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Heatwaves and public health in Europe

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Public health measures need to be implemented to prevent heat-related illness and mortality in the community and in institutions that care for elderly or vulnerable people. Heat health warning systems (HHWS) link public health actions to meteorological forecasts of dangerous weather. Such systems are being implemented in Europe in the absence of strong evidence of the effectiveness of specific measures in reducing heatwave mortality or morbidity. Passive dissemination of heat avoidance advice is likely to be ineffective given the current knowledge of high-risk groups. HHWS should be linked to the active identification and care of high-risk individuals. The systems require clear lines of responsibility for the multiple agencies involved (including the weather service, and the local health and social care agencies). Other health interventions are necessary in relation to improved housing, and the care of the elderly at home and vulnerable people in institutions. European countries need to learn from each other how to prepare for and effectively cope with heatwaves in the future. Including evaluation criteria in the design of heatwave early warning systems will help ensure effective and efficient system operation.

Keywords: early warning, elderly, evaluation, heatwaves, heat stroke

The 2003 heatwave event in Western Europe has underscored the need for the development and implementation of public health measures to reduce the health burden associated with extreme high ambient temperatures. In 2003, Central Europe experienced the hottest summer since 1500,[1] and the heatwave in early August caused an estimated 14800 deaths in France.[2] Public health measures implemented after 2003 have centred almost exclusively on heat health warning systems (HHWS) that use forecasts of high-risk weather conditions to trigger public warnings.[3] We review the public health aspects of heatwaves and evaluate the relative effectiveness of public health responses (observed and proposed) in Europe.

Health burden of heatwaves

Heatwave events are associated with marked short-term increases in mortality (figure 1). Populations in regions where extremely hot weather is relatively infrequent are most vulnerable to heatwaves owing to a lack of behavioural adaptations and inappropriate housing (for example, the Midwestern US[4,5] and Northern France[2]). Where heatwaves have been reported as 'disasters', they were more frequent in southern Europe and the Balkans.[6] No population is completely acclimatized or adapted to very hot weather, and all European populations studied so far, including those in Southern Europe,[7] have shown that mortality increases at extreme temperatures.

Table 1 lists published studies that quantified the impacts of selected heatwaves using routine death registration data in Europe. Such estimates of excess mortality were associated with different attributes of hot weather including the temperature increase (from the long term average), duration, and the timing of heatwave in the summer season. Estimates are sensitive to the method used to estimate the 'expected' mortality and no standard approach has been developed.[4] Episode studies show that effects are overwhelmingly concentrated in the older age groups, but attributable deaths in adults are also apparent.[8–10] There is no evidence of mortality attributable to heatwaves in children. The elderly are most at risk of heat-related mortality for a range of physiological reasons. High temperatures decrease blood viscosity leading to an increased risk of thrombosis[11] and older persons have impaired kidney function and thermoregulation.[12] Good cardiovascular fitness is also essential for thermoregulation.[13] The excess mortality associated with heatwaves can be considerable, but there are important unresolved questions about the extent to which deaths are brought forward in time, and the extent to which many of these deaths are preventable. The evidence from France indicates that for a major heatwave event very little of the attributable mortality was due to short-term displacement.[2,14] We assume that there is a sufficient avoidable burden to develop preventative measures, especially in the most extreme events, given the knowledge that heatstroke deaths in individuals are easily preventable[15,16] (table 1).

The risk of heat illness exists for the entire population. Case–control studies in the US, however, have identified important social factors that put people at higher risk of dying during a heatwave or from heat stroke, such as living alone, being socially isolated, no working air conditioning; and those in top floor apartments.[27–29] Studies that have investigated heat-related mortality rates in different neighbourhoods indicate some effect of deprivation.[28,30,31] The physical and social isolation of elderly people in the US further increased their vulnerability to dying in a heatwave.[5] Results from France and Italy in 2003 indicate that, in addition, residents in maison de retraite (retirement homes) and nursing homes were also at high risk during the heatwave.[32,33] In general, there is very little epidemiology on individual-level factors for heatwave-related illness and death, and important risk factors are likely to be location specific.

Information on the non-fatal effects of heatwaves is mostly from reported increases in emergency hospital admissions or ambulance call-outs.[2,34–37] There are contrasting patterns between impacts on mortality and hospital admissions during heatwaves by age group and cause. For example, excess mortality is usually greatest for cardiovascular and respiratory diseases in the elderly. Hospital admissions during heatwaves increase for adults as well as for the elderly, and for the classical heat illnesses (heat stroke, heat exhaustion) and related conditions (dehydration), neurological conditions, renal disease, and mental illness. There is burden of heat-related illness in adults that may be related to living in institutions,[38] as well as those who have to work outdoors. The relatively low increase in admissions for the elderly, indicates persons dying in heatwaves die quickly

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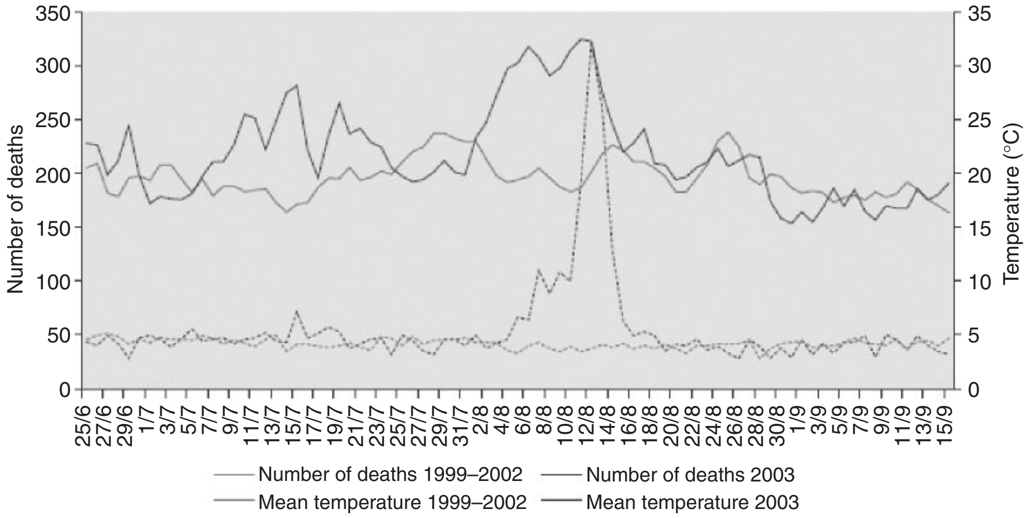

Figure 1 Daily mortality and mean temperature in Paris, France, June to September 2003

Table 1 Mortality attributed to hot summers or heatwave periods in Europe: published reports 1980–2004[2,9,17–26]

Heatwave event	Excess mortality (all causes, all ages)[a]	Baseline measure	References
1981—Portugal	1906 excess deaths in Portugal, 406 in Lisbon	Predicted values	26
1983—Rome, Italy	35% increase in deaths in July 1983 in 65+ age group	Deaths in same month in previous year	23
1987—Athens, Greece	>2000 estimated excess deaths in heatwave period 21–31 July 1987	Time trend regression adjusted	25
1991—Portugal	997 estimated excess deaths in heatwave 12–21 July 1991	Predicted values	24
1995—London, UK	23% (184 estimated excess deaths) in heatwave 30 July–3 August 1005	31-day moving average of daily mortality in previous 2 years	9
2003—France	14 802 deaths during heatwave period 1–20 August (60% increase). Excess mortality greatest in Paris, Dijon, Poitiers, Le Mans and Lyon (>78% increase)	Average of deaths for same period in years 2000–2002	2
2003—Netherlands	Estimated 500 excess deaths during heatwave 31 July–13 August	Predicted values from regression model of weekly temperature and mortality series	20
	1400–2200 excess deaths in summer 2003 (June–August inclusive). 3–5% increases		
2003—Switzerland	Approximately 975 excess deaths (7% increase) in period June–August 2003 (inclusive)	Deaths in previous years 1990–2003	22
2003—Spain (50 Provincial Capitals)[b]	Approximately 3166–4151 excess deaths in June–August 2003 (inclusive), 8–11% increase in mortality. Excess mortality in August was 2175 deaths, a 17% increase	Predicted values from regression model of daily temperature and mortality time series	19
2003—Portugal	1317 excess deaths (36% increase 95% CI 29–48%) during 10 day heatwaves (30 July–12 August 2005)	Average daily deaths in period 15–28 July 2003. Estimates for mainland Portugal extrapolated from deaths reported in district capitals	18
2003—Rome, Italy	In Rome, 944 excess deaths (19% increase) in June to August 2003 (inclusive)	Smoothed daily mean mortality for same period in years 1995–2002	21
2003—England only	2091 excess deaths, 16% increase in 10 day heatwave 4–13 August 2003	Average of deaths for same period in years 1998–2002	17

a: Many studies also report deaths by age group, gender, and region or city—refer to the original source for further details
b: 35% of total population of Spain
Note: Comparisons of impacts between countries and between different heatwaves should be avoided because of different methods of estimating the excess, for different heatwave periods, for different populations (urban, rural, major cities), etc. No standardized estimates across European countries have been made for the 2003 heatwave event

before they can be admitted to hospital, and/or persons are dying before they come to the attention of others, either because they live alone or because of lack of care, institutional or otherwise. This clearly has implications for the development of prevention measures.

Heat health warning systems

A HHWS is defined here as a system that uses meteorological forecasts to initiate acute public health interventions designed to reduce heat-related impacts on human health during atypically hot weather.[3] An effective heat health warning system requires[39]:

- reliable meteorological forecasts for the population or region of interest
- robust understanding of the cause-and-effect relationships between the thermal environment and health outcomes at the population level, including the evidence-based identification of 'high risk' meteorological conditions to activate and deactivate response activities.
- effective response measures to implement within the window of lead-time provided by the warning (1–3 days, approximately)[40]
- the involvement of institutions and civil society that have sufficient resources, capacity, knowledge, and political will to undertake the specific response measures.

HHWS are implemented at the local level and, therefore, vary widely in structure, partner agencies, and the specific interventions deployed. Some are linked to national systems for issuing the warning, although the meteorological 'thresholds' for action need to be population specific, as they relate to the local population's adaptation to their local climate (table 2).

In the earlier heatwave 'alert' systems, simple temperature and duration thresholds were used to identify heatwaves.[3] Temperature–humidity indices were also used with thresholds based on physiological limits of healthy individuals (for example, the Heat Index was used until recently by the US National Weather Service to classify hot days).[41] In the 1990s, synoptic methods were developed to identify city-specific air masses associated with particularly high mortality days.[42,43] The ICARO system in Lisbon uses an algorithm derived from the relationship between maximum temperature and mortality, and when the threshold is exceeded a warning is issued.[44] Little information has been published on the relative predictive value of the various indices used to trigger warnings.[45] Temperature forecasts are generally highly accurate (e.g. 3 day forecast of maximum temperature for London in August 2003 was 96% correct, M. Gibbs, Met Office, personal communication). However, several systems also incorporate health surveillance to either improve the forecast model of excess mortality for determining the level of heat alert (e.g. in Milan) or as confirmation that the heatwave is affecting health (e.g. monitoring of NHS Direct in the UK).

The setting of a threshold for initiating a health response needs to be based on operational criteria as well as the observed weather–mortality relationship.[46] A high threshold would trigger response to only the most extreme heatwaves (the 2003 heatwave was greater than one in 1000 year event for France). But such a system would not aim to 'prevent' the majority

Table 2 Heat health systems in Europe in 2005[19]

Description	Country	Populations covered by system
The Italian Department for Civil Protection implemented a national programme for the prevention of the health effects of heatwaves	Italy	National programme, with city-level implementation (e.g. Rome, Milan, Turin)
SACS (Systeme d'alert canicule et sante)	France	All 14 main cities France [Marseille, Toulouse, Lyon, Bordeaux, Grenoble, Strasbourg, Tours, Paris, Nantes, Limoges, Nice, Lille, le Havre]
		System in Marseilles, since 1985
Plan de acciones preventivas contra los efectos del exceso de temperaturas sobre la salud (www.msc.es) Ministerio de Sanidad y Consumo	Spain	A country wide warning system that is controlled at a national level – but health officials at the regional level decide if they warn the population or not, and take what ever measures they need. The system has three alert levels.
		Daily mortality surveillance system.
		Voluntary register of high-risk people, awareness campaigns
		Temperature based alert system
UK Heatwave Plan	UK	System for England and Wales (not Scotland), with region-specific temperature thresholds for action. The plan has four alert levels
ÍCARO Surveillance System. Warnings are communicated to the Civil Protection Agency and the General Directorate of Health, which in turn communicates the warnings to the five regional Health Authorities and the Health Authority Network	Portugal	Lisbon areas since 1999, and the other regions of Portugal since 2004
German Heat Health Warning System—the meteorological component of the is based on the HeRATE (Health Related Assessment of the Thermal Environment) approach	Germany	A country wide warning system that is controlled at a national level—but health officials at the regional level (Bundesländ) decide if they warn the population or not, and implementation of interventions

Source: Information from Euroheat network
Systems also operational in Hungary, Slovenia and Switzerland

of heat-related deaths that occur on less extreme days. US heat watch/warning systems (HWWS) often have fairly low thresholds for warnings that are expected to be exceeded at least once per year.

The majority of HHWS implemented after 2003 have more than one level of response (figure 2). The different responses are initiated within each identified level based on the confidence in the heatwave forecast or the magnitude of the heatwave event. A one-tiered system will issue a warning or 'heat advisory' when the threshold is forecast to be exceeded within a matter of days. Cities in the US also have two-tiered or three-tiered warning procedures.[46,47] Many cities in Europe have some form of emergency planning, which can be deployed for extreme heatwaves.[48] The Greek government implemented its Xenocrates emergency plan for natural disasters during severe heatwaves in 1998 and 2002. The highest level of the UK Heatwave plan triggers a 'Major Incident' response.[49]

Table 3 lists specific interventions that have been incorporated into HHWS. However, it is difficult to find which actions are actually implemented at the local level in response to a warning. A recent review of HHWS in the US found that

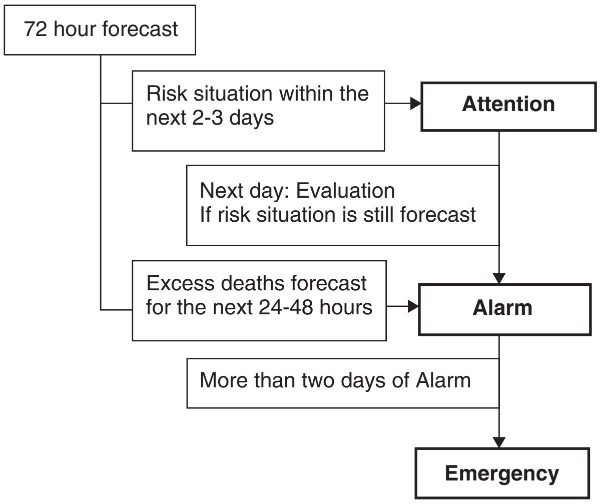

Figure 2 An example of a heat health warning system with three levels of alert (attention, alarm, emergency)

Table 3 Public health measures in US and European HHWS[3,39,50]

Measure, strategy	**Level of implementation[a]**	**Comments**
Media announcements (radio, television)	+++	Provide general advice on heat stress avoidance to general public
Bulletin or webpage	+++	May be restricted access, to relevant professionals or accessed by anybody
Leaflets	++	General advice, and advice for nursing home managers. Often distributed at beginning of the summer via health centres, and places where vulnerable people may be
Telephone help-line	++	Either a dedicated telephone service is opened (e.g. Heatline in Portugal) or people are encouraged to phone a pre-existing general health advice line (e.g. NHS Direct in the UK)
Opening of cooling centres	++	Some evidence that cooling centres not used by high-risk individuals, but used by low-risk individuals
Alert to hospital emergency rooms, ambulance services	+	Used to improve operational efficiency (e.g. if need to deploy extra staff). Needs to be based on local information and carefully evaluated
Home outreach visits to vulnerable persons	+	Important but usually expensive. Use pre-existing networks of volunteers (e.g. Buddy systems in Philadelphia), or professionals (e.g. social workers). Requires some registry of vulnerable people
Evacuation of vulnerable persons from their homes to cooling centres	+	Using a registry of vulnerable people, who are visited at home, and evacuated, if necessary
Outreach to homeless	+	High-risk group in southern US (11 homeless people died in heatwave in Phoenix, July 2005)
Electricity companies cease disconnection for non-payment	+++	Utility companies have initiated and financially supported HHWS in the US. Most important where population relies on heavily air conditioning (as in the US)
Water companies cease disconnection for non-payment	+	
Fan distribution	++	Fans are effective when they circulate cooler air, but not above temperatures ~37°C

Based on direct contact with agencies and the following sources: Refs. (3, 39, and 50)
a: Level of implementation as reported and not observed. + rarely implemented, ++ often implemented, +++ very often implemented

only 10 of the 18 cities considered had written heat response plans, and one-third of these were cursory.[39]

A communication and public education strategy is an essential part of the warning system, public health messages should be disseminated to all age and risk groups to increase awareness of symptoms of heat-related illness.[39] However, there is evidence that perception of ambient temperature is poorer in the elderly.[50] The most susceptible individuals are socially isolated, elderly, and may have a mental illness or disability that causes cognitive/behavioural problems.[15,28] An understanding of human behaviour and physiology during heat events is, therefore, needed before the most appropriate messages can be developed and targeted. It is clear that the passive dissemination of heat avoidance advice is insufficient to prevent many deaths.

There is very limited information on what public health interventions have actually been implemented as part of an HHWS system (table 3).[39,51] The focus of the measures is primary prevention of hyperthermia, as heat stroke progresses rapidly and is very often fatal. Secondary prevention (identifying and treating people with early stages of heat illness) should also form part of an HWWS. In this paper, we do not discuss heat alert or prevention programmes in occupational or sports settings as these have been addressed elsewhere.[52] An example of heat avoidance advice is given in Box 1. Advice focuses on the hazards of a heatwave, how to recognize the symptoms of heat exhaustion and heat stroke, and how to deal with the effects of too much heat.

One strategy is to encourage at-risk individuals to visit cool areas. During a heat emergency, it may be advisable to extend the opening hours of public swimming pools, beaches, public parks, or large cooled buildings such as shopping centres. Anecdotal evidence from the US indicates that dedicated cooling centres were not well attended, and that the people who do attend are not those at most risk.[39]

For effective outreach, high-risk individuals need to be identified and outreach services initiated early in the heatwave. The outreach may be undertaken by professionals (health workers) or by volunteers, including friends or relatives. The Philadelphia HWWS was able to exploit a pre-existing community-based Buddy system that enables neighbours to check on vulnerable individuals.[47,53] Systems in Europe have used pre-existing registers of vulnerable people, or have asked persons to register themselves or their relatives voluntarily.[54]

At the time of the heatwave in 2003, only two cities in the WHO European region had operational HHWS: the ICARO system in Lisbon[3,24] and a heat health watch warning system in Rome.[55] Following the 2003, heatwave, France,[56] Italy,[57] Germany, Spain, and the UK[48] all developed and launched heatwave plans in 2004 (table 2).

Evaluating HHWS

A public health intervention is typically evaluated based on estimates of the lives saved (premature deaths avoided) and other criteria such as acceptability or reduction of health inequalities.[58] HHWS, when accompanied by specific health interventions, are considered to be effective in reducing deaths during a heatwave.[3,39,53,59–61] However, there is very little published information on formal (quantitative or qualitative) assessments of the effectiveness of the systems as a whole or of individual intervention measures.

HWWS are extremely difficult to evaluate. Heatwaves are rare events and high temperatures have different impacts on different populations. It is not possible to directly compare the impacts of heatwaves in terms of death rates either in different cities or in the same city over time. Fewer heat-related deaths occurred in Chicago during the 1999 heatwave compared with the 1995 event, and some of this reduction was attributed to the successful implementation of prevention measures, such as the opening of cooling centres.[59] As well as an increase in the use of air conditioning by vulnerable groups between the two events, there would also have been an increase in the general level of awareness of the impacts of heatwaves and how to respond effectively. Similarly, an observed decline in heat-related mortality in Marseille, France, following the introduction of preventive campaign (based on warning messages) cannot be robustly attributed to that intervention.[61]

Box 1 Advice issued to prevent heat-related illness by the Department of Health

Keep out of the heat
- If a heatwave is forecast, try and plan your day in a way that allows you to stay out of the heat.
- If you can, avoid going out in the hottest part of the day (11 a.m.–3 p.m.).
- If you cannot avoid strenuous outdoor activity, like sport, DIY, or gardening, keep it for cooler parts of the day, like early morning.
- If you must go out, stay in the shade. Wear a hat and light, loose-fitting clothes, preferably cotton.
- If you will be outside for some time, take plenty of water with you.

Stay cool
- Stay inside, in the coolest rooms in your home, as much as possible.
- Close the curtains in rooms that get a lot of sun.
- Keep windows closed while the room is cooler than it is outside. Open them when the temperature inside rises and at night for ventilation. If you are worried about security at least open windows on the first floor and above.
- Take cool showers or baths, and splash yourself several times a day with cold water, particularly your face and the back of your neck.

Drink regularly
- Drink regularly even if you do not feel thirsty—water or fruit juice are best.
- Try to avoid alcohol, tea, and coffee. They make dehydration worse.
- Eat as you normally would. Try to eat more cold food, particularly salads and fruit, which contain water.

Seek advice if you have any concerns
- Contact your doctor, a pharmacist or NHS Direct if you are worried about your health during a heatwave, especially if you are taking medication or have any unusual symptoms.
- Watch for cramp in your arms, legs or stomach, feelings of mild confusion, weakness or problems sleeping.
- If you have these symptoms, rest for several hours, keep cool and drink water or fruit juice. Seek medical advice if they get worse or do not go away.

Helping others
- If anyone you know is likely to be at risk during a heatwave help them get the advice and support they need.

Older people living on their own should be visited daily to check whether they are OK.

One component of effectiveness is to measure the positive predictive value of the meteorological ‘threshold’. There are a variety of statistical techniques to test the robustness of the weather–health predictive model, as well as the meteorological forecasts themselves. In all cases, the model should be tested on independent data (i.e. years not originally included in the model). The test should not include years when the HHWS is operational as this could alter the original weather–health relationship. Given the infrequent nature of heatwave events, the short time most systems have been running, and the low number of deaths avoided (some systems have a trigger at two excess deaths per day), it is difficult to formally assess the benefit using observed mortality data. It is, therefore, important that other components of the systems be evaluated.

A process evaluation of the system is recommended. Do the various components of the system do what they are supposed to do? Are interventions implemented in a timely and appropriate manner and is there good communication between agencies? A simulation exercise was held to ascertain the level of preparedness in large cities in Canada for an extreme heatwave. The evaluation found the need to define role and responsibilities, as well as improve inter-agency cooperation.[62]

Criteria for evaluation of HHWS

We suggest the following criteria for the evaluation of heat warning systems to be used for planning, implementing, and on-going evaluation to promote the best use of public resources through the development of effective and efficient HHWS.

Describe the components and operation of the system

The objectives of the system should be agreed on before the system is set up. These should be as specific as possible. We also recommend that a flow chart of the system be created to illustrate the discrete steps in the process of issuing a warning, including who is responsible for which components and who has overall responsibility. Where possible, the system should be based on existing systems, which the public is aware of. For example, the HWWS in the US are partially based on well-known tornado warning systems.

The components of the system can be sub-divided between the weather and the public health parts:

- Describe the indicator/threshold used to issue the warning(s) and how it was derived (include estimated attributable/probable mortality/morbidity per level of Warning).
- Describe the indicator/threshold used to end the warning period.
- What is the target population (area addressed by warning, e.g. specify metropolitan area).
- Who monitors the meteorological forecasts and provides the warning? During which time period, and how often?
- How is the information transferred to the relevant agencies?
- What is the lead time of the warning(s)
- How often have warnings been issued since the system began?
- What data need to be collected in order to evaluate the system?

The roles and responsibilities of the participants need to be described as specifically as possible. The development of a communication strategy is particularly important.

Describe resources used to operate the system

- Costs of setting up system (initial costs)
- Cost per year of maintaining system
- Estimate cost per warning (direct, and indirect)
- Estimate benefits per warning in terms of years of life saved

Evaluate the system for each of the following attributes

These attributes are important for any HHWS system and should be regularly evaluated.

Simplicity. The simplicity of a system refers both to its structure and ease of operation. HHWS should be as simple as possible while still meeting objectives. Factors to consider include

- Type of information required to issue a warning
- Number of people and agencies involved in issuing a warning
- Time spent maintaining the system
- Time spent issuing a warning

Acceptability. The acceptability of a system reflects the willingness of individuals and organizations to participate in the system. Factors to consider include

- Interaction between agencies
- Participation of agencies other than that issuing the warning
- Completeness of response of participating agencies

Sensitivity. The sensitivity of the warning is the number of times a warning is issued and the forecast meteorological conditions actually occurred. How often was a warning not issued but adverse meteorological conditions did occur?

Timeliness. Are the warnings timely with respect to the different response activities? Are there any delays in the steps of the HHWS.

Effectiveness of individual response measures. It may not be possible to assess this in a formal way (see above). However, epidemiological methods can be used to compare more than one intervention over a summer, providing a sufficient number of subjects are recruited. For ethical reasons, it is not possible to have a comparison group that receives no warning or related public health measures.

Specificity The specificity of the forecast (the prediction of heat attributable mortality) should be estimated, as well as the accuracy of the meteorological forecasts on which they depend, in order to avoid false positive forecasts of heatwave mortality, which will undermine the credibility of the system.

Discussion and conclusions

Heatwaves are a public health problem that has received insufficient attention from both meteorological and public health agencies. Issues identified at a WHO/EEA workshop in 2004[33] were similar to those previously identified in the US following the Chicago disaster in 1995.[63] Successful interventions require information and data sharing between the relevant health and meteorological agencies. A key barrier in effectively implementing a warning system is the lack of clear decision-making protocols among the relevant institutions. Clear performance standards and regular performance evaluations can help to build public awareness and confidence in the systems. It is also important to involve the system’s end users or their advocates (e.g. organizations for the elderly) while developing and implementing the warning systems.

Acute responses linked to warning systems only address late stage issues for primary prevention or early detection of clinical heat stress. Other, more long-term interventions are necessary such as training and education of staff and carers, improvements to domestic housing and health care infrastructure, and the care of the elderly at home. In France, the government has recommended that institutions for the elderly have at least one air-conditioned room.[54] The climate is changing, and increases in heatwaves are forecast throughout Europe.[64,65] Infrastructure that is being built will not be appropriate for future climates. European countries need to learn from each other how to prepare for and effectively cope with heatwaves in the future. Including evaluation criteria in the design of heatwave early warning systems will help ensure effective and efficient system operation.

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Key points

- Heat health warning systems should be implemented locally, with a range of health and social care agencies, with careful description of roles and responsibilities in order to ensure a coordinated response.
- The passive dissemination of heat avoidance advice is likely to be ineffective given the current knowledge of high-risk groups.
- Research is needed on the effectiveness of specific measures in reducing heatwave mortality or morbidity.

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