Chapter 3
Heat/Health Warning Systems: Development, Implementation, and Intervention Activities

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Abstract There is an increasing awareness that heat is a major killer in many larger urban areas, and many municipalities have taken renewed interest in how they deal with oppressive heat. The implementation of sophisticated heat/health watch warning systems (HHWWS) is becoming more widespread, and these systems are becoming an important mechanism to save lives. One primary consideration in HHWWS development is the knowledge that response to heat varies through time and space. The more elaborate systems consider not only the intensity of heat, but the variability of the summer climate, which is closely related to urban population vulnerability. Thus, thresholds that induce negative health responses vary from one city to another, as well as over the season cycle at any one city. Warning system development involves a clear and consistent nomenclature (e.g. heat advisory, excessive heat warning), coordination between the agency issuing the warning and other stakeholders, public awareness of the system, targeted intervention procedures, and evaluation of effectiveness. This chapter describes these attributes in greater detail.

Over the course of recent decades, significant heat waves (e.g., North America in 1980 and 1995, Europe in 1976 and 2003, East Asia in 2004) have resulted in significant loss of life and exposed considerable weaknesses in the infrastructure of heat wave mitigation plans and human adaptation to oppressive weather (Klinenberg 2002).

In response to these heat events, many municipalities around the world have taken renewed interest in how they deal with the oppressive heat. In this chapter, we discuss the mechanisms for the development and implementation of heat/health

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watch warning systems (HHWWS), one of the key methods by which heat events are forecast and their effects are mitigated. We begin by describing the details by which thermal stress is evaluated in current HHWWS and the process by which warning criteria are determined. We then discuss the real-time development of HHWWS along with the "message delivery" to the public, heat mitigation strategies, and checking the effectiveness of HHWWS.

3.1 The Evaluation of Thermal Stress

There is robust literature (Kovats and Koppe 2005) associating what is generally termed "oppressive" heat with some negative health consequence. However, the means by which "oppressive" is defined varies widely (Watts and Kalkstein 2004); accordingly, the HHWWS that have been developed across the world in recent years have utilized a diversity of methods. Each of these methods has their respective strengths and weaknesses.

The utilization of a temperature threshold is perhaps the simplest of all methods. However, as outdoor temperature alone is significantly correlated with human mortality during excessive heat events (EHEs), temperature is considered by some to be a fairly reliable indicator. Moreover, the sole utilization of temperature has a further advantage in that it is the most commonly measured of all meteorological variables and thus is available for more locations. A number of nations, including Spain (Ministero de Sanidad y Consumo 2005), France (Pascal et al. 2006), the United Kingdom (UK Department of Health 2005), and Portugal (Paixao and Nogueira 2002), utilize maximum and/or minimum temperature thresholds in determining heat stress (Fig. 3.1).

An extension of the temperature threshold is the utilization of an "apparent temperature" that takes into account humidity (and wind speed in certain cases) as well as temperature. Several different formulations of the apparent temperature exist, including the *Heat Index* (Steadman 1984), used widely in the USA and Australia, and the *Humidex* (Masterton and Richardson 1979), developed in Canada. These indices are especially useful in locations where summer absolute humidity levels can vary widely, hence their widespread use in North America. Thresholds can then be developed as with temperature; the 40.6°C threshold of heat index across much of the USA is a prime example (Watts and Kalkstein 2004).

Another method of assessing meteorological conditions for application to the heat-health issue involves the classification of weather types, or air masses. The philosophy behind this "synoptic" methodology is to classify an entire suite of meteorological variables and thus holistically categorize the atmospheric situation at a given moment for a particular location or region (Yarnal 1993). This categorization when applied to heat is usually based upon surface weather variables, although upper atmospheric variables may also be incorporated. By categorizing the atmosphere into one of several internally homogeneous groups, other factors, such as solar radiation, wind speed, and cloud cover are inherently accounted for. For example, as a building's "heat load", as expressed by solar radiation income, has been associated with variability in human mortality, cloud cover or a some direct measure of solar radiation can be an important inclusion (Koppe and Jendritzky 2005). In synoptic approaches, discrete categories are created rather than a meteorological threshold
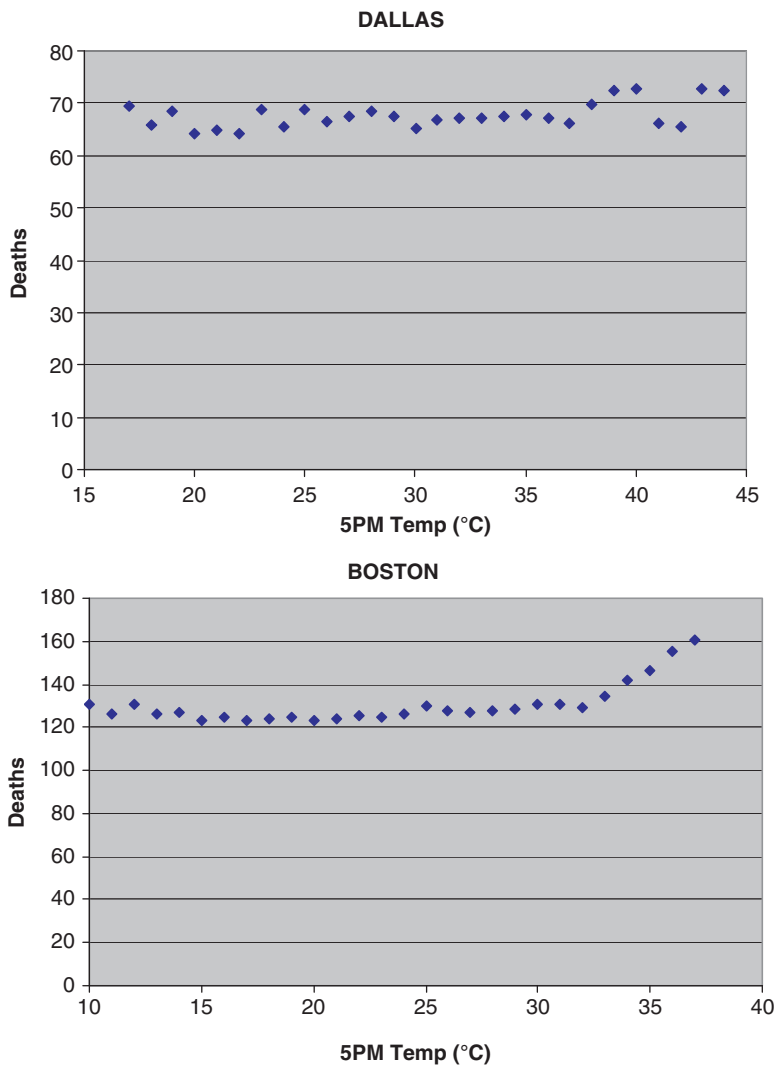
DALLAS

BOSTON

Fig. 3.1 Mean daily mortality in relation to 1700hr temperature for Dallas and Boston, USA

value along the continuum of a continuous variable (e.g., temperature); the result is a determination of "oppressive" synoptic categories that are historically associated with negative health outcomes. The synoptic-based systems generally require meteorological data that is more comprehensive than the temperature- or apparent temperature-based models, including hourly surface data for a number of variables.

A number of systems employ the synoptic methodology. Most notable are around 20 of the newer HHWWS across the USA (Sheridan and Kalkstein 2004), that incorporate the Spatial Synoptic Classification (SSC, Sheridan 2002). Several systems in Italy (Michelozzi and Nogueira 2004), Canada, South Korea, and China (Tan et al. 2003) also utilize the SSC.

A more physiologically based approach by which heat stress is evaluated includes those that are based on modeling the response in the human thermoregulatory system to ambient weather conditions. Rather than rely on proxy indicators, these methods aim to provide a direct assessment based on radiative fluxes to and from a typical human being. In the HeRATE system (Koppe and Jendritzky 2005), the thermal stress of ambient conditions is combined with an evaluation of short-term adaptation in assessing the overall level of heat stress upon the average individual. While thorough, the thermoregulatory system does require the most detailed array of meteorological conditions: in order to correctly model radiative fluxes, detailed information on temperature, humidity, wind, and cloud type and cloud cover at different levels must be assessed. The German HHWWS is the foremost advocate of the thermoregulatory system, and utilizes the HeRATE system as the foundation for its warning system structure (Koppe and Jendritzky 2005).

3.2 Considerations in Evaluating Thermal Stress

Regardless of which procedure above is utilized when devising a HHWWS, several key considerations must be made when correlating meteorological parameters with a human health response. Three of the most important considerations are the spatial variability, temporal variability, and persistence.

One of the primary considerations within the heat-health evaluation is that meteorological conditions in one location do not elicit the same response as they would in another location. There are a number of examples (e.g. Kalkstein et al. 2008; WHO, WMO, and UNEP, 1996) that depict significant differences in the heat/health relationship on the regional or national scale. Those who are accustomed to warmer conditions generally have a higher threshold before becoming stressed; moreover, in regions where the heat is more persistent during the summertime, the mortality response is generally less than in locations where the heat is intermittent (Kalkstein and Davis 1989). These spatial relationships have also changed over time (Davis et al. 2003) as air conditioning has become more commonplace.

Though virtually all HHWWS base forecasts upon local conditions, thereby accounting for local variability in ambient conditions, fewer modify the threshold values to account for local climatology. Many systems, such as the original US National Weather Service, lack regional definitions, and only more recently incorporate them on a basic level (dividing the US into a "northern" and "southern" region, with recommended threshold levels 5°F (3°C) different (NOAA 1995). The number of times different locations will exceed these thresholds varies greatly. The ICARO system in Portugal also utilizes a single threshold of 32°C (Paixao and Nogueira 2002). Most of the newer systems across Europe, including Italy (Michelozzi and Nogueira 2004), Spain (Ministero de Sanidad y Consumo 2005), the United Kingdom (Department of Health 2004), and France (Institute de Veille Sanitaire 2005), incorporate regionally defined thresholds (e.g. France, Fig. 3.2) that vary according to climatology.

The systems with the more elaborate methodology account for spatial variability inherently. For example, HHWWS that utilize the Spatial Synoptic Classification in the US, Canada, Italy, and China identify air masses whose definitions change across space (as well as time), so the spatial component is included (Sheridan and Kalkstein 2004). Similarly, as the HeRATE system evaluates heat stress on a local level, it too defines localized thresholds (Koppe and Jendritzky 2005).

Below the regional scale, an issue of disparity in vulnerability between urban and rural residents also needs to be addressed. In some cases, where thresholds are divided based on regional units, this can be accounted for in the general spatial variability (e.g. see Paris, France in Fig. 3.2). In other cases, where the jurisdiction includes rural and urban areas (as is the case within many US forecast offices), there is little differentiation, although at least one office, Wilmington, Ohio (G. Tipton, 2006, personal communication) uses lower thresholds for urban areas than rural areas, although some recent work (Sheridan and Dolney 2003) suggests that differences in vulnerability from rural to urban areas are minimal.

Just as the heat-health relationship varies spatially, it also varies over the course of the summer season. This *intra-seasonal acclimatization* has been well documented (WHO/WMO/UNEP 1996). Early season heat waves elicit a stronger response than late season heat waves of identical character, as the local population has had a chance to acclimatize to the warmer weather. Additionally, there is a "mortality displacement" effect that is very apparent in many locales shortly after a heat wave has ended; 20–40% of the mortality during an EHE would have occurred shortly afterward had the event not occurred (WHO/WMO/UNEP 1996).

Despite its importance, relatively few systems account for intra-seasonal variability. Nearly all of the systems based on an apparent temperature or temperature threshold do not modify this threshold over the course of the year. Several of
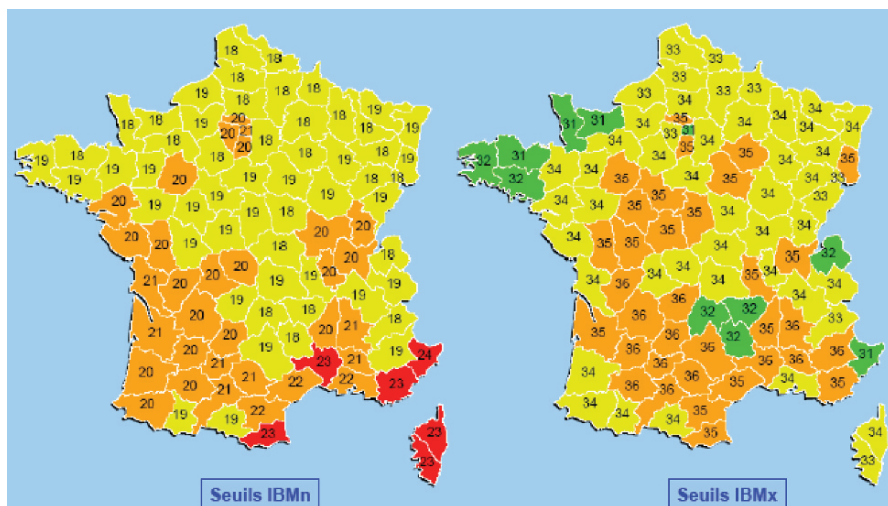

Fig. 3.2 Minimum (*left*) and maximum (*right*) thresholds by division in France's HHWWS (Institute de Veille Sanitaire 2005)

the Italian cities that utilize apparent temperature thresholds are an exception (Michelozzi and Nogueira 2004), with a modifier for time-of-season included in the calculation of heat-related mortality, for example, for Milan (only on days categorized as Moist Tropical Plus by the SSC):

$$MORT = -3.36 + 0.67 \; DIS + .36 \; T6 - 0.039 \; TOS, \text{ where}$$

MORT = forecast mortality, *DIS* = day in sequence of offensive weather, *T6* = 06 h temperature, and *TOS* = time of season (1 May = 1, 2 May = 2, etc.). Similarly, the HeRATE system as well as all air mass-related systems account for this intra-seasonal acclimatization by altering thresholds throughout the year (Koppe and Jendritzky 2005; Sheridan and Kalkstein 2004; see Fig. 3.3 for example).

The persistence of an EHE is another factor that impacts heat-related mortality in an important manner (Kalkstein 2000). Vulnerability, as expressed by increasing mortality, generally increases through the first several days of an EHE, and then may decrease thereafter. There are two methods by which this can be accounted for. Several systems base their thresholds upon repeat occurrence – for instance, the Swiss heat warning system is based upon the exceedence of a heat index of 32°C on three consecutive days (MeteoSwiss 2006). In other cases, predictive equations account for the persistence of offensive weather by determining mortality changes as thresholds are exceeded over a longer time interval.

3.3 The Determination of Thresholds

Once a meteorological methodology has been selected for HHWWS development, the next stage is the determination of when to describe weather conditions as being "oppressive". Most modern HHWWS are developed using an *inductive* method,
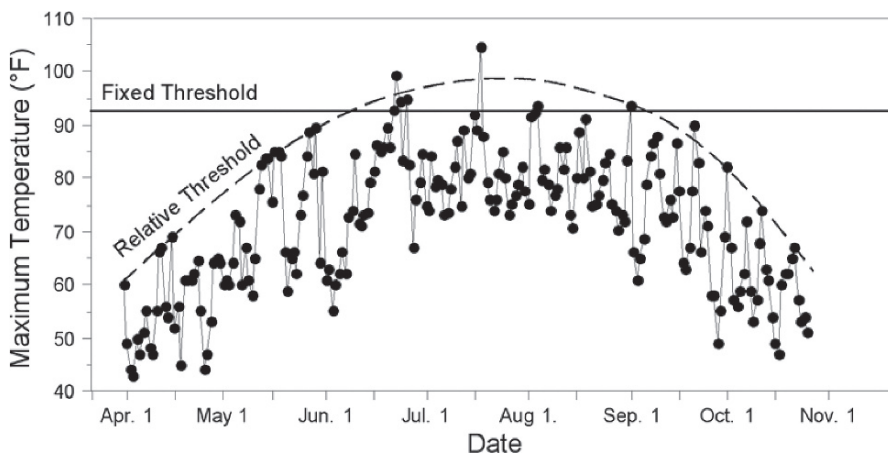

Fig. 3.3 Seasonally adjusted relative temperature threshold compared. Absolute temperature threshold for defining oppressive conditions (B. Davis, August 2005, Personal communication, New Hope EnvironmentalServices)

by which past weather and past health information are analyzed to determine what weather conditions lead to excess mortality. This can be done in either a subjective or statistical fashion.

Regardless, nearly all of the studies that have assessed the heat-health relationship for HHWWS development have utilized mortality data. While this certainly should not imply that the only negative health outcome from excessive heat is death, this dataset is nevertheless the most popular as it records a dichotomous event (either one is dead or alive, unlike hospital admissions, where there are levels of severity), and the records are generally the most readily available and most complete.

Past mortality data are generally obtained for either the total population or the total senior (aged 65 and older) population within a city, region, or metropolitan area (Sheridan and Kalkstein 2004). Mortality of all causes, or almost all causes (sometimes with the exception of accidents) are used in place of just those deaths that are termed by a medical examiner as "heat-related," since this restriction would result in a significant undercount of vulnerability (Sheridan and Kalkstein 2004). Data are usually standardized to account for demographic shifts over time as well as intraseasonal variability in mortality, and may be standardized to allow for comparison across locations.

Whether mortality data are utilized or not, one critical point in setting up a HHWWS is the determination of a threshold at which a heat warning is called, which is based on operational considerations (Smoyer-Tomic and Rainham 2001). If the threshold is set too low, too many heat warnings may be called, and the population may suffer from warning fatigue and disregard warnings. Conversely, if the criterion is set too high, days that are significantly hazardous may go unheralded.

In many of the synoptic-based HHWWS, the identification of an "oppressive air mass" is made when any air mass is associated historically with a statistically significant mean above the normal, "baseline" mortality (Sheridan and Kalkstein 2004). A rise in mortality of 5–10% or more on average is often significant. In contrast, other systems are developed with a specific mortality increase threshold in mind. France's HHWWS is the best example of this, where the threshold temperature values are associated with mortality rises of 50% in Paris and other urban centers, and 100% (i.e., a doubling) in rural locations (Pascal et al. 2006). Similarly, in Portugal, the ICARO system requires a value of 0.31 (representing a 31% increase above normal) for a warning to be called (Paixao and Nogueira 2002).

In a number of other cases, no clear mortality-related threshold is specified. For Germany's HeRATE system, as it is thermal heat load that is quantified, there are no mortality benchmarks but rather the inherent levels of thermal stress that are utilized to determine the warning (Koppe and Jendritzky 2005). In other systems, such as the Swiss system or the original US National Weather Service system, thresholds are defined with no direct association made to specific mortality increases.

Most HHWWS contain greater than one level of warning, with a set of municipal responses based on the level of negative health outcomes (as discussed further below). Where mortality thresholds are defined, it is often a higher threshold that determines a higher warning; for example, in the Philadelphia HHWWS it is a minimum of four excess deaths forecast that leads to an "Excessive Heat Warning;" the lower "Heat Advisory" is associated with excess mortality forecasts of 1–3 deaths (Sheridan and Kalkstein 2004). Similarly, the higher Level 4 in the ICARO

system in Portugal is associated with at least a 93% increase in mortality forecast, compared with the lower Level 3, associated with a 31% increase, as noted above (Paixao and Nogueira 2002). With other HHWWS, it is a matter of duration. For example, in the Toronto HHWWS, no higher-level Extreme Heat Alert is called until at least 1 day after a lower-level Heat Alert has been issued, regardless of the magnitude of the heat (U.S. EPA 2006). In France, the third (lower) level of mobilization is associated with the first day of a heat wave, whereas the fourth (higher) level of mobilization is associated with subsequent days (Institute de Veille Sanitaire 2005).

3.4 Creation of a Warning System

Ultimate HHWWS development and the impact of the system on the community is linked with the quality of the message delivery system to both the public and important stakeholders (Bernard and McGeehin 2004). To accomplish this successfully, many current systems have turned to the internet as a way of increasing the speed of communication among all interested parties (Sheridan and Kalkstein 2004). Ideally, meteorological data must be made available in digital form from a forecasting office for at least the next 1–3 days. These data can then be processed and produce an informational web page as output for all associated stakeholders (Fig. 3.4).
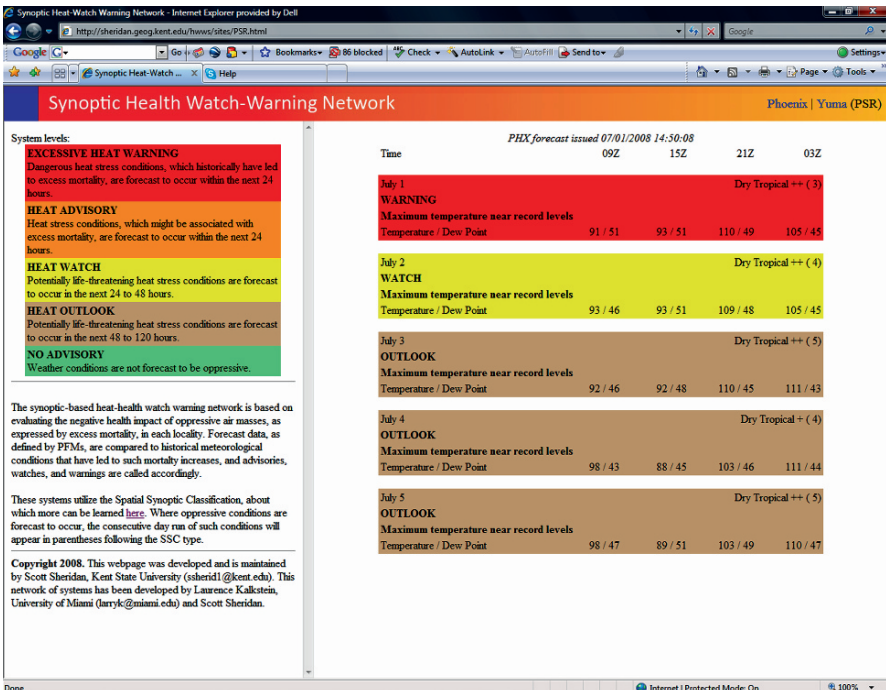

Fig. 3.4 The operational webpage for the Phoenix/Yuma, USA HHWWS

The Philadelphia (USA) HHWWS has served as a prototype for many other systems across the world since its inception (Kalkstein et al. 1996; Sheridan and Kalkstein 2004). The current system begins its daily run by the ingestion of digitized forecast data provided by the local National Weather Service (NWS) office. The computer program determines the SSC air mass type and then categorizes each of the next 7 days based on its potential for leading to a negative health response. These categorizations include an **excessive heat warning** or **heat advisory** for the first day, a **heat watch** if the offensive weather is forecast 2 days out, and an **excessive heat outlook** for days 3–7. Warnings and advisories differ in that the former is forecast to produce significant loss of life, while the latter is not, in spite of the presence of an offensive air mass. If there is an excessive heat warning or heat advisory, the NWS contacts the Philadelphia Department of Health to inform them of their decision. The Department of Health then formulates its intervention plan based on whether a warning or advisory has been issued, and contacts the numerous stakeholders in Philadelphia who must react in some manner when loss of life is expected; this is expanded upon below. Forecasts may be modified by the Philadelphia National Weather Service Office at any time during the day as conditions warrant; the HHWWS software then reassesses the forecast automatically.

It is clear that this process generally requires the collaboration of those in the meteorological field and the public health sector. In a number of cases, the decision on whether or not to call a warning is made on the meteorological end, including many locations in the US (Sheridan and Kalkstein 2004), and Germany (Koppe and Jendritzky 2005). In these cases it is then up to the local health authorities to decide whether to and how to act upon this warning. In other cases, the health authorities bear the primary responsibility for the calling of warnings, including Italy (de'Donato et al. 2005) and Portugal (Calado 2004). Either method can work efficiently, as long as the collaboration between the meteorological and health community within the municipality is close.

It is important that the public understands the message being issued when excessive heat is forecast. Nomenclature varies considerably from one country to the next; in Toronto, "Emergencies" and "Alerts" are issued; in Philadelphia, "Warnings", "Advisories", and "Watches" represent the nomenclature; in Rome, the terminology is "Alarms" and "Advisories". Differing nomenclature among nations is fine, but it is important that the terminology is consistent within countries so the public can understand the consistent message if traveling from one locale to the next. Thus, the media plays a large role in utilizing the proper terminology and in explaining the level of concern to individuals tuning in. Often when a new HHWWS is developed in an urban area, a press conference is scheduled, and the messages to be issued by the HHWWS are explained in detail to the media and the public at large.

3.5   Intervention Measures and Public Outreach

No matter how efficient HHWWS are in estimating the health outcome of an excessive heat event, they cannot be successful in saving lives if proper intervention procedures are not in place. Intervention describes the actions taken by local

communities whenever excessive heat warnings are issued by the local or regional weather service or health department. For intervention activities to be successful, there must be close stakeholder interaction between a number of agencies assigned with increasing the well-being of the local population. Some of these include, beyond the local weather service, the department of health, emergency management, local utility companies, institutions that house the elderly, police, civic associations, and church groups. Intervention also implies "getting the message to the people"; even if extensive intervention activities are developed by a particular locale, they are less effective if people are unaware of the existence of an EHE, and the proper response to such an event. Thus, outreach and message delivery are major components to intervention, and sometimes these aspects is ignored.

The intensity of intervention activities varies widely from community to community, region to region, and country to country. Many areas recognize that heat is possibly the major weather-related health issue in their jurisdiction, and these areas tend to have the most elaborate intervention systems. The development of HHWWS in many regions has enhanced awareness and stakeholder collaboration; one good example is Seattle, USA, where prior to the establishment of a HHWWS in 2005, no heat advisories were ever issued by the local National Weather Service office. This cool, marine city did not consider heat to be a major (or even minor) health issue. Today, not only are advisories being issued utilizing a new synoptic-based HHWWS, but the city and surrounding communities have developed a comprehensive intervention plan, fact sheets on how people and agencies should respond to the heat, and recently the area sponsored a highly successful "Partners for Preparedness Conference" attended by the Mayor, a U.S. senator, county health commissioners, utility companies, and of course the developers of the HHWWS for Seattle (National Weather Service 2005; Seattle Partners in Emergency Preparedness 2005).

Although intervention procedures vary across locales, a broad consensus is emerging which describes the most vulnerable segments of the population, and some universal procedures that should be undertaken to lessen the negative health outcomes of excessive heat events. The elderly, very young, homeless, poor, socially isolated, those with mobility restrictions, those on medication, alcoholics, and those engaging in vigorous outside physical activity are most at risk (US EPA 2006). In many communities, these population segments are identified and kept under surveillance to lessen the probability of increased health problems. In addition, the following activities have been broadly accepted as being constructive to lessen the number of heat-related fatalities:

- Establishing and facilitating access to air conditioned public shelters
- Ensuring real-time public access to information on the risks of excessive heat conditions and appropriate responses through broadcast media, web sites, toll-free phone lines, and other means
- Establishing systems to alert public health officials about high risk individuals or those in distress during an excessive heat event (e.g., phone hotlines, high-risk lists)
- Directly assessing and, if needed, intervening on behalf of those at greatest risk (e.g., the homeless, older people, those with known medical conditions)

Beyond these baseline interventions, some communities have developed sophisticated plans to protect their inhabitants from heat-related illnesses. Two of the most

elaborate programs are in Philadelphia, USA and Toronto, Canada (Table 3.1), and outreach efforts are not only extensive but costly; the total cost for intervention

Table 3.1 Summary of confirmed EHE notification and response program elements in Philadelphia and Toronto

Program elements	Philadelphia[a]	Toronto[b]
Prediction		
Ensure access to weather forecasts capable of predicting EHE conditions 1–5 days in advance	√	√
Risk assessment		
Coordinate transfer and evaluation of weather forecasts by EHE program personnel	√	√
Develop quantitative estimates of the EHE's potential health impact	√	√
Use of the broader criteria for identifying heat-attributable deaths	√	√
Develop information on high-risk individuals	√	
Develop information on facilities and locations with concentrations of high risk individuals	√	√
Notification and response		
Coordinate public broadcasts of information about the anticipated timing, severity, and duration of EHE conditions and availability and hours of any public cooling centers	√	√
Coordinate public distribution and broadcast of tips on how to stay cool during an EHE and symptoms of excessive heat exposure	√	√
Operate phone lines that provide advice on staying cool and recognizing symptoms of excessive heat exposure, or that can be used to report heat-related health concerns	√	√
Designate public buildings with air-conditioning or specific private buildings as public cooling shelters and provide transportation to those locations.	√	√
Extend hours of operation at community centers with air-conditioning	√	
Arrange for extra staffing of emergency support services	√	
Directly contact and evaluate the environmental conditions and health status of known high-risk individuals and locations likely to have concentrations of these individuals	√	√
Increase outreach efforts to the homeless and establish provisions for their protective removal to cooling shelters	√	√
Suspend utility shut-offs	√	√
Reschedule public events to avoid large outdoor gatherings when possible	√	
Mitigation		
Develop and promote actions to reduce effects of urban heat islands (e.g., increase urban vegetation and albedo of surfaces)	Not evaluated	

[a]NOAA 1995; Kalkstein 2002.
[b]Kalkstein 2002; M. Vittiglio and N. Day, 2005, personal communications, Toronto Public Health.

activities in Philadelphia for summer, 2002 was over $100,000 (Kalkstein 2002). Other locales have no formal heat wave mitigation plan, such as Phoenix and New Orleans, USA. Although both cities have sophisticated heat/health warning systems in operation, these are much less effective in saving lives if they are not pared with the proper intervention procedures.

3.6   Effectiveness of Intervention Activities

One criticism of urban intervention programs is that they do not reach the most vulnerable segments of the population in time to help ameliorate negative health outcomes. Many locales disseminate "passive" heat avoidance advice, which often doesn't reach the intended vulnerable targets, such as homeless and homebound people (Kovats and Ebi, 2006). Some communities, especially in Europe, have registers of vulnerable individuals, but many of these are developed voluntarily by relatives of high-risk people. Thus, intervention programs must include a vigorous dissemination program if they are to be successful.

There have been some evaluations to determine how effective heat intervention outreach has been. During the 2003 heat wave in Portugal, the mass media reached over 90% of the population. TV was the main source of dissemination, followed by radio and newspapers. Less than 5% consulted information on the internet. Less than 2% called the public health emergency line. In summary, it was concluded that the behavior of the people changed during the heat wave and the instructions were closely followed by a large segment of the population (Paixao 2004).

Results obtained from a recent US/Canada study on "getting the message out" were somewhat different (Sheridan 2006). Although there was clear recognition of deadly heat events by the general population, there was considerable confusion involving how people should handle themselves during such an event. Most respondents knew that they should remain hydrated, but few knew that they should not overexert themselves. It appeared that people listened intently to the forecasts indicating dangerous heat, but blocked out the intervention procedures suggested by the local health departments. Additionally, in this study, few people actually modified their behavior or considered themselves highly vulnerable to the negative impacts of excessive heat.

Another issue that may lessen effectiveness in disseminating of heat intervention advice is potential confusion between heat and pollution warnings. In a Toronto and Phoenix evaluation, ozone alerts often coincided with heat events, and some vulnerable individuals chose not to drive to cooling centers because of the pollution alert (Sheridan, in press). Thus, people were deprived the benefit of a cooler surrounding because the pollution alert suggested that driving be limited. One of the future challenges of heat warnings is to determine whether they should be combined with pollution warnings (not recommended by the authors), or whether they should remain separate. If the latter is chosen, it is important that the media does not send "mixed messages" to vulnerable segments of the population.

3.7   Methods to Check Effectiveness of Urban Heat Programs

Heat health watch warning systems are very difficult to evaluate because of the interactive nature of the systems (Kovats and Ebi, in press). Of course, the goal of the systems is to reduce the negative health outcomes in urban areas, particularly heat-related mortality. However, how can you separate mortality reductions attributed to, for example, increased air conditioning penetration, from reductions directly related to HHWWS operation, greater public awareness, and associated intervention activities?

Effectiveness requires evaluation of the system on several different fronts (Kalkstein 2006):

1. How accurate is the actual weather service forecast of a heatwave?
2. Assuming forecast accuracy, how precise is the system in estimating the negative health outcome that is anticipated from the forecast heat event?
3. Is the system, and ancillary intervention activities, actually saving lives?

Forecast accuracy is vital if the system is to be a useful tool to stakeholders. Errors in forecasting come in two forms: false positives and false negatives. A false positive arises if the forecast calls for an excessive heat event and no event materializes. The result would be loss of money to the community, since an advisory or warning would be called when it would not be necessary. There would also be a loss in public confidence, since "crying wolf" too often renders the population skeptical to the overall message that is attempted to be delivered. A false negative occurs if the forecast does not anticipate an excessive heat event and one actually occurs. This is a worse outcome than a false positive, because the local populous is not aware that a dangerous extreme weather event will occur, the system will not call an advisory or warning, and greater numbers of lives will be lost. The newest systems in the U.S. now forecast 5 days out, and care must be taken not to overreact when adverse heat conditions are predicted to happen that far in advance (Sheridan and Kalkstein 2004).

There have been several manuscripts published that have assessed the accuracy of the HHWWS itself in estimating heat-related mortality. The synoptic-based Philadelphia system seemed to accurately estimate heat-related deaths during the hot summer of 1995 (Kalkstein et al. 1996), and the more recent generation detected 21 of 22 hot days when heat-related mortality occurred in 2005 (Szatkowski 2006). Evaluations of the Italian system have shown mixed, but generally positive, results. There was an underestimation of deaths in Rome for the intensely hot summer of 2003 (Michelozzi et al. 2004), but more positive results have been obtained when the Rome system was redeveloped after that oppressive heat event (de'Donato et al. 2005). Obviously it is imperative that HHWWS show some sense of accuracy in estimating negative heat-related health outcomes, as a number of systems tie their intervention activities to these estimates.

Determining if the systems are saving lives is a tricky business, and only a few studies to date have looked into this issue. Probably the best-known study was performed by Ebi et al. (2004) during a 4 year period after the inauguration of the Philadelphia heat/health system in 1995. The evaluation determined that, during the

summers of 1995–1998, the system saved 117 total lives. It was concluded that, for each day the National Weather Service office in Philadelphia called a warning, an average of 2.6 lives were saved on the warning day and on each of the following 3 days. The study also estimated that the net benefits of system operation totalled over US$400 million, based upon a conservative standard of US$4 million per statistical life.

Clearly other studies of this type are necessary, but in most cases the newest generation of heat/health systems have not been running sufficiently long to collect the requisite data on lives saved. Nevertheless, it is clear that an accurate system, based on sound biometeorological science, coupled with a quality intervention program and an efficient public delivery system can contribute mightily to lives saved during extremely hot weather.

3.8 Conclusions

Awareness that heat is the major weather-related killer in most large urban areas has increased considerably (Kalkstein et al., 2008), and it is apparent that quality heat/health programs can save lives (Kalkstein 2000). There is no single system or methodology that is "best" when it comes to meteorological methodology or efficiency of operation. Rather, each municipality must choose between an array of possible approaches to deal most effectively with heat outcomes. The chosen approaches are dependent upon the type and frequency of meteorological variables forecast by the local weather service office, the political composition of the urban area, the stakeholder collaboration that exists in the region, and the ultimate intervention plan that each locale must develop. However, there is one unifying theme that is important to emphasize: *systems should be based on finding thresholds that lead to negative health outcomes*. Arbitrary, absolute thresholds are much less efficient, and each urban populous responds differently to extreme heat.

The public is becoming more aware that there are many tools available to them to combat extreme heat/health problems. With the inauguration of each new HHWWS in the United States and Canada, there is an associated press conference that is organized by the local National Weather Service office, the Department of Health, and several other stakeholders. Invitees include the media, politicians, civic leaders, fire and police departments, and other relevant stakeholders. These press conferences are important; they are widely broadcast and familiarize the public with the dangers of excessive heat.

However, there is still evidence that, although the public generally knows when an EHE is occurring, they either feel that they are not vulnerable to the impacts or they are unaware of how to deal with the situation. One study indicates that relatively few people modify their behavior when an excessive heat warning is called (Sheridan 2006). A similar study, which was developed by interviewing over 200 people in Phoenix, USA, a particularly hot city, indicated that people were aware of the issuance of excessive heat warnings (86%), but a much smaller proportion actually modified their behavior during dangerously hot weather (50%; Kalkstein 2006). Thus, even with the most sophisticated HHWWS available, the systems will be less effective if the general populous is unaware of how to respond. This appears to be the "weak link" in system operation and implementation.

The rapid spread of quality HHWWS around the world is a very welcome development, recognized by local and national weather and health officials as well as the World Meteorological Organization and World Health Organization. The links, from system development to public response, are becoming stronger as awareness increases, but there is still considerable work to be done to minimize the vulnerability of the general population to the vagaries of heat.

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