What is the Evidence on Applicability and Effectiveness of Public Health Interventions in Reducing Morbidity and Mortality during Heat Episodes?

A review for the National Collaborating Centre for Environmental Health

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Research question to be addressed:

What is the evidence on applicability and effectiveness of public health interventions in reducing morbidity and mortality during heat episodes?

Overview: This report is a synthesis of the public health interventions used to mitigate the adverse effects of heat episodes on human health and any evidence for their effectiveness in reducing associated morbidity and mortality. We aimed to present the broad diversity of interventions with substantiation from evidence in the literature and examples from both local and international public health jurisdictions. We also present the few evaluations that have been completed to assess the effectiveness of these interventions. Reasons for the lack of evaluative work in this area are described. Our aim is to add value to current knowledge by assembling and rationalizing information from the sparse peer-reviewed and grey literature on public health interventions for heat episodes and their effectiveness to provide important information to practitioners and policy makers in this increasingly important area of environmental health.

Main themes:

- Diversity of public health interventions that are used in practice (each with various strengths and barriers to use or effectiveness)
- Minimal evidence of their effectiveness in reducing morbidity and mortality
- From the available evidence it seems that although many people are aware of heat messages, there is confusion around their meaning and applicability; vulnerable populations may not be reached adequately, which is a great concern as they are at the highest-risk for adverse health impacts.

1.0 Background

Heat-related illness is a growing concern, particularly for urban areas, and one that requires both rapid and longer-term interventions. Environmental health practitioners and policymakers are faced with the challenge of deciding both which public health interventions are most appropriate and when and how they should be implemented at the regional and local level. However, information regarding the effectiveness of public health interventions to reduce morbidity and mortality during heat episodes is currently lacking. To better equip environmental health practitioners and policymakers in making these important decisions, a comprehensive review was felt to be useful to assemble current knowledge on this topic. Practitioners and policymakers need to know the kinds of interventions currently in use, and their effectiveness. This could contribute to their ability to instigate interventions or make any necessary modifications to current public health interventions. In this way, they should be more able to make informed and evidence-based decisions in designing programs, services, and policies directed at heat-related illnesses in Canada.

In an effort to provide this much-needed information to practitioners, the current review was undertaken to address the question: **What is the evidence on applicability and effectiveness of public health interventions in reducing morbidity and mortality during heat episodes?** The key objectives of this review were to provide a catalogue of the kinds of public health interventions that have been implemented both locally and internationally to mitigate the adverse effects of heat on population health and to summarize evidence of the effectiveness of such interventions. In this way we aimed to provide practitioners with current, evidence-based information that can guide practice.

To accomplish this, we invited environmental health practitioners and policymakers to participate from the outset of the project. Their role was both advisory, to assist us in identifying research gaps and priorities in this area, as well as resourceful, by directing us to relevant materials that may not have been detected by our search. In this way we sought to ensure that their needs were addressed in the review and that the final recommendations would be useful in their decision-making around heat health interventions. This involvement of stakeholders is in agreement with recommendations on the process of systematic reviews relevant to public health policy (Ebi 2006; Greenhalgh et al. 2005).

This expert group included public health practitioners, Associate Medical Officers of Health, epidemiologists, academic partners, and managers in heat emergency planning (complete list, page 2). The individuals represent organizations including Toronto Public Health, Peel Region Public Health, Niagara Public Health, the Ontario Public Health Association Environmental Health Workgroup, the Department of Earth and Atmospheric Sciences at the University of Alberta, the Department of Public Health Sciences and the Centre for the Environment at the University of Toronto. In this regard, the current project is truly interdisciplinary; it builds on the current capacity and network development of practitioners and policymakers in heat-related health by providing an opportunity for collaboration across governmental, academic, and non-governmental organizations relevant to the review topic.

Review of the findings and suggestions for ways forward were provided by both the expert group and members of a multi-stakeholder workshop convened by the Region of Peel in April, 2007. At the latter, results of the review were presented and the implications for further development of heat response systems and their evaluation explored.

2.0 Search and Selection Strategy

The research plan was developed to include two major information sources: peer-reviewed literature; and grey literature, the latter including non-published sources such as conference proceedings, government documents, theses, working papers, and reports.

2.1 Peer-Reviewed Literature

Following initial discussions with our expert advisory group and a scan of the literature we anticipated that limited information would be available in the peer-reviewed literature. As a result, our search strategy was designed to be as comprehensive as possible in an effort to capture any relevant materials.

The databases searched included Medline, PreMedline, and Scholars Portal. We did not include a date or other restrictions on the kinds of papers retrieved at this stage as the aim of this part of the process was to get a broad view on the state of the peer-reviewed literature on the topic.

Terms were used in the search strategy included:

At least one of: plan, planning, program, response, intervention, evaluation, response, warning, alert, watch, public health response , implementation, prevention, awareness, education, preparedness, control, measures, strategy, system, risk management, disaster management, emergency management

"And" with at least one of: heat or heat stroke or heatstroke or extreme weather or summer weather or heat wave or heat event or heat stress or heat episode or hot weather or excessive weather

For each search the titles, abstracts, and sometimes the full text of articles were reviewed to determine relevance. Articles that were selected included those that presented public health interventions used during heat episodes, as well as those that considered an evaluation of effectiveness. Stringent inclusion and exclusion criteria were not applied, given the limited information encountered but we maintained a focus on interventions designed specifically for human health rather than planning, landscape ecology, or architectural literature, more broadly addressing urban form and heat load.

After this stage of the search the reference lists of the selected articles were reviewed for other relevant material. Key authors of the papers were contacted via email for additional information and direction to relevant resources. Relevant books were searched using the University of Toronto electronic library catalogue.

The articles that were limited to descriptions of public health interventions for heat illness were used for the descriptive section of this review and the relevant information about the public health intervention was extracted to be added to the catalogue on intervention types. The articles that included some kind of evaluation of the intervention were assessed slightly differently in an effort to provide a more analytical perspective on the methods used. For these papers an assessment was done by two pairs of reviewers. One pair focussed on the studies that considered health outcomes and the other pair on the studies that assessed public perception and practice. This division was made based on the expertise of the group. A data extraction form was developed and used for this part of the review to identify relevant information and highlight major strengths and weaknesses in the study design (completed forms cited further in this document with reference to examples in appendices).

2.2 Grey Literature

Several specialized strategies were used to capture the grey literature related to the review topic.

a. Internet search engines: Major search engines including Google, GoogleScholar, and Scirus were used to search for other non-published literature, conference proceedings, government documents, theses, working papers, and reports. Similar terms used in the formal peer-reviewed literature search were also used here.
b. Personal communication: Public health units in Canada were contacted by email and phone to determine whether they have a warning system and/or response plan in place. In addition to basic descriptive information about their responses to extreme heat, health units were also asked whether their response protocol had ever been evaluated for effectiveness (References, grey-literature; Appendix 1). Heat stress researchers, as identified in the literature, were also

contacted to identify any evaluative work not picked up in our search (References, grey-literature).

c. Web-sites: Specific global and national web-sites were visited that include public health/heat information. These include the World Health Organization, Health Canada, Public Health Agency of Canada, Department of Health – United Kingdom, Australian Institute of Health and Welfare, the U.S. National Institutes of Health, and other major agencies identified in other phases of the search strategy.
d. Institutional repositories: These were searched for faculty publications that may or may not be included in peer-reviewed sources, theses, and conference proceedings e.g. University of Toronto TSpace.
e. Policy documents, memos and reports generated by municipalities and public health units
f. Reviewed government publications using GPO Cat/Pac and the Canadian Research Index

We ended up expanding our grey literature search much more than anticipated as several sources referred us to others. This method of "snowball sampling" allowed us to find resources that were difficult to identify and access using traditional methods.

A complete list of resources can be found in Section 8.0 in the reference lists, divided according to category (i.e. peer-reviewed or grey literature).

3.0 Burden and Typology of Public Health Interventions

3.1 Public Health Impact of Extreme Heat

The adverse effect of heat on human health is of significant public health importance and will likely become even more important with global warming and the increasing frequency of heat waves. Although heat waves are partly predictable and heat-related mortality is preventable, heat waves are responsible for significant morbidity and mortality. The most recent example of this in North America was the 1995 heat wave in Chicago which resulted in over 700 excess deaths and 33,000 emergency room visits due to heat-related illness (HRI) (Klinenberg 2002). Additionally, the 2003 heat waves in Europe were associated with over 45,000 heat-related deaths (Kosatsky 2005; Sardon 2007).

There is a strong relationship between heat episodes and morbidity and mortality (Basu and Samet 2002). Although the risk of HRI exists for everyone, the effect of heat on health is not experienced equally among all members of the population. There is substantial evidence to suggest that heat-related mortality is greatest among high risk groups like the elderly, homeless, infants and young children, and people with pre-existing illness (Ballester et al. 1997; Barrow and Clark 1998; Smoyer et al. 2000; Stafoggia et al. 2006). Young children have a greater body surface area-to-mass ratio compared to adults, thus providing a greater surface for heat gain (Bernardo et al. 2006). In addition, they have less efficient cooling mechanisms when compared with adults, lessening their ability to dissipate body heat.

The elderly have a weaker thermoregulatory system and impaired kidney function, making them particularly susceptible to the effects of heat (Kovats et al. 2006; Worfolk 2000). They are often unable to increase their cardiac output sufficiently during very hot weather. Furthermore, sweating efficiency decreases with age. The highest death rates from HRI are typically seen in the elderly and in particular, in those that have a pre-existing chronic disease, and a lack of mobility (Vandentorren 2006). This was evident during the 1995 Chicago heat wave where heat-related mortality increased with age, ranging from 3 per 100,000 for individuals under 55 years of age, to 258 per 100,000 for those over 84 (Whitman et al. 1997). Individuals of low socioeconomic status (SES), who live in poor housing quality and have limited or no access to air conditioners are also at an increased risk (Semenza et al. 1996).

The "harvesting" phenomenon has also been reported as an effect of extreme temperatures on health. This refers to a mortality displacement effect where deaths that would have occurred anyway, are brought forward as a result of triggering medical conditions that can be exacerbated by the heat. Evidence to support this is the lower than expected mortality immediately following a heat episode (Kovats and Koppe 2005). Thus, extreme high temperatures have direct and indirect effects on mortality and morbidity; heat episodes cause susceptible individuals to die earlier, and increase otherwise preventable deaths (Hajat 2005).

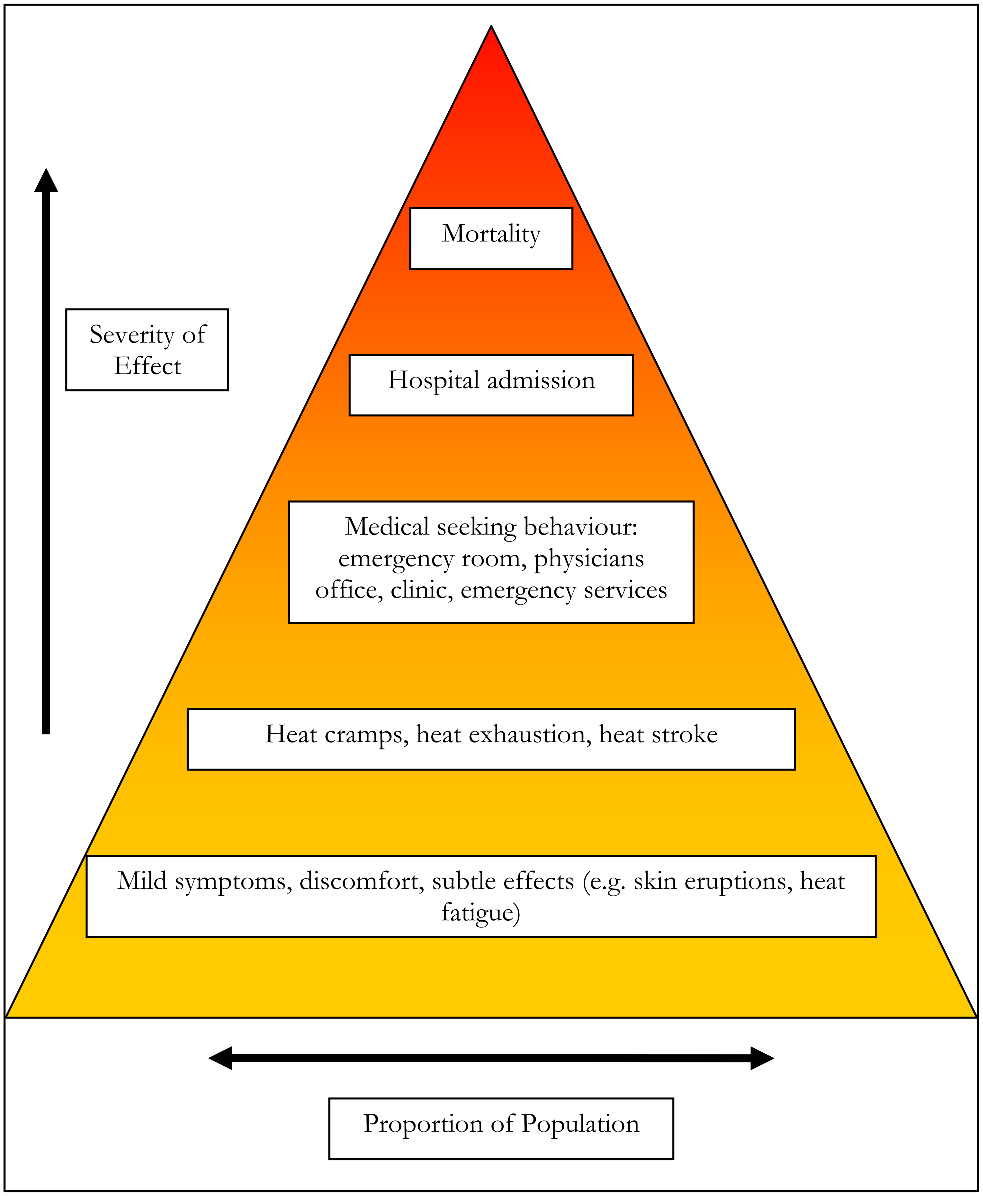
Hot days occurring early in a heat episode typically have a larger effect than those occurring later on because the affected population has not had the opportunity to acclimatize to the changed conditions (Hajat et al. 2002). Prolonged periods of high temperatures have a stronger impact on health compared with periods with extreme peak values but shorter duration (Hajat et al. 2006). Urban areas are particularly affected given the presence of urban "heat islands" – a metropolitan area that is significantly warmer than its surroundings due to a combination of factors that may include the presence of large expanses of concrete, intensive use of asphalt, and other diverse construction materials (Sheridan and Kalkstein 1998). Cities with older structures, typically multi-family, brick dwellings with poor ventilation and a high heat load, are especially at risk.

There are several challenges in understanding the epidemiology of HRI. One major limitation involves the outcome measures used, and specifically, the lack of a universal definition for HRI (Kilbourne 1997; Smoyer-Tomic and Rainham 2001). The US Centers for Disease Control provides the following definition (CDC 2001): "HRI is made up of three clinical syndromes of increasing severity, all of which are due to some form of dehydration:

- 'Heat cramps' which include muscle pains or spasms;
- 'Heat exhaustion' which is characterized by intense thirst, heavy sweating, headache, dizziness, weakness, nausea and vomiting, dark urine, and cool moist skin (the most common heat-related illness); and
- 'Heat stroke' which is clinically defined by fever (body temp >40ºC), severe headache, confusion, red, hot, and dry skin (no sweating), and, in extreme cases, unconsciousness/coma, death."

There is clearly a broad spectrum of illness and health outcomes (Figure 1). In this document, HRI will refer to the standard definition of HRI as described in addition to the other indirect effects on overall mortality and any other health effect (e.g. cardiovascular, respiratory morbidity).that may be triggered by heat and thus is important to consider for public health action.

Figure 1: Heat-Related Illness Pyramid



Adapted from sources: Angus (2006); Health Canada (2006).

There are also a number of different terms used to refer to periods of high temperature, or "heat episodes" as we refer to them in this document. A complete list of these terms used can be found in Box 1.

Box 1: Commonly Used Terms to Describe Heat Episodes

Heat event
Heat episode
Heat wave
Extreme temperature
High temperature
Heat stress
Hot weather
Excessive weather
Ambient temperatures
Heat period

Linked to this challenge of defining HRI there is the difficulty of attributing mortality to heat-related causes. While there is data regarding mortality associated with HRI this may be imprecise and underestimated; although HRI may contribute to death it is often not listed on the death certificate unless it is considered the underlying cause of death (Basu and Samet 2002). A study that counted deaths in which hyperthermia was listed as a contributing factor on the death certificate, but not the underlying cause, revealed that these deaths increased the number of heat-related deaths by 54%, suggesting that the number of heat-related deaths would be underestimated (Luber 2006). Thus, much of the work to date considers 'excess mortality' rather than mortality specifically caused by HRI (WHO 2004). In general, this measure is calculated by subtracting the expected mortality from what is observed; there is a discrepancy between studies, however, in the way that these numbers are derived, again making comparisons between studies difficult.

High temperatures have also been associated with poor air quality, specifically increased smog in urban environments. This is primarily a result of increases in ozone, a phytochemical air pollutant which is rapidly formed under warm and sunny conditions and is the primary contributor to smog. Heat and poor air quality both carry their own burden of illness. For example, in Toronto it has been estimated that on average from 1954 to 2000, of the acute deaths that occurred annually approximately 120 were heat-related and 822 related to air-pollution (Cheng et al. 2005; Pengelly et al. In press). These poor air quality conditions are also associated with increased mortality; as illustrated in several studies following the 2003 heat waves in Europe which found that part of the deaths attributed to high temperatures can actually be attributed to air pollution. This effect may be independent, or the result of the interaction between high temperatures and air pollution to produce a greater combined effect on mortality than each factor acting alone (Basu and Samet 2002; Dear et al. 2005; Fischer et al. 2004; Katsouyanni et al. 1993; Ren et al. 2006a; Ren et al. 2006b). It is important to consider this overlap between heat and smog on human health as it carries implications for the delivery of public health interventions for both.

3.2 Public Health Interventions

This section identifies and describes the breadth of interventions implemented by public health authorities to mitigate the adverse human health effects of heat episodes. The first intervention considered is the identification of a lead coordinating agency. The next intervention reported is heat health warning systems (HHWS), followed by a detailed description of the associated interventions included in a response plan. The warning system will be considered a public health intervention in this context given that it is the first step in identifying dangerous meteorological conditions and is directly linked to a series of public health responses; essentially, the warning system and subsequent interventions go "hand-in-hand". As a result, both need to be considered, as it is the combination of the two that will mitigate adverse health impacts. One is not effective without the other. However, for our purposes we will not provide a detailed discussion of the different kinds of HHWS, rather emphasize they are important and needed to initiate public health intervention implementation. While there has been substantial work conducted to evaluate the effectiveness of the warning systems themselves, in terms of thresholds, algorithms, meteorological data used, etc., this will not be described in detail in this report as we learned that a systematic review of HHWS has already been conducted and is pending publication (Tom Kosatsky, personal communication). Rather, they will be described to illustrate their use and link as public health interventions.

3.2.1 Framework for Implementation – Identification of a Lead Agency

One type of intervention that begins in the earliest stages of a heat response plan is the identification of a lead agency to coordinate the efforts, and conduct periodic reviews of the plan. This is the organizational context for implementing a heat response plan.

Given the multi-intervention nature of the response there are usually a number of partners and stakeholders that need to be involved and coordinated. Often, the group responsible for operating the warning system is not the same group involved in the public health response. This requirement for coordination across government and non-government agencies as well as private sector participants is one of the greatest challenges in implementing a heat event response plan.

Typically, when present at the local level, the lead agency in Canada is the local public health unit. Commonly participating organizations include emergency management offices, warning system partners, and local agencies including housing services, parks and recreation, community access centres, and volunteer organizations like the Canadian Red Cross. In Toronto over 800 partner organizations are contacted during a heat alert period, indicating the magnitude of the number of community organizations that are potentially involved in an urban heat response plan (Angus 2006).

There are significant costs associated with the operation of a heat response plan. These include both direct costs associated with salary support, operation of the warning system, and those associated with opening cooling centres, as well as indirect costs that are more difficult to track. Such costs mean that local public health agencies must prioritize resource allocations to such a response plan among other priorities they must consider. Within this framework the key interventions include the development of an alert/warning system and then the implementation of a series of appropriate public health responses aimed at the community.

3.2.2 Heat Health Warning Systems (HHWS)

A HHWS can be defined as "a system that uses meteorological forecasts to initiate acute public heath interventions designed to reduce heat-related impacts on human health during atypically hot weather" (Koppe et al. 2003). Several necessary components of HHWS systems include (Bernard and McGeehin 2004):

- Reliable/valid meteorological forecasts for the region and population 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 the response activities
- Effective response measures to implement within the window of lead-time provided by the warning
- The involvement of institutions and civil society that have sufficient resources, capacity, knowledge, and political will to undertake the specific response measures.

HHWS are typically implemented at the local (or, in Europe, national) level. As a result, they often vary in the structure, stakeholder agencies, and associated interventions implemented. One of the advantages of this is that interventions can be tailored to the specific population. However, the downside is that if local levels each create their own criteria and method they may be "re-inventing the wheel" and not taking advantage of the existing knowledge and previous work. To address these challenges, some systems, like the synoptic approach developed by Kalkstein, use standard criteria for defining air masses, but the heat warning criteria for each locale are based on their own unique historical heat/mortality relationships. This system is currently used in several European countries that are linked to national systems in this way. In addition, the US National Weather Service is currently developing a national HHWS (Larry Kalkstein, personal communication).

Surprisingly few countries and cities have a HHWS, although the numbers have increased since the 1995 heat wave in Chicago and the 2003 heat waves in Europe. A recent survey of 45 counties in Europe found that 15 had a HHWS in operation (WHO 2004). Toronto, Montreal, Philadelphia, Shanghai, France, Portugal, Italy, Germany, Phoenix, and Dayton, Ohio are among those that do have a HHWS in place (Table 1). These systems use different approaches for determining thresholds for action, including humidex, apparent temperature, and the synoptic classification method. The first two measures incorporate high temperature and high humidity and are absolute indices rather than relative because they have predetermined health impacts associated with various levels of the index (Koppe et al. 2003). A synoptic approach considers a number of meteorological conditions including air temperature, dew point temperature, visibility, cloud cover, wind speed and direction, to group conditions into air mass types (Kalkstein 2002; Kalkstein et al. 1996; Kalkstein 1991; Sheridan and Kalkstein 2004). These air masses are linked to mortality so that it is possible to predict the likelihood of excess mortality based on the predicted arrival of an offensive air mass categorized with local weather forecast data. In this way, the synoptic approach recognizes the fact that people respond to the total effect of all weather variables interacting simultaneously on the body (Sheridan and Kalkstein 1998). In addition to the commonly used approaches, other places use systems based on minimum and maximum temperature (e.g. France, Montreal) or maximum temperature only (e.g. Lisbon).

Table 1: Examples of Heat-Health Warning Systems (HHWS)

Country/City	**System Description**
Italy	National with city-level implementation; Rome uses a synoptic approach with a three-tiered response.
Lisbon, Portugal	ICARO Surveillance System. The model uses a 3-day forecast of maximum temperature (32°C) to predict heat-related deaths.
Germany	Model is based on the perceived temperature exceeding a given threshold (greater than 26°C). Perceived temperature is a complex indicator derived from a heat budget model. Warnings are particularly aimed at resort areas.
Philadelphia	The Philadelphia Hot Weather-Health Watch/Warning System was one of the first systems to use a synoptic approach and is considered one of the most advanced in operation (joined with an extensive public health response). It uses a three-tiered response.
Toronto	The Toronto Heat Health Alert System (HHAS) uses a synoptic approach and a two-tiered level of response.
UK	The UK Heatwave Plan uses region-specific temperature thresholds and a four-tiered response plan.

(Sources: Kovats and Ebi. 2006; Menne 2003; NHS 2004; WHO 2003).

This marked heterogeneity in the prevalence and sophistication of responses to heat episodes is also evident in Canada (Appendix 1). From our communication with public health practitioners across the country, it is clear that there is no standardized mechanism for identifying or responding to heat episodes, and that many regions have no formal heat response plans. However, several municipalities/regions were hoping to implement new plans, and several hoped to evaluate the effectiveness of their current plans in 2007.

Linked to these warning systems are levels of public health response. A one-tiered system will issue a warning or "heat advisory" when the threshold is forecast to be exceeded within a matter of days (Kovats and Ebi 2006). However, the majority of HHWS, particularly in North America, have multiple levels of response, typically two- or three-tiered. For example in Toronto the probability of weather-related excess mortality exceeds 65% a "heat alert" is declared by the Medical Officer of Health. An "extreme heat alert" is issued when the probability of weather related excess deaths is expected to exceed 90%. The associated public health interventions vary depending on the level of response. For example, 24 hr city cooling centres are only opened during an "extreme heat alert" (Marco Vittiglio, personal communication).

Given the link between the HHWS and a public health response, the time lag between the two is an important factor. It has been suggested that a heat stress indicator should be forecast 12-48 hours in advance in order to provide enough time for the response plan to be implemented (Diaz et al. 2006).

HHWS are the important first step in appropriate public health responses to heat episodes. This was particularly apparent in the late detection of health effects during the heat wave in Europe in 2003. It was nearly a week after substantial impacts on mortality had developed that an official public health response was started in France, one of the countries where the effects were most extreme (Lagadec 2004; Leonardi et al. 2006). This has been attributed to the lack of a warning system to trigger the implementation of public health action. A retrospective assessment found that there had been an excess of approximately 3,900 deaths at the time when only 10 specific deaths had been reported during the episode (Ebi and Schmier 2005). In addition to this lack of a warning system, there was also a lack of public health responses. For example, air conditioning was generally not available, even for high-risk populations like the elderly in nursing homes (Ebi and Schmier 2005).

Thus the public health interventions cannot be implemented without some kind of prediction or forecasting method, like a HHWS. Similarly, the warning system alone is not sufficient. Public health resources and action are necessary to respond to these alerts. As such, the HHWS and associated public health interventions must be linked and implemented together.

3.2.3 Public Health Response Plan

Following the identification of a lead agency to coordinate the response, and the implementation of a HHWS to trigger the timing of the response, a public health response plan is implemented to mitigate the adverse effects of heat episodes. Some general recommendations that have been suggested for an effective response plan include (Ebi and Schmier 2005; EPA 2006):

- The implementation of the response activities should be carried out in a transparent manner that includes all stakeholders
- The response activities should reflect the cultural, social, economic, and political context of the targeted community
- The plan's components, including thresholds for action and the interventions enacted, must be evaluated and modified to maximize response effectiveness

Similar recommendations have been made as guidelines for describing the implementation of a response plan (Ebi and Schmier 2005):

- Where the response plan will be implemented: geographic boundaries
- When interventions will be implemented: thresholds for action
- What interventions will be implemented: those aimed at the entire population versus those targeting specific sub-populations
- How the response plan will be implemented: written plan description, roles and responsibilities, back-up plans, budget, etc.
- Communication strategy: this is not just to the general population and targeted groups, but also to key stakeholders and agencies.)

The interventions that make up a response plan can be broadly categorized into "general" and "targeted" or "short-term" and "long-term" interventions. These interventions aim to drive change in practice in individuals during heat episodes (e.g. increasing fluid uptake, finding relief from heat in an air conditioned environment, etc.), as well as change factors that are outside of their direct control but will have a beneficial effect (including economic, environmental, and social factors). General interventions apply to the broad population and are the most commonly used interventions, particularly in one-tiered response plans, usually involving mass media announcements as short-term interventions. Short-term targeted interventions are aimed at known vulnerable groups and involve greater collaboration and organization given the numerous stakeholders and agencies involved. Long-term interventions aim to reduce heat load through environmental modifications. For example, Chicago, Toronto, and Shanghai are among cities doing both environmental cooling through planning and architectural design recommendations in addition to other cities that have started broad adaptation strategies (Penney 2006).

Specific public health interventions that have been incorporated into response plans are listed in Table 2. Although the majority of interventions are short-term, and respond directly to a heat episode, successful programs have plans in place with regular preparation before a heat event occurs. For example, educational materials about the heat risks associated with heat events may be distributed in the spring, before a heat episode actually occurs.

Table 2: Examples of Public Health Interventions for Heat Episodes

Type of Intervention	**Description**
Mass media messages	Public broadcasting is used to inform the public of heat events, and educate them on measures they can take to mitigate the effects (e.g. stay in air-conditioned environments, drink fluids, etc.). This is typically through TV, radio, newspapers, and web-sites (although sometimes access to websites is restricted to relevant professionals).
Distribution of educational materials	Educational information is usually also provided in the form of fact-sheets, brochures, leaflets, etc. Educational materials are also distributed to other venues, like hospitals, physician offices, pharmacies, and clinics. It is typically targeted towards individuals so that they can protect themselves, but also caregivers like managers and staff of residential and nursing care homes. Some Canadian examples of these online resources are available in Appendix 3.
Automated notification systems	Some cities have a notification system that will place automatic telephone calls to warn at-risk individuals of an impending heat event (these are typically auto-dialling telephone programs). Individuals have to register (or have someone register for them) online, at city departments, libraries, etc.). Chicago is an example of a city that uses this system.
Cooling centres	Air-conditioned venues are opened (e.g. libraries, schools, recreational centres, senior centres). Often, transportation is provided to these venues from pick-up points across the city or public transit tokens provided. Many cities extend opening hours of local pools to encourage people to cool off. "Emergency" cooling centres tend to be used at night. Hotels with air conditioning have also been used. For example, un July/Aug. 2006 Chicago evacuated residents of housing projects that lost power and bussed them to hotels with air conditioning.
Information phone lines	Phone lines are provided so that the public can get further information about heat-related issues and also to report situations that need further assistance, but may not warrant a call to emergency services. Mobile field teams then visit those callers who need assistance specifically related to heat (non-emergency). These phone lines are

	either ones established specifically for heat health (i.e. Heatlines) or people are encouraged to use pre-existing advice lines (i.e. Telehealth in Ontario, NHS Direct in the UK).
Suspension of utility service shutoffs and/or provision of emergency energy funds	Utility services do not terminate electricity supply to individuals due to non-payment during heat events. A similar process has also been reported in use by some water companies, although very rarely when compared with electrical ones.
Alert to hospitals and emergency support services	Alerts are sent to these services so that extra staffing can be arranged to deal with increased demands for service associated with ambient temperature conditions.
Rescheduling of public outdoor events	Outdoor public events are rescheduled for different days or the event schedule rearranged to reduce outdoor exposure during heat events.
Street outreach to homeless	Street patrols visit the homeless and where needed, provide transport to cooling centres and bottled water. It has also been documented that restrictions on the homeless sleeping in parks overnight are relaxed during heat episodes (Kosatsky et al. 2005).
Outreach to vulnerable individuals through partnerships with community agencies	This typically includes communicating with various partners and stakeholders who collaborate with other city social services (e.g. Red Cross, Housing Services, Recreational Services) to encourage them to take action to protect their clients during heat events. These services then implement a variety of outreach measures including checking on vulnerable individuals, street outreach distributing water, etc. by building on pre-existing networks. Many of these have pre-existing registries of vulnerable people that they can use to identify and check-on people.
Promotion of "buddy systems"	"Buddy systems" are sometimes in the form of media announcements, encouraging the public to check on friends, family, and neighbours. Volunteers may also make home visits to vulnerable, particularly the elderly. Philadelphia incorporated a unique system of "block captains" who are assigned by the city to check on elderly residents in their neighbourhood. These "buddies" make sure that the vulnerable have the resources they need to cope with ambient temperature (i.e. ventilation, fluids).
Fan distribution programs	The issue of distributing fans to the public is somewhat controversial given the fact that they are only effective when they circulate cooler air, and at temperatures lower than 37°C. However, it has been documented that this is an intervention sometimes implemented as part of heat response plans in conjunction with education about safe fan use (Bernard and McGeehin 2004; Kovats and Ebi 2006).

Air conditioner (AC) donations	AC donations have been used particularly in the US where AC units are provided to residences.
Environmental interventions	Strategies for urban cooling and modification through architecture, planning, landscape, ecology (e.g. green roofs, adding green space).

Typically a combination of these are implemented, but not usually all of them; some are used often and some rarely. This concept of multi-interventions is important for public health practitioners, given the complexity of management and organization involved. Each intervention has particular strengths and weaknesses as outlined in Table 3. In light of these, practitioners need to adapt their response plan to their respective settings. For evaluators, this complexity poses challenges (see Angus 2006, and below).

Table 3: Strengths and Weaknesses of Interventions for Heat Episodes

Type of Intervention	**Strengths**	**Weaknesses**
Mass media messages	Reach a large number of people, including many of the vulnerable socially isolated living alone in apartments but with access to mass media.	These messages do not necessarily reach some of the vulnerable groups, like the homeless population.
Distribution of educational materials	Provide specific advice for individuals to follow during heat events.	These messages do not necessarily reach or are easily understood by many vulnerable groups.
Automated notification systems	Active approach of reaching individuals at-risk.	Limited to individuals who have a telephone.
Cooling centres	Air-conditioning is known to be one of the most protective factors against the effects of heat. Cooling centres provide this at no cost to the individual. Cooling centres that use venues like senior centres can be particularly successful for groups like the elderly who may be more likely to visit a centre that they are familiar with, have a relationship with, rather than a city cooling centre.	It has been suggested that people are reluctant to leave their homes for cooling shelters at night due to safety concerns or the distance needed to travel to get to the cooling centre. (Smoyer 1997). There is some evidence to suggest that cooling centres are not used by high-risk individuals, but by low-risk individuals (Kovats and Ebi 2006).

Information phone lines	Individuals can have their specific questions answered. In addition, it serves as a reporting system for individuals to notify authorities of individuals or residences that are of concern so that further investigation can occur.	Limited to individuals who have access to a telephone.
Suspension of utility service shutoffs/emergency energy funds	This is extremely beneficial in areas where the population relies heavily on air conditioning (most parts of the US).	Not as useful in areas that do not rely on air conditioning.
Alert to hospitals and emergency support services	Improves operational efficiency (Kovats and Ebi 2006).	Needs extensive collaboration at the local level.
Rescheduling of public outdoor events	Directly removes people from the outdoors during heat events.	Not always feasible given organizational and scheduling constraints.
Street outreach to homeless	Targets one of the key vulnerable groups.	This can be expensive so often requires volunteers.
Outreach to vulnerable individuals through partnerships with community agencies	Directly targets vulnerable groups and builds on existing relationships with stakeholders.	This can be expensive, so many are using pre-existing networks. Difficult for the public health unit to follow or evaluate the activities of the partner agencies to know whether the messages are actually reaching the vulnerable.
Promotion of "buddy systems"	Similar to outreach strengths and weaknesses.	
Fan distribution programs	Can be effective if used properly.	Fans are not effective when they circulate warmer air. It is important that those using fans understand how to use them appropriately. It is unclear whether or not fan use is harmful or beneficial to health during heat events.

Air conditioner (AC) donations	Air conditioning has been shown to be one of the greatest protective measures against the health effects from heat. (O'Neill et al. 2005)	The challenge is that it needs to be done in conjunction with funds to cover AC operation as that is a barrier to use. Furthermore, increasing AC use adds heat load to the ambient environment, so cities increase in temperature as people use AC. AC use adds to the greenhouse gas effect and decreased air quality. It is not a sustainable intervention if used alone.
Environmental interventions	A long-term strategy rather than a response to acute events. Potentially greater benefits than the short-term interventions. These have additional benefits such as energy savings, air quality improvement, increased attractiveness and recreational/leisure benefits, as well as reducing heat load.	Requires more elaborate and longer-term planning involving with a greater number of partners.

4.0 Evaluations of Effectiveness

4.1 Process for Evaluating Public Health Interventions

Public health interventions in general are typically complex, programmatic, and context dependent (Rychetnik 2002). For heat, ideally we should understand the effectiveness of the entire response plan, as well as that of each of the individual components. Such knowledge would help guide decision makers when determining which elements to include in their own plans, particularly given resource limitations that require practitioners to make decisions based on the most effective intervention.

There is not a standard process for evaluating public health interventions for heat episodes. Most early evaluations primarily considered the impact of heat episode response plans on mortality. They did not consider the many other components of the system that have an impact on effectiveness. In response to this, a new evaluative framework has been developed that includes both qualitative and quantitative approaches to evaluate response program quality and to capture the breadth of system components (Angus 2006). This framework includes the following program quality criteria (modeled on evaluation of surveillance systems) to be addressed through both quantitative evaluation of mortality/morbidity trends and qualitative evaluation through interviews with stakeholders (Angus 2006):

- Expected effects: goals of the system, what should the outcomes of interest be?
- Activities & resources/cost: what are the resources used in each partnering agency; what are the direct and indirect costs of each component of the plan; what are the costs of the personnel involved?

- Simplicity: type of information, number of people, time required
- Acceptability: with partnership agencies
- Accessibility/reach: Are vulnerable populations targeted or the entire population or both?
- Sensitivity: number of times a warning is issues; perception of appropriateness of the numbers of alerts
- Effectiveness: mortality/morbidity trends; synthesis of other quality criteria
- Timeliness: rapidity of response

4.2 Challenges in Evaluating Public Health Interventions for Heat

There are several characteristics specific to heat episodes and their associated response plans that make them very difficult to evaluate. Heat episodes are rare events that have differential impacts on each affected population. This is due to a variety of factors (i.e. differential distributions of individual vulnerability, level of acclimatization, etc.), making it difficult to compare different populations in different cities in response to a heat event. Even if there is the opportunity to study the same population over different time periods, the heat events themselves vary over time. This is due to the meteorological variation between heat events. The fact that no two heat episodes are the same makes attribution of changes in health outcomes to public health interventions versus different weather conditions or different underlying populations particularly difficult.

There are usually several public health interventions included in a response plan that are implemented simultaneously. This makes it difficult to attribute any beneficial effect to one intervention over another. Furthermore, many of the interventions are aimed at encouraging changes in individual practise. Whether people actually change their behaviour or not is challenging to assess.

Most HHWS and their associated response plans have been implemented only recently, with a marked increase in interest following the 2003 heat waves in Europe. This is an added challenge given the relatively short-time frame available for evaluation. However, St. Louis is the one exception to this general rule; their system has been in place since 1981, potentially making them a good place to conduct a formal evaluation (see below).

Finally, there is a challenge in defining “effectiveness” in the case of interventions for heat episodes. Possible meanings or indicators along a causal chain might include messages actually reaching people, reported changes in individual practise, reduced mortality and morbidity, etc. Thus, in our search for evaluations of effectiveness we considered the broader definition that reports on impacts on public perceptions, and changes in population practices as well as health outcomes.

4.3 Existing Heat-Health Evaluations

The vast majority of evaluations in this area have been evaluations of HHWS and their robustness as meteorological forecasts. Very few evaluate the effectiveness of interventions put in place as a result of warnings generated from these systems. In particular, few Canadian jurisdictions have undertaken formal evaluations of effectiveness (Appendix 1).

However, it should be noted that there is some significant work forthcoming. The EuroHEAT project will be publishing results of its evaluation of the 2003 European heat waves and response early in summer 2007 (EuroHEAT website; Kristie Ebi, personal communication). The UK has recently received funding to evaluate their plan; this project is expected to last for approximately 3 years with results following (personal communication, Sari Kovats).

For the purpose of this review we examined effectiveness in terms of two key sets of indicators:
1. Public awareness of an extreme heat episode and a subsequent change in practice
and
2. Documented changes in morbidity and mortality attributed to the implementation of public health interventions.

4.3.1 Warning Systems

Many places implemented HHWS after a severe heat wave that resulted in many deaths; others implemented HHWS after seeing the adverse effects elsewhere. For example, prior to the Chicago heat wave, heat was not well recognized as a major killer, even by public health and city officials (Klinenberg 2002) in the city. Since this event HHWS have received much more attention in the US and been implemented in many cities. HHWS provide an alarm. Even if no further public health action is taken, the public can be made aware of dangerous heat conditions. There is evidence to suggest HHWS have a positive impact on health outcomes, including mortality (i.e. Palecki et al. 2001; Smoyer-Tomic and Rainham 2001; Tan et al. 2007; Weiskopff et al. 2002).

4.3.2 Awareness and Change in Practices

Two of the measurements of effectiveness we consider in this review are the awareness of interventions on the individual level, and any reported change in individual practices that resulted from this awareness. One possible indicator is information about the use of resources provided in public health response plans (e.g. visits to cooling centres, calls to information lines).

There is some evidence from Philadelphia that illustrates the high use of their phone information line, Heatline (Kalkstein 2002). During the summer of 2002 the Heatline received over 2300 calls. As the summer progressed fewer calls were received. This was attributed to less media attention and therefore less advertising of the Heatline in addition to a reduced need for information given the acclimatization of the population over the course of the summer. Similar data is available in other jurisdictions (e.g. Toronto), but has not yet been analyzed (Marco Vittiglio, personal communication). Data collection on use of cooling centres (for cooling off during waking hours as opposed to places to spend the night) is essential in evaluating the effectiveness of cooling centres as a heat intervention. These measures of utilization can be considered indicators of effectiveness in terms of awareness of the interventions and subsequent use by the public. Alternatively, staff involved in operating HHWS and those who work with vulnerable groups can been surveyed (Angus 2006). Respondents in Toronto, for example, felt that most people were aware of a heat alert being declared except for the vulnerable, elderly and socially isolated.

A recently used method to assess awareness and change in practices is through the use of public surveys, as will be illustrated in the following examples. More complete details of these studies in addition to methodological critiques of sampling methods, measure properties, response rates, etc., can be found in Appendix 4.

4.3.2.1 St. Louis (Smoyer 1997)

A survey regarding awareness of the "St. Louis Operation Weather Survival" among the elderly and health service providers was conducted in 1995. Health and social service providers noted that elderly often were not concerned about heat (e.g., "I've lived here all my life, never had AC, so why would I have a problem now?") or not taking advantages of resources ("cooling shelters are only for really poor people"). Interviews with elderly supported these perceptions.

4.3.2.2 Portugal, August 2003 Heat Wave (Paixao et al. 2005)

A postal survey was conducted after the 2003 heat wave in Portugal to assess individual heat protective measures both during hot episodes and specifically during the 2003 heat wave. Again, knowledge of the heat warning was nearly universal (92%). In general, there were significantly better practices by those who had obtained information. However, the elderly (75+) and less-educated were less likely to heed advice, which is of major concern given these are more vulnerable groups.

4.3.2.3 INPES (Institut National de Prévention et d'Education pour la Santé) 2006

A survey was conducted in France between 2005 and 2006 to assess the awareness and practices of the public during heat alerts. Again, recall of heat alerts from radio and television broadcasts was high (74%). This awareness was associated with a relatively high level of change in practice: 63% of respondents took protective measures in 2006 versus 48% in 2005. All practices polled (increased hydration, closing sun-facing windows, etc.) showed increased uptake from 2005 to 2006, from 6-15%. Similarly, respondents reported increased efforts to support vulnerable friends and family, with 73% of respondents reported helping someone. However, only 63% of the elderly respondents reported having been helped and only 14% reported asking for help when they felt discomfort.

4.3.2.4 Phoenix, Arizona (Kalkstein & Sheridan 2007)

This recent study distributed 201 surveys to individuals in metropolitan Phoenix, Arizona, to gauge risk perception and warning response to heat episodes. The majority of individuals surveyed reported that they were aware when a heat advisory was issued. However, there was variation in this awareness across different demographic categories (women more aware than men, respondents over the age of 65 years reported the highest level of awareness).

Despite the nearly universal awareness of a heat advisory, it did not necessarily translate into action - less than 50% of those over 65 changed their behaviour during a heat warning. There was an elevated perception of risk among Hispanics that translated to increased response. The conclusions from this study were that while most people receive the messages, only about half of the population actually change their behaviour in response to a heat event.

4.3.2.5 North American Cities (Sheridan 2007)

This study took place in four cities (Dayton, Philadelphia, Phoenix, Toronto) to assess knowledge of heat warnings. A telephone survey of 908 participants was conducted to gather this information. Knowledge of the heat warning system was nearly universal (90%) and likely due to pervasive media coverage (primarily television). However, knowledge of the details of the message of the mitigation plans were less well understood, and few individuals actually changed practice in response. Many respondents did not believe they were vulnerable or that the messages applied to them. There was also reported confusion around the difference between ozone precautions and heat precautions.

4.3.2.6 Peel Region Summer 2006 (Region of Peel Heat Response Meeting 2007)

The Region of Peel, just west of Toronto, Ontario recently evaluated the impacts of its heat alert and response plan in collaboration with Dr. Larry Kalkstein (Region of Peel Stakeholder Meeting 2007). The evaluation was conducted to determine the effectiveness of the alerts in notifying stakeholders and the population, in changing stakeholder behaviour in responding to alerts, in changing the public's behaviour in responding to alerts, and in predicting and reducing heat-related mortality. Initial findings from this work suggest that Peel residents are less aware of the heat alert system as compared to other populations in Toronto and the US. However, the Peel system has only been in operation for one year, so it is still in early stages. Interestingly, radio was the most important medium for conveying the alert messages, as compared with television, which is the most commonly reported medium in other studies, particularly in the US.

4.3.3 Change in Health Outcomes (morbidity and mortality)

The other commonly used method in the public health heat interventions evaluation literature is to compare the occurrence of adverse health outcomes in time periods with and without warning systems and response plans in place. The outcome typically assessed is change in mortality, with change in morbidity infrequently assessed. As previously discussed, there are several challenges in these kinds of studies (Section 4.2). Our findings from this literature are discussed below. Further details and critiques can be found in Appendix 5.

4.3.3.1 Philadelphia (Ebi et al. 2004)

This study calculated the number of lives saved and the economic benefit of warnings in reducing heat-related mortality as a result of implementing a HHWS. The authors conclude that issuing a warning lowered daily mortality by 2.6 lives. The operational costs of running this warning system was practically at a "noise" level compared to the economic benefits (using the EPA valuation of a statistical life at $6.12 million) of saving 117 lives in three years. This is the only attempt to assign an economic value to the potential lives saved as a result of implementing a HHWS. However, there are challenges in assigning such tangible values, which may only partially reflect the full "value" of a life lost which also includes less quantifiable, intangible components such as the intrinsic value of a person to their family/community). Similarly, appropriate economic evaluation would require full costing of all interventions, at least on a marginal basis.

4.3.3.2 Milwaukee, Wisc. (Weisskopf et al. 2002)

This study used heat-related morbidity and mortality during 1995 and 1999 heat waves to compare heat-related mortality rates and EMS runs. The lower rates in 1999 were attributed to improvements in public health response. However, due to differences in the heat event and the relatively short period between events (4 years), it is unclear to what extent the mortality or morbidity reduction could be attributed to intervention efforts versus meteorological factors or reduced susceptibility of the population.

4.3.3.3 Midwestern US (Palecki et al. 2001)

This study compared the heat waves during 1995 and 1999 in the Midwestern US (with a focus on Chicago and St. Louis). The authors conclude that in 1999, Chicago more successfully mitigated the effects than it did in 1995 (more than 500 deaths during the 1995 heatwave as compared with 119 deaths during the 1999 heatwave). This was attributed to improvements in public health response (in addition to characteristics of the heat wave). A key factor was also felt to be the upgrading and better performance of the electrical supply which was maintained during the 1999 heat wave, whereas it failed during the 1995 episode.

4.3.3.4 St. Louis, Missouri (Smoyer 1998)

This study compared mortality in the 1980 and 1995 heat waves and found higher mortality in 1980, primarily because the 1980 heat wave was more severe and longer in duration than the 1995 event. A simulated model of 1980 weather conditions and 1995 population suggested the St. Louis population was more vulnerable in 1995 than in 1980 despite an increase in air conditioning availability and improved public health response. The author attributes this to increases in the "frail elderly" population over 74, and rising poverty rates among the general population as well as persons over 65 years.

5.0 Synthesis - Arising Themes

From the collected evaluation literature several common themes arise. The first is that awareness of heat events/alerts is nearly universal in the general public. However, it is important to consider that the surveys reported in this paper did not usually include the most vulnerable groups, including the homeless or shut-in elderly so it is not clear whether these groups are aware of heat events. The uncertainty of whether public health messages actually reach the most vulnerable was one of the most commonly cited concerns in our discussions with public health practitioners, and this information is incomplete in both the peer-reviewed and grey literature. This underlines the importance of having both general and targeted messages and outreach strategies.

Related to this is the definition of "vulnerable groups" and consideration of other groups that are not commonly included within this term but are also at a higher risk for the adverse effects of heat. This includes tourists, organizers/participants of outdoor events, and individuals who work outdoors. It is important that interventions for heat also incorporate these groups. Novel methods to target these groups should be developed (e.g. contacting employers in parks and recreational jobs to educate and protect outdoor employees during heat events). This is a particularly important consideration for Canada, which has a large amount of resource- and construction-based employment outdoors, putting workers at risk.

Another theme in our review is that although many people are aware of heat events, relatively few actually change their practices in response. This is partly due to the general perception by many that heat is not a killer, or that the heat message only applies to small sub-populations which the interviewees do not consider themselves to be part of; this has changed somewhat since the highly publicized 1995 and 2003 heat waves. One reason for this suggested in conversations with public health practitioners is that the media often tend to focus on stories about occupational dangers in heat (i.e. parks employees, roofers, etc.) or one of the most commonly reported, of children or pets left in cars during heat events. This focus by the media on these specific sub-populations can lead the general population to believe that the messages are not applicable to them. This has important implications for framing the content of the messages and collaboration with media partners in ensuring accurate messages are being presented to the public.

A third theme arising from this work is the confusion in understanding and interpreting these public health messages. One commonly cited reason for this is the overlap between smog and heat warnings. Many public health units issue these warnings from separate divisions, but the findings from this report suggest that there should be coordination in these messages to better and more clearly inform the public about how they should respond e.g. turn on air conditioners to reduce heat load versus turning them off to reduce electrical load and air pollution from coal fired stations .

With regards to developing and implementing a HHWS and response plan, while having a HHWS is recognized as the first step in protecting the public, most cities do not have one in place. These cities are encouraged to develop a HHWS in consultation with experts. This allows practitioners to take advantage of work that has already been done in this area, and aid in creating systems that are comparable and more readily evaluable for effectiveness. Plans should be both proactive and reactive. These plans should be coordinated by some kind of lead agency with involvement from partners and stakeholders with periodic reviews.

6.0 What are the Implications of these Findings for Canada?

Canada's expansive land area, along with its diverse coastal, mountainous, continental, and high latitude climates, gives rise to dramatic variations in summer weather. The risk of heat episodes, as well as population sensitivity to heat health impacts, also varies dramatically within Canada. The St. Lawrence River Valley of Quebec and Ontario (extending into Southern Ontario), the Prairies, and the interior of British Columbia can be considered 'heat wave zones' as they are most likely to experience heat episodes. In these regions, the 95th percentile of summer maximum temperatures exceeds 30^{o}C, with heat waves occurring infrequently outside of these zones (Smoyer-Tomic et al. 2003; Bellisario et al. 2001). Due to urban heat island effects, metropolitan areas in these regions are more at risk than surrounding less developed areas due to higher maximum as well as higher minimum temperatures, which limit cooler, overnight "relief" periods during a heat wave.

So how big a threat are heat episodes to the health of Canadians? Compared to the heat wave risk regions in the United States and Europe, summers generally are cooler in Canada, including in the heat wave zones. To date, Canada has not experienced a heat wave paralleling the severity of those that occurred in the Midwestern United States in 1980, in the Chicago and Milwaukee areas in 1995, and in Europe in 2003. The likelihood of Canada developing the climatological conditions that result in severe and persisting heat episodes is lower than in the United States or Europe. However, due to lower exposure to hot summer conditions, Canadians may have more difficulty in physiologically acclimatizing to heat episodes when they do occur.

6.1 Population Risk

Elderly populations are disproportionately at risk of HRI, particularly when they are low-income, urban, and lack access to air conditioning (Semenza et al. 1996; others). As Canada's population continues to age, a larger number of people will enter high risk groups. Some Canadian municipalities will face unique challenges, such as language barriers for diverse immigrant populations, particularly if high-risk elderly citizens cannot understand warning messages.

Other factors influencing HRI risk have to do with housing type, air conditioning, and urban design. Many Canadian cities have newer housing and less dense settlement patterns than many European and U.S. cities, which may reduce heat load. Still, Montreal, Ottawa, Toronto, and Winnipeg are particularly at risk from heat waves, with older housing stock (including heat-retaining brick) and less universal air conditioning availability (Smoyer-Tomic et al. 2003).

Canada's lower levels of urban socioeconomic and material deprivation compared with the U.S., along with its universal health care system, are likely to lessen vulnerability and increase resilience of high-risk populations. Nevertheless, isolated individuals will continue to be at high risk regardless of income or access to health care.

6.2 Health Care Delivery

Some of the factors noted in excess deaths in the European heat wave of 2003 related to healthcare service delivery. Many hospitals lacked air conditioning, and thus cooling heatstroke patients was difficult; further, patients hospitalized for other factors were at risk of heat stress while in the facility. Another factor was that the heat wave occurred during a period of severe staff shortages due to the common practice of taking vacation during the late summer. Newer Canadian hospitals are likely to have central air conditioning throughout, but older facilities may lack air conditioning in some areas, which could be a concern during an extreme heat wave. An inventory of air conditioning prevalence in Canadian hospitals, particular those in areas at risk of heat episodes, would be useful in assessing heat episode vulnerability in the health care sector. Consideration of health care organization staffing to maintain availability during likely heat episodes would also be important.

Additional factors occurring with heat waves can have indirect health impacts, such as loss of power from shorted out power lines and inability to meet energy demands. Loss of power for air conditioning and refrigeration could affect population health directly as well as through disruption in health care and other emergency services.

6.3 Types of Interventions

A wide variety of reactive and innovative long-term proactive interventions have been used in cities around the world to reduce HRI (see Section 3). Public health preparation is essential – in the event of a heat wave, health care and social services need to be able to respond quickly. Since heat waves are relatively infrequent in Canada, but the population would be poorly acclimatized should an extreme event occur, there is benefit to developing long-term solutions to modify the urban environment so as to reduce heat load and reliance on high energy use for air conditioning. These efforts have benefits in addition to those for reducing HRI; they tend to be cost-efficient in the long-term in reducing energy use, increase recreational use, and are attractive and generally well received e.g. more urban green spaces. Integrated efforts among public health providers, urban planners, architects, and landscape ecologists can be used to develop long-term, sustainable efforts to cool cities through urban design, rather than relying solely on air conditioning, which requires energy use and emits both heat and pollutants to the atmosphere.

6.4 Planning for the Future

Although heat episodes occur relatively infrequently in Canada, their frequency, intensity, and duration could increase with climate change (Kalkstein and Smoyer 1993; Smith et al. 1998). Already, an increasing trend in summer maximum temperatures has been observed over the period 1943-1998 for a range of urban areas across Canada (Bellisario et al. 2001). Thus, well-planned heat episode warning and health intervention systems are recommended for urban areas in heat wave zones, but may be less of a priority in cooler areas (e.g., coastal, mountainous, and high latitude).

Among Canadian municipalities, Toronto's heat warning and health intervention system is probably the most developed. It has been in place for the longest time and provides a starting point for designing and evaluating other Canadian heat-health systems. Information on existing interventions in Canada, the U.S. and Europe is likely to be useful to Canadian policy makers, but differences in the risk of heat waves, the population sensitivity and resilience, institutional preparedness, and implementation issues both between countries and within Canada need to be considered.

A national warning or intervention system is probably neither cost-effective nor appropriate for Canada because of its diverse climates (even within the heat wave zone) and unique public health and social service provision in each municipality. Rather than a national system, which may be effective in smaller countries with limited climatological variation (such as France), Canada might benefit from a national clearinghouse with guidelines for defining a heat wave or episode, setting up a local HHWS, and suggestions for potential health interventions and a collaborative evaluation capacity to improve local systems over time. A systematic heat wave intervention process, with clearly defined criteria that are able to measure a variety of benchmarks, is needed to reduce inefficiency in developing systems and improve effectiveness in existing heat episode warning systems.

7.0 Conclusions

The findings from this report have important implications for policy and practise. Public health practitioners need to make important decisions regarding their response to heat episodes based on a complexity of factors including population risk and available resources. Identifying a lead agency to develop and coordinate a HHWS and associated interventions is an important first step. There is diversity of types of interventions used for heat episodes in different cities and countries. These have been synthesized and critically summarized in this report. We anticipate that this catalogue of possible interventions will be useful to practitioners in making decisions about the kind of system and response that would be the most effective in their own locale. The evaluative work that has been done suggests a positive impact of these systems and effectiveness in reducing mortality and morbidity. However, concern persists about whether the most vulnerable groups, like the elderly and homeless, are being reached in these approaches.

There are clear implications of these findings for future research. Developing a framework for evaluating public health interventions for heat is the next important step to build on the findings of the current work. These draft criteria could then be applied to a selection of public health sites that have heat interventions in place to assess its utility as an evaluation framework. Ideally these could be coordinated through a national organization.

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Appendix 1: Canadian HHWS and Response Plans by Region/Municipality

Region	Plan Summary	Evaluation	Contact
Alberta			
Lethbridge	Focus on sun safety; some advertisement/education around heat stroke and exhaustion.	No	Population Health Lethbridge
British Columbia			
BC Interior	No specific heat plan; regularly have 2-3 weeks >40ºC each summer. Large elderly population; some homelessness Rely on proximity of very large lake to downtown area; media alerts during high heat and a general municipal "Emergency Response Plan"	No	Kelowna Public Health
South Fraser/ Surrey	No specific heat plan; advertise largely with posters; rely on beaches	No	
Vancouver Island	News releases advising hydration, rest, care for seniors and caution leaving pets and children in sun or hot cars.	No	Vancouver Island Health Authority
Manitoba			
Winnipeg	The extreme weather program is focused on cold weather; hoping to implement a plan for 2007.		Environmental Health Unit, Manitoba Health
New Brunswick			
Fredericton	No specific plan	No	Fredericton Public Health
St. John	No set policy; media alerts/interviews/press releases in the event of high temperatures advising protecting behaviour.	No	St. John Public Health
Newfoundland			
St. John's	Municipal emergency response plan is gear more to winter weather, flooding, and storms; no specific heat plans.		
Nova Scotia	Note: Co-ordinated at the provincial rather than municipal level		
Halifax (HQ)	They use a three-tiered alert system (Humidex, Advisory and Alert) using Environment Canada's posted temperatures and humidity values. The first two alerts involve media releases. An alert system is currently in development		Medical Officer of Health Annapolis Valley, South West, South Shore

Ontario			
Greater Toronto	Toronto uses a synoptic based approach HHWS that has two levels of alert (heat alert, extreme heat alert). A multi-intervention hot weather response is implemented and includes media releases, opening of cooling centres, distribution of water bottles through the Red Cross, community outreach through partnering agencies, and activation of an information Heatline.	No, although Toronto Clean Air Council is conducting a broader review.	Toronto Public Health
Halton	They issue a heat alert in response to forecasts from Environment Canada of a humidex advisory in the region. During an alert period media advisories are issued, community partners are contacted, and educational material distributed. They have information for the public on their website.		The Regional Municipality of Halton
Lambton	They are working on a plan for 2007; have researched plans in other Ontario municipalities.		Lambton Health Unit
London-Middlesex	They have an Extreme Temperature Protocol which is a comprehensive plan with that includes an alerting system and multi-sectoral response. Alerts are based on humidex levels and humidex advisories declared by Environment Canada. Open pools/libraries, advertise heat risks, etc. The media is notified and educational messages distributed.	Ongoing self-check, no formal audit	Environmental Health and Chronic Disease Prevention Services, Middlesex - London Health Unit
Ottawa	Ottawa has a three-tiered alerting system where a Heat Alert, Heat Warning, or Heat Emergency is declared based on exceedances of Environment Canada humidex forecasts. Comprehensive plan with multi-sectoral approach including vulnerable building visits. Open pools/libraries, advertise heat risks, etc.	Home visits involve a small, informal feedback component.	City of Ottawa; Ottawa Public Health
Peel	This alert system is tiered to severity, specific to two climatologically different areas within the region, and provides up to 60 hours predictive notice to stakeholders.	Yes; early results expected in 2007.	Peel Region Public Health
Peterborough	Does not have a formal response plan. The city does keep a cooling room; advises of its availability when temperature >30; respond to media inquiries but do not issue releases. They do have information for the public about the danger of heat waves on their website.	No	Peterborough Public Health
Simcoe	Issue 'Air Quality/Smog' advisories, but no specific heat plans or heat advisories. They do have information for the public about the danger of heat waves on their website.	No	Simcoe Public Health

Waterloo	Did have a formal plan 2003-2004; cancelled in 2004 for two main reasons, a) forecasting science was imperfect, and b) Waterloo had no real interventions to respond with once alerts were posted. Similar to Halton, they issue heat alerts based on humidex advisories from Environment Canada.	Yes; from resource-allocation point of view; cancelled program	Waterloo Public Health
Prince Edward Island			
Charlottetown	Use Environment Canada cut-offs to issue warnings; high heat is a rarity, so local media generally contact PEI Health during heat.	No	PEI Environmental Health
Saskatchewan			
Regina	No formal policy	No	Regina/Qu'Appelle Public Health
Quebec	Note: In most of Quebec, heat health is administered by the Province. Montréal's municipal plan is an exception.		
Montreal	Montreal has a formal alert and response plan based on air temperature and apparent temperature forecasts. Comprehensive, multi-sectoral approach based on analysis of heat-related mortality from 1984-2003.Distribute literature to high-risk populations (primarily the elderly) and engage public and private sector partners in outreach.	To be reviewed summer 2007.	Sante Publique - Montreal

Note: this information was collected as part of the grey literature search; approach is outlined in the methodology section.

Appendix 2: Examples of Canadian Heat Education Online Materials

"Summer Safety Tips to Beat the Heat – Toronto Public Health"
http://www.toronto.ca/health/beatheat.htm
Toronto Public Health

"Beating the Heat – and Dehydration"
http://www.health.gov.on.ca/english/media/articles/archives/ar_03/080103_ar.html
Ontario Ministry of Health and Long-Term Care

"Hot Weather Toolkit"
http://ottawa.ca/residents/health/environments/issues/hot/index_en.html
Ottawa Public Health

"Hot Weather – Peel Public Health"
http://www.peelregion.ca/health/heat/index.htm
Peel Public Health

"Heat Waves – Information for the Public"
http://www.santepub-mtl.qc.ca/english/heatwave.html
Sante Publique – Region de Montreal

"It's Your Health – Extreme Heat and Your Health"
http://www.hc-sc.gc.ca/iyh-vsv/environ/heat-chaleur_e.html
Health Canada

"Extreme Heat"
http://www.simcoehealth.org/pdfs/extreme%20heat_FINAL.pdf
Simcoe-Muskoka District Health Unit

"Working or Being Active Outdoors During Smog Alerts and Summer Heat"
http://chd.region.waterloo.on.ca/web/health.nsf/vwSiteMap/A3F8CCBFEC9C1BA7852571BD0074EF8E/$file/Smog%20Alert%20&%20Summer%20Heat%20Brochure.pdf?openelement
Region of Waterloo Public Health

"Extreme Heat"
http://www.halton.ca/health/Resources/healthy_environment/pdf/extreme_heat_fact_sheet.pdf
The Regional Municipality of Halton

Appendix 3: Data Collection & Critique Tables – Awareness and Change in Practices

Reviewer Name: Kate Bassil

Date: 3 March 2007

Part 1. Summary of Literature Considering Public Perception and Practices

Article	Population	Measures	Analysis	Evaluation strengths	Evaluation weaknesses
Kalkstein & Sheridan. 2007	Phoenix, Arizona. 201 surveys distributed over 4 days in front of shopping centres; English-speaking only. More younger respondents.	Survey focused on behavioural changes as a result of heat warnings. The majority of individuals surveyed reported that they were aware when a heat advisory was issued. However, there was variation in this awareness across different demographic categories (women more aware than men, respondents over the age of 65 years reported the highest level of awareness).	Basic descriptive stats of percentages; no tests of significance.	Investigates link between perceived risk and mitigating action	Sample not necessarily representative of general population or those most at risk (i.e. few elderly, low-income not captured); brief sampling time frame.
Sheridan. 2006	This study investigated 4 cities (Dayton, Philadelphia, Phoenix, Toronto) – telephone survey of 908 participants.	Surveys conducted over 2 summers (2004, 2005). Phone interviews. Knowledge of the heat warning system was nearly universal (90%) and likely due to pervasive media coverage (primarily TV). However, knowledge of the details of the message of the mitigation plans less understood, and few actually changed behaviour. Many respondents did not believe they were vulnerable and that the messages apply to them. There was also confusion around the difference between ozone precautions and heat precautions.	Descriptive stats; % respondents for each question.	Multi-city, broad time frame. Phone sampling that focused on families with head of household over 65.	Telephone sampling will not capture vulnerable.

Reviewer Name: Mike Callaghan

Date: March 8, 2007

Part 1. Summary Chart of the Literature

Article	Population	Measures	Analysis	Key Results	Strengths for Eval.	Weaknesses for Eval.
Sheridan 2006	Dayton, OH, Philadelphia PA, Phoenix AZ, Toronto ON	Comprehensive review of city plans; city telephone surveys (n=908); median respondent age ~73.5y	Awareness and response by city;	High general awareness (~90%) with majority citing TV; only 46% modified behaviour Awareness not necessarily linked to official heat warning plans; some "warning fatigue" suggested in Toronto 60% feel warning are not directed at them, or that heat not a major problem Large public confusion between ozone/air quality warnings and heat warnings	Focused on elderly; Method allows 4-site comparison	recall issues; problematic analytic framework: agency and risk perception; comparability of 4 sites debatable
Kalkstein/ Sheridan 2006	Metro Phoenix, AZ; opportunistic sample n=201	Handed-out questionnaires, 21-24 Dec; 17 multiple-choice questions (included in appendix) on awareness and behaviour change	Descriptive statistics for awareness and behaviour controlling for demographic factors	High general awareness; differences for gender (m=75.3%, f=90.2%), Age (18-29=67%, 42-53=96%) Income (<$20k=65%, >100k = 95%) 'Race' ('white'=90.5%, 'hispanic'=81%) Strong positive correlation between perceived danger of heat and behaviour change	Subtle linkings of awareness and behaviour; suggested improved strategies	Sampling – sample includes few elderly; self-reporting problematic Phoenix climate is unique
INPES (France)	Representative sample of 1006 ppl age	Face-to-Face questions asked bet. 9-16 Oct	Basic descriptive statistics	Similarly high levels of awareness but significant changes in behaviour across time (2005 vs. 2006). <u>Knowledge:</u>	Large sample size; inclusion of specific	No test statistics; little detail on

	> 15yo, plus sample of 234 ppl age > 75	2006		97% identified elderly as most vulnerable 74% recalled at least 1 media spot on heat 63% at least one TV spot 45% at least one radio spot <u>Behaviour 2005 vs. 2006</u> Use protective measures during heat: 48vs63% Closing sun-facing shutters: 37vs55% Open windows at night: 37vs51% Closing windows during day: 37vs50% Increased hydration (ignoring thirst): 35vs50% Decreased trips in hottest hours: 32vs40% 2-3 hours cool rest per day: 24vs30% Cool baths/showers: 16vs30% 73% knew someone vulnerable and took steps to help (vs. 70% in 2005) However: only 63% of elderly recalled a visit from family or friends; only 14% of elderly who were in discomfort asked for help	elderly demogra-phic; simple survey format; useful comparative data	methods or results; Applicable to Cdn. context?

Reviewer Name: Donald C. Cole

Date: 3 March 2007

Part 1. Data from one heat-event practices survey

First Author (date)	Population	Measures	Analysis	Key results	Strengths for Evaluation	Weak-nesses for Evaluation
Paixão (2005)	Permanent household panel (ECOS) Adults 18 y.o. or over. 29% household response rate, covering 26% of eligible individuals (769 persons)	Mail survey, consisting of 11 questions on heat protective measures. Referred to in general when hot and specifically during heat wave in July-August 2003. Questionnaires sent out in October, 2003 and last one returned in January, 2004.	Calculation of prevalence of responses by groups with 95% confidence intervals. Weighting for some responses, Chi-square for dif-ferences across strata.	Among individual factors associated with practices, focus on age and level of education as vulnerability indicators. <u>Hot periods</u> Traveling during hot hours and drink alcohol – rare among 75+ (73& 93% rarely or never). Activities that require physical exertion – non-literate (55%) and 75+ (75%) rarely or never. Note likely overlap in these poplns. Wear light clothing – 65-74 often (81%) but 75+ rarely or never (7%) Being in air-conditioned spaces – non-literate (72%) and 75+ (78%) rarely or never. <u>During August 2003 heat wave</u> Received info – 75+ lowest for all media Traveling increased among youth, 75+ rarely or never 74% Open windows at night– 65-74 most frequent (58%), 75+ least (19%). Reduce alcohol – 65+ ,83% Increase liquids – literate 72% Wear light clothing – 65-74 increased most (62%), 75+ decreased most (6%) Use fans – 65-74 reduced most (21%) 75+ increased most (44%) Being in air conditioned spaces – non-literate reduced most (33%), 65+ least likely (29%) (see full table attached	Stratification of responses by education level and age.	Recall issues. Not pre and post.

				for good example of dose-response on this key factor) Significantly better practices (all but two) by those that had obtained information. For being in air-conditioned spaces only those via internet (extremely rare among elderly). Having air conditioning at home, or in transport that use – least common in non-literate (2% & 3%). "no Emprego" [at work, I think] also declined with lower education and older age		

Appendix 4: Data Collection & Critique Tables – Changes in Health Outcomes

Reviewer Name: Donald C. Cole

Date: 3 March 2007

Part 1. Summary of Literature comparing heat-wave associated mortality across waves as an indicator of effectiveness of heat-wave interventions (in chronological order to reflect learning from wave to wave)

First author (year)	Locations, year wave comparisons	Health outcomes	Analysis	Evaluation strengths	Evaluation weaknesses
Smoyer KE (1998)	1980 (severe, 30 days) and 1995 (moderate, 18 days) St. Louis, Missouri. Prime focus on impact of potential changes in population vulnerability on differential all cause elderly mortality.	Mean daily heat wave elderly mortality for simulated severe heat wave using 1995 parameters (15.5, 10.3 to 26.5) was significantly higher than using 1980 parameters (14.4, 13.5 to 15.0) i.e. increased population vulnerability (table 4).	Independently modeled meteorological predictors of mortality for each applied to the 1995 populations.	Good control for different heat wave characteristics and demography	Limited information on public health dept. interventions (p 50). No control of morbidity levels in popln.
Palecki MA (2001)	1999 vs. 1995 for Midwestern US, particularly Chicago, Illinois and St. Louis, Missouri. Entire section (5) on mitigation responses in both cities.	Heat-wave attributed fatalities from multiple sources (health departments, CDC, newspapers) and multiple definitions (heatstroke only, heat stress contribution). Assessment that 1995 inter-city comparison (8.8/100,000 in Chicago vs. 1.1/100,000 in St. Louis) attributable to more coordinated and substantive mitigation response in St. Louis. Assessment that reduction in Chicago between 1995 and 1999 (to 1.4/100,000) attributable to improved response.	Primarily graphic description (Sn 2) and comparisons (Sn 3) both ranking of 2-day and 12 day periods and time series (Fig 11).	Almost a quasi-exptl design with pre-post, response change in one city with already response in comparison city.	No modeling to take into account climatological differences in a more nuanced way. Assessment of coverage by response limited.
Weisskopf MG (2002)	1999 vs. 1995 for Milwaukee, Wisconsin. Question whether the	Fatalities from county medical examiner, excessive heat as underlying or contributing cause of death. EMS dispatches less clear	Poisson distrbn & log-link function, GENMOD, SAS,	Only one to look at morbidity	Lack of comparison city. Potential co-

	reductions in heat-related deaths and paramedic runs were the result of differences in heat levels alone.	criteria. 1) Ratios per degree of excessive heat during and after (10 days) heat wave days. 2) Equation predicting heat related deaths or EMS using year and 3 heat index-time indicators. O/E ratios (n=12) ranged from 0.17 to 0.51, CIs for two including 1. Decrease in proportion from poor (55 to 27%) and very poor (33 to 9%) neighbourhoods.	comparing observed in 1999 vs. expected based on 1995, adjusted to 1999 popln.	through EMS dispatches. Inclusion of census tract poverty data, diagnoses (CV primarily), psychotropic medcn & age.	interventions not described (though intervention reference to website).
Ebi K (2004)	1995-1998 heat waves in Philadelphia, Pennsylvania. Benefits of Hot Weather-Watch/ Warning System (PWWS) vs. costs	Excess daily mortality as difference between that during heat waves and "underlying mortality trend" prior to 1995. Estimate that 2.6 lives saved per day on average for each day warning issued (45 days of 210 days in 3 summers) = 117 lives (CI -45 to +275). Converted via EPA value of statistical life – 1/3 drop off for older population to $4 million per life saved.	Multiple linear regression, Excel. Co-efficient on warning indicator (and time in season)	Only public data on cost estimates for PWWS. Linking of improved plans to PWWS system development.	One city, ? underlying distribution, decision makers usually face cost-cost comparisons vs. cost-benefit ones.

Part 2. General conclusions from this literature

Single pre-post comparisons (3/4 studies) are generally regarded as weak quasi-experimental evaluation designs, yet given the infrequent nature of heat waves and the limited comparability of data sets across settings, they have been the most feasible to date. Sophisticated modeling approaches within these designs, inclusion of more than one health outcome, sensitivity analysis with various heat index scenarios and taking account of other plausible explanatory variables (Weisskopf et al., 2002) or inclusion of a cotemporaneous comparison city (Palecki et al., 2001) strengthen the evidence of effectiveness of heat wave responses. These two better studies provide ranges of best estimates of mortality and morbidity reduction from about 15% through 50% (Weisskopf et al, 2002) to about 80% (Palecki et al, 2001).

Improvements in internal validity could be achieved by greater discussion of potential co-interventions or changes in the cities over the time period of interest. A consistent focus on the most vulnerable (income only considered in one study and age related differentially across the studies) would also help. Improvements in economic evaluation could include more explicit costing e.g. city budget allocation data, and consideration of other foregone opportunities for budget allocations and their associated benefits.

Issues remain in the method and cut-point for threshold of instituting different levels of heat wave responses – something all the authors have contributed to. Some of this discussions requires examination of scenarios outside these highly impacted US Midwest cities in which both the attributable burden of morbidity and mortality are estimated i.e. how important a health problem, and likely reductions among vulnerable populations that could be attributed to responses.

Reviewer Name: Kate Bassil

Date: 3 March 2007

Part 1. Summary of Literature Considering Health Outcomes

Article	**Population**	**Health outcomes/Measures**	**Analysis**	**Evaluation strengths**	**Evaluation weaknesses**
Ebi et al. 2004	All heat waves between 1995-1998 in Philadelphia	Excess mortality (defined as the difference between the reported mortality and the underlying mortality trend estimated from years prior to 1995) in the 65-yr and older age group. Suggest 2.6 lives saved for every day a heat warning was issues. Used EPA estimates of $ value of a statistical life to conclude that $4mill per one life saved…117 lives saved in Philadelphia over this time period.	Multiple linear regression. Software: Excel	This is one of very few attempts of an evaluation and the only one we have found that addresses the important issue of resources and costs.	Difficult to attribute solely to HHWS rather than meteorological factors (although this an inherent problem in topic). Only considered deaths over age 65.
Weisskopf et al. 2002	Two heat waves in Milwaukee, Wis (1995 and 1999). Aim was to quantify the changes in health outcomes between these two heat waves.	1) Heat-related deaths (as id'ed on death certificates) 2) EMS runs	Poisson. Software: SAS (proc genmod). Observed to expected ratios for heat-related deaths (age adjusted).	Considers both mortality and morbidity outcomes. Morbidity outcome are very rare in the heat illness literature.	Problem with looking at deaths where heat was listed as underlying cause on death certificate – likely underreported.
Palecki et al. 2001	Compared two heat waves in US Midwestern cities: 1995 and 1999. Cities: Chicago, St. Louis	Mortality. Found that in 1999 Chicago was better at mitigating the effects than it did in 1995 (more than 500 deaths during the 1995 heatwave as compared with 119 deaths during the 1999 heatwave). This was attributed to improvements in public health response (in addition to characteristics of the heat wave). The electrical supply was	Meteorological analysis of the heat waves to determine difference in conditions between the events. Comparison of	Multi-city. Includes a detailed discussion and assessment of the meteorological conditions (not just the health	Not statistically very rigorous or in-depth. Unclear what/if formal analysis and modeling was done.

		maintained during the 1999 heat wave, whereas it failed during the 1995 episode which also likely had an effect.	mortality rates.	outcomes) which provides information regarding what can be differences due to differences in the heat waves themselves (versus public health interventions).	
Smoyer. 1998	Compared the heat waves and associated mortality during two heat waves in St. Louis, Missouri (1980 and 1995).	Mortality, all-causes. People over the age of 64.	Poisson regression; simulated model with 1980 weather conditions and 1995 population; accounted for many features of heat wave (i.e. timing, duration…)	Included heatwave characteristics that many studies do not include.	