weather events, such as floods, heat-waves and cold spells, may change in the future. Recent extreme weather events caused serious health and social problems in Europe, particularly in urban areas”.¹ The hot summer of 2003, for example, had higher death rates than previously estimated. Within the Canicule project nearly 45 000 excess deaths were observed in 12 European countries in August 2003.² A ten-year analysis in 15 European cities, carried out as part of the PHEWE³ project, estimated a 2% increase in mortality in northern cities and a 3% increase in southern cities for every 1 °C increase in apparent temperature above the city threshold level.

Despite the greenhouse gas mitigation policies that are now being implemented in Europe, some degree of global climate change is inevitable. As a result, heat-waves are projected to increase in number, intensity and duration over most land areas in the 21st century.⁴ This trend will increase the risk of heat-related mortality and morbidity, especially for the elderly, chronically ill, very young and socially isolated individuals. The project’s general aim is to improve public health responses to weather extremes and to heat-waves in particular.

The key research results, public health recommendations and further actions to be taken can be summarized as follows.

Key research results

Hot weather can cause illness and kill.

There is no standard definition for a heat-wave. In the EuroHEAT project a heat-wave was defined as a period when maximum apparent temperature ($T_{app_{max}}$)⁵ and minimum temperature (T_{min}) are over the 90th percentile of the monthly distribution for at least two days. Applying this definition, during the heat-wave episodes the percentage increase of mortality estimated ranged from 7.6% to 33.6% in nine European cities. Results show a high heterogeneity of the effect between cities and populations.

Heat-waves characterized by long duration and high intensity have the highest impact on mortality. Each heat-wave was also characterized by intensity and duration. The impact of heat-waves characterized by longer duration (more than four days) was 1.5–5 times higher than for short heat-waves. During the 2003 heat-wave the highest impacts were observed in the cities of Paris and London.

¹ WHO Regional Office for Europe (2004). Budapest Declaration (<http://www.euro.who.int/document/e83335.pdf>, accessed 28 March 2008).

² Robine J-M et al. (2008). Death toll exceeded 70 000 in Europe during the summer of 2003. *Comptes Rendus Biologies*, 331(2):171–8.

³ PHEWE: Assessment and Prevention of acute Health Effects of Weather conditions in Europe. Web site: <http://www.epiroma.it/phewe/>.

⁴ IPCC (2007). Summary for policymakers. In: ML Parry et al., eds. *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, Cambridge University Press: 7–22.

⁵ Apparent temperature is a measure of relative discomfort due to combined heat and high humidity. It was developed by RG Steadman in 1979 (The assessment of sultriness. Part II. Effects of wind, extra radiation and barometric pressure on apparent temperature. *Journal of Applied Meteorology*, 18:874–885) on the basis of physiological studies on evaporative skin cooling and can be calculated as a combination of air temperature (Temp) and dew point (Dew) in °C.

There is growing evidence that the effects of heat-wave days on mortality are greater on days with high levels of ozone and fine particulate matter (PM₁₀).⁶ This affects the elderly (75–84 years) in particular and the total daily number of deaths in this age group increased by 16.2% on heat-wave days with high ozone levels and by 14.3% on days with high PM₁₀ levels, respectively, compared to an increase of 10.6% and 10.5% on days with low levels of ozone and PM₁₀. Future heat-wave studies need to adjust for air pollutants in their effect estimates and there is growing evidence that reduction in PM₁₀ and ozone exposure reduces the risk of death.

Some people are more vulnerable to heat stress than others. In the European cities the greatest effects of heat-waves were seen among the elderly and the impact on mortality was greater in women than in men. A range of conditions increase the risk of heat stress in an individual, such as diabetes, fluid/electrolyte disorders and some neurological disorders. However, results between countries tend not to be consistent and a wide range of chronic diseases are implicated.

Global climate change is projected to further increase the frequency, intensity and duration of heat-waves and attributable deaths. For 2030, under a high carbon dioxide emission scenario more than 400 deaths per year due to hot temperatures are expected, for example in Athens, Paris, Rome and Budapest.

Public health recommendations

The adverse health effects of heat-waves are largely preventable through the development and implementation of heat–health action plans at national and regional levels in Europe. These plans aim to prevent, react to and contain heat-related risks to health and they should include measures for long-term prevention, medium-term preparation and short-term emergency measures.

Recommended elements of heat–health action plans are:

- the establishment of collaborative mechanisms between bodies and institutions, and a lead body to coordinate responses;
- an accurate and timely alert system;
- heat-related health information strategies;
- strategies to reduce individual and community exposure to heat;
- improved urban planning, transport policies and building design to reduce energy consumption;
- particular care for “vulnerable” populations;
- provision of health care, social services and infrastructure;
- real-time surveillance, evaluation and monitoring.

Multipurpose collaborative mechanisms need to be established between bodies and institutions and a lead body set up to coordinate responses. Responsibilities and roles should be made clear for actors in the political sphere and in science, health and social professions at the national/regional level. Financial incentives, legislation and synergies with the International Health Regulations and existing national disaster plans could be explored.

Accurate and timely alert systems are essential. Collaboration with meteorological services is needed to develop heat–health warning systems, trigger a warning, determine the threshold for

⁶ Particulate matter with a diameter under 10 µm.

action and communicate the risks. It is important that a heat–health warning system is targeted to local needs. Experiences of various countries should be shared.

A heat-related health information plan is best established in advance. As heat-waves are likely to occur every summer, although in different locations in Europe, it is advisable to have established a communication plan before the start of the summer. It is recommended that this includes advice to people in general on how to protect themselves and others, how to reduce heat exposure indoors, how to recognize heat-related symptoms and who to call for help. It could also include targeted information for particular groups, such as health care institutions and caregivers. The scientific uncertainty around certain measures, such as how much to drink and which drugs interfere with heat, needs to be clarified before giving clear targeted advice.

The most important action during a heat-wave is the avoidance or reduction of exposure. There are multiple ways of reducing individual heat exposure. This includes individual behavioural measures, short-, medium- and long-term housing measures and long-term improved urban planning, building design and transport and energy policies.

Medium-term and short-term options are available for passive cooling. These include cool paints, external shading, radiant barriers and insulation of buildings. Advice should be given on how to best reduce indoor temperatures, with particular attention to pollutant avoidance and measures to avoid electricity shut-offs and reduced water availability.

In the long term, improved urban planning, building design, energy and transport policies will ultimately reduce heat exposure. Building design, urban planning, land-use changes and mitigation of climate change through energy efficiency are highly effective but require political will to be implemented. The fact that there are long lead times before the benefits of these measures are apparent may be an argument in favour of early implementation.

Particular care for vulnerable population groups needs to be provided. It is helpful to identify populations at high risk before the summer and plan and target interventions accordingly. The identification and active care of individuals vulnerable to heat-waves needs to be undertaken at the local level. Community organizations, medical practitioners and care providers play an important role in advising individuals at high risk from heat-related illness and following up people at particular risk.

Provision of health care, social services and infrastructure is important to prevent heat-related illness. This includes summer staff planning, health service provision, infrastructure provision and training of health personnel and other interest groups. It is advisable that care homes and hospitals meet the European Union criteria for the thermal indoor environment in order to prevent heat-related illness in patients and staff. Emergency departments of hospitals could be alerted to heat-waves in order to manage an increase in admissions.

Real-time health surveillance should be incorporated into the planning process. Real-time surveillance is important to detect the early impacts of hot weather, to potentially modify interventions and to share information about abnormal outbreaks or clusters of health impacts. The most useful real-time data seem to be all-cause mortality, emergency calls, emergency department visits, hotlines and general practitioner records, but they need to be available within a maximum of one to two days.

Monitoring and evaluation are essential elements of heat–health action plans. It is important at the end of the summer to evaluate whether the heat–health action plan has worked. This includes the a priori definition of process and outcome criteria. Monitoring health outcomes over time in relationship to heat-waves is another important component.

Within the framework of the EuroHEAT project, the German Weather Service has developed a climate information decision support tool with medium-term heat forecasting.⁷ This tool, which maps the probability of a forthcoming heat-wave, can support health services in planning and in making decisions.

Further actions to be taken

Member States of the WHO European Region can be supported by the WHO Regional Office for Europe in the development and implementation of adaptation measures in relation to health risks from climate change. This can be facilitated through:

- technical advice;
- support for strengthening surveillance systems to better describe climate-related health effects;
- valid and reliable evidence on heat-related mortality and morbidity;
- guidance for the definition of criteria for triggering heat–health interventions;
- options for heat–health preparedness and response;
- information exchange on monitoring and evaluation of public health interventions in the frame of heat–health action plans.

The Regional Office is planning to transform the EuroHEAT web site into an open accessible information platform linked to existing information platforms such as the European Union portal.

A similar exchange of information and best practice will be facilitated for other extreme weather events. These are projected to increase under climate change scenarios in Europe (for example, flooding or drought) and guidance documents will be elaborated in collaboration with Member States of the WHO European Region.

⁷ Web site: <http://www.euroheat-project.org/dwd>.

1. Introduction

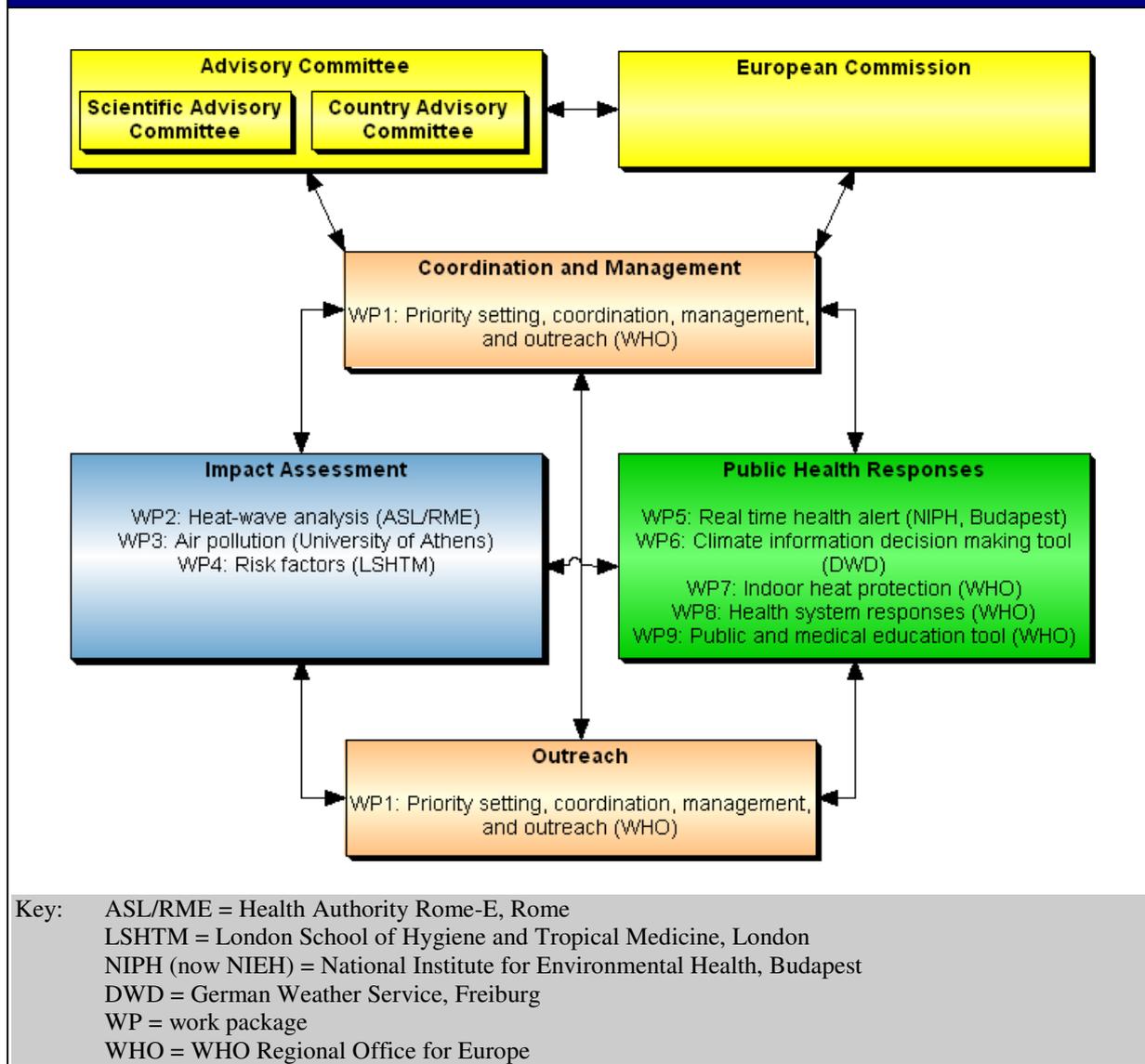
In June 2004, at the Fourth Ministerial Conference on Environment and Health, European ministers of health and the environment recognized that “the climate is already changing and that the intensity and frequency of extreme weather events, such as floods, heat-waves and cold spells, may change in the future. Recent extreme weather events caused serious health and social problems in Europe, particularly in urban areas. These events will continue to pose additional challenges to health risk management and to the reliability of the power supply and other infrastructure. This demands a proactive and multidisciplinary approach by governments, agencies and international organizations and improved interaction on all levels from local to international” (WHO, 2004a). Ministers decided to take action to reduce the current burden of disease due to extreme weather and climate events based on the working paper “Public health responses to extreme weather and climate events” (WHO, 2004b). They invited the WHO Regional Office for Europe, through its European Centre for Environment and Health and in collaboration with other relevant organizations, to support these commitments and to coordinate international activities to this end.

This document summarizes the overall results of the two-year project “EuroHEAT – Improving public health responses to extreme weather/heat-waves”, co-funded by the European Commission and to be published in more detail in the EuroHEAT monograph (Matthies & Menne, in press). The EuroHEAT project had the general aim of improving public health responses to weather extremes and, in particular, to heat-waves. The project was organized in nine work packages (Fig. 1) and the specific objectives of the EuroHEAT project were:

- to share information and data between different networks: cities, national ministries and international organizations, as well as epidemiologists, meteorologists, emergency preparedness planners and decision-makers at European level;
- to identify synergies between exposures to heat stress, risk factors for mortality and morbidity and co-exposure to air pollutants, for the development of Europe-wide information on reducing the health effects of heat stress;
- to develop tools for early warning of extreme weather/heat-waves and detection of effects on health;
- to develop models of good/best practice for national/local preparedness planning for extreme weather events, through the heat-wave example;
- to develop guidance for intervention strategies at European level;
- to communicate the results in a coordinated fashion.

This reflects many of the public health lessons learnt from the European heat-wave in 2003 and actions taken as a result. Among the most important messages is that adverse health effects of hot weather and heat-waves are largely preventable, at least under current climate conditions. Prevention requires a portfolio of actions at different levels, including health system preparedness coordinated with meteorological early warning systems, timely public and medical advice and improvements to housing and urban planning. Many European countries have taken action in this regard, mainly by developing and implementing heat–health action plans. Future years will illustrate how effective these actions have been in preventing heat-related mortality.

Fig. 1. Framework of the EuroHEAT project



This document provides:

- an overview of recent research results regarding the impact of heat on health;
- information for WHO and EU Member States on developing actions to reduce heat-health effects;
- guidance on core elements of heat-health action plans;
- assistance to countries in evaluating actions taken and adjusting action accordingly.

Through the elements elaborated within this project, it is hoped that criteria have been set for the future sharing of good practices as well as for the monitoring of developments and review of achievements.

This work would not have been possible without wide consultation of experts and stakeholders, analyses, country surveys, case studies and literature assessments. This document is mainly

targeted at health decision-makers, health professionals and institutions in charge of developing heat–health action plans.

The following chapters reflect the work on impact assessment as well as the development of public health responses according to the division of work packages.

2. The relationship between temperature and health

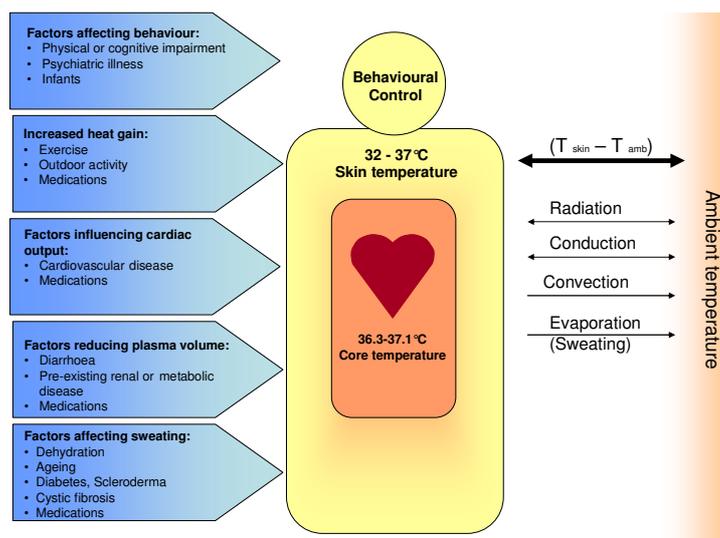
The public health outcomes of hot weather and heat-waves depend on the level of exposure (timing, frequency, intensity and duration of the heat-wave), the size and the demographic profile of the exposed population, population sensitivity (chronic diseases, drug treatment, etc.) and the prevention measures in place. It is therefore not surprising that the relationship between daily weather and health varies between populations and between studies.

In this chapter we describe the relationship between temperature and mortality and the specific effect of heat-waves on health, and investigate the combined effects of heat and air pollution. Vulnerable population groups and risk factors for mortality in heat-waves are identified.

Pre-existing knowledge

Thermophysiology

Fig. 2. Factors affecting human thermoregulation and the risk of heat illness



Source: adapted from Bouchama, 2007.

The normal body temperature range (36.1–37.8 °C) is maintained by the hypothalamus which constantly regulates production and loss of heat. Heat is lost to the environment by radiation, convection, conduction and evaporation of sweat. Conduction, radiation and convection require a temperature gradient between the skin and its surroundings and evaporation entails a water vapour pressure gradient. When the outdoor temperature is higher than the skin temperature, the only heat loss mechanism available is evaporation (sweating). Therefore, any factors that hamper evaporation, such as high ambient humidity, reduced cardiac output, reduced air currents (no breeze, tight fitting clothes) or drugs with anticholinergic⁸ mechanisms, could result in a rise of body temperature that can culminate in life-threatening heatstroke (Fig. 2).

⁸ Anticholinergic drugs are a class of medication that inhibit parasympathetic nerve impulses by selectively blocking the binding of the neurotransmitter acetylcholine to its receptor in nerve cells. Anticholinergic drugs are used to treat a variety of disorders such as gastrointestinal cramps, urinary bladder spasm, asthma, motion sickness, muscular

Thermoregulation during severe heat stress requires a healthy cardiovascular system (Box 1).

Box 1. Thermoregulation during severe heat stress

Excessive heat exposure constitutes a major stress for the organism but particularly for the cardiovascular system. When environmental heat overwhelms the body's heat-dissipating mechanisms, core temperature rises. An increase of less than 1 °C is immediately detected by thermoreceptors disseminated through the skin and deep tissues and organs. The thermoreceptors convey the information to the hypothalamic thermoregulatory centre, which triggers two powerful responses to increase dissipation of heat: an active increase in skin blood flow and initiation of sweating (through cholinergic pathways). The cutaneous vasodilatation results in marked increases in blood flow to the skin and cardiac output, at the expense of other major blood supplies. These cardiovascular adjustments to accelerate the transport of heat from the core to the periphery for dissipation to the surroundings represent a major load on the cardiovascular system. Accordingly, thermoregulation during severe heat stress requires a healthy cardiovascular system. Initiation of sweating results in the production of up to 2 litres per hour of sweat rich in sodium and potassium. This is additional stress on the cardiovascular system if the plasma volume is not properly restored.

Inability to increase cardiac output because of cardiovascular diseases or heart medications that depress the heart will increase the susceptibility to heatstroke and/or cardiovascular failure and death. In addition, inability to increase the skin blood flow because of peripheral vascular diseases (for example, diabetes, atherosclerosis) or medications (for example, sympathomimetics) increases the risk of severe heat illness. Factors that promote excessive fluid loss such as the presence of diarrhoea or febrile illness in the paediatric population, and pre-existing renal or metabolic disease and taking diuretics in the elderly, may increase the risk of heat-related illness and death.

Source: Bouchama et al., in press.

Relationship between temperature and mortality

Populations typically display an optimum temperature at which the (daily or weekly) death rate is lowest. Mortality rates rise at temperatures outside this comfort zone (Fig. 3).

Seasonal patterns in mortality were described as soon as routine data on deaths became available. Studies published in Europe between 1993 and 2003 from several European cities attributed a change of between 0.7% and 3.6% in all-cause mortality to a 1 °C increase of temperature above a certain threshold (Kunst et al., 1993; Ballester et al., 1997; Michelozzi et al., 2000; Basu & Samet; 2002, Hajat et al., 2002, Pattenden et al., 2003).

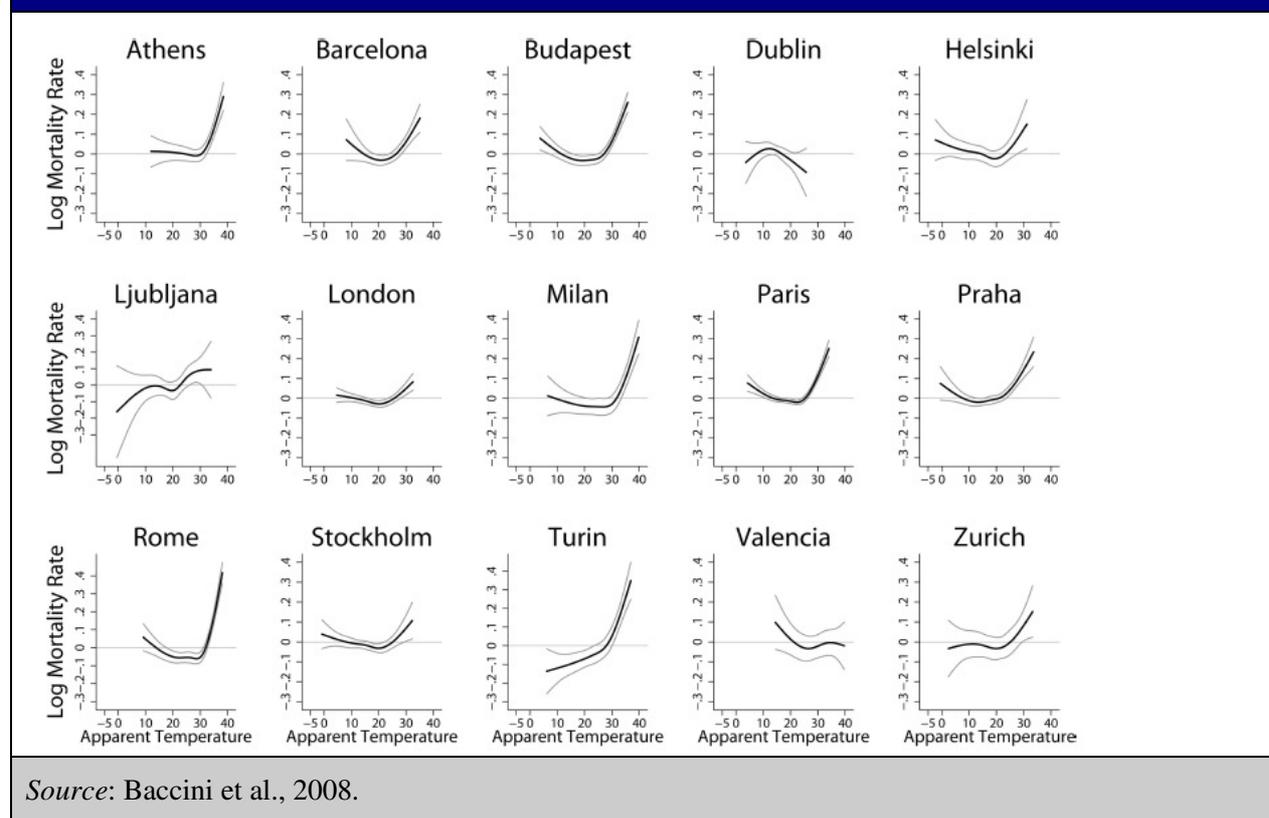
The more recent research project on the "Assessment and Prevention of acute Health Effects of Weather conditions in Europe" (PHEWE) estimated an increase in mortality for every 1 °C increase in apparent temperature above thresholds of 2% (95% confidence interval (CI): 0.06–3.64) in northern cities and 3% (95% CI: 0.60–5.72) in southern cities. The variability in the relationship between the daily maximum apparent temperature ($T_{app,max}$)⁹ (lag 0–3) and natural mortality is shown for 15 European cities in Fig. 3. The strengths of the relationship between daily outdoor temperature and health outcomes differ between countries, between cities and even in the same location from one year to the next. For example, Valencia reports less than a 1% increase in mortality per 1 °C increase in apparent temperature and Athens and Rome observe a

spasms, poisoning with certain toxic compounds and as an aid to anaesthesia. (<http://www.answers.com/topic/anticholinergic?cat=health>, accessed 19 March 2008).

⁹ Apparent temperature is a measure of relative discomfort due to combined heat and high humidity. It was developed by RG Steadman (1979) on the basis of physiological studies on evaporative skin cooling and can be calculated as a combination of air temperature (Temp) and dew point (Dew) in °C.

more than 5% increase (Table 1). The effect of heat was seen within three days of high temperatures (Baccini et al., 2008).

Fig. 3. Regression splines (pointwise 95% confidence bands) describing, on log scale, the adjusted relationship between daily $T_{app,max}$ (lag 0–3) and natural mortality in 15 European cities: Athens, Barcelona (mean apparent temperature), Budapest, Dublin, Helsinki, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia and Zurich



Before 2003, the highest mortality was observed for respiratory and cardiovascular mortality and the PHEWE study confirmed these results. 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 from respiratory causes was observed for both the Mediterranean and the north-continental regions in all ages and the 75+ age group. There is a clear increase in the effect with increasing age.

Table 1. Regional meta-analytic estimates and city-specific estimates of threshold and percent change in natural mortality associated with a 1 °C increase in Tapp_{max} above the city-specific threshold

	Threshold (°C) (95% CrI/CI) ^a	% Change (95% CrI/CI) ^a
Region		
North-continental	23.3 (22.5 to 24.0)	1.84 (0.06 to 3.64)
Mediterranean	29.4 ^b (25.7 to 32.4)	3.12 (0.60 to 5.72)
City		
Athens	32.7 (32.1 to 33.3)	5.54 (4.30 to 6.80)
Barcelona	22.4 ^c (20.7 to 24.2)	1.56 (1.04 to 2.08)
Budapest	22.8 (21.9 to 23.7)	1.74 (1.47 to 2.02)
Dublin	23.9 (20.7 to 27.1)	-0.02 (-5.38 to 5.65)
Helsinki	23.6 (21.7 to 25.5)	3.72 (1.68 to 5.81)
Ljubljana	21.5 (15.0 to 28.0)	1.34 (0.32 to 2.37)
London	23.9 (22.6 to 25.1)	1.54 (1.01 to 2.08)
Milan	31.8 (30.8 to 32.8)	4.29 (3.35 to 5.24)
Paris	24.1 (23.4 to 24.8)	2.44 (2.08 to 2.80)
Praha	22.0 (20.4 to 23.6)	1.91 (1.39 to 2.44)
Rome	30.3 (29.8 to 30.8)	5.25 (4.57 to 5.93)
Stockholm	21.7 (18.2 to 25.3)	1.17 (0.41 to 1.94)
Turin	27.0 (25.2 to 28.9)	3.32 (2.53 to 4.13)
Valencia	28.2 (23.7 to 32.7)	0.56 (-0.35 to 1.47)
Zurich	21.8 (16.5 to 27.0)	1.37 (0.49 to 2.25)

^a95% credibility interval for regional meta-analytic estimates and 95% confidence interval for city-specific estimates.
^bExcluding Barcelona.
^cMean apparent temperature.

Source: Baccini et al., 2008.

Relationship between temperature and hospital admissions

In the United States, there are increases in emergency hospital admissions during heat-waves. In London, no significant excess in admissions was seen during the modest 1995 heat-wave (Kovats, Hajat & Wilkinson, 2004), but an increase in admissions in the 75+ age group was seen in 2003 (Johnson et al., 2005). In France, many hospitals were overwhelmed during the 2003 heat-wave and a number of heatstroke cases were reported (Misset et al., 2006). In Spain, an increase in admissions was seen in 2003. About 40% of patients had heat-related health problems, but no patient was diagnosed as having heatstroke (Villamil Cajoto et al., 2005).

Results from the PHEWE project showed that in Europe the impacts on morbidity in terms of hospital admissions are not consistent with the effect observed on mortality. Higher temperatures do not appear to be associated with a significant increase in admissions for cardiovascular disease, as seen in the United States, while a positive association between high temperatures and hospital admissions for respiratory causes was observed in most of the cities (Michelozzi et al., 2008).

These results suggest that during periods of high temperature many deaths occur rapidly before receiving medical treatment or admission to hospital, and this may be particularly true for acute events which are more common within the cardiovascular diagnostic group (Norris, 1998). These results may be important when planning preventive strategies to reduce heat-related mortality among susceptible population groups.

Heat-waves and human health

The objective of the EuroHEAT study was to estimate the effect of heat-waves on mortality in a subgroup of cities already included in the PHEWE project and others (Athens, Barcelona, Budapest, London, Milan, Munich, Paris, Rome and Valencia), using an integrated and standardized approach to allow comparison of results among the selected cities.

Different research groups have reported different estimates of the number of excess deaths attributable to the European heat-wave of 2003. Well-documented excess mortality was reported in studies, for example, from England and Wales, Italy, Portugal, Spain, the Netherlands, Germany, Belgium and Switzerland (Johnson, Kovats & McGregor, 2005; Pirard et al., 2005; Nogueira et al. 2005; Simón et al., 2005; Garssen, Harmsen & de Beer, 2005; Michelozzi et al., 2005; Sartor, 2004; Sozialministerium Baden-Württemberg, 2004; Grize et al., 2005). In addition, the Canicule study reported nearly 45 000 more excess deaths in August 2003 in 12 European countries compared to earlier years (Robine et al., 2008).

Time series studies provide mean estimates of heat-related mortality for the entire study period, thus suggesting that the effect of individual episodes is underestimated (Hajat et al., 2006). Episode analyses have been employed to provide a better insight into the impact of individual heat-wave events and specific characteristics of the population at risk. The number of excess deaths attributable to the heat-wave is evaluated by a comparison of deaths observed during the episode and the expected mortality baseline (that is, a period before the heat-wave or the same period in previous years) (Basu & Samet, 2002).

Methods

Descriptive analysis of demographic variables, relevant meteorological variables and air pollution levels was performed for Athens, Barcelona, Budapest, London, Milan, Munich, Paris, Rome and Valencia. The mortality data included the daily number of deaths, by gender and age group (0–14, 15–64, 65–74, 75–84, 85–94, 95+ years), from:

- all causes (ICD-9: 1–799)¹⁰
- cardiovascular diseases (ICD-9: 390–459)
- respiratory causes (ICD-9: 460–519)
- cerebrovascular causes (ICD-9: 430–438).

The meteorological data consisted of air temperature, dew point temperature, wind speed and direction, sea level pressure, total cloud cover and precipitation.

The protocol for analysis was based on the PHEWE protocol with appropriate modification in order to deal with heat-waves. The apparent temperature was used to define the days with heat-waves. The relationship between daily mortality and hot weather during the summer period was investigated using Generalized Estimating Equations (GEE) models, considering the following structure:

- period: June–August
- exposure: heat-wave days
- Poisson distribution
- first-order autoregressive structure

¹⁰ ICD refers to the International Classification of Diseases.

- other covariates: calendar months, holidays, day of the week, pollutant (nitrogen dioxide – NO₂) at lag 0–1, wind speed, barometric pressure at sea level (lag 0–3) and linear and quadratic trend.

Heat-wave definition

Heat-waves are rare events that vary in character and impact even in the same location. Arriving at a standardized definition of a heat-wave is difficult. The World Meteorological Organization (WMO) has not yet defined the term. Qualitatively speaking a heat-wave is a “prolonged period with an unusually high heat load”. Within EuroHEAT it was planned to test an operational definition of the term “heat-wave” within nine European cities, in order to better understand which types of heat-wave do have an effect on human health. The qualitative definition of a “prolonged period with an unusually high heat load” does not provide an indication as to what is meant by “prolonged” and what is meant by “high heat load”. Therefore a small working group created within EuroHEAT decided to test the following heat-wave definitions for epidemiological analysis:

- the 90th percentile of the daily distribution of $T_{app_{max}}$;
- the 90th percentile of the daily distribution of $T_{app_{max}}$ and the 90th percentile of the daily distribution of minimum temperature (T_{min}).

Each heat-wave was also categorized by duration, intensity and time interval between different heat-waves (Table 2).

Table 2. Definition of heat-wave characteristics used in the EuroHEAT project

Characteristic	Definition
Duration based on median value	short: if duration \leq median value long: if duration $>$ median value
Intensity based on number of days with extreme values for $T_{app_{max}}$	low: if $T_{app_{max}} \leq$ monthly 95th percentile high: if $T_{app_{max}} >$ monthly 95th percentile
Time interval between heat-waves	1st category: 0 days = 1st heat-wave 2nd category: 1–3 days 3rd category: $>$ 3 days

These definitions were tested on the time series data available from the nine participating European cities.

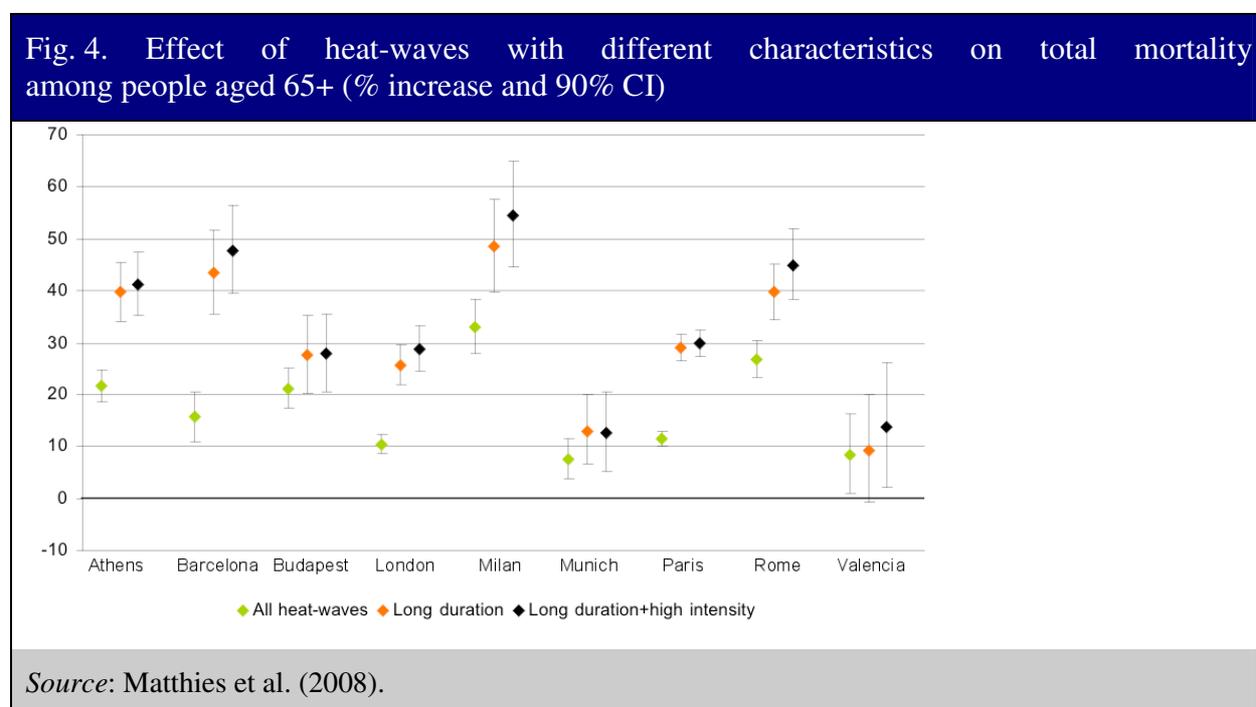
Results

Heat-wave exposure was modelled using the operational heat-wave definition established. Consequently, “heat-wave days” were identified as days in which $T_{app_{max}}$ exceeds the threshold value (90th percentile of the city-specific monthly distribution) for at least two days or days in which T_{min} exceeds its correspondent threshold value (90th percentile of the city-specific monthly distribution) and at the same time $T_{app_{max}}$ is higher than its median value. In order to investigate more in detail the characteristics of different heat-waves, the duration, intensity and time interval between different heat-waves are also considered in the analysis.

In each model the basic effect of the heat-wave on mortality and the effect of the heat-wave combined with duration, intensity and time interval between different heat-waves were investigated, using the definitions given in Table 2.

All values are city-specific and refer to all heat-wave days included in the available time series. From this model the effect of heat episodes was estimated in terms of percentage variation in mortality compared to days without heat-wave. In each city, sociodemographic characteristics of the population were considered as potential effect modifiers and separate models for gender and different age groups are considered. The role of air pollutants is described below.

The results indicate that high values of both $T_{app_{max}}$ and T_{min} were associated with an increase in mortality and the impact of heat-waves characterized by longer duration was 1.5–5 times higher than for short heat-waves (Fig. 4). The heat-wave effect was stronger in the elderly. The highest increase was observed in Athens, Budapest, London, Rome and Valencia, in persons in the 75+ age group. In all cities, females were at higher risk than males. In the EuroHEAT study, heat-waves of higher intensity and duration were generally more dangerous. Moreover, the first heat-wave of the summer appeared to be more dangerous in only some cities (Athens, Budapest and Munich). For subsequent heat-waves, those occurring after a short time interval generally had less effect than those occurring after three or more days (Michelozzi et al., 2008).



Interaction between heat and air pollution

Air pollution is often worse during a heat-wave. Hot, calm weather conditions during a heat-wave tend to worsen air pollution as well. Because hot weather and air pollution often coincide, it can be difficult to separate the effects of the two exposures. One possibility is that the effects of heat and air pollution are essentially equivalent to the effect of the two exposures occurring separately (an additive effect). Alternatively, it is plausible that there might be a greater than additive effect of simultaneous exposures to air pollution and heat. To better assess the potential impact of current climate change scenarios on human health, it is necessary to understand not only the independent effects of temperature and other meteorological variables (adjusting for confounders, including pollutants), but also to elucidate any synergistic effects between meteorology and air pollution. It is reasonable to hypothesize that any such effects will become more important under the extreme conditions that could occur in the future due to greater climate instability. The EuroHEAT project carried out a literature review (Kosatsky et al., in press) and a separate city-specific assessment of the relationship between heat-waves and air pollution (Analitis & Katsouyanni, in press).

Literature review

There is an abundance of literature on the short-term effects of air pollution and of meteorological variables on human health. However, literature on the topic of potential interactions between temperature and other meteorological variables on the one hand, and air pollutants on the other, remains very sparse. In this chapter a summary of the current evidence pointing towards interactions between these two environmental factors is given (Kosatsky et al., in press).

Methods

Details of the methods used, such as the databases, search terms and inclusion and exclusion criteria of the literature review are described in Box 2.

Box 2. Search strategy for the literature review on the interaction between heat and air pollution

Databases

Ovid MEDLINE(R) 1966 to June Week 4 2005

Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations July 05, 2005

Biological Abstracts/RRM 1992 to 2002

Biological Abstracts 2002 to June 2005

Current Contents/All Editions 1993 Week 27 to 2005 Week 28.

Search terms and logical expression (? and \$ denote wildcards)

heat-wave? or heatwave? or (heat wave?) OR heat or hot\$ or warm\$ or (high\$ temperature?)

AND temperature? or weather or meteorolog\$ or climat\$ or season\$ AND (air pollut\$) or (atmospheric pollut\$) or “air quality” or ozone OR (particles OR particulate) and pollut\$

AND health or morbidity or mortality or death? or admission? or consult\$ or disease? or disorder?

Exclusion criteria

There is an abundance of literature on the short-term effects of air pollution and of meteorological variables on human health (WHO, 2004c, Curriero et al., 2002; Dematte et al., 1998; Diaz et al., 2002; Keatinge & Donaldson, 2001; Keatinge et al., 2000) and these will not be reviewed here.

Inclusion criteria

Air pollution studies with seasonal or cross-city effects, formal studies of interactions.

Source: Kosatsky et al., in press.

Table 3. Studies estimating the interactive or synergistic effects of meteorological variables and various pollutants on mortality

Reference	Study period	Location	Days included	Exposure (meteorological and pollution variables)	Outcome	Main result
Katsouyanni et al. (1993)	1983–1987	Athens, Greece	March – September	Temperature; relative humidity; Thom’s index; ozone; black smoke; SO ₂	Total mortality	Evidence for positive interaction between heat and pollution
Sartor et al. (1995)	1985–1994	Belgium	May 15 – September 15	Temperature; relative humidity; TSP; SO ₂ ; NO; NO ₂ ; ozone	Total mortality 0–64yrs and 65+ yrs	Evidence for positive interaction between heat and ozone
Sartor et al. (1997)	1994	Belgium	May 15 – September 15	Temperature; relative humidity; ozone	Total mortality 65+ yrs	Evidence for positive interaction between heat and ozone
Morris & Naumova (1998)	1986–1989	Chicago, United States	All days	Temperature; relative humidity; CO; PM ₁₀	Hospital admissions for congestive heart failure	Evidence for interaction of high CO concentrations and low temperature
Piver et al. (1999)	1980–1995	Tokyo, Japan	July and August	Daily temperature (max); NO ₂ ; ozone	Heat stroke emergency transport cases	Lag 0 temperature and NO ₂ were important risk factors, but interaction terms not nominally significant
Hales et al. (1999)	1988–1993	Christchurch, New Zealand	All days	Temperature (min/max); hot; cold; SO ₂ ; NO _x ; CO; PM ₁₀	Total, cardiovascular, respiratory mortality; total 65+ yrs	No evidence for interaction between temperature and PM ₁₀
Smoyer et al. (2000)	1975–1988 1974–1988	Philadelphia, Birmingham, Alabama, United States	June 1 – August 31	TSI; ozone; TSP	Total mortality	Inconsistent results
Roberts (2004)	1987–1994	Cook County & Allegheny County, United States	All days	Temperature; dew point temperature; PM ₁₀	Non-accidental mortality 65+ yrs	Evidence for interaction of PM ₁₀ and temperatures above the 10th percentile. For low temperatures results are inconsistent
Parodi et al. (2005)	1993–1996	Genoa, Italy	All days and May – October	Temperature; relative humidity; ozone	Non-accidental and cardiovascular mortality; all ages and 75+ yrs	Evidence for positive interaction between heat and ozone effect on cardiovascular disease mortality especially for 75+ yrs
Ren, Williams & Tong (2006)	1996–2001	Brisbane city, Queensland, Australia	All days	Temperature (min); relative humidity; rainfall; PM ₁₀ ; ozone	Respiratory and cardiovascular visits and admissions; natural and cardiovascular number of deaths	Evidence for interaction of high PM ₁₀ and high temperatures on mortality and weaker evidence for admissions.

Key: SO₂ = sulfur dioxide; TSP = total suspended particles; NO = nitrogen oxide; NO₂ = nitrogen dioxide; NO_x = nitrogen oxides; CO = carbon monoxide; PM₁₀ = fine particulate matter with a diameter under 10 μm; TSI = temporal synoptic index.

Results

Several studies (from Europe, the United States and Canada) have found that ozone effects are higher during the summer (Kosatsky et al., in press). This may be explained by the higher ozone concentrations observed during the summer combined with non-linear responses; or by a higher population exposure, as people spend more time outdoors in summer; or as an interactive effect. One result that appears with some consistency is the evidence for a synergistic effect between high temperatures (these studies all included extreme heat-wave periods in their data series) and ozone concentrations on total mortality and deaths due to cardiovascular diseases (Table 3).

Heat-wave/air pollution analysis

Since both meteorological variables and the concentrations of air pollutants vary on a daily basis, it is reasonable to address their mutual confounding as well as the possible synergistic effect they may have on health (Katsouyanni et al., 1993; Samet et al., 1998; O'Neil, Zanobetti & Schwartz, 2003). However, although it has been usual practice to adjust for meteorological variables (mainly temperature and humidity) when analysing the effects of air pollution, the adjustment for air pollutants when assessing the temperature effects has not been common. Furthermore, the studies formally addressing the synergy between pollutants and meteorological variables are relatively few.

Methods

In addition to the data collected for the analysis of the relationship between temperature and human health the air pollution data included gaseous and particulate pollution indicators and, specifically, SO₂ (mean 24-hours), TSP or black smoke (mean 24-hours), PM₁₀ (mean 24-hours), PM_{2.5} (with a diameter under 2.5 µm), if available (mean 24-hours), NO₂ (maximum 1-hour, mean 24-hours), ozone (maximum 1-hour, maximum 8-hours moving average), carbon monoxide (CO) (maximum 8-hours moving average).

The methods used are similar to those implemented in the PHEWE project, described in Michelozzi et al. (2007) and Baccini et al. (2008). Here, air pollutants were adjusted for in each model alternatively. The heat-wave effect was estimated firstly without adjusting for pollution and then after adjustment for each pollutant, in order to assess the magnitude of confounding. For the investigation of interaction between heat-wave and pollutant effects, an interaction term between heat-wave and each pollutant separately was introduced in the model and the effect of heat-wave days was estimated during “high” and “low” pollution days. As “low” pollution days we have defined the days at the 25th percentile of the overall pollutant distribution across all cities and as “high” pollutant days those at the 75th percentile.

Results

There is increasing evidence for a synergistic effect on mortality between high temperatures and ozone concentrations. Analyses of daily mortality, meteorological and air pollution data from nine European cities (1987–2004) in EuroHEAT confirmed that the effects of heat-wave days are much larger for older age groups, and this remains after adjusting for air pollutants (Analitis & Katsouyanni, in press). The effects of heat-wave days on mortality were greater when ozone or PM₁₀ levels were higher, particularly among the elderly (75–84 years). The total daily number of deaths in this age group increased by 16.2% on heat-wave days with high ozone levels and 14.3% on days with high PM₁₀ levels, respectively, compared to an increase of 10.6% and 10.5% on days with low levels of ozone and PM₁₀ (Fig. 5 and Fig. 6). The effects of heat-wave days with high ozone levels were less evident for those people in the 85+ age group (Fig. 5). The fact that the interaction appears less for those in the 85+ age group may be a result of them spending more time indoors where ozone is much lower.

Fig. 5. Percent increase in the total daily number of deaths in days with a heat-wave and a “low” or “high” level of ozone, adjusting for barometric pressure, wind speed, calendar month, day of the week, holiday and time trend (results from random effects meta-analysis)

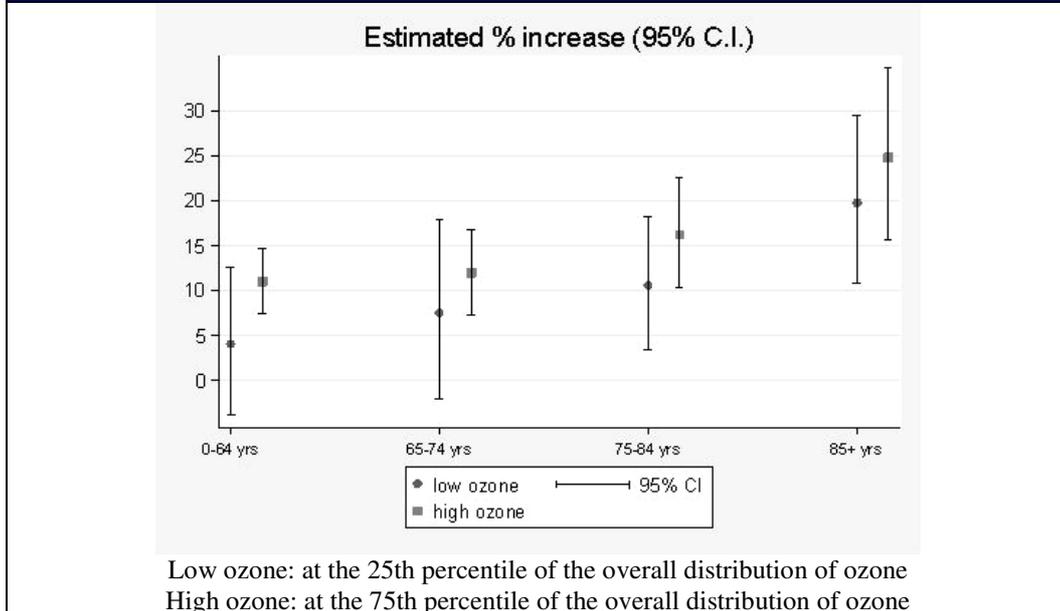
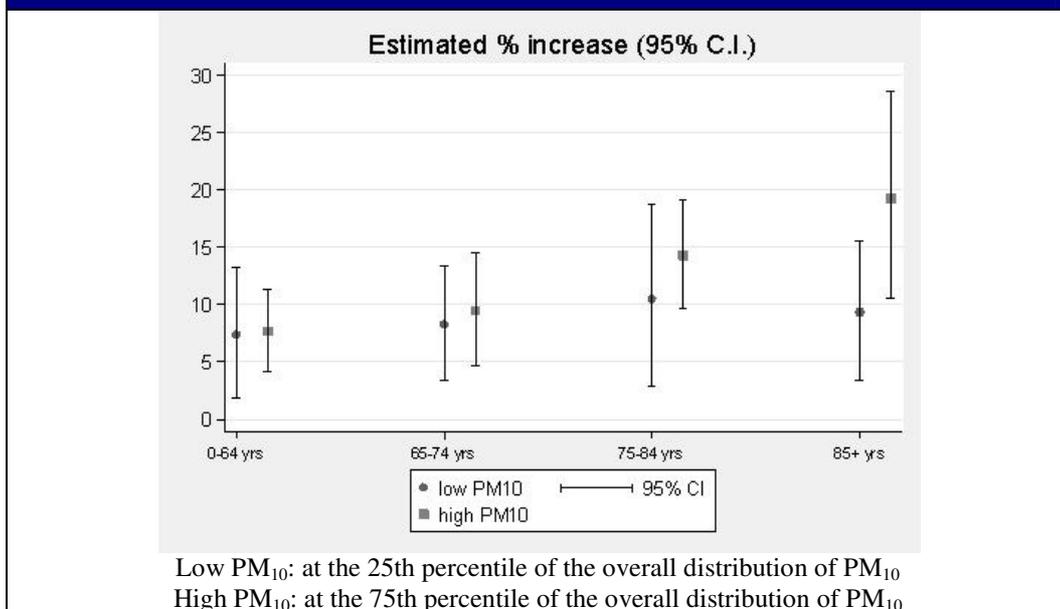


Fig. 6. Percent increase in the total daily number of deaths in days with a heat-wave and a “low” or “high” level of PM₁₀, adjusting for barometric pressure, wind speed, calendar month, day of the week, holiday and time trend (results from random effects meta-analysis)



Similar but less pronounced differences have been found for other pollutants (PM₁₀, black smoke, NO₂, SO₂). Using data from 21 European cities, it was found that PM₁₀ effects were higher in warmer cities. The mortality increase per 10µg/m³ of PM₁₀ was 0.3% in cooler cities and 0.8% in warmer cities. When adjusting for PM₁₀, the estimates of heat-wave effects on

mortality were reduced by about 30% and when adjusting for ozone they were reduced by about 15–25% (depending on the age group). The fact that, in contrast to ozone exposure, the interaction here seems to affect the elderly as well might be explained by the high penetration of PM indoors (Fig. 6). There was no evidence of confounding or interaction between heat-wave days and the concentrations of NO₂, SO₂ or CO (Analitis & Katsouyanni, in press).

From these findings it seems necessary that every effort should be made to keep levels of ozone and PM as low as possible during high temperature periods.

Future city estimates of attributable deaths for 15 European cities

Researchers in the PHEWE project were interested in understanding to what extent attributable deaths could be expected in future years on the basis of scenarios of heat exposure (M Baccini, T Kosatsky & A Biggeri, unpublished data, 2008). In the EuroHEAT project, temperature projections that were used for calculating the future impact of heat-waves come from the Intergovernmental Panel on Climate Change special report on emissions scenarios (SRES) (IPCC, 2000).

Methods

In the PHEWE study (M Baccini, T Kosatsky & A Biggeri, unpublished data, 2008), the impact of high apparent temperature on mortality was quantified in terms of attributable number of deaths. It was assumed that all the population was exposed to the same daily $T_{app_{max}}$. According to the model adopted in PHEWE it was assumed that increases in $T_{app_{max}}$ under a city-specific threshold did not affect health and that the effect was linear above the threshold. The Monte Carlo approach¹¹ was used to estimate uncertainty in relation to the city-specific effects of heat. For each city, researchers sampled 10 000 values from the city-specific posterior distributions of the slope and from the city-specific posterior distributions of the threshold obtained from the Bayesian meta-analysis. Then, for each sample (b_c , h_c), a time series of daily number of attributable deaths was calculated from the observed time series of daily $T_{app_{max}}$ at lag 0–3 (T_t) and the observed time series of daily number of deaths (Y_t). As a result of the Monte Carlo procedure, for each city a 10 000 time series of attributable deaths was obtained. Researchers were interested in the distribution of the number of attributable deaths by calendar day or by season. Separate attributable death evaluations were obtained by age group (15–64, 65–74, 75+). For each city, the total number of attributable deaths was produced by adding these over the three age groups. We assumed independency between threshold and slope, but in a sensitivity analysis different levels of correlation were assumed, leading to similar results (not described here).

For each city, four different scenarios were defined by selecting exposure and mortality within the range of data observed. Two extreme scenarios consisted of a six-month daily time series of apparent temperature and corresponding baseline mortality selected over all the observed years, for each day and month:

- scenario S1: the second hottest day;
- scenario S2: the second coldest day.

For example, for the first scenario (S1) corresponds to a hypothetical summer composed of the second hottest 1 April, the second hottest 2 April ... the second hottest 30 September.

¹¹ A Monte Carlo simulation is one of many methods that allow the “translation” of uncertainties in the variables of a model into probability distributions. The production of independent random numbers generated from probability distributions, just like a game of chance in a casino, is a characteristic of this kind of simulation.

Two further scenarios were defined:

- scenario S3: the summer characterized by the highest mean level of apparent temperature;
- scenario S4: the summer characterized by the lowest mean level of apparent temperature.

These four scenarios were used for evaluating the impact of heat during summers hypothetically warmer and cooler than the observed ones.

Building on the methodology of the PHEWE study, future impacts of heat were estimated for temperature projections from the SRES of the Intergovernmental Panel on Climate Change (IPCC, 2000). These scenarios are defined on the basis of different future levels of greenhouse gas emission to which different projected levels of warming are associated.

We considered three different scenarios:

- scenario B2 (low emission scenario): best estimate of the temperature change equal to 1.8 °C at 2090–2099 relative to 1980–1999;
- scenario A1B (middle emission scenario): best estimate of the temperature change equal to 2.8 °C at 2090–2099 relative to 1980–1999;
- scenario A2 (high emissions scenario): best estimate of the temperature change equal to 3.4 °C at 2090–2099 relative to 1980–1999.

With the aim of obtaining projections of heat impact for 2030, a constant rate of change was assumed over the 1999–2099 period and for each scenario the attributable number of deaths was calculated, adding to each observed daily apparent temperature (T_t) the corresponding projected average temperature change (ΔT).

Results

The average number of attributable deaths observed during the study period varied from 0 in Dublin to 423 per summer in Paris. Large variability affected the results, the size of the 80% credibility intervals being frequently larger than 50% of the mean. Under the second coldest day scenarios (S2), the number of attributable deaths strongly decreased. Less extreme results were obtained considering the coldest year among the observed ones (scenario S4). In this case, the percentage of saved deaths ranged from 0 to 26%, the only exception being Paris (66%). The second hottest day scenario (S1) and the hottest year scenario (S3) produced sometimes very different impacts (see, for example, Budapest, Paris and Rome). For comparison purposes, for each city, the expected number of attributable deaths per year over total number of inhabitants (10 000) was calculated under the observed scenarios and in the coldest and in the hottest summer (S3, S4). We did not observe impacts larger than 3 attributable deaths per year per 10 000 inhabitants. The highest impact rates were found in four Mediterranean cities (Barcelona, Rome, Turin and Valencia) as well as in Paris and Budapest (M Baccini, T Kosatsky & A Biggeri, unpublished data, 2008).

The pattern of the average daily number of attributable deaths over the warm season was also studied (A Biggeri, unpublished data, 2008). For most cities, attributable deaths are concentrated during the hottest months (July–August). A moderate impact was observed also during June. Projections for the year 2030 under the SRES scenarios are reported in Table 4. Differences among the three proposed scenarios are not very large. It is interesting to note that usually the number of attributable deaths under the SRES scenarios is lower than the number of attributable deaths calculated for the observed hottest year (scenario S3).

Table 4. Actual impact of heat and projections for 2030 of the average number of attributable deaths per year (80% credibility intervals) calculated under the B1, A1B and A2 SRES scenarios, by city

City		B1 $\Delta T=0.54$	A1B $\Delta T=0.84$	A2 $\Delta T=1.02$
Athens	230 (172, 290)	316	376	415
Barcelona	290 (212, 374)	319	338	350
Budapest	399 (346, 463)	457	490	511
Dublin	0 (0, 1)	0	1	1
Helsinki	11 (6, 17)	14	17	18
Ljubljana	13 (1, 34)	13	15	15
London	142 (99, 185)	183	206	220
Milan	95 (70, 123)	116	130	139
Paris	423 (57, 488)	500	546	574
Prague	72 (53, 92)	84	93	98
Rome	388 (339, 440)	470	520	552
Stockholm	21 (13, 30)	19	21	22
Turin	121 (80, 168)	136	148	156
Valencia	72 (29, 123)	56	59	61
Zurich	29 (18, 41)	32	35	37

Source: A Biggeri, unpublished data, 2008.

Social determinants of heat-related mortality

The public health outcomes of heat-waves depend on the level of exposure (timing, frequency, intensity and duration of the heat-wave), the size and the demographic profile of the exposed population, population sensitivity (chronic diseases, drug treatment, etc.) and the prevention measures in place.

A literature review of the epidemiological studies on heat-related mortality was undertaken. A meta-analysis of case-control studies for heat-related risk factors is also described.

Review of the epidemiological evidence

The scientific evidence base for the social and environmental determinants of heat-related mortality is still limited, although much is known about the physiological basis for adverse health effects. In this work package we reviewed the epidemiological literature on heat and heat-wave impacts. The studies, from both Europe and North America, related to a range of heat

exposures, including the impact of individual heat-wave events, heat-related mortality and recognized heatstroke deaths.

Results were summarized for key vulnerability factors.

- The greatest effects of heat and heat-waves were in the elderly but effects are also apparent for adults and children.
- The effect of heat and heat-waves appears to be greater in women than in men in Europe and the effect on women is most apparent in the elderly. However, the cause of this difference is not understood and may be due to both social and physiological factors.
- Clinical and physiological evidence indicates a range of conditions that increase the risk of heat stress in an individual. The epidemiological evidence for certain medical conditions as risk factors for mortality in heat-waves is less clear, but a range of serious conditions are indicated: diabetes, fluid/electrolyte disorders and some neurological disorders (see Table 5). However, results between countries are not very consistent and a wide range of chronic diseases are implicated, which is consistent with the limited information on the pathophysiology of heat.
- Hospital inpatients and nursing home residents are at higher risk of heat-related mortality despite being under the care of professionals.
- There is very little information on how housing quality and characteristics may modify the heat–mortality relationships. There is also no information on the benefits of air conditioning in relation to mortality risk in Europe, which is unsurprising given the current low coverage of this intervention.

Table 5. Chronic conditions that increase risk of heat mortality (epidemiological evidence)

Group	ICD-10 chapter
Diabetes mellitus, other endocrine disorders	E10–E14
Organic disorders mental disorders, dementia, Alzheimer’s	F00–F09
Mental and behavioural disorders due to psychoactive substance use, alcoholism	F10–F19
Schizophrenia, schizotypal and delusional disorders	F20–F29
Extrapyramidal and movement disorders (e.g. Parkinson’s disease)	G20–G26
Cardiovascular diseases, hypertension, coronary artery disease, heart conduction disorders	I00–I99
Diseases of the respiratory system, chronic lower respiratory disease (e.g. chronic obstructive pulmonary disease, bronchitis)	J00–J99
Diseases of the renal system, renal failure, kidney stones	N00–N39

Source: Kovats & Hajat, 2008.

Results

There is some limited evidence that lower income groups in urban areas were more at risk of heat-wave related mortality in August 2003, but many studies also show that there is no modification of the temperature–mortality relationship by socioeconomic status. Therefore, it is not clear that poor urban populations are more at risk from heat-related mortality in Europe.

In the United States there is good evidence that people of lower socioeconomic status are at increased risk of heat death during a heat-wave. Some European studies report no apparent effect of socioeconomic status. A study in Italian cities used level of education as an indicator as it is available on individual death certificates. Excess mortality in Rome during the summer of 2003 was 6% in persons with the highest level of education and 18% in persons with the lowest level of education, and a similar pattern was observed in Milan (Michelozzi et al., 2005).

It was also apparent that excess mortality was greater in single persons (that is, those not married or cohabiting) and this was most apparent for men. Two studies from France, during the heat-wave of 2003, report that the mortality of widowed, single and divorced subjects was greater than that of married people. This may indicate that individuals with less social support were more at risk. Four case-control studies reported that increased social contact was a protective factor. The effects of social isolation or the role of social networks in coping with hazards is not straightforward and requires further research (Kovats & Hajat, 2008).

Meta-analysis study

Methods

A meta-analysis of case-control studies looking at risk and protective factors for heat-wave mortality was performed (Bouchama et al., 2007). A computerized literature search on the Medline database covering the period from January 1966 to March 2006 was carried out according to the strategy described in Box 3.

Box 3. Search strategy for risk and protective factors for heat-related health problems

Databases

Medline database, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane database and web pages of the European Centre for Environment and Health (WHO Regional Office for Europe), the Institut National de Veille Sanitaire (INVS) and the Centers for Disease Control and Prevention (CDC).

Search terms

heat wave, heat stroke, heatstroke, sunstroke, and heat stress disorders.

Inclusion criteria

Preventive studies: case-control or cohort studies which analysed the risk and protective factors in heat-wave-related fatalities and general odds ratio (OR) and 95% CI.

Exclusion criteria

Studies reporting only physiological, biochemical and/or immunological end-points (clinical chemistry, hormones, cytokine levels, immune cell responses)

Heat stress disorders, such as occupational or induced whole body hyperthermia

Reviews, case reports and case series of less than seven patients

Experimental studies using normal volunteers or animal models.

Source: Bouchama et al., 2007.

Results

Eligible studies were case-control or cohort studies. Six case-control studies comprising 1065 heat-wave-related deaths were identified.

Social precariousness and poor general health were associated with the highest risk of dying during a heat-wave (Table 6).

The meta-analysis has some limitations, however. As the findings of a meta-analysis depend on the methodology and design of the individual studies, their potential biases may affect the pooled estimate of the odds ratios. Surrogate postmortem reports may be inaccurate and case definitions may be different leading to misclassification or weighting of risk factors. The difference in geographic locations (United States and France) may have led to the heterogeneity in results due to different ethnic and social backgrounds. Nevertheless, the analysis gave important insights which could be useful for targeting and for formulating recommendations for the prevention of heat-wave-related mortality and morbidity. Areas for further research, for example on the intake of fluid and the use of electrical fans, could also be identified. The results of the systematic reviews on first aid for life-threatening heatstroke are shown under the section on treatment of heat-related illness and heatstroke.

Table 6. Risk and protective factors for dying in a heat-wave

Risk factor	Odds ratio (OR)	95% CI
Being confined to bed	6.44	4.5–9.2
Not leaving home daily	3.35	1.6–6.9
Unable to take adequate self-care	2.97	1.8–4.8
Pre-existing cardiovascular condition	2.48	1.3–4.8
Pre-existing pulmonary condition	1.61	1.2–2.1
Pre-existing psychiatric condition	3.61	1.3–9.8
Having working air conditioning at home	0.23	0.1–0.6
Visiting cool environments	0.34	0.2–0.5
Increasing social contact	0.40	0.2–0.8
Taking extra showers or baths	0.32	0.1–1.1
Use of electric fans	0.60	0.4–1.1

Source: Bouchama et al., 2007.

Drugs that increase the risk of heat illnesses

Dehydration, drugs with anticholinergic properties, ageing and chronic diseases, as well as their treatment, can considerably increase the risk of hyperthermia and heatstroke.

Methods

A computerized literature search was performed on the Medline database, covering the period from January 1966 to March 2006. The search was also performed on the CINAHL database for the period 1982 to 2006, as well as the Cochrane database using the OVID interface. The researchers also visited the web pages of the European Centre for Environment and Health (WHO Regional Office for Europe – www.euro.who.int), the INVS (www.invs.sante.fr/display/?doc=surveillance/canicule/alerte.htm) and the CDC (www.bt.cdc.gov/disasters/extremeheat/index.asp). Guidelines on health interventions in heat were examined and cross-checked for references used to establish the guidelines. The bibliography of retrieved articles was also checked. The search was limited to human studies without language restriction, using the following medical subject headings (MeSH): heat stroke, sunstroke, heatstroke and heat stress disorders (Bouchama et al., in press). Review of existing European heat–health action plans (for example, from Lazio (Italy), England or France), consultation with experts and involvement of the European Medicines Agency (EMA) resulted in an overview of medications that can either affect thermoregulation or aggravate heat illness (Bouchama et al., in press; Matthies et al., 2008).

Results

Medications that increase the risk of heat illness

Many medications can directly affect the central and peripheral mechanisms of thermoregulation, namely the thermoregulatory centre or afferent and efferent pathways, sweating, cutaneous vasodilatation and/or an increase in cardiac output and thereby heat elimination (Ellis, 1976; Vassallo & Delaney, 1989; Martinez et al., 2002).

Anticholinergics are present in several widely used medications, such as antihistamine, antipsychotic, antispasmodic, antidepressant and antiparkinson preparations (Hahn, 1975; Schwartz, 1976; Ducrot et al., 1979; Caldrony, 1981; Lefkowitz et al., 1983; Adubofour et al., 1996; Albukrek, Moran & Epstein, 1996; Martinez et al., 2002; Kerwin, Osborne & Sainz-Fuertes, 2004), and they are potent inhibitors of sweating.

Antipsychotics, in addition to their peripheral effects through the cholinergic pathway, interfere with the thermoregulatory centre and afferent pathways to the hypothalamus, slowing efferent responses, namely cutaneous vasodilatation, and thereby reducing heat elimination. Both conventional (haloperidol, chlorpromazine) and atypical antipsychotic medications (clozapine) have been implicated (Ducrot et al., 1979; Lefkowitz et al., 1983; Martinez et al., 2002; Kerwin, Osborne & Sainz-Fuertes, 2004; Kwok & Chan, 2005).

Sympathomimetics increase heat production by increasing motor activity while reducing heat dissipation via peripheral vasoconstriction and decrease of cutaneous blood flow. Drugs with sympathomimetic effects include the over-the-counter nasal decongestants (ephedrine, pseudoephedrine, phenylephrine), appetite-suppressing drugs, amphetamines and cocaine (Kew, Hopp & Rothberg, 1982; Martinez et al., 2002; Kraemer, Armstrong & Watson, 2003).

Medications that can aggravate heat illness

Medications such as nitrates and calcium channel blockers used pharmacologically as a vasodilator, for instance in angina pectoris or hypertension, can theoretically precipitate

hypotension in people who tend to be dehydrated during excessive heat exposure, particularly the elderly.

Effects of heat exposure on the toxicity and/or efficacy of medication

Dehydration and changes in blood volume distribution associated with excessive heat exposure and the thermoregulatory response can influence drug levels, their kinetics and excretion and hence their pharmacological activity (Weihe, 1973). This may enhance their toxicity, especially those drugs with a narrow therapeutic index, such as digoxin or lithium.

High ambient temperatures can adversely affect the efficacy of drugs, as most manufactured drugs are licensed for storage at temperatures up to 25 °C (Crichton, 2004). This is particularly important for emergency drugs used by practitioners, including antibiotics, adrenalins, analgesics and sedatives.

3. Preventing heat-related health effects

The adverse health effects of heat-waves are largely preventable. Prevention requires a portfolio of actions at different levels: from health system preparedness coordinated with meteorological early warning systems to timely public and medical advice and improvements to housing and urban planning. These actions can be integrated in a defined heat–health action plan. Many European countries have taken action mainly by developing and implementing heat–health action plans. The EuroHEAT project identified the common core elements of heat–health action plans and these are described in more detail in the following sections of this chapter.

Survey of existing heat–health action plans in Europe

Methods

A survey was carried out to collect information on existing heat–health action plans in Europe (Matthies & Menne, 2009). For this purpose a questionnaire was administered to selected health officials in charge of functional heat–health action plans in 2006. Questionnaires were sent out on the basis of the pre-existing WHO network on heat and health that was established in the course of previous projects, such as cCASHh (climate Change and Adaptation Strategies for Human health in Europe). They were also sent to respondents to an earlier survey on heat and health (T Kosatsky, personal communication, 2007), during which 51 Member States of the WHO European Region were contacted in 2004. For the EuroHEAT questionnaire survey only countries that had established a functional heat–health action plan were selected. The questionnaire, asking for key characteristics of existing and functional heat–health action plans, was sent to seven countries. Completed questionnaires were received from Catalonia (Spain), England, France, Hungary, Italy, Portugal and 10 of the federal states of Germany. Personal communications on the status of heat–health action plan development were received from Slovenia, Slovakia and Lithuania and a report on the existing heat–health system from Israel. Further information was obtained on heat–health action plans from Belgium and Switzerland and, later on during the course of the project, from Luxembourg and the Netherlands (as the national plan was developed). This information was used in particular for the comparison of public health information and advice (see section on “Provision of health care, social services and infrastructure”). Common characteristics of heat–health action plans were identified from the completed questionnaires. In addition, a (non-systematic) literature review was conducted searching for descriptions of heat–health action plans and related documents on the Internet, for example on web sites of national ministries and departments of health. A meeting with eight external experts was organized in December 2006 in Rome to discuss the preliminary results of the survey and to identify core elements of heat–health action plans. In an iterative process, an expert group subsequently developed the guidance for heat–health action plans from all available results (Matthies et al., 2008).

Results

Lead agency and administrative level

The majority of the investigated existing heat–health action plans are organized at a national level (England, France, Portugal and Hungary) with regional components, while some others are implemented on a regional and local level (Catalonia, Rome/Lazio (Italy) and various federal states in Germany). Almost all systems were initiated and designed by the Ministry or Department of Health (lead agency) and all had an official link to the national meteorological services. The systems in Italy, France and Hungary had a legal basis (law). The heat–health action plans in Hungary, England and Catalonia are integrated into the national disaster plan.

Actors

Most heat–health warnings are issued by the national meteorological office. The communication campaigns triggered by these warnings are mostly the responsibility of the ministries or departments of health, or institutes of public health in collaboration with the health services. Behavioural and medical advice is launched through health services, general practitioners (GPs) and pharmacies. Implementation of guidance for hospitals and care homes is usually in the hands of hospital and care home managers as well as their staff. GPs and health centres, as well as also social services, are often the main partners in the surveillance of people at risk.

Table 7. Public health interventions during the summer and periods of hot weather

Action	Actor	When	Country
Issue and update of warning	Meteorological Service Meteorological Office	June – August; whenever threshold may be reached; hot days	Hungary England
	Dept. of Epidemiology on behalf of Dept. of Civil Protection		Rome/Lazio
Transmission of warnings	Local Health Authority	Warning levels 2 and 3	Rome/Lazio
Communication campaign	Chief Medical Office/Ministry of Health Directorate of Health and health services	May – August May During surveillance period (15 May – 30 Sep) Summer	Hungary England Portugal
	Dept. of Health		Catalonia
Advice on changes of treatment or medication	GPs/health professionals	When temperature levels require it	England
Guidance followed for patient care	Hospital managers/staff	June – August; when temperature levels require it	Hungary England
Guidance followed for patient care	Care home managers/staff	June – August; when temperature levels require it Summer	Hungary England
	Dept. of Welfare and Family		Catalonia
Review of staff capacity	Health and Local authority	Alert level 2	England
Surveillance of identified individuals at risk (susceptible elderly)	GPs	Warning level 2 and 3	Rome/Lazio
Special follow-up of people at risk	Health services and health centres	Summer	Catalonia

Source: adapted from Matthies & Menne, in press.

Interventions

Awareness raising, information and communication through the media can be identified as part of most heat–health action plans, giving behavioural as well as medical advice to the public. Specific information to actors within the health system (GPs, hospitals and nursing homes) as well as medical (and behavioural) advice via medical professionals and help lines is part of many heat–health action plans (Table 7). A special strategy has been developed in Rome/Lazio, where GPs are the main backbone of activities targeted at the most vulnerable people and the elderly. Active contact with risk groups is established within the public health components of the heat–health action plans in Rome/Lazio, Catalonia and England.

Target population

According to the questionnaires, 10 main population groups with a slight variation in age thresholds (defining the elderly as 65+ and 75+ years, respectively) and combinations of groups are targeted by the activities of the respective public health services. Consensus exists in targeting the elderly, people with pre-existing diseases and people taking medication as vulnerable population groups. Athletes and workers are only specifically considered by France and Portugal and small children are considered in Portugal and Catalonia. Various ways of including social factors in defining target population groups (such as social isolation) are reflected in only a few examined heat–health action plans.

Communication strategy

Printed leaflets and information through the mass media are the most common communication channels to inform the public in heat–health action plans. The Internet is often used to provide information and advice to medical professionals or health institutions (for example, in England). A small survey in Hungary, however, has shown that the Internet is not very actively used by the public for information during a heat-wave and it may be particularly difficult for the main target audience, that is, the elderly. Thus the use of the Internet needs to be reviewed and its effectiveness for different purposes assessed. Some heat–health action plans do not describe how the GPs, medical and social professionals receive the information and advice in practice. A distinction between information given for the summer and information given on particularly hot days is made in some heat–health action plans (Catalonia, France, Portugal and Rome/Lazio). In most countries the advice and information is available in the local language only, raising questions with regard to its accessibility for tourists and foreigners and the responsibility for them (home country or host country and the magnitude of the problem).

Real-time health data

Real-time health data are reported to be used in a number of heat–health action plans for the monitoring of health impacts of the heat-wave and the effectiveness of interventions (Table 8). In most cases mortality data (in three heat–health action plans: England, Catalonia and Rome/Lazio), hospital admissions (in two heat–health action plans: Catalonia and France) and phone calls (in two heat–health action plans: England and Catalonia) are used. The lag time between data collection and availability of these data was registered to be between one and three days. From the questionnaires it does not become entirely clear what the real-time health data are used for in detail and whether modifications and adjustments of the public health responses are made.

Table 8. Use of real-time data in European public health response plans

Data	Lag time	Country
Mortality	7 days 1 day 1–3 days	England Catalonia Rome/Lazio
Morbidity		
Hospital admissions	1 day (data series of 3 weeks for analysis) 1–3 days (4 big hospitals)	France Catalonia
Phone calls	1 day Available daily	England Catalonia
Ambulance calls	1 day (actions not modified)	Hungary
Activities of emergency departments	1 day (data series of 3 weeks for analysis)	France
Fire brigade interventions	1 day (data series of 3 weeks for analysis)	France
No use of real-time data		Portugal

Source: Páldy et al., in press.

Process evaluation

A few countries carry out an assessment of their heat–health action plan every year and present a report (for example, Rome/Lazio, Catalonia and France). In Italy, the heat–health warning system (HHWS) has been assessed for its sensitivity and specificity of forecasting a meteorological condition that is linked to excess mortality (De’Donato et al., 2005; Department for Civil Protection, 2007). Hungary has carried out a telephone survey in five cities among 2500 responders to evaluate the communication campaign of the heat–health action plan (Kishonti, Páldy & Bobvos, 2006). Results show that television was the channel consulted most often for information (by 78% of the respondents), while the Internet was used least for information on heat and health. Drinking more fluids, staying in the shade or an air-conditioned space was mentioned most often by respondents as prevention measures, but 25% of the respondents did not know what to do. The Health Protection Agency (HPA) in England assessed the level of awareness among actors in the health system through telephone interviews and questionnaires (HPA, 2007). Results show that awareness of the heat–health action plan across the health and social care sector is very high and most organizations found the plan useful before and during alerts. Of the responders, 100% were aware of the plan and 100% of strategic health authorities (SHAs), primary care trusts (PCTs) and National Health Service (NHS) trusts were aware that level 3 was reached during summer 2006. All of the SHAs, 88% of the PCTs and 62% of the NHS trusts judge the awareness in their organization as good to excellent. In the NHS survey, effectiveness in the protection of vulnerable population groups was not assessed. It was also not possible to assess the contribution of the heat–health action plan to the reduction in heat-related mortality.

In France, close collaboration between meteorological and health services was seen to contribute most to effectiveness. In Catalonia the importance of the whole package of activities together was stressed (Generalitat de Catalunya, 2006). As analysed in the report for summer 2006 in Catalonia, most deaths occurred in private retirement homes and better control of these homes could improve this situation in future (N Cardeñosa Marin, personal communication, 2007).

Among the main barriers to implementation of heat-related public health responses identified in the questionnaire survey were: (i) lack of funding of specific activities; (ii) lack of communication of the heat–health action plan among actors and within other organizational units; and (iii) lack of timely access to mortality and morbidity data.

Cost

While France spent €0.14 per protected person (that is, children less than 1 year old and adults more than 75 years old), Catalonia invested €9.2 per vulnerable person (€921 763 in total for the public health component of the heat–health action plan plus €3 415 700 for additional medical personnel and €3 025 047 for the Department of Welfare). In England €214 912 were spent for printing information materials but no other additional costs for the health system were calculated. As each national system was assessed in a different way, considering different costs, a comparison between different heat–health action plans is very difficult. Standardized cost–benefit analyses of the various heat–health action plans would be interesting.

In comparison to the estimated costs of heat–health action plans, the cost of inaction may be high. In Rome, for example, the cost of inaction (monetized mortality damage) has been calculated to amount to €281 million in the year 2020 (based on the value of the euro in 2004) (Alberini & Chiabai, 2005).

The results of the questionnaire survey (summarized above) were scrutinized and experiences from various European countries included in an expert consultation, through which a set of core elements of heat–health action plans were identified. Subsequently, through a consultative and iterative process, a team of experts developed a guide for the development of heat–health action plans (Matthies et al., 2008).

Core elements of heat–health action plans

From the results of all work packages, the literature review, the European questionnaire survey and the expert consultations, EuroHEAT identified eight core elements of heat–health action plans and these were published in a guidance document aimed at local, regional and national governments (Matthies et al., 2008). These eight core elements are:

- **agreement on a lead body** (to coordinate a multi-purpose collaborative mechanism between bodies and institutions and to direct the response if an emergency occurs);
- **accurate and timely alert systems** (heat–health warning systems trigger warnings, determine the threshold for action and communicate the risks);
- **a heat-related health information plan** (about what is communicated, to whom and when);
- **a reduction in indoor heat exposure (medium- and short-term strategies)** (advice on how to keep indoor temperatures low during heat episodes);
- **long-term urban planning** (to address building design and energy and transport policies that will ultimately reduce heat exposure);
- **particular care for vulnerable population groups;**
- **preparedness of the health and social care system** (staff training and planning, appropriate health care and the physical environment);
- **real-time surveillance and evaluation.**

These elements are not sequential, though some are primarily about planning and can be defined as longer-term development, preparation before the summer (pre-summer), prevention during the summer, specific responses to heat-waves and monitoring and evaluation.

Several EuroHEAT work packages investigated in detail the specific core elements of heat–health action plans (for example, meteorological forecasts, options for the reduction of indoor heat exposure or real-time surveillance; see also Fig. 1). The following sections will summarize the detailed analysis of each core element.

Accurate and timely meteorological forecasts

Heat early warning systems are short-term responses before and during heat-wave events. Medium range heat information has lead times of 3–10 days and HHWS have lead times of 12–48 hours. Both can be useful for decision-makers.

The recommended components of an HHWS are the identification of weather situations that adversely affect human health, monitoring of weather forecasts (meteorological component), implementation of mechanisms for issuing warnings when the adverse weather situation is forecast (communication) and promotion of public health activities to prevent heat-related morbidity and mortality. Until 2001, only one HHWS was operational in Europe (Lisbon). In 2000, the WMO chose Rome as a pilot city for the development and implementation of an air-mass-based HHWS, which became fully operational in summer 2001. The high numbers of heat-related mortality in summer 2003, however, resulted in an increase in the number of HHWS.

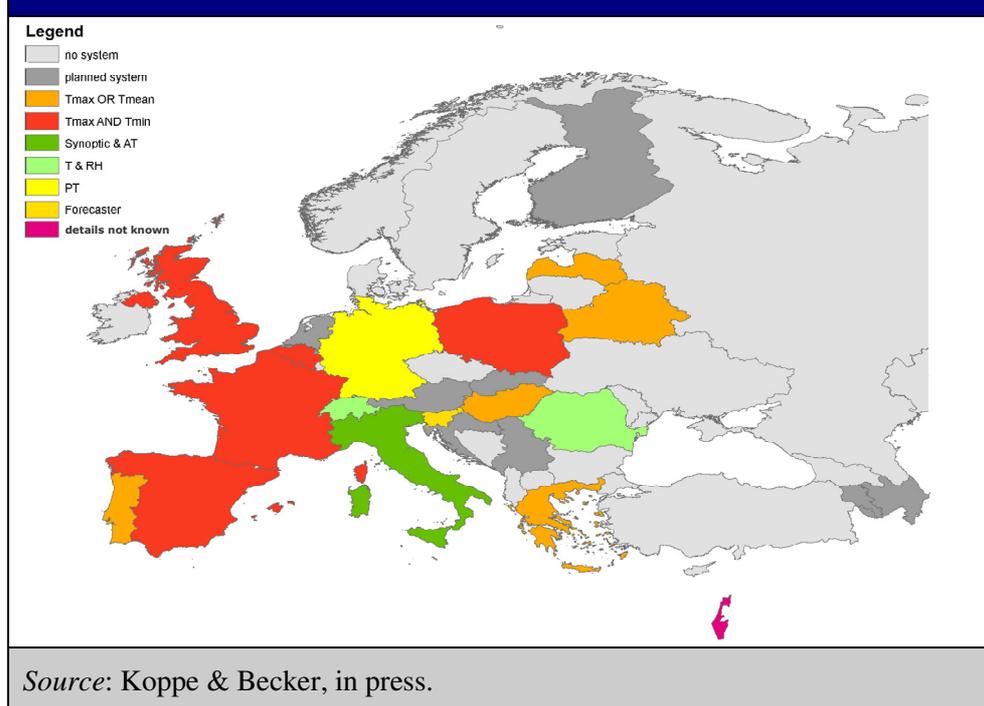
Methods

In spring 2006 a questionnaire on the existence, structure and methodology of heat–health warning systems was sent to 44 WMO member states (Koppe & Becker, in press). The questionnaire was returned by 34 national meteorological services (77%).

Results

The survey showed that HHWS were operational in 16 countries and that, furthermore, several countries were planning to implement an HHWS (Fig. 7). Ten national meteorological services (22%) stated that they issue heat warnings or already had an operational HHWS in 2006, and 13 (29%) are planning to implement a heat warning procedure. The remaining 11 countries (25%) which returned the questionnaire have no system and did not plan to implement one during the next few years.

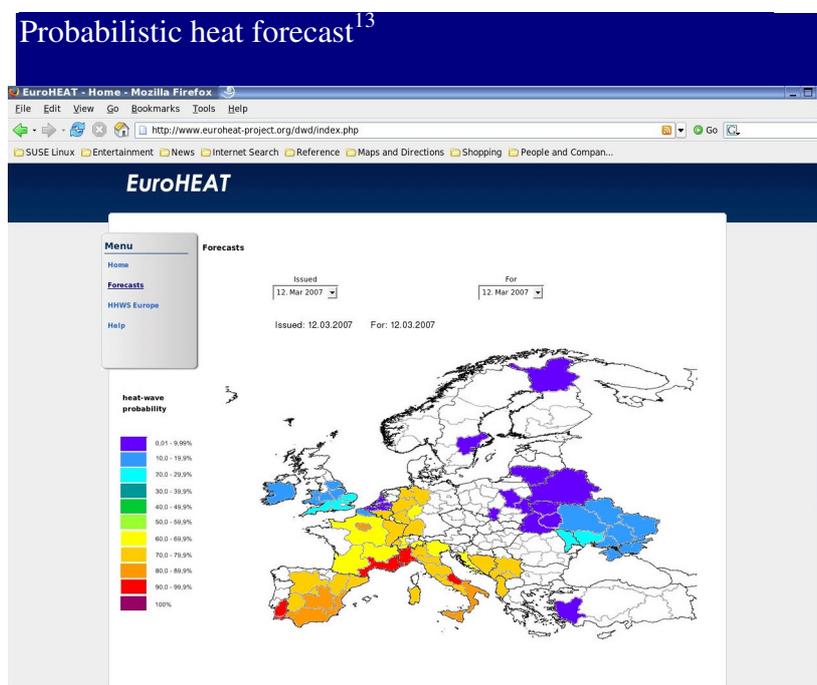
Fig. 7. Heat–health warning systems in Europe¹²



The first step to develop an HHWS is to identify weather situations that adversely affect human health (hereafter referred to as heat-waves or heat events). As there are no general definitions of the terms “heat event” or “heat-wave” the HHWS in Europe use different methods to define and to identify such situations. Most of the systems use air temperature and duration as indicators of a heat-wave. Some systems use more complex methods to characterize heat situations, such as synoptic or heat balance approaches. These complex methods require not only air temperature as a meteorological input parameter but also other meteorological parameters that allow a more sophisticated description of the thermal situation, such as, for example, humidity, wind speed and cloud cover. The accuracy of forecasts based on several meteorological parameters is generally lower than the accuracy of forecasts based on single parameter indexes. Therefore, the use of these complex methods is restricted to forecasts with shorter lead times. A clickable map showing countries with HHWS and a more detailed description of each is linked to the web-based climate information decision support tool. This decision support tool, which has been developed by the German Weather Service, is one of the major products of the EuroHEAT project (Box 4).

¹² On 3 June 2006, the Permanent Representative of the Republic of Serbia to the United Nations and other International Organizations in Geneva informed the Acting Director-General of the WHO that “the membership of the state union Serbia and Montenegro in the United Nations, including all organs and the organizations of the United Nations system, is continued by the Republic of Serbia on the basis of Article 60 of the Constitutional Charter of Serbia and Montenegro, activated by the Declaration of Independence adopted by the National Assembly of Montenegro on 3 June 2006”. Estimates used or referred to, as well as, maps published in this document cover a period of time preceding that communication.

Box 4. Information about forecasts of imminent heat-waves – a web-based tool



The web-based climate information decision support tool has been developed by the German Weather Service and provides probabilistic information about the imminent heat situation for the next 9 (14) days at the regional level (Koppe, Becker & McGregor, in press).

Methods

The web-based decision support tool was developed for Europe which was defined as the area between -15° and $+45^{\circ}$ longitude and between 30° and 80° latitude. Europe has been divided into 212 regions which, in general, correspond to NUTS2 or NUTS3 regions (NUTS = Nomenclature des Unités Territoriales Statistiques).

In the climate information decision support tool a heat event is defined by the temperature 2 m above the ground (= 2 m temperature) exceeding a variable threshold. These temperature forecasts from the ECMWF (European Centre for Medium-Range Weather Forecasts) Ensemble Prediction System (EPS) are used in order to forecast heat episodes up to 10 days in advance. The EPS consists of a 51-member ensemble forecast (50 perturbed forecasts and one control run). These forecasts were validated against the operational analysis with the same spatial and temporal resolution.

A challenge of analysing an area that extends over 50° longitude is that the 12 UTC (Coordinated Universal Time) temperature does not mean the same all over Europe. In the east, 12 UTC is three hours after the maximum altitude of the sun and corresponds quite well with the daily maximum temperature. In the west at 12 UTC the maximum altitude of the sun is reached at 13 UTC. Therefore 12 UTC temperature is generally lower than the daily maximum. Thus, it would be more useful to use daily maximum or minimum values to evaluate the thermal situation. Nevertheless 12 UTC values

¹³ On 3 June 2006, the Permanent Representative of the Republic of Serbia to the United Nations and other international organizations in Geneva informed the Acting Director-General of WHO that “the membership of the state union Serbia and Montenegro in the United Nations, including all organs and the organizations of the United Nations system, is continued by the Republic of Serbia on the basis of Article 60 of the Constitutional Charter of Serbia and Montenegro, activated by the Declaration of Independence adopted by the National Assembly of Montenegro on 3 June 2006”. Estimates used or referred to, as well as maps published in this publication, cover a period of time preceding that communication.

were used in this study because for maximum and minimum temperatures no operational analysis is made. So the skill of forecasted maximum or minimum temperature cannot be tested. In order to establish a relationship between maximum temperature and 12 UTC temperature linear regression models have been calculated for each grid point. The mean correlation coefficient was 0.9899.

On the web site (<http://euroheat-project.org/dwd/index.php>) the region-specific probabilities for a heat-wave for lead times from 0 (current day) to 9 (extension to 14 days planned) days are displayed (see figure above). In addition to the forecast issued on the actual day (this becomes available at 10.40 UTC) the forecast issued on the previous 10 days can also be displayed. The forecast is updated and available every day at around 11.45 (mean European summer time). Medium range heat information with lead times of 3–10 (15) days can be a useful complement to HHWS for decision makers to give the health system more time to prepare for an imminent heat-wave and to react.* The target group for this tool are health professionals who are involved in the national/local HHWS rather than the general public. The early information about possible imminent heat situations will help health professionals to prepare for periods of very hot temperatures and to monitor the situation in neighbouring regions. As there are links to the web sites of the national HHWS in Europe the user has quick access to actual issued heat warnings. For countries that have no heat warning system or for which the web site of the system could not be identified, the web sites of the national meteorological services are linked, so that the user can access the respective weather forecasts.

Guidance on the use of the web-based decision support tool is presented in the format of two flyers (“How to use the medium-range heat information tool” and “Scientific background”). Both flyers can be downloaded from <http://euroheat-project.org/dwd/index.php> under “help”.

Source: Koppe, Becker & McGregor, in press.

*A case study has shown that the amount of under- and over-forecasting of heat events becomes minimal for an exceedance probability of 30%. For lower exceedance probabilities there is an over-forecasting of heat events (more false alarms but fewer misses) and for higher exceedance probabilities there was an under-forecasting of heat events (more misses but fewer false alarms) in 2006.

Defining a heat event that triggers a warning depends not only on the relationship between the warning indicator and mortality but also on the scope of the particular warning system and on the set of intervention measures that is activated when a warning occurs. If the scope of the system is to prevent heat-related health impacts only in the case of very extreme heat-waves, the threshold for issuing a heat warning will be relatively high. In general such systems also trigger a more complex set of intervention measures than systems that also issue warnings in less extreme situations.

It is important that an HHWS is targeted to local needs, takes into account local restrictions and is accurate and timely. Only very few systems have been evaluated to date so conclusions cannot yet be drawn (Koppe & Becker, in press).

Awareness raising

It is important to create greater awareness of the dangers of heat-waves and to inform individuals about how to minimize the risks. Everyone is potentially at risk from heat-related illness, and death can result. For the design of heat–health action plans a combination of a risk-based and a population-based approach for raising awareness seemed advisable.

Methods

Information material and leaflets on the health impacts of heat and their prevention and treatment have been collected through project partners and Internet research. All European heat–health action plans included in the questionnaire survey have been checked for information materials. In some countries leaflets are made available even in the absence of a structured national heat–health action plan (for example, Germany or Switzerland) and a sample of these materials has been accessed via the Internet. Messages from all information materials have been translated into

English and listed in tables. Categories of messages have been defined and the following information recorded for each message: (i) advice; (ii) specific information; (iii) country or region; (iv) target population; (v) scientific evidence; (vi) country-specific evidence; and (vii) comments. For the analysis of advice to the public, leaflets from Catalonia, France, England, Italy (Milan), Hungary, Switzerland, Belgium and some federal states of Germany (Bavaria, Baden-Württemberg, Hessen, Rheinland-Pfalz) were included. Messages that appeared in all, almost all or in at least three different leaflets were defined as key messages. Some selected messages have been defined as key messages despite not having been included in more than one heat–health action plan, on the basis of work package 8 results (core elements of public health components of heat–health action plans). All selected key messages were also scrutinized according to specific risk factors for heat-related morbidity and mortality and thus vulnerable population groups (work package 4 and meta-analysis). These were then discussed with the group of experts and the selection and wording finalized accordingly.

Results

The review of existing information materials was useful for an overview of the whole range of topics. The fact that a message is mentioned in numerous leaflets and information materials can be used as an indication of its “perceived” importance. However, some messages may be essential or innovative even though they are only mentioned in one or only a few documents. In some cases, messages are known to be important (for example, spending 2–3 hours in a cool environment) but were nevertheless only mentioned in a couple of leaflets. Special practical advice particularly aimed at caregivers was only mentioned in one or two leaflets but may be usefully adopted by others (for example, alternative methods to cool rooms or ways to facilitate drinking for the elderly). The results of this review and the expert discussion which followed could lead to an update of existing information materials.

Advice to the public could be grouped into five overall measures through which potential damage from heat can be avoided:

- Keep your home cool
- Keep out of the heat
- Keep the body cool and hydrated
- Be alert
- Help others, especially those in vulnerable groups.

Key messages to the public are given in detail in Box 5. Being alert includes the ability to recognize symptoms of heat exhaustion and heatstroke and to know when and who to call for help. Attention must be paid to the exact formulation of the advice, as wrong behaviour can lead to serious health effects. This is the case in particular for general advice such as “keep cool and drink plenty of fluids”. Both drinking too little (resulting in dehydration and hypernatraemia) as well as drinking too much (resulting in over-hydration and hyponatraemia) can be a problem. In France during the heat-wave of 2006, for example, hyponatraemia was reported as a cause of illness as people were in fact drinking too much (Ambrosi et al., 2004).

Box 5. Recommendations for the public during heat-waves

Keep your home cool

During the day, close windows and shutters (if available) especially those facing the sun. Open windows and shutters at night when the outside temperature is lower, if safe to do so.

If your residence is air conditioned, close the doors and windows.

Electric fans may provide relief, but when the temperature is above 35 °C, fans may not prevent heat-related illness. It is important to drink fluids.

Keep out of the heat

Move to the coolest room in the home, especially at night.

If it is not possible to keep your home cool, spend 2–3 hours of the day in a cool place (e.g. air-conditioned public building).

Avoid going outside during the hottest time of the day.

Avoid strenuous physical activity.

Stay in the shade.

Do not leave children or animals in a parked vehicle.

Keep the body cool and hydrated

Take cool showers or baths.

Alternatives include cold packs and wraps, towels, sponging, foot baths, etc.

Wear light, loose fitting clothes of natural materials. If you go outside wear a wide brimmed hat or cap and sunglasses.

Drink regularly and avoid beverages with sugar or alcohol.

Help others

If anyone you know is at risk, help them to get advice and support. Elderly or sick people living alone should be visited at least daily.

If the person is taking medication, check with the treating doctor how they can influence the thermoregulation and the fluid balance.

If you have a health problem:

- keep medicines below 25 °C or in the fridge (read the storage instructions on the packaging);
- seek medical advice if you are suffering from a chronic medical condition or taking multiple medications.

If you or others feel unwell:

- try to get help if you feel dizzy, weak, anxious or have intense thirst and headache; move to a cool place as soon as possible and measure your body temperature;
- drink some water or fruit juice to rehydrate;
- rest immediately in a cool place if you have painful muscular spasms, most often in the legs, arms or abdomen, in many cases after sustained exercise during very hot weather, and drink oral rehydration solutions containing electrolytes; medical attention is needed if heat cramps are sustained for more than one hour;
- consult your medical doctor if you feel unusual symptoms or if symptoms persist.



If one of your family members or people you assist presents hot dry skin and delirium, convulsions and/or unconsciousness, call the doctor/ambulance immediately. While waiting for the doctor/ambulance move him/her to a cool place and put him/her in a horizontal position and elevate legs and hips, remove clothing and initiate external cooling, such as with cold packs on the neck, axillae and groin, continuous fanning and spraying the skin with water at 25–30 °C. Measure the body temperature. Do not give acetylsalicylic acid or paracetamol. Position unconscious person on their side.

For service providers:

Information on helplines, social services, ambulances, cool spaces and transport should be provided on the information material!!

Provide access to cool spaces and ensure active assistance for those most at risk.

Source: Matthies et al., 2008.

Advice on avoiding and managing heat-related illness can be widely distributed via the media. Messages should include information about what the public can do to make themselves safer, but the exact content of specific behavioural and medical advice varies across public health response plans and cultures. Key messages need to be targeted at the public, but also adjusted to the needs of specific vulnerable population groups such as the elderly or certain occupational groups. Anyone having to work outside in hot weather without appropriate protection, particularly if this involves heavy physical activity, is at increased risk of suffering health effects from heat. Air temperature, radiant temperature, air velocity, humidity, clothing and activity are recognized as factors that interact to determine heat stress.

The channels of communication also need to be selected according to the patterns of use of the targeted population groups. Information for the elderly should contain feasible practical tips (for example, for drinking) and important contact details for social and emergency services.

Much of the existing educational material appears to be based on common sense and, for some of the advice, strong physiological or epidemiological evidence is missing. Formulating exact general advice on drinking or the use of fans, for example, is rather difficult, as both measures very much depend on the specific situation and health condition of the individual and the temperature conditions, respectively. Therefore, careful advice should be given by medical doctors tailored to the individual older person or patient. Backing up the selected messages with scientific evidence is an ongoing process according to which information material needs to be constantly reviewed and updated.

Reduction of exposure

Health outcomes depend on the duration, frequency and intensity of the heat exposure. It is therefore important to take action to reduce exposure as much as possible. The goal of this work is to reduce the vulnerability of the European population to heat stress indoors. Vulnerability is understood as a function of three components – exposure, sensitivity and adaptive capacity – which are in turn influenced by a range of factors. The vulnerability profiles are based on the assumption that exposure to extreme heat will influence sensitivity and that people will respond to these changes provided that they have the capacity to adapt. Vulnerability is thus seen as a composite of adaptive capacity and temperature sensitivity. In the case of extreme heat, there is only limited potential for improvement of the physiological adaptive capacity of human beings. However, the exposure to extreme heat can be mitigated more easily through technological and behavioural measures. A number of measures that can be applied for keeping the indoor environment cool were identified and described (Hales et al., in press). These measures will be most effective in conjunction with urban planning and measures to keep air pollution low.

Methods

A working group of seven external experts was established to review scientific literature, to assess measures to reduce indoor heat exposure and contribute to the overall chapter (Hales et al., in press). The experts agreed to first identify the vulnerable populations by evaluating sensitivity and exposure. Evidence on the distribution of sensitivity in the population is expected to be produced in other work packages of EuroHEAT. This information was then used to better define the main clusters of vulnerability to heat stress indoors. Information on the risk factors for high exposure to heat stress indoors (defined as a combination of temperature, humidity and wind speed) due to building characteristics was identified within work package 7. Clusters of vulnerable populations could be identified by cross-referencing these two dimensions. The expert consortium included in their assessment short- and medium-term measures for existing buildings, housing regulations, urban planning options, energy and transport policies (see sections below). Measures to reduce indoor heat stress were assessed in relation to qualitative

criteria, including reliability, energy use, potential health impacts of the method, feasibility and equity.

Results relating to indoor climate

Because people spend most of their lives indoors and tend to shelter indoors during hot weather, the indoor climate is of particular importance for policy interventions. Most homes have an indoor temperature of 17–31 °C. Humans cannot comfortably live in temperatures outside this range. Three main factors are associated with indoor heat exposure: the thermal capacity of buildings, the position of an apartment and the behaviour of the occupants. In France, the risk of death was increased by living in buildings with few rooms, with poor insulation or with a larger number of windows. Living on upper floors, especially the top floor, or having the bedroom under the roof also increased the risk (Vandentorren et al., 2006).

To limit exposure to heat, a number of measures are available. They can be divided into short-term (during a heat-wave), medium-term (this summer) and long-term measures (years to decades needed to complete) (Table 9; long-term measures are referred to later).

Table 9. Short- and medium-term measures to reduce indoor heat exposure	
Short-term measures	Medium-term measures
Ensure access to cooled spaces	Identify areas at risk of urban heat island effects
Install thermometers in buildings (awareness raising)	Restrict living on top floors, or improve roof insulation
Use electric fans with care (they may provide relief, but when the temperature is above 35 °C, fans may not prevent heat-related illness) and drink fluids (important – see Table 12)	Building envelope: increase reflection of heat from the surface (albedo)
If no alternative technical solution is available consider installing energy efficient mobile evaporative coolers	Apply cool paints on outside walls
If no alternative technical solution is available consider installing energy efficient mobile dehumidifiers and air conditioning	Increase external shading
Restrict traffic in cities	Cool pavements
	Attach radiant barriers, insulation to building structures
	Install energy efficient air conditioning
<i>Source:</i> Hales et al., in press.	

Table 10. Advantages and disadvantages of short- and medium-term measures for existing buildings

Short- and medium-term measures for existing buildings	Reliability/robustness	Energy use/ CO₂ emissions	Health impacts	Feasibility	Equity
Access to cooled spaces	Poor, may not affect behaviour of the most vulnerable people	+		+++	May not be accessible to the most vulnerable people
Mobile air conditioning	Moderate, provided temperature and humidity are not too high. May not affect behaviour of the most vulnerable people	++	May have adverse effects on indoor air quality (building-related symptoms); airborne infections	++	May not be accessible to the most vulnerable people
Electric fans and rehydration measures (fluids)	Moderate, provided temperature and humidity are not too high.	+	Include warning of dehydration from use of fans	+++	Cheap to buy and run, but may not affect behaviour of the most vulnerable people
Mobile evaporative coolers	Moderate, efficient only in dry climates.	+		++	May not be accessible to the most vulnerable people
Dehumidifiers	Moderate, provided temperature and humidity are not too high.	+		++	May not be accessible to the most vulnerable people
Restrictions on traffic in cities	Unclear	– (reduces use of energy in transport)	Likely to have short-term health benefits	++	+++
Thermometers in buildings (awareness raising)	Unclear	+ (may lead to increased use in active cooling)		+++	+++
Identification of areas of risk (urban heat islands)	Unclear, probably useful if combined with targeting of long-term measures	–	Potentially beneficial	++	+++
Restrictions on living on top floors	+	–		++	
Envelope: increased albedo	++	–		++	
Cool paints	++	–		++	
More external shading	++	–		++	
Cool pavements	++	–		++	
Building structures: radiant barriers, insulation	++	–		++	
Efficient central air conditioning	++	++	May have adverse effects on indoor air quality (building-related symptoms); airborne infections	++	May not be accessible to the most vulnerable people

Key: – = none; + = low; ++ = medium; +++ = high

Source: Hales et al., in press.

Details of the advantages and disadvantages of these measures are given in Table 10. In many European educational leaflets, fans are advised. However, fans should not be used as a primary cooling device during extended periods of excessive heat. Electric fans may provide relief, but when the temperature is above 35°C, fans may not prevent heat-related illness. Fans can contribute to heat exhaustion with additional heat released indoors and forced convection during high heat stress conditions when skin convection is no longer useful. Evaporative coolers are only effective if the humidity is low enough; air conditioners are progressively less efficient and not useful above about 40 °C (Hales et al., in press).

Passive cooling methods such as increasing external shading or use of cool paints are effective, but their usefulness is dependent upon local factors such as the building type. One simulation study in the United Kingdom found that a combination of passive cooling methods could reduce indoor temperatures to about 2.5 °C below the ambient temperature. With careful design it is usually possible to reduce summer temperatures without increasing winter heating demand.

Withdrawing the population at risk from heat, even for a short time, is an important protective factor in a severe heat-wave. Spending a few hours in a cool environment was also found to be protective, although quantitative information, such as the number of hours needed, on which to base practical recommendations has yet to be studied (Bouchama et al., 2007). The role of air conditioning as a protective factor has been assessed in a number of case-control studies, mainly in the United States (for example, Kaiser et al., 2001; Semenza et al., 1996; Naughton et al., 2002). In Europe, although the use of air conditioning is growing, air conditioning is still relatively uncommon (EECCAC, 2002). In some countries power failures are common during heat-waves because of sudden increases in electricity demand. The impact of a power failure is likely to exacerbate the impacts on health.

Results relating to urban planning, energy and transport policies

Despite the greenhouse gas reduction measures that have started to be implemented in Europe, some degree of global climate change is inevitable in this century, even if we would stabilize greenhouse gas emissions now. Under the expected climate change heat-waves are expected to become more frequent, more intense and last longer. This means that despite the portfolio of actions that can be taken in the preparation of heat-waves and during heat-waves, the reduction of health effects will be most effective if long-term measures in the housing, energy and urban sector are implemented.

Other things being equal, people living in cities are likely to be at higher risk than rural dwellers because of the urban heat island effect, though this issue has not been systematically studied. Location therefore affects people's vulnerability to the impacts of heat. For example, Athens is often 5 °C hotter than the surrounding countryside in the summer months. Excess mortality observed in France ranged from +4% in Lille to +142% in Paris, suggesting that either heat gain by city buildings or traffic patterns may influence this. As an exception, mortality impacts were more pronounced in rural villages than in provincial capitals in Spain (Simón et al., 2005).

Urban planning, land-use changes and mitigation of climate change through energy efficiency are highly effective but potentially costly, and their implementation requires political will (Hales et al., in press; Table 11). Measures to reduce the urban heat island focus on: increasing green spaces and planting trees in streets (trees provide shade but can also improve air quality); increasing ventilation and air flow between buildings (which also improves air quality); increasing the number of courtyards and other open spaces; increasing the albedo of a city (for example, painting roofs white); and decreasing anthropogenic heat production (for example, natural space cooling, see above). The urban heat island is, to some extent, an inevitable consequence of urban development, but appropriate urban planning can reduce its magnitude.

For example, the benefits of tree planting projects are shading, cooling due to evapotranspiration, dust control, runoff control, consumption of carbon dioxide and water conservation. There are many competing priorities for urban planning. In practice, climate issues often have a low impact on urban design. Although urban planners are interested in climatic aspects, the use of climate information is unsystematic.

Table 11. Advantages and disadvantages of Long-term measures for new buildings or city developments

Long-term measures for new buildings or city developments	Reliability/robustness	Energy use/CO ₂ emissions	Health impacts	Feasibility	Equity
Cooling methods: earth to air heat exchangers, deep energy ponds, groundwater coupled cooling, cooling towers	++ Evaporative methods work well in dry climates, but may require a large land area for installation	Relatively energy efficient	May have adverse effects on indoor air quality (building-related symptoms), airborne infections		++
Roofs (gardening, insulation, etc.)	++	–			
Energy management during peak hours (foresee and reduce risk of a breakdown of electricity system)	++	+		++	+++
Multidisciplinary education of architects and urban planners (include summer time comfort in planning)	?			+++	+++
Trees with big leaves, shading streets, water bodies, courtyards, etc.	+	–		+++	+++
Improve urban ventilation	?	?	Beneficial if reduces air pollution		
Legislation: review national building codes for residential buildings (taking extreme conditions into consideration)	+++	Could greatly increase overall energy efficiency	?	+++	+++
Review temperature related health and safety regulations in the workplace	+++	+/- impact depends upon how policy is implemented	?	+++	+++
Urban planning (climatic rehabilitation of the cities), land-use changes	+++	Could greatly increase overall energy efficiency	Highly beneficial (if combined with measures to reduce air pollution and increase active transport)	Long-term measures, relatively difficult to implement	+++
Mitigation of climate change (e.g. energy efficiency of building structures, including heating methods in winter)	+++		Highly beneficial (if combined with measures to reduce air pollution and increase active transport)	Long-term measures, relatively difficult to implement	+++

Key: – = none; + = low; ++ = medium; +++ = high; ? = not known
Source: Hales et al., in press.

There are potential adverse public health impacts associated with some measures (such as airborne infections and building-related symptoms related to air-conditioning systems). On the other hand, medium- and long-term measures could be combined with related public health

strategies. For example, changing the design of cities to reduce urban heat island effects by increasing green spaces could encourage active travel as well as reducing energy use and air pollution.

The fact that there are long lead times before the benefits of these measures are apparent may be an argument in favour of early implementation. These measures could be combined with reductions in air pollution and increases in active transport (for example, walking and cycling), with large potential health benefits. Greenhouse gas mitigation measures are now being implemented in the wider context of global climate change. Without effective mitigation of climate change, short-term measures will be increasingly less useful in reducing heat-related health impacts in vulnerable populations.

Particular care for vulnerable population groups

Heat-waves and hot weather kill and can aggravate existing health conditions. Some people are more at risk of heat-related illness and death than others. Public health interventions need, therefore, to be targeted particularly at the elderly, disabled, mentally ill or isolated members of society. Within the vulnerable groups, individuals at special risk need to be identified. Various strategies for identifying and reaching vulnerable individuals are in place across Europe (examples given in Matthies et al., 2008) and need to be adapted to the respective health system context, including the local level for implementation (WHO, 2008).

GPs, care providers and social services play an important role in the care of vulnerable groups of people. Developing activities for populations at high risk is highly dependent on local service organization and social structures. Reaching the most vulnerable at home or those socially isolated has proven to be difficult and experiences need to be shared. Recent lessons learnt might also be important in the case of other emergencies.

Methods

The questionnaire survey of European heat–health action plans (from Catalonia, England, France, Hungary, Italy, Portugal and 10 Federal States of Germany) revealed the importance of GPs, care providers and social services for assuring protection and care for vulnerable population groups during heat-waves. Expert consultation and the integration of lessons learnt during the EuroHEAT meetings lead to a selection of examples on how to integrate and use these services in the development and implementation of heat–health action plans.

Results

In general, experiences of heat–health action plans and results from work package 4 suggest that active contact with vulnerable population groups is more effective than passive information, in particular for the elderly, the socially isolated and the homeless.

European countries have developed different strategies to identify and contact persons at risk, which can be summarized as:

- organization of local and social services (for example, France);
- the important role of the GPs (for example, Italy).

In France, reaching the most vulnerable is part of a complex multi-agency organization. The local organization reflects the multi-departmental national organization. At the beginning of the summer, the *Préfet* (Prefect) of each *département* (district) is supposed to convene a board consisting of representatives of various services. Responsibilities for how to reach and assist those identified as at risk are shared between the various services; for example, associations of volunteers help to take care of old or disabled people at home (Box 6).

Box 6. Heat–health action plan in France – people at risk identify themselves

The duties of the board, set up by the *Préfet* and involving various local services, are to make sure the recommendations reach the different groups at risk from heat. This board must also evaluate the measures taken during the summer and report back to the national board. The official listing of vulnerable and isolated people at risk is made by the mayors. At the vulnerable people's request, the mayors collect information about them before the summer to help the targeted intervention of health and social services when there is a heat-wave warning and when the emergency plan for the elderly and disabled is activated. These lists of vulnerable people are more or less complete according to data from the cities and they will have to be completed in the next years. One of the problems is that the most isolated people cannot be reached by this means because they do not even know about the existence of these lists or refuse to be listed.

Source: K Laaidi & L Jossieran, personal communication.

In Italy, the GP plays a key role in the identification and surveillance of particularly vulnerable individuals (Box 7).

Box 7. GPs look after vulnerable individuals – the Italian example

In Rome, the intervention programme for the prevention of heat-related health effects is based on a heat–health watch warning system, the identification of population subgroups susceptible to heat and the surveillance of these persons during the summer months. Susceptible subjects are identified on the basis of demographic and health information retrieved from the population and hospital admission registries. In 2006, following guidelines of the Health Ministry, GPs were involved in the programme. Before the summer, each GP received the list of his/her at-risk patients identified through the standardized procedure. These lists were then reviewed by the GP on the basis of their personal knowledge of individual patients and a final list drawn up. GPs were invited to carry out active surveillance in terms of extra home visits to their at-risk patients during the summer months. These actions appeared to be an effective way of reducing heat-related mortality among the population over 65 years of age.

Source: Lazio Region, 2007.

The general applicability of these approaches is limited as only selected examples from existing heat–health action plans have been included and no systematic review of all existing approaches has been carried out. Each approach for the identification of vulnerable population groups and individuals and the role of GPs, care providers and social services in the provision of special care before and during heat-waves needs to be scrutinized with regard to its applicability in the respective national and local context, depending, for example, on the characteristics of the health system and on legal restrictions (for example, data protection issues).

Evidence-based guidance and options for medical treatment by practitioners during heat-waves, as well as advice on prescription of drugs and preventive measures, have been drawn up (Bouchama et al., 2007; Bouchama, Dehbi & Chaves-Carballo, 2007; Bouchama et al., in press; Matthies et al., 2008). For this purpose a meta-analysis on the risk and protective factors in a heat-wave was carried out and six case-control studies involving 1065 heat-wave-related deaths were identified (Bouchama et al., 2007; Box 3).

Provision of health care, social services and infrastructure

The heat-wave in 2003 had a severe impact on elderly people in hospital and in residential homes. In France, mortality in “retirement homes” doubled during their more extreme August 2003 heat-wave (INVS, 2005) and increases in mortality were reported in nursing homes in northern Italy (CRRC-SER, 2005). Increases in heat-related morbidity were also reported, as well as failures in care. Such institutions were generally lacking cooling facilities. The residents of institutions therefore represent an important target group for heat-wave interventions.

Methods

The questionnaire survey of European heat–health action plans (from Catalonia, England, France, Hungary, Italy, Portugal and 10 federal states of Germany) described above also addressed the provision of health care and social services during heat-waves in the various heat–health action plans and requirements for health infrastructure. The country examples were reviewed on the basis of the results of work package 4 (determinants of mortality) and work package 7 (indoor heat exposure) and submitted for discussion by the experts (also during the EuroHEAT meetings).

For the formulation of treatment recommendations a systematic review of published literature on first aid for life-threatening heatstroke as well as one of health service treatment practices for heat-related health problems, respectively, were performed. For the compilation and formulation of treatment and management recommendations for heat-related illnesses and heatstroke, a systematic review of all clinical studies published in Medline (1966–2006), CINAHL (1982–2006) and the Cochrane database was performed using the OVID interface without language restriction. Search terms included heatstroke, sunstroke and heat stress disorders (Bouchama, Dehbi & Chaves-Carballo, 2007).

Results

It is advisable that heat–health action plans include advice on service delivery, hospital emergency plans, management of large numbers of casualties and chronic disease treatment during heat, as well as education of doctors, nurses and other staff to enable them to identify heat problems and be familiar with the most appropriate treatments and recommendations for the cooling of health facilities and nursing and retirement homes (Matthies et al., 2008). Curricula for specific training modules and seminars for medical professionals need to be designed to improve their knowledge and skills in relation to the prevention and treatment of heat–health effects. There are many open questions, for which no standardized guidance is available and this includes the treatment of heatstroke and management of chronic diseases during extreme heat, as well as management of nutrition and fluid intake.

Health service delivery needs to be assured during the summer and during heat-wave emergencies. Service delivery is the combination of inputs into a service production process that delivers health interventions to individuals or to the community. This function aims to produce the best and most effective mix of personal and non-personal services, and to make them accessible. Service delivery is challenged in the summer when it needs to achieve maximum coverage of the population (for example, work force coverage during summer holidays in hospitals and nursing homes), reaching the poor and socially vulnerable, understanding the impact of different service delivery strategies (for example, public–private mix) on the entire health system and improving and monitoring the quality, safety and responsiveness of services.

Box 8. Preparedness of retirement and care homes and health care professionals

Retirement and care homes buildings and facilities

Buildings

Check that windows can be shaded.

Check there are no problems opening windows, including security considerations.

Ensure staff know which rooms are most easy to keep cool, and which are the most difficult, and review the distribution of residents accordingly.

If one exists, check that the cooling or air-conditioning system works properly. It should be able to keep the air temperature at or below 25 °C in at least one large room. Otherwise consider installing or renting an air-conditioning unit.

Make sure you have enough thermometers to accurately monitor temperatures throughout the building.

Facilities

Check you have an adequate supply of fans and water sprays.

Check water and ice are widely available.

Arrange for water to be distributed in the event of a heat-wave.

Adapt menus preferably with high water content, such as fruit and salads, in consultation with residents.

Working arrangements

Work out a protocol for changes to management arrangements in the event of a heat-wave to cover:

Mobilization of staff, including recall of those on holiday.

Changes to rotas.

Getting extra help from relatives of residents.

Getting extra help from volunteers.

Residents

Make sure you know who is most at risk – ask primary care staff if you are unsure.

Ensure you have protocols to monitor residents most at risk and to provide additional care and support.

Ask GPs of at-risk residents about possible changes in treatment or medication in the event of a heat-wave.

Check that residents have light, loose-fitting, cotton clothing to wear.

Health care professionals

For health and social care professionals who visit vulnerable individuals at home, similar advice is given in relation to preparing the home. The following points are mentioned in addition.

Facilities

Check fridges and freezers work properly.

Check fans and cooling devices work properly.

If you plan to move the person somewhere cooler in the event of a heat-wave, consider what equipment or help you might need.

Organization

Check that extra care and support is available if needed.

Check that the person can contact the primary care team if one of their informal carers is unavailable.

Check that their care plan contains contact details for their GP, other care workers and informal carers.

Check that there are adequate arrangements for food shopping.

If a heat-wave is forecast for your region:

- make sure you have taken the steps outlined above;
- monitor the current situation by checking the “heat-health watch” level on the Internet (www.metoffice.gov.uk) or listening to local weather news;
- make sure you know what advice to give people at risk (a public information leaflet with tips on what to do in a heat-wave is available from GP practices, pharmacies, NHS walk-in centres, hospitals, care homes, benefit offices and voluntary organizations);
- suggest people at particular risk consult their GP about possible changes to their treatment and/or medication.

In addition, emergency treatment advice is given for the situation when heatstroke is suspected and pre-existing diseases and medication that put people at particular risk are listed.

Source: adapted from the *Heatwave plan for England*, Department of Health, 2007.

Social factors such as social isolation further determine vulnerability in an important way and health care system planning needs to take them into account, for example through collaboration with social services. Health system and social service delivery planning are recommended. Reaching the most vulnerable at home has proven to be difficult and experiences need to be shared and new strategies developed. Countries can identify the most feasible and appropriate options based on data availability and structure of their respective social and health care systems.

In France, the government has since recommended that institutions for the elderly have at least one cooled room (République Française, 2005). However, overall housing for elderly people, care homes and hospitals should meet the category I requirements for the thermal environment under the Energy Performance of Buildings Directive (European Commission, 2003).¹⁴ In hospitals and nursing homes the provision of functioning cooling rooms has proved to be important.

In England, information for care home managers and staff has been developed (Box 8). The leaflets list who is particularly at risk, describe the health risks and give advice on how to reduce these risks – before and during a heat-wave (Department of Health, 2007). In France, based on the different alarm levels of the HHWS, different actions are taken. For example, the blue and the white plans (in retirement homes or hospitals) foresee reinforcement of summer staff, provision of sufficient number of available beds and perfusion facilities (Ministère de la Santé, 2008).

Again, the general applicability of these requirements and recommendations is limited as only selected examples from existing heat–health action plans have been taken up. Ways to ensure provision of special and routine health and social care during heat-waves and adaptation of facilities and infrastructure to hot temperatures need to be developed according to national and local needs and possibilities. In addition to health system activities, a number of potential restrictions should be kept in mind when designing a heat–health action plan, such as potential cuts in power and water supply. Recommendations can be strengthened through a growing number of examples of heat–health action plans, ongoing exchange of experiences and the results of evaluations of effectiveness.

The main findings of the review on treatment of heat-related illnesses and heatstroke can be summarized as follows (Bouchama, Dehbi & Chaves-Carballo, 2007).

- During heat-waves, heatstroke is a leading cause of morbidity and mortality.
- Immediate cooling and effective haemodynamic resuscitation are crucial to prevent irreversible tissue damage and death from this illness.
- There is no evidence of superiority of any one cooling technique: non-invasive, evaporative or conductive-based cooling techniques, singly or combined, appeared equally effective. No evidence was found of a specific endpoint temperature for safe cessation of cooling.
- Hypotension is often due to either relative or absolute hypovolaemia and it responds favourably to cooling and judicious volume replacement.

Overall, health personnel have an important role to play in heat–health protection by identifying and advising individuals at high risk from heat-related illness and providing initial treatment (Bouchama et al., in press; WHO, 2008; Matthies et al., 2008; see Table 12).

¹⁴ The European Standard EN 15251 specifies the main parameters for the calculation of energy used in buildings, the evaluation and monitoring of the indoor environment and the display of energy characteristics, as recommended in the European Energy Performance of Buildings Directive (European Commission, 2003).

GPs have an important role to play (Box 9) in informing patients about the effects of heat, the side-effects of medications and recommended dose changes during hot weather.

Training of medical professionals and caregivers may need to be reviewed and updated according to new guidance.

Box 9. The role of GPs

Medical professionals should:

- understand the thermoregulatory and haemodynamic responses to excessive heat exposure;
- understand the mechanisms of heat illnesses, their clinical manifestations, diagnosis and treatment;
- recognize early signs of heatstroke, which is a medical emergency;
- initiate proper cooling and resuscitative measures for the treatment of heatstroke and other mild heat-related illnesses;
- be aware of the risk and protective factors in heat-wave-related illness;
- identify the patients at risk and encourage proper education regarding heat illnesses and their prevention (education of guardians of the old and infirm and infants is also important);
- include a pre-summer medical assessment and advice relevant to heat into routine care for people with chronic disease (reduction of heat exposure, fluid intake, medication);
- be aware of the potential side-effects of the medicines prescribed and adjust dose, if necessary, during hot weather and heat-waves;
- make decisions on an individual basis, since there are – according to current knowledge – no standards or formal advice for alteration in medications during hot weather;
- be aware that high temperatures can adversely affect the efficacy of drugs, as most manufactured drugs are licensed for storage at temperatures up to 25 C; ensure that emergency drugs are stored and transported at proper temperature;
- be prepared to monitor drug therapy and fluid intake, especially in the old and infirm and those with advanced cardiac diseases.

Source: adapted from Bouchama, 2007.

Table 12. Management of mild and moderate heat illnesses and heatstroke

Medical condition	Signs and symptoms/mechanisms	Management
Heat rash	<p>Small red itchy papules appear on the face, neck, upper chest, under breast, groin and scrotum areas.</p> <p>This can affect any age but is prevalent in young children. Infection with <i>Staphylococcus</i> can occur.</p> <p>It is attributed to heavy sweating during hot and humid weather</p>	<p>Rash subsides with no specific treatment. Minimize sweating by staying in a cool place, taking frequent showers and wearing light clothes.</p> <p>Keep the affected area dry.</p> <p>Topical antihistamine and antiseptic preparations can be used to reduce discomfort and prevent secondary infection.</p>
Heat oedema	<p>Oedema of the lower limbs, usually ankles, appears at the start of hot season.</p> <p>This is attributed to heat-induced peripheral vasodilatation and retention of water and salt.</p>	<p>Treatment is not required as oedema usually subsides following acclimatization. Diuretics are not advised.</p>
Heat syncope	<p>This involves brief loss of consciousness or orthostatic dizziness. Common in patients with cardiovascular disease or taking diuretics, before acclimatization takes place.</p> <p>It is attributed to dehydration, peripheral vasodilatation and decreased venous return resulting in reduced cardiac output.</p>	<p>The patient should rest in a cool place and be placed in a supine position with legs and hips elevated to increase venous return.</p> <p>Other serious causes of syncope need to be ruled out.</p>
Heat cramps	<p>Painful muscular spasms occur, most often in the legs, arms or abdomen, usually at the end of sustained exercise.</p> <p>This can be attributed to dehydration, loss of electrolytes through heavy sweating and muscle fatigue.</p>	<p>Immediate rest in a cool place is advised.</p> <p>Stretch muscle and massage gently.</p> <p>Oral rehydration may be needed with a solution containing electrolytes.</p> <p>Medical attention should be sought if heat cramps are sustained for more than one hour.</p>
Heat exhaustion	<p>Symptoms include intense thirst, weakness, discomfort, anxiety, dizziness, fainting and headache. Core temperature may be normal, subnormal or slightly elevated (less than 40 °C). Pulse is thready with postural hypotension and rapid shallow breathing. There is no mental status alteration.</p> <p>This can be attributed to water and/or salt depletion resulting from exposure to high environmental heat or strenuous physical exercise.</p>	<p>Move to a cool shaded room or air-conditioned place. The patient should be undressed. Apply cold wet sheet or cold water spray and use fan, if available. Lie the patient down and raise legs and hips to increase venous return. Start oral hydration. If nausea prevents oral intake of fluids, consider intravenous hydration.</p> <p>If hyperthermia above 39 °C, impaired mental status or sustained hypotension occurs, treat as heatstroke and transfer to hospital.</p>
Heatstroke	<p>Body temperature rapidly increases to greater than 40 °C and is associated with central nervous system abnormalities, such as stupor, confusion or coma. Hot dry skin, nausea, hypotension, tachycardia and tachypnoea are often present.</p> <p>Heatstroke results from exposure to a high ambient temperature (classic heatstroke) or secondary to vigorous physical activity (exertional heatstroke) overwhelming the heat dissipating mechanisms.</p> <p>Exaggeration of acute phase response and alteration of heat-shocks protein regulation have been recently suggested.</p>	<p>This is a medical emergency.*</p> <p>Measure core temperature (rectal probe).</p> <p>If > 40 °C, move to a cooler place, remove clothing and initiate external cooling:† use cold packs on the neck, axillae and groin, and fan continuously while skin is sprayed with water at 25–30°C.</p> <p>Position unconscious patients on their side and clear airway.</p> <p>Administer oxygen 4 L/min.</p> <p>Give isotonic crystalloid (normal saline).</p> <p>Rapidly transfer to an emergency department.</p>

Source: adapted from Bouchama & Knochel, 2002.

* Diagnosis of heatstroke should be suspected in any patient with mental status changes during heat stress even if the temperature is < 40 °C.

†No evidence that one cooling technique is superior to another. Non-invasive techniques that are easy to apply, well tolerated and less likely to cause cutaneous vasoconstriction are preferred.

Real-time surveillance

Real-time data systems can be used to describe rapidly what is happening during a heat-wave and during the summer. Real-time data systems can inform health decision-makers during the summer about abnormal outbreaks or clusters of health impacts.

Methods

A worldwide literature survey on rapid alert systems for mortality and morbidity was carried out and 137 scientific articles were analysed. The objective of the literature survey was to identify those public health areas where real-time data have been used, to explore the results related to real-time data research and to make a systematic evaluation of the effectiveness and public health relevance of the use of real-time data. Five public health areas – outbreaks, gastrointestinal diseases, emergency departments, nosocomial infections and bioterrorism – were identified, where surveillance systems are used.

Results

The literature search and the data collection on heat–health warning systems revealed that only five European Union countries run surveillance systems for heat purposes (Portugal, France, Italy, Spain and the United Kingdom). In the case of a heat-wave the most useful real-time data seemed to be all-cause mortality, emergency calls, emergency department visits, hotlines and GP records, the advantages and disadvantages of which are summarized in Table 13 (Páldy et al., in press). No information was available to deduce how intervention strategies are changed or adjusted once the real-time information is communicated.

In many countries the collection of rapid mortality data is limited and, where syndromic surveillance exists, the systems could be tested for expansion to mortality, GP information and emergency calls.

Recommended data sources for the operation of the systems related to heat-waves are the following (Páldy et al., in press):

- Mortality data are an important source of information. The experience gained during the 2003 heat-wave shows a minimum of rapid information that is important for the ministries of health. Standardized collection of mortality data within 48 hours is recommended for all countries.
- Emergency department data records provide information about the main problems presented by patients. Data often become available during or shortly after a patient's visit, thus providing a basis for real-time surveillance. It should be borne in mind that the data vary in quality if they are recorded prior to physician involvement in care.
- Call centre data are widely used. Events are registered as they occur at the call centre and the data are forwarded to the health institute for further analysis. Call centre data seem to be suitable for monitoring heat-related illnesses within a heat–health action plan.

Table 13. Characteristics of various real-time data for heat–health action plans

System	Data	Advantages	Disadvantages	Cost	Applicability
Sale of over the counter drugs	Time, space and product specific	Data are available promptly	No information about the purchaser, confounded by the promotion and availability of the drug, low specificity	Relatively low	Not applicable
Ambulance calls	Age, sex, home postcode, date and time of call	Time and space specificity	First medical diagnoses are not final diagnoses	Relatively low	Yes
Emergency visits	Age, sex, home postcode, date and time of visit, chief complaint	Detection of the temporal and spatial accumulation High sensitivity	Aetiology is not certain, time consuming, low specificity	Technical and personal support	Yes
Hospital admission	Age, sex, home postcode, date and time of visit, chief complaint	No extra work for physicians, rapid and sensitive alarming	A lot of false alarms	Cost vary widely	Yes
Internet/home page based systems		Good for detecting non-serious cases	Require resources from the patient, gender specific (women use it more frequently), low sensitivity and specificity	Relatively low	Partly
Hotline calls	Chief complaints, postcode	Easy to operate	Patient data are not available, local outbreaks are not detectable	Low	Yes

Source: Páldy et al., in press.

The development and maintenance costs of these systems do not justify a focus on a single syndrome or health outcome, but it can be recommended that existing systems expand to heat-related syndromes. Therefore, the use of existing available systems is recommended where possible. A good example of this is the use of data collected by NHS Direct in the United Kingdom. Countries like France, Italy and the United Kingdom have already developed heat specific syndromic surveillance systems and could be used as examples (Box 10). Operation of a common European Union syndromic surveillance system is highly recommended for European Union member states. For non-EU countries the extension of existing surveillance systems to collect heat relevant data is advisable (Páldy et al., in press).

Box 10. Heat-wave and syndromic surveillance – the French experience

Following the 2003 heat-wave, a syndromic surveillance system based on emergency department admissions and crude mortality has been developed in France. In 2006, France experienced a heat-wave lasting 19 days (10–28 July). To monitor the health impact of hot weather the following indicators were developed: total number of daily cases of three pathologies linked to high temperatures (hyperthermia, dehydration and hyponatraemia). The correlation between the indicators and temperature showed that emergency departments are a very relevant source of information for environmental health impact surveillance. Concerning mortality, a significant increase during the hottest week of July was observed. The excess deaths observed in that week were around 2000. With syndromic surveillance reports were rapidly delivered to the Ministry of Health.

Source: Laaidi et al., 2005.

Monitoring and evaluation

Monitoring and evaluation constitute key elements of heat–health action plans and the general principles of good public health evaluations apply. However, heat–health action plans are extremely difficult to evaluate as they vary widely in structure, partner agencies and the specific interventions and they change from year to year in response to events. Heat-waves are rare events; the impact of each heat-wave is different and heat-related deaths can be difficult to identify (Kovats & Ebi, 2006; Matthies et al., 2008).

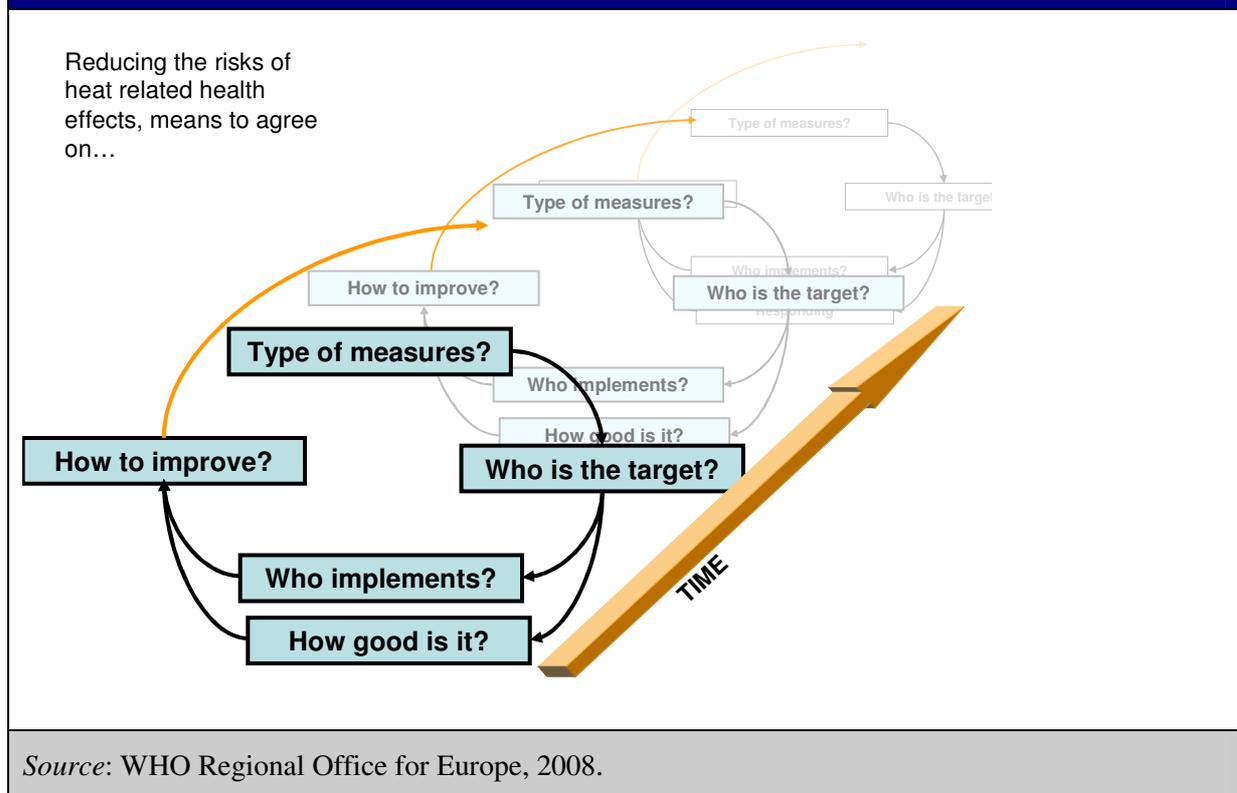
Methods

Through an expert consultation the general principles of public health evaluations were scrutinized for their applicability in the evaluation of heat–health action plans. Together with methodological examples from those heat–health action plans in Europe that have started integrating elements of both process and outcome evaluation, a selection of approaches and methods were compiled (Matthies et al., 2008).

Results

A structured evaluation, comprised of process evaluation as well as outcome evaluation can be integrated into a heat–health action plan. This can facilitate identification of the most effective interventions in a national or local context, as well as barriers to (and opportunities for) implementation. Methods for monitoring and evaluation are still under development. Suggestions have been compiled for the development of performance management standards, including stakeholder involvement and consultations. Feasible measurements for the impact on mortality (outcome evaluation) need to be developed. Long-term evaluation of heat–health action plans and the integrated public health measures may be needed to demonstrate significant effects on health outcomes. For the monitoring, evaluation and adjustment of existing heat–health action plans or the development of new heat–health action plans, the following iterative process can be followed (Fig. 8).

Fig. 8. Framework for the development and the assessment of heat–health action plans



One of the classical evaluation models (Donabedian, 1988) addresses structures, processes and outcomes. Structural considerations should include:

- whether there is a national plan;
- what the components of the plan are;
- whether the objectives of each component and responsibility for them are described;
- if the plan includes an HHWS and, if so, whether it is described clearly.

Important questions of process and outcome evaluation of heat–health action plans are listed in Table 14.

Most of the functional heat–health action plans are evaluated following each summer with regard to their implementation (process) and annual reports are being made available (see, for example, Department for Civil Protection, 2007; Generalitat de Catalunya, 2006 and 2007; HPA, 2007). To assess the effectiveness of the interventions in reducing heat-related morbidity and mortality, however, is more difficult and further development of methodology and evaluation needs to be promoted.

Table 14. Questions to be addressed in process and outcome evaluation of heat–health action plans

Process evaluation should assess:	Outcome evaluation should assess:
<ul style="list-style-type: none"> • whether key messages were provided to the population; • if the population was aware of the plan and its messages; • whether warnings were issued at the right time; • whether the organizations and professionals acted appropriately and if they followed the plan; • whether the organizations and professionals found the plan helpful. 	<ul style="list-style-type: none"> • mortality – daily temperatures and deaths before, during and after heat-wave periods, mortality in different settings, such as care homes; • morbidity; • health care utilization; • non-health-related outcomes such as productivity and work absence; • an assessment of the temperature–mortality function; • health behaviour changes related to heat.

Source: Matthies et al., 2008.

4. Conclusions

Global climate change is projected to further increase the frequency, intensity and duration of heat-waves and attributable deaths. Public health prevention measures over the long term, medium term and during emergencies are all important, but may not prevent all additional health threats from climate change. The available information and experience can be used for further steps and action at national and European level. From this project the following conclusions emerged.

Health risks

Hot weather events can kill and cause illness. The heat-wave of 2003 caused thousands of deaths in Europe and highlighted some of the weaknesses of the public health response. Hot weather days outside heat-waves are also responsible for health impacts.

Some people are at particular risk of heat stress, including the elderly, children, persons with chronic diseases or taking medication, outdoor workers and some dependent or socially isolated individuals.

Air pollution is often worse during a heat-wave. Because hot weather and air pollution often coincide, it can be difficult to separate the effects of the two exposures. There is growing evidence that hot weather and air pollution interact so that air pollution has greater health effects when the weather is extremely hot. Actions need to be taken to reduce air pollution.

Public health action

The adverse health effects of heat-waves are largely preventable. It is recommended that Member States develop heat–health action plans. The following elements are recommended for inclusion in heat–health action plans:

- the establishment of collaborative mechanisms between bodies and institutions and a lead body to coordinate responses;
- an accurate and timely alert system;
- heat-related health information strategies;
- strategies to reduce individual and community exposure to heat;
- improved urban planning, transport policies and building design to reduce energy consumption;
- particular care for “vulnerable” populations;
- provision of health care, social services and infrastructure;
- real-time surveillance, evaluation and monitoring.

Knowledge gaps

Although a lot of knowledge has been acquired on the health effects of heat and heat-waves and measures to prevent them over recent years, there are still many knowledge gaps. Specific components and measures of heat–health action plans need to be further investigated and developed.

- The climate information decision support tool is available for piloting and its accuracy and user friendliness needs to be assessed. Suggestions from users could be integrated into an updated and improved version.
- Treatment recommendations for heat illnesses, particularly heatstroke, need to be further investigated in order to issue official guidelines. Specific training modules need to be developed for health professionals to enable the early recognition of the symptoms of heat illnesses, including heatstroke, and their treatment.
- In many countries little is known about heat–health risk perception among the public and which communication strategy is best to reach the respective target groups, particularly those most at risk.
- Experiences with running real-time surveillance need to be collected and shared in order to improve them.
- Policy advice and options need to be developed for the reduction of air pollution during very hot weather and heat-waves.
- To date, very little is known about the costs and benefits of heat–health action plans and their components. Analyses would provide important information for decision-makers when considering the development of a heat–health action plan.

Activities to be further developed

Implementation of national and regional heat–health action plans

Countries may consider developing or improving heat–health action plans depending on their assessment of health risks related to climate change. For each of the core elements of heat–health action plans, based on the results of the EuroHEAT work packages and through review of existing heat–health action plans and their interventions, literature reviews and expert consultations, best practice examples were selected and compiled as guidance for the development of heat–health action plans (Matthies et al., 2008). This guidance may be useful for the development, as well as for the improvement, of national or regional heat–health action plans.

Evaluation

To develop the evidence base for heat–health protection and to ensure that plans are as effective and efficient as possible, it is essential that heat-wave plans are evaluated and that the evaluations are published. The methodology for systematic evaluation still needs to be established and could be jointly developed and tested at a European level through the EuroHEAT network.

Dissemination of information

A prerequisite for the implementation of heat–health action plans is the broad dissemination of the products developed by EuroHEAT to Member States, including translation into the Russian language of important guidance materials. An information platform and regular meetings of the EuroHEAT network can also foster an exchange of experiences and joint development of methods (for example, for real-time surveillance or evaluation).

Heat-related morbidity and mortality need to be monitored and data made available at the national and if possible at the European level. International collaboration supports the improvement of existing surveillance systems and the establishment of new ones, as well as the compatibility of these systems and the data collected.

Strengthening of health systems

The climate has the potential to put additional stress on health systems and vulnerable population groups and to worsen inequities within and among countries. It needs to be reviewed whether current health care, facilities, public health measures and equipment are sufficient to address extreme events and changing health outcomes as projected under climate change. What health systems can do to prepare for climate change, including heat-waves, has been outlined in the recent WHO publication “Protecting health in Europe from climate change” (Menne et al., 2008). Among the options are:

- strengthening health security and health systems intelligence;
- setting an example for adaptation to and mitigation of climate change (for example, greening the health services);
- building partnerships across agencies and sectors.

Health system stewardship is important for effective advocacy of health with different actors and stakeholders. Health service delivery and disaster preparedness are fundamental in preparing for climate change (Menne et al., 2008).

How can WHO help?

Technical assistance can be provided through the WHO Regional Office for Europe to countries that intend to develop heat–health action plans. Capacity building and training of health professionals need to be integrated into these plans. Further information exchange and development of methods (for example, for evaluation) will be fostered through provision of the respective platforms (for example, web-based information platform, workshops and international meetings). More advocacy may be necessary for implementation of long-term measures to reduce heat exposure (for example, in urban planning and housing) and for promoting health in other sectors. Eventually, development of the evidence base for health effects of other extreme events such as floods and droughts should allow for similar action plans and sets of measures to be designed. Investigation of options to include these plans into overall emergency preparedness plans is suggested.

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