Systematic review: How efficacious and how practical are personal health protection measures recommended to reduce morbidity and mortality during heat episodes?

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Abstract:

In this review we aim to establish what health protective advice is offered by public health and civil protection authorities in general and specifically during heat episodes. We have evaluated the incoherencies and discrepancies of health messages given by various sources and critically assessed the efficacy of this advice by reviewing current evidence supporting these measures on the basis of observational studies and from the physiology of heat response.

Firstly, we performed an internet search intended to replicate the results found by a typical member of the general public looking for local heat health advice from local health departments of or more authoritative sources in anticipation of a coming heat wave, or during one. We identified 60 public health, disaster relief, weather service, and patient advocacy websites between June 2006 and March 2007 and 44 documents were identified which gave heat-specific health advice. After classifying and ranking the advice messages, we selected six topics chosen on the basis of inconsistency in messaging among agencies, vagueness or ambiguity as to message targets or instructions, or where optimal messaging appeared most likely to protect health. In order to explore these areas in more detail, we systematically examined peer-reviewed articles to support, refute, and contextualize the recommendations given (acclimatization, air-conditioning, fan use, medications, hydration, and activity reduction).

For this strategy, we searched Medline, PubMed, and hand-searched references of identified reviews and articles, consulted colleagues and internet search engines (Google Scholar). By reviewing the relevant epidemiological, physiological, and experimental studies in each area, we were able to draw conclusions and highlight areas where more research needs to be done.

Among the insights gained from this undertaking, we were able to identify advice that was practical, notably increasing hydration, monitoring those taking medications that disrupt heat responses, acclimatizing slowly to the heat, reducing activity level and using electric fans to enhance evaporative cooling or supplement other cooling techniques. Some of the advice which was not well supported by scientific evidence was avoidance of fan use, avoidance of caffeinated and sweetened drinks, and avoiding all alcoholic beverages. Areas where knowledge gaps exist were found concerning the use of devices other than air conditioning to enhance cooling and ventilation, hydration and activity needs and limitations of heat-vulnerable populations, and the level of risk presented by commonly taken medications during heat waves.

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Introduction

The potential impact of elevated temperatures on mortality and morbidity are severe. In the U.S., for example, from 1979 to 1999, the deaths of 8,015 Americans have been directly associated with excessive heat exposure (CDC, 2002). As recently as August 2006, there were over 100 heat-related deaths during one week in New York City (Perez-Pena, 2006). These US estimates undercount the full impact of heat, however, as there are no widely accepted criteria for determining a heat-related death, and death certificates often do not identify when heat has acted as a contributing factor in exacerbating pre-existing cardiovascular, respiratory, psychiatric and other conditions (Basu & Samet, 2002). A broader impact of heat is suggested by the observation that every year, hospitalizations and deaths in numbers well above average, occur during and just after days of extreme heat, particularly in vulnerable populations. In 2003, Western and Central Europe experienced the hottest summer since 1500, and the heat wave in early August caused an estimated 14,800 deaths in France alone (Sardon J-P, 2007). Urban Canada has also been affected: a 1994 heat wave in Montreal led to over 100 excess deaths (Kosatsky T, Henry B, & King N, 2005).

Persons over the age of 65 consistently show the highest rates of heat-related mortality. Persons living in urban environments may be at particularly increased risk for mortality from ambient heat exposure, since urban areas are typically warmer than surrounding suburban or rural areas, a phenomenon known as the "urban heat island effect". Other vulnerable groups identified as being susceptible to heat-related mortality are: infants and children up to four years of age; persons in poor general health – especially those with cardiovascular, neurological and psychiatric conditions, endocrine disorders and chronic pulmonary disease, liver and kidney diseases or high blood pressure; persons who take medications that aggravate dehydration and heat exhaustion, such as diuretics, neuroleptics, antidepressants, benzodiazepines, amphetamines, analgesics, beta-blockers, ACE inhibitors, anti-inflammatory drugs and many others; persons who are overweight; those who are socially isolated; persons who overexert during work or exercise; and those confined to bed and unable to care for themselves .

With a world of both warmer summers and climatic instability, and given an aging population, increasingly more isolated and more medicated, efficient measures to reduce the risk of heat-related death are crucial.

Various expert bodies have promoted measures designed to decrease vulnerability to heat-related death, and to provide early recognition of and first aid to persons affected by heat. Among these organisations are the World Health Organisation , the US Environmental Protection Agency , the US Centers for Disease Control, the French Institut de Veille Sanitaire, the UK Department of Health, and many state and city departments of public health, including those for Toronto and Montreal. Professional organisations such as the American Pediatric Association have also published guidelines for the protection of health in the heat (Anderson, Griesemer, Johnson, American Academy of Pediatrics, & Committee on Sports Medicine and Fitness, 2000). Sport medicine, the military, and occupational health bodies have also produced guidelines, which are of particular interest given their emphasis on work in the heat, and on optimal clothing for the heat, which are of relevance beyond the realms of sport, work, and war.

Objectives

1. To establish what health protective advice is offered by public health and civil protection authorities in general and specifically during heat episodes.
2. To review current evidence supporting these measures on the basis of observational studies and from the physiology of heat response.
3. To critically assess the efficacy of this advice and review the incoherencies and discrepancies of health messages given by various sources.
4. To identify knowledge gaps that may limit our ability to evaluate these measures.
5. To assist clinicians and public health professionals in developing health protection measures most likely to protect the population from the adverse effects of heat.

Methods

Individual health protection measures identified
Numbers in bold (1**) refer to websites identified in Appendix A*

Our internet search was intended to replicate the results found by a typical member of the general public looking for local heat health advice (metropolitan and provincial health departments) or more authoritative sources (World Health Organization, CDC) in anticipation of a coming heat wave, or during one. Many sites provided links to other sites within their own agency where one could find recommendations targeted to the elderly, parents of young children, athletes, or outdoor labourers (**6, 21, 31, 33**). We included those sites aimed at the general public and those aimed at the elderly and caretakers of heat-vulnerable people. We performed a systematic search of web-accessible advice for protection against heat-related illness available to the general public in North America, Europe and Australia. Our search criteria are summarized in Table 1. We searched seven categories of websites which include public health or civil protection agencies most likely to provide authoritative health protection advice. A complete list of websites searched can be found in Appendix A. From these sites, were able to distinguish 12 basic categories of commonly recommended health protection measures pertaining to staying cool, well hydrated, reducing heat stress, and seeking help from appropriate sources.

Table 1. Selection criteria to identify health protection measures against heat-related illness

Included websites:	Websites potentially accessed by the general public in North America, Australia and Europe: 1. Intergovernmental organizations (World Health Organization, Centers for Disease Control and Prevention) 2. Disaster relief organizations (FEMA, American Red Cross) 3. Weather services (Environment Canada, Météo-France) 4. Private agencies (American Association of Retired People, etc.) 5. Public health authorities a. Federal, State or Provincial, Municipal 6. Care providers (American Academy of Family Physicians) 7. Patient advocacy groups, and patient information services (American Heart Association)
Included languages	English, French, Italian, Spanish
Keywords on websites search engines	"Heat", "heat wave", "heatwave", "extreme heat", "canicule", "chaleur", "chaleur accablante", "heat exhaustion", "heat stress", "heat-related illness", "ondate di calore", "ola de calor"
Included populations	General adult public, people with chronic illnesses
Excluded populations	Outdoor workers, athletes, students, children, homeless, health care professionals
Included health protection measures	Individual protection measures regarding: 1. Pre-seasonal advice 2. Hydration 3. Mineral replacement 4. Nutrition 5. Clothing 6. Indoor behaviour 7. Outdoor behaviour 8. Activities 9. Fan use 10. Home adaptation 11. Using air conditioning or cooling 12. Health awareness
Excluded measures	Measures to be taken in certain climates (desert), during sporting activities (hiking), measures to insure the safety of perishable foods or to protect property or pets.

Search methods

Approximately 60 public health, disaster relief, weather service, and patient advocacy websites were searched between June 2006 and March 2007 and 44 documents were identified which gave heat-specific health advice. 242 separate individual messages for protection against extreme heat directed to the general public were identified. 23 supplementary messages were identified for vulnerable populations (elderly, young children, people taking medication, anyone with a chronic medical condition – particularly cardiovascular disease). In addition, 12 messages aimed at cooling of residential buildings were identified from five different sites. Certain sites gave information directed primarily at outdoor workers (OSHA, Canadian Centre for Occupational Health and Safety, US Army, CDC).

We reviewed health protection messages issued by the following 44 organizations:

WHO Regional Office for Europe, *Ministère de la Santé et des Services sociaux* (Québec), *The Department of Health* (United Kingdom), *Centers for Disease Control and Prevention*, *Toronto Public Health Department*, *The American Red Cross, United States Environmental Protection Agency*, *Health Canada, American Heart Association*, *Harvard Health Letter*, *Direction de la santé publique de Montréal*, *American Academy of Family Physicians, Federal Emergency Management Agency (FEMA), Public Health Agency of Canada, Vancouver Health Department, British Columbia Ministry of Health*, *New York City Department of Health and Mental Hygiene*, *American Association of Retired People, Illinois Department of Public Health*, *Direction général de Santé (France), Insititut national de prévention et d`éducation pour la santé* (France), *Météo-France*, *Environment Canada, National Oceanographic and Atmospheric Administration, Illinois State Climatologist Office, Laboratoire de Santé Publique* (Faculté de médecine de Marseille), *Texas A & M University/ Texas Cooperative Extension Health Hints, Santé publique*, *Sécurité de la Chaîne alimentaire et Environment* (Belgique), *Office federal de la santé publique/ Plan d´Action environment et santé* (Suisse), Ministerio *de Sanidad é Consumo* (España), *Ministero della salute* (Italia), *Ontario Ministry of Health and Long Term Care, Texas Department of State Health Services*, *Wisconsin State Government/Department of Health and Family Services, California Department of Health Services*, *California Department of Aging, Department of Human Services, Victoria* (Australia), *Santé Ontario, Ottawa Public Health, Maricopa County Department of Health Services* (Phoenix, Arizona), *Milwaukee Health Department, Chicago Department of Public Health*, City of Columbus – *Columbus Public Health*, and the *Los Angeles County Health Department*.

What heat protection advice is given?

In general, we found that sites which give comprehensive heat advice cover most of the following subjects.

To the general public:

Seasonal and heat wave preparation

- Install air conditioning
- Talk to your doctor about changes to your treatment in the heat
- Prepare to check in on the elderly
- Be familiar with community resources

Environmental

- Keep residence cool – close shutters, windows, drapes when outdoor temperature is higher than indoor
- Use of fans –advice varies (mostly, use fans with open window when outside is cooler than inside).
- Air conditioning – people are advised to use during hot hours.
- Reduce stove and electricity use to cool interior and reduce strain on power grid.

Behavioural

- Avoid peak hours of sun exposure
- Hydration, mineral replacement, food – drink more even if not thirsty, eat lightly and drink or eat small quantities of items with some sugar or salt.
- Activity restriction – avoid strenuous activities and new exercise regimes.
- Seek a cooler space if no air conditioning at home
- Personal cooling techniques – shower, bath, sponge often etc.
- Wear appropriate clothing – loose, lightweight, light colour.
- Know how to recognize and treat signs of heat illness

Social

- Check on the elderly
- Don't leave children in a parked car

<u>What heat protection advice is given to persons with medical conditions?</u>

- Consult physician for medication tailoring, fluid restriction
- Monitor yourself, others for signs of heat-related illness
- Know where to get help
- Know which medications put people at increased risk

The most commonly offered advice oriented to protection when the temperature is extremely high is listed in order of frequency (categories created by the authors)

1. Avoid drinking alcohol (34 of 44 sources).
2. Wear lightweight, loose fitting clothing (31 of 44 sources).
3. Drink regularly without waiting for thirst (28 of 44 sources).
4. If you have no air conditioning at home, seek out an air conditioned or cool environment (21 of 44 sources)
5. Stay indoors in an air conditioned environment (20 of 44 sources)
6. Wear a hat (18 of 44 sources).
7. Avoid or reduce physical activities (18 of 44 sources).

8. Protect yourself from the sun (17 of 44 sources).
9. Know the symptoms of heat illness and know how to respond (15 of 44 sources)
10. Look in on vulnerable people (15 of 44 sources)
11. Do not leave children in a closed, parked car (15 of 44 sources)
12. Avoid going out during the hottest part of the day (13 of 44 sources)
13. Take frequent baths or showers (11 of 44 sources).

Topics for review of evidence (fan use, acclimatization, medication use, hydration, air conditioning use, reducing activity):

We evaluated evidence for individual health protection measures against heat-related illness, prioritising six areas chosen on the basis of inconsistency in messaging among agencies, vagueness or ambiguity as to message targets or instructions, or where optimal messaging appeared most likely to protect health.

We chose to study fan use for several of these reasons. The message that fan use is ineffective when temperatures are high is repeated verbatim in five sources (**4, 5, 6, 25, 42**), inconsistencies are rampant on comparing the many websites which give threshold temperatures above which fan use is discouraged, and we observed a divergence of opinion between European and North American sources. The subject of physiologic acclimatization, of potential value to the elderly, was chosen because it is rarely mentioned and only in the context or school or amateur athletics. Medication use is cited by many websites as a potential risk for heat-related illness, but little specific advice is directed at readers taking potentially harmful medications, other than to advise that they ask their doctor or pharmacist to tailor their treatment regimen; the extent to which health professionals are knowledgeable about how to tailor these medications is unclear; the long list of medications posted on many websites raises awareness of risk without providing concrete strategies. We chose to explore optimal hydration and activity reduction because these issues are among the most common pieces of advice, and it remains unclear from many of the sites reviewed whether the advice is truly oriented to the elderly and other heat-vulnerable groups. Air conditioning use was targeted because with global climate change and an aging population, jurisdictions where air conditioning is limited are now contemplating potentially costly changes to infrastructure to protect their aging citizens.

We systematically examined peer-reviewed articles according to criteria summarized in Table 2. We searched for epidemiological, observational and experimental studies covering the effectiveness of heat protection mitigation measures and the physiology of heat response in humans. For this strategy, we searched Medline, PubMed, and hand-searched references of identified reviews and articles, consulted colleagues and internet search engines (Google Scholar). Preliminary hypotheses were reviewed by experts in the field of epidemiology, physiology, occupational medicine and public health.

Table 2. Criteria for evidence for health protection measures

Databases	Medline 1950-2007, PubMed, Google Scholar
Types of studies	Experimental, epidemiologic, observational
Included languages	English, French
Included population	Humans in temperate climates
Included topics	Electric fans, air conditioning, hydration, acclimatization, medication
Subject/MeSH headings	Fans; ventilation; air currents; evaporative cooling; wind; heat-related illness; heat waves; mortality; climate; temperature; acclimatization; air-conditioning, thermal shock; hydration; dehydration; medication; drugs.
Excluded studies	Non-human,
Excluded population	Populations in tropical climates
Excluded topics	none

Inconsistencies, discrepancies and areas that need to be addressed

Recommendations are often incompatible to a greater or lesser degree. Most US sites discourage fan use in general, while others in the United Kingdom support it. Even among sites which caution against it, some recommend against directing the flow of a portable fan towards oneself when the room is hotter than 90˚ F (32.2˚C), others recommend against using a fan when the temperature is above 99˚ F (37.2˚C). Some sites recommend replacing salt and minerals, while others specify avoiding salt tablets. Nearly all suggest drinking cool liquids, but others cautioned against drinking very cold liquids advising that they can cause cramps. Most agreed on avoiding liquids which contain caffeine or large amounts of sugar.

Advice for cooling a residential building includes drawing the curtains and closing windows during the day and opening windows at night. Recommendations aimed at elderly adults and people with chronic medical conditions includes asking a physician to advise them about changes to medication or activities, and for fluid restricted patients, asking a physician how much one should drink when the weather is hot. For people with cardiovascular disease, the *American Heart Association* issues more specific recommendations, such as "monitor your body fluid level by weighing yourself every morning after using the bathroom (if you weigh two pounds less than normal in the morning, you're probably dehydrated and need to drink more water before doing any vigorous physical activity)", and "if you plan to exercise outside in hot and humid weather, wear very light, comfortable clothing and work out in the early morning or late evening", and "know the symptoms of heat exhaustion and heat stroke".

Among the areas that receive little attention, one potentially valuable subject is the notion of gradual acclimatization to heat in the elderly in order to build up their physiologic defences. This area is touched on by four sites (**1, 13, 23, 42**), but they do not specify to what degree the elderly can acclimatize to heat the way young, fit people do. Recommendations also address the subject of dealing with the heat, but few sites other than disaster relief organizations (*FEMA, American Red Cross*) give recommendations on preparing for the heat. Pre-seasonal advice may be necessary for people who are newly at-risk, people who recently moved to warmer climates, or for parts of the world where extreme heat is now becoming more frequent.

Conclusions

- Individual health protection messages against extreme heat conditions can be summarized in three categories: (1) decreasing exposure to high temperatures by avoiding outdoor exposure and accessing cool environments (2) keeping oneself well hydrated with the right amounts of the proper fluids and avoiding those with diuretic effects, and (3) knowing what to look for in terms of symptoms of heat illness and knowing whom to contact for help
- Few references are cited to support these recommendations, and few discuss potential adverse effects of the recommended behaviours.
- We identified inconsistencies between agencies, and occasionally within the same agency, emphasis on potential risks without practical solutions (medication issues), and potentially harmful advice (listing many beverages as "to be avoided", which could lead to insufficient hydration).
- The search of medical databases for evidence to support these recommendations may highlight gaps in our knowledge.

SECTIONS

The possibilities and limitations of acclimatization for protection against extreme heat

Introduction: protective benefit of acclimatization

Several observational studies have evaluated acclimatization as a protective factor against heat-related mortality (Ellis, 1972; Gover M, 1938; Marmor, 1975). Extreme heat episodes later in the summer will typically extract a lesser toll of heat-related deaths than heat waves of equal levels of intensity in late spring and early summer (Gover M, 1938; Marmor, 1975). This drop in mortality may be partly attributable to an early summer reduction in the pool of vulnerable people after the first event, but evidence suggests that survivors of the first heat wave become physiologically acclimatized and hence deal more effectively with extreme heat (Kalkstein LS & Valimont KM, 1987). Geographic acclimatization to heat has also been cited as a factor in a lower heat illness risk among people living in warm climates (Ellis FP, 1976). Epidemiologic evidence points to a higher risk of heat-related death among populations living in temperate regions where extreme heat is typically uncommon (Basu et al., 2002; Curriero F et al., 2002; Gover M, 1938).

Temperature indices used currently by meteorologists to convey the impact of combined weather parameters (Humidex in Canada, Heat Index in the US) use absolute values only, without taking previous weather into account (Kalkstein LS et al., 1987). This may not give an accurate picture of heat risk due to the protective effect of acclimatization. In our survey of hot weather messaging, we found little mention of acclimatization, or instructions on how to acclimatize as a means to protect against elevated temperatures.

Adaptive behaviours and physiological changes that enable people to better cope with heat can be described as short-term or long term acclimatization. Long-term acclimatization is largely dependent on behavioural adjustments (clothing, activity level, etc.) as well as cultural changes (design of housing, use of air-conditioning, siestas, etc.). Short-term acclimatization depends on physiologic changes, typically over a period of days to weeks, that represent reduced strain for a given heat load. These changes are most apparent in the cardiovascular system and in altered body fluid volumes and electrolyte distribution (Bass DE, 1963).

Advice given

We found that the websites searched gave little information or advice on heat acclimatization. Only four sites advised to start slowly and gradually increase activities if one is not used to working or exercising in the heat (**1, 13, 23, 42**). Only Texas A & M University (Texas Cooperative Extension Health Hints Guide) specifies an acclimatization schedule. They advise athletes unused to high temperatures to work out in the heat for 20min/day, and to work up to 30-60min 5-10 days ahead of the sports start date. Further, young athletes may need up to 14 days to safely acclimatize. They give other safety tips for exercising in the heat pertaining to avoiding dehydration and sun exposure. None of the acclimatization advice on the websites we searched was aimed at elderly or other heat-vulnerable populations.

What is the evidence that gradual exposure to heat may confer benefits to elderly or vulnerable populations?

Physiological studies on typical subjects:
Extensive experimental studies were carried out, mostly in the 1960s and ‘70s on fit, young, male subjects largely in support of increasing fitness and productivity in industrial settings (studies by Wyndham on South African gold miners) (Wyndham et al., 1968a; Wyndham, Williams, Morrison, Heyns, & Siebert, 1968b), in sports training, and for military manoeuvres in tropical climates. Subjects exposed to vigorous exercise in heated thermal chambers were found to have improved heat stress responses (heart rate, core temperature, stroke volume) after a period of several days (Edholm OG, 1969b; Ellis FP, 1976; Mitchell D et al., 1976; Shapiro Y, Pandolf KB, & Goldman RF, 1982).

Measurements of certain stress parameters following this type of controlled, artificial acclimatization generally show improvement starting around day three, with increases up to day 10; in some cases further gains are measured up to day 14 (Edholm OG, 1969b; Ellis FP, 1976; Mitchell D et al., 1976; Shapiro Y et al., 1982; Wyndham et al., 1968a; Wyndham et al., 1968b). Heart rate is reduced, stroke volume increased, core temperature is reduced and there is an earlier and greater sweat response with a lowering of salt content in sweat (Mitchell D et al., 1976).

According to Bass, changes in body fluid spaces are observed on day five, notably a significant increase in plasma and interstitial volume, a rise in total body water, a smaller but still significant increase in plasma volume and total body water on day 17 (Bass DE, 1963). Hemodilution and an increase in plasma volume occur only when the subject is in salt and water balance (Wyndham CH, Strydom NB, Benade AJS, & Van Der Walt WH, 1973). Senay proposes that an increase in concentration of plasma proteins causes the expansion of the intravascular volume during acclimatization (Senay LC, 1972). Edholm finds that, unlike acclimatization to cold, physical fitness does not substitute for heat acclimatization (Edholm OG, 1969a).

Physiological studies on atypical subjects:

We were unable to find experimental studies of acclimatization using subjects older than 60, but two studies using older men who were still in the workforce were found (Lind, Humphreys PW, Collins KJ, Foster K, & Sweetland KF, 1970; Robinson, Belding HS, Consolazio FC, & Turrell ES, 1965). Lind, in 1970 published the results of the influence of age and heat exposure on two groups of British coal miners (Lind et al., 1970). The average age of the younger group was 27 (range 23 – 31), while that of the older group was 47 (range 39 – 53). Thermal chamber experiments where subjects simulated an eight-hour-day’s work were carried out over a two week period, but temperatures were randomly varied between neutral, warm and hot, so acclimatization effects were not significant. However, differences between the age groups was marked in hot conditions, where older men showed a pattern of consistently higher core temperature, less sweat during work and more during rest, and indicators of increased cardiac strain. Lind concluded that rates of acclimatization in the older group may be somewhat delayed and diminished (Lind et al., 1970).

Robinson conducted a small study where he retested men between the ages of 44 and 60 (mean age 52) who had completed thermal chamber acclimatization studies 21 years prior, to see if they could obtain the same level of acclimatization to heat (Robinson et al., 1965). All but one of the four subjects tolerated work in the heat as well or better than 21 years earlier. Essentially the same pattern of change in heart rate, rectal temperature, and average skin temperature was obtained after 5 – 13 days of exposure as was seen in the early study. This contrasts with a decline in metabolic rate for the earlier study of 7.4% after acclimatization, and no significant change in the repeated study. The older men displayed a lower overall heart rate, lower metabolic rate and sweated less than the previous study, which led Robinson to suspect that perhaps design flaws in the second study made the work easier. Alternatively, he concluded that the participants may have gained stamina along with age, or perhaps the sensory or integrating nervous system mechanisms concerned may have become less responsive, leaving men less aware of potentially harmful strain as they grow older (Robinson et al., 1965).

Physiologic age-related changes:

Circulatory system

In the elderly, there is a decreased ability to pump and redistribute blood to the skin. There is a decline in cardiac reserve and age-related reduction in vascularity which subsequently decreases peripheral blood flow. These changes would reduce the efficiency with which heat can be removed. Weiss et al. concludes that the magnitude of skin blood flow is altered in aging skin (Weiss M, Milman B, Rosen B, Eisenstein Z, & Zimlichman R, 1991). This lower cutaneous perfusion of older individuals is associated with a loss of capillary plexus functional units. Furthermore, conditions such as atherosclerosis, heart failure and hypertension reduce even further the body’s ability to respond to extreme heat (Worfolk, 2000).

Sweat glands

Glandular function gradually declines in the 70s and 80s (Sato K, 1993). Aging causes a reduction in the number of sweat glands and the sweat gland response (Worfolk, 2000). In normal ageing, there is reduction of cutaneous vasodilation, reduction of volume of sweat per gland, caused by atrophy of sweat glands, and a reduction in the density of active sweat glands. Lifetime ultraviolet exposure and other environmental factors contribute with chronological age to reducing sweat gland responsiveness (Ellis FP, Exton-Smith AN, Foster KG, & Weiner JS, 1976).

Are the elderly chronically dehydrated?

Many elderly are in a state of chronic dehydration because of age-related decreases in total body water and ability to concentrate urine as well as low fluid intake from decreased sense of thirst (Ham RJ, 1992). There is an age-related decline in plasma renin and aldosterone levels which predisposes to excreting large quantities of salt and water in the urine, leading to a state of salt depletion in older persons. After the age of 40, there is a linear age-related decline in glomerular filtration rate even in the absence of kidney disease. Furthermore, when older persons are unable to obtain sufficient volumes of water due to infirmity or impaired thirst in hot weather, they are prone to hypernatremia, which is associated with hyperviscosity and increased risk of cerebral and coronary thrombosis and central nervous system dysfunction (Flynn A, McGreevy C, & Mulkerrin EC, 2005).

Cardiovascular disease—how does it affect heat response?

Aging is associated with reduced cardiac output as well as less redistribution of blood flow from the intestinal and renal circulations (Kenney & Thayne A, 2003). In a study comparing the cardiovascular responses of young and old men during direct passive heating to the limits of thermal tolerance, Minson et al. found that reduced cardiac output was primarily the result of a lower stroke volume, since the older subjects were able to increase their heart rate to a similar extent as the young men. However, the older men had to attain a greater proportion of their heart rate reserve (Minson, Holowatz, Wong, Kenney, & Wilkins, 2002). People suffering from cardiac disease are unable to augment their cardiac output adequately to produce the necessary level of vasodilation to dissipate heat by evaporation (Minson et al., 2002).

Behavioural age-related and chronic disease-related changes
Described risk factors for death or morbidity during severe heat episodes characterize the "at risk" population as being socially isolated and elderly (esp. over 75 years old) (Centers for Disease Control, 1995), living in urban areas, often housebound or unable to care for themselves independently, and disproportionately living in institutions (Basu et al., 2002; Bouchama et al., 2007; Kovats RS & Hajat, 2007; Semenza et al., 1996). From experimental studies on people in their 40s and 50s, it appears that healthy elderly may be able to attain levels of physiologic acclimatization close to younger counterparts, but lack of activity and lack of exposure to a range of temperatures may deprive them of the opportunity to effect this protective adaptation (Robinson et al., 1965). Further, as mentioned earlier, people with cardiac and renal impairment may not be able to achieve these results.

What advice regarding acclimatization should we give to vulnerable populations?

- *One of the most frequent recommendations given for heat protection among the websites we reviewed (30 out of 44 sources), is to stay in a cool or air-conditioned environment. This advice seems well supported by evidence to protect vulnerable people from episodes of extreme or unusual heat (see air-conditioning section). However, there may be benefits derived from some degree of heat exposure when temperatures are not so extreme. It is possible that the avoidance of outdoor temperatures and strenuous exercise deprive seniors of the opportunity to "train sweat glands". Experiments on men as old as 60 suggest that training in thermal chambers can promote physiologic changes which indicate an improvement in cardiovascular and endocrine mechanisms to lower heat strain (Robinson et al., 1965).*

- *The premise for the need to provide a closely controlled thermal environment for seniors has been challenged by Stoops (Stoops, 2008), who argues that, like the cardiovascular system, the human thermoregulatory system needs to be stimulated by temperature extremes for efficient thermal responses.*

- *We still do not know to what extent these changes can be attained by people in their 70s and 80s, people who do not engage in strenuous exercise, or those with chronic medical conditions. More research needs to be done to answer these questions, particularly with an aging Canadian population and global climate change potentially bringing more variable and hotter weather.*

Evidence for recommending air conditioning to prevent heat-related illness and mortality

One of the most frequent recommendations given for heat protection (30 out of 44 sources), is to stay in a cool or air-conditioned environment. This recommendation does not often specify using a home air conditioner, but rather spending time in a place that has air conditioning or is naturally cool, such as a basement, church or park. Following the 2003 heat wave in Europe where a significant number victims affected were in non-air-conditioned health care facilities or retirement homes (Crabbe, 2003; Fouillet A et al., 2006), many health authorities in areas that are unaccustomed to extreme heat have investigated the introduction of air-conditioning to health care facilities and contemplated making recommendations for use of home units. In areas where air conditioners are commonly used, notably in Southern and Midwestern US regions, robust evidence from epidemiologic studies of heat-related mortality show a strong protective effect in groups having a working air-conditioner (Bouchama et al., 2007; Chestnut, Breffle, Smith, & Kalkstein, 1998; Curriero F et al., 2002; Kilbourne, Choi, Jones, & Thacker, 1982; Kilbourne, 2002; Semenza, McCullough JE, Flanders D, McGeehin MA, & Lumpkin JR, 1999; Basu et al., 2002). Studies which investigated the degree to which this response is confounded by socio-economic factors have found robust evidence of mitigation of mortality attributed to central air conditioning ownership independent of race or socio-economic status (O'Neill, Zanobetti, & Schwartz, 2005; Rogot E, Sortie PD, & Backlund E, 1992). Problems of resources and power infrastructure argue against the blanket recommendation to introduce air-conditioning on a large scale into areas, such as Western Europe, that have historically relied on alternative methods (such as natural ventilation and structures affording solar protection) to cope with heat. However, predictions of more frequent and intense heat episodes in temperate regions (IPCC Working Group II & Intergovernmental Panel on Climate Change, 1997) require health authorities to make difficult decisions between short-term protection of vulnerable citizens by promoting increased use of air-conditioning, and long-range sustainable efforts to be fuel efficient.

Here we investigate current recommendations given to the general public by health and civil protection authorities concerning air-conditioning use. Identifying those people for whom air-conditioning may be most advisable, as well as the optimal duration and intensity of cooling, may help in the prescription of air conditioning and avoidance of negative effects of its use in heat-vulnerable persons and for society as a whole.

Advice Given

Heat mitigation advice to the general public promotes staying out of the sun, staying indoors in a cool environment. Twenty-eight out of 44 sites specifically suggest staying in an air-conditioned environment during hot weather. It must be remembered that some of the sites sampled were in countries without widespread residential air conditioning usage, or they were aiming their recommendations for non-air conditioned situations like schools (*Chicago Department of Public Health*), and desert resort areas that appeal to outdoor hikers (*Maricopa County Department of Emergency Management*). Only three sites give limited recommendation or specifically do not recommend air conditioning:

- *Los Angeles Health Department* limits its recommendation to using air conditioning only during the hottest time of the day, or if you become “overheated” (**44**).
- *The French Health Department* recommends air conditioning only in “certain circumstances” (not specified) (**21**).
- *Ontario Ministry of Heath* recommends using a fan rather than air conditioning to save electricity and to turn it off when leaving the room (**30**).

Those websites which neither advised home use of air conditioning, nor visiting air-conditioned (or cooler) places during hot weather were Canadian and British sites (*Vancouver Health Department, Ontario Ministry of Health and Long-term Care, and the Department of Health, U.K.*). Advice on what range of temperatures to keep indoor air is rarely addressed. Three sites list specific temperatures, while a few others caution not to set maximum temp too low.

- The *French Health Dept* and *Public Health Agency* based in Marseille recommend keeping air conditioning 5˚C less than ambient air during extreme heat (**21**) (*Direction generale de sante, France* provides a special report on air conditioning recommendations separately where they advocate keeping air conditioning 25 -26˚C in hot weather) (AFSSE, 2007).
- *NOAA* suggests keeping air conditioning at 25.5˚C to 26.6˚C when home and 29.4˚C when away (**26**).
- The *New York City Department of Health and Mental Hygiene* also endorses 25.5˚ C (**17**).

Most sites advise spending some time every day in a cooler place for persons who have no air conditioning at home (28 out of 44 sites). Some of these cooler environments include basements, churches, parks, beaches, pools, libraries, cinemas and shopping centers. Advice on how long to stay in these cooler environments is vague. Of the 28 sites urging people to spend time in a cool or air conditioned environment, only 17 sites make mention of how long to spend.

- 12 sites recommend several hours/a few hours a day.
- Six sites list "at least 2 hours per day"
- One site recommends "at least 2-3 hours a day"
- Two suggested "at least 3 hours a day".
- *NOAA* recommends that spending 15-20 minutes intervals in air conditioning can help (**26**).

There is no differentiation in advice between central and window air conditioning, even in those sections referring to buying and installing air conditioning (except the *Direction generale de sante, France*, which publishes air conditioning recommendations for institutions and residential buildings in a special report). Adverse effects of air conditioning use are rarely discussed. One site (*New York City Department of Health and Mental Hygiene*) caution users that rapid cooling after being outdoors in the heat can cause hypothermia in children or the elderly.

Several sites discourage the use of electric appliances during heat waves to minimize heat and reduce the chance of blackouts, but only the *Ontario Ministry of Health and Long-term Care* suggests to use a fan instead of air conditioning to conserve energy, while many other sites caution against using a fan to substitute for air conditioning when the temperature is high because it is a less efficient way to cool (**4, 5, 6, 7, 16, 22, 25, 27, 32, 37, 42**). Other air conditioning advice regards maintenance, installation and cleaning tips.

Evidence for health protection measures

Epidemiologic evidence for the protective effect of air conditioning on heat-related mortality.

The effect of air conditioning in lowering vulnerability to heat-related health effects has been assessed in epidemiologic analyses of deaths and illnesses during urban heat waves (Curriero F et al., 2002; O'Neill et al., 2005; Rogot E et al., 1992; Semenza et al., 1996; Chestnut et al., 1998; Naughton MP et al., 2002; Bouchama et al., 2007; Basu et al., 2002; Kilbourne, 1997; Kilbourne et al., 1982). Kilbourne's case-control analysis of risk factors for heatstroke in St. Louis and Kansas City, Mo found a strong inverse association between daily hours of home air conditioning and heatstroke, risk reduction for spending time in air-conditioned places and a protective effect for visiting air-conditioned places beyond that provided by home air-conditioning alone (Kilbourne et al., 1982). However, as inability to leave the house daily because of high levels of dependency is also a risk factor for heat-related mortality, inability to do so may obscure the protective benefit afforded by visiting a cool environment (Kilbourne et al., 1982; Semenza et al., 1996; Belmin, Auffray, Berbezier, Boirin, & Mercier, 2007; Davido et al., 2006). Similar results were found in a case-control study of the 1995 heat wave in Chicago (Semenza et al., 1996). Larger-scale analyses have found that a higher percentage of homes with air-conditioning was associated with small, but significant effects of hot temperature on mortality at the city level, even after adjusting for latitude (Curriero F et al., 2002). In two studies that looked at central versus room-unit air conditioners, only central units showed a consistent benefit (O'Neill et al., 2005; Rogot E et al., 1992): O'Neill examined heat-related mortality risk in four major U.S. cities over seven years and found that for each 10% increase in central air-conditioning prevalence, heat-associated mortality, pooled across all four cities, dropped by 1.4% (95% CI = -0.1 to 2.9). Rogot compared deaths in persons with and without air conditioning during hot as opposed to cool months by state across the US. He found that on hot versus cool months, persons with central air conditioning had an odds ratio for death of 0.73 (i.e., a benefit of 1.36), and that among people whose dwellings had one to three rooms, room-unit air conditioning units were significantly beneficial, showing an odds ratio of 0.41 (i.e., a benefit of 2.43) (Rogot E et al., 1992). Declining rates of heat-related mortality among the elderly in the United States have been attributed to increased use of air conditioning (Barnett AG, 2007; Davis RE, Knappenberger PC, Michaels PJ, & Novicoff WM, 2003; Donaldson GC, Keatinge WR, & Nayha S, 2003; Kalkstein LS, 1998).

Is there a risk of adverse effects due to a sudden temperature change when going in (and out) of air-conditioning?

Based on observation it may be assumed, even for the elderly and people vulnerable to heat stress, that sudden changes in temperature would be fairly well tolerated physiologically, especially if entering a cool environment from an unpleasantly warm one. In wintertime, people tolerate brief exposures to cold temperatures; i.e. indoor temperatures of 22˚C to outdoor temperatures of 0˚C or less with no serious consequences even if not adequately dressed for the cold. The subjective experience of thermal shock may be uncomfortable, but in certain cultures, extreme changes in temperature are even considered therapeutic (sweat lodges, Finnish saunas followed by ice-bathing, etc.). A literature review found that sauna bathing (and exiting a sauna to an environment often 60˚C cooler) did not appear to be particularly risky to patients with hypertension, coronary heart disease, and congestive heart failure (Kukkonen-Harjula K & Kauppinen K, 2006).

Australian physiologist de Dear looked into the correlation between subjective thermal sensations resulting from sudden ambient temperature changes and the physiological structures (mainly peripheral skin thermoreceptors) which give rise to subjective sensations of thermal discomfort (de Dear RJ, Ring JW, & Fanger PO, 1993). Experimental subjects reported their subjective thermal sensations when entering or exiting a "neutral" thermal chamber into a warmer or cooler environment. He found that, unlike changing to a warmer temperature, entering a cooler temperature from a warmer one produced an intense sensation of difference that tended to overshoot the steady-state response to the new temperature. This appears to result primarily from cold receptors being closer to the skin surface than warm receptors, but also that the higher sensitivity of cold receptors contributes to their stronger dynamic response. This "thermal shock" takes place before autonomic central nervous system responses, such as shivering or sweating, are activated. The immediacy of the subjective response indicates that cutaneous thermoreceptors must be triggered not just by absolute skin temperature, but also how quickly skin temperature changes. He concludes that that the more dynamic response to cold, in contrast to heat, is related to the human organism's dependence on behavioural, rather than physiological adaptation to cold (de Dear RJ et al., 1993).

<u>Going from neutral temperature to cool?</u>

Depending on the intensity of the colder environment, heat-conserving responses may be produced, such as shivering, slowing of the heart rate, increased vascular resistance, increased blood pressure, and shunting blood flow away from the skin (Keim SM, Guisto JA, & Sullivan JB, 2002).

<u>Going from neutral temperature to hot?</u>

Heat stress responses to hot environments include increased heart rate, decreased vascular resistance, lowering of blood pressure and increased blood flow to the skin. Sweating will take place when steady state conditions are met (Keim SM et al., 2002).

<u>Adverse health effects from going in and out of air conditioning?</u>

The *Agence française de sécurité sanitaire environmentale* in its special report on air conditioning advised that a large deviation (>7˚C) in temperature upon entering an air-conditioned environment can cause a thermal shock resulting in shivering, neck pains and torticollis (AFSSE, 2007). No references are cited to support this assertion. (This report was commissioned as a scientific paper, not as advice to the general public). We found scant evidence in the medical literature of any ill effect from the sudden cooling effect produced by entering an air conditioned environment. One experimental study documents an increase in sinus symptoms and inflammatory changes in nasal mucosa when subjects suffering from chronic allergic rhinitis were exposed to rapid air-conditioning temperature change even when controlling for the confounding effects of dryness, dust and allergens (Silviero-Graudenz S et al., 2006). We found no cases of hypothermia attributed to excess air conditioning during hot weather.

Is there a minimum time period or temperature range for air conditioning to minimize heat stress? Central versus window air conditioning: does uniform temperature throughout the residence have an impact?

Benefit as a function of degrees of cooling

No epidemiological study that examined risk-lowering effects of air conditioning recorded indoor temperatures as part of their studies, therefore no epidemiologic evidence allows us to target a minimum or maximum temperature threshold for home air conditioning.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) defines an acceptable range of temperature difference between air-conditioned interiors and ambient temperatures as 8 - 12˚C, not based on any heat-related health effects, but based on a measure called “predicted mean vote”, essentially a subjective survey which aims to minimise the percent of people dissatisfied with the temperature (Hukmani NS, 2004). Hukmani argues that the ASHRAE standard 55, used for office buildings to keep sedentary workers comfortable, mandates a narrow range of 21˚C -23.9˚C, which many people in hot climates may find unacceptably low and prohibitively costly for energy expenditure (Hukmani NS, 2004). Because air movement in air conditioned offices is kept to a minimum and “still air” feels warmer, temperatures are set lower. Hukmani suggests instead to base indoor temperature on the *Nichol equation* for thermal comfort (see Appendix), which takes long-range and mid-range acclimatization to outdoor temperature into account. Using this method, indoor temperature in Montreal in July should be 24.4˚C, whereas in Delhi, thermal comfort is found at a temperature of 29.1˚C (Hukmani NS, 2004)**.**

The public health recommendation of 25˚C **–** 26˚C (**17, 21, 26**) for home air conditioning (or 5˚ C lower than ambient temperature suggested by the *Direction générale de Santé*, France) during heat episodes was chosen empirically, but does seem a reasonable means to lower risk without using undue energy resources (Dixsaut G, 2005).

One experimental study comparing post-exercise cooling methods demonstrated the highest rate of lowering core temperature consisted of passive cooling at a temperature of 22˚C (Mitchell JB, Schiller ER, Miller JR, & Dugas JP, 2001a). It was found that compared with more active methods (fanning and misting), allowing skin temperature to remain at 32˚C promoted more rapid cooling of core temperature than techniques which lowered skin temperatures to as much as 24˚C, likely because it did not induce a vasoconstrictive reaction (Mitchell JB et al., 2001a).

Benefit as a function of hours of cooling per day – As for temperature recommendations, there is no scientific evidence to support the current recommendations of how long to remain in an air conditioned environment. Most sites suggest “a few hours”, roughly based on estimated time needed to restore core temperature to normal with a margin of safety. Several studies have found a protective effect of air conditioning in a dose-response fashion; Kilbourne et al. (1982) found spending increased time in air-conditioned places decreased heatstroke risk, with 24 hour-day AC use being the most protective (Kilbourne et al., 1982). Rogot et al. (1992) in a case-only study examined the protective effect of home air conditioning ownership on risk of death during a hot month versus a cold month using five-year retrospective summer mortality. They found that the effect of air conditioner ownership was the strongest for women, people who were not in the workforce, and older persons: in other words, people who were likely to spend more time at home (Rogot E et al., 1992).

Is merely sleeping with air conditioning on advisable?
Although we did not find any studies examining using air conditioning only for sleeping, or only in the bedroom, we were able to extrapolate from studies on central versus room air conditioning.

Many people place their room air conditioner in the bedroom when central air conditioning is absent. No studies have specifically examined the risk of heat-related health effects and night time air conditioner use, but lack of night time relief from heat has been blamed for the increase in deaths when heat episodes linger for several consecutive days (Kilbourne et al., 1982; Smoyer KE, Rainham DGC, & Hewko JN, 2000; Pengelly D et al., 2007; Ellis & Nelson, 1978). In urban areas, particularly, buildings and paved areas retain heat during the night and differences in minimum temperatures between urban and rural areas have registered as much as 9˚C (McGregor G, Pelling M, Wolf T, & Gosling S, 2007). In his analysis of heat-related mortality in the US, Rogot et al. found that, unlike central air conditioning, room air conditioning offered no risk reduction except in dwellings of 1 – 3 rooms (Rogot E et al., 1992). This would not support the conclusion that bedroom-only air conditioning was protective, except in the case of very small apartments.

Is there a loss of acclimatization if air conditioning is overused?

Repeated expose to hot environments results in the progressive adaptation of several physiological systems to the thermal stress. Among these are the circulatory, sweating, and body fluid control systems. When people are acclimated in the laboratory, they are put into the thermal chamber at very hot temperatures (40˚C – 45˚C), and are required to exercise strenuously. They start sweating early and keep sweating for long periods. This protocol is repeated daily for 10 days, with physiological changes of heat acclimatization generally apparent after the first three days. They normally start the study with very elevated rectal temperatures, low sweat rates, and fast heart rates, but are observed to have a reduction in all these heat strain parameters after 3 days, with further acclimatization over the remaining 10-day period (Mitchell D et al., 1976). Furthermore, water and salt are conserved by increasing anti-diuretic hormone and decreasing the level of salt secreted in sweat (Wyndham, 1973). It is thought that merely exposing a person to high temperature can produce similar protective adaptations to heat.

For the human body to acquire protective physiologic changes associated with heat acclimatization, exposure to heat is necessary. It has been speculated that becoming habituated to air-conditioned homes, workplaces and automobiles can endanger this physiologic acclimatization and perhaps even threaten behavioural adaptation as well (Ellis, 1972; Kovats RS et al., 2007). It has been observed that heat waves early in the summer season typically claim a heavier toll on mortality than those later in the season, both by claiming lives of the most vulnerable population and thereby shrinking the pool of susceptible people, as well as allowing the remaining population to acclimatize to heat and adopt adaptive behaviours (Green JS & Kalkstein LS, 1996; Hajat, Kovats RS, Atkinson RW, & Haines A, 2002; Paldy A, Bobvos VJ, & Vamos A, 2005; Kilbourne, 1997). No scientific papers have addressed the issue of deacclimatization by air conditioning use in relation to the elderly population who are most at risk for heat-related mortality.

Ellis cites recent reductions in indoor temperature limits (from 25.6˚C to 23.3˚C) on U.S. Navy ships as evidence that modern sailors acclimatized to air-conditioned decks had lost their long-term acclimatization to heat (Ellis, 1972). In his 1972 study of mortality from heat illness in the US, Ellis criticizes the design requirements of modern buildings which rely entirely on air conditioning and lack windows that open. He states that these structures are at the mercy of power supplies and could become death traps for some in the event of a power outage (Ellis, 1972). This became the case when 21 of 89 residents of a nursing home in Florida became hyperpyrexic and five died when the air-conditioning system was shut down for repairs (Sullivan-Bolyai JZ et al., 1979). Ellis reports significant mortality excess from the summer of 1970 in New York resulting from electrical power cuts during a heat wave (Ellis, 1972).

From an ecologic perspective, areas with greater air-conditioning penetrance (Southern US) demonstrate a reduced susceptibility to heat-related mortality and areas in the US in areas where both high temperatures and availability of air conditioning are less common, i.e., Northern and Midwestern States, have consistently shown a greater susceptibility to heat (Chestnut et al., 1998). Additionally, the trend towards a decreased vulnerability of the US population to heat-related death has paralleled a trend towards greater air-conditioning availability (Donaldson GC et al., 2003; Kalkstein LS, 1998). It has been speculated that long-term acclimatization and air conditioning expansion will not compensate for the pace of global warming and an estimated overall net increase in heat-related premature mortality can be expected by mid-century in New York City (Knowlton K et al., 2007).

Based on evidence, what is the benefit of air conditioning? For whom? How cool to keep interiors? How long to stay in air conditioning?

- *The recommendation that the vulnerable elderly use home air conditioning and visit air conditioned places during heat episodes is well supported by the evidence, however, the short-term impact on existing power structures and longer-term impacts on the surplus energy use contributing to global warming supports the argument to limit its unqualified use. To mitigate effects on power systems and contribution of greenhouse gasses to the environment, the possibility of supplementing air conditioning with apparatuses to augment air movement (ceiling or standing fans) and reduce the synergistic effect of humidity (dehumidifying units) should be explored by researchers and public health officials.*
- *The advice given by public health authorities to spend 2-3, or several, hours a day in an air-conditioned environment, and to set home air conditioning*

temperature to 25˚C – 26˚C seems rather modest in light of evidence that "more is better" in terms of hours spent in air conditioning, and demonstrates that experimental subjects (hardly comparable with our vulnerable population) tolerate post-exercise cooling temperatures of 22˚C without compensatory heat-retaining mechanisms (shivering, for example).

- *Based on the scientific evidence, recommendations for the use of air conditioning as part of a public health campaign to mitigate the effects of heat on vulnerable populations are unlikely to run the risk of causing hypothermia or torticollis (as cautioned by the* New York City Department of Health and Mental Hygiene *and the* Direction générale de Santé, France, *respectively). An indoor temperature below the recommended level of 5˚C less than outdoor temperature (**21**) also seems unlikely to endanger health. Current recommendations of keeping indoor air temperature no cooler than 25 - 26˚C may be inappropriate in climates where high temperatures are unusual, and perhaps using the Nichol's equation which adjusts for population acclimatization may be a better protective index.*
- *The suggestion of spending several hours a day in an air-conditioned environment (**2,5,7,12,18,21,24,26,27,31,32,40**) seems reasonable and practical for people who have no access to air conditioning at home, but indirect evidence suggests that more hours are more protective. Evidence to support sleeping in an air conditioned room comes from Kilbournes's analysis of the 1980 heat wave in St. Louis and Kansas City who observed a strong inverse relationship between daily hours of home air conditioning and heatstroke (Kilbourne et al., 1982), but Rogot found little benefit from single-room units except in very small apartments (Rogot E et al., 1992).*

<u>Nichol's equation for indoor thermal comfort</u>:

$$T = 17.0 + 0.38\, T_0$$

T_0 = the mean monthly maximum and minimum temperatures

<u>Website advice on electric fan use for preventive cooling</u>

Advice Given

In this section we examine heat protection messaging concerning the use of electric fans for cooling people and residences during extreme heat episodes. While the use of an electric fan is mentioned in the majority of sites sampled, fewer than one quarter support their use as a way of preventing heat-related illness. Most agencies advise that fan use is not effective at cooling people when temperature and humidity levels are high, and several sites warn that their use can accelerate heat-related illness due to thermal stress or dehydration.

Most sites recommend that people should spend time in an air-conditioned environment for optimal heat relief, and caution that fans do not cool the air and should not be used to substitute for time spent in an air conditioned space. Many agencies favour techniques for increasing air circulation in the home, however, nearly all of these propose the use of natural ventilation (keeping windows and doors open to circulate air) ignoring the use of fans. Artificial air currents generated by a fan are generally discouraged except when used for convective cooling, that is, moving cooler outdoor air into the home or venting warm air out.

Five of the websites (**4, 6, 12, 25, 42**) warn against using a fan in a closed room without windows and doors open to the outside[1]. Only the Toronto Public Health Department website offers an explanation, "When fans are used in rooms where the temperature is hot and the windows are closed, they tend to cause people to feel the effects of heat sooner. This happens because the hot air is being moved by the fan over your body causes your body to fight against the heat by sweating more". The Environmental Protection Agency states in its more detailed *Excessive Heat Events Guidebook* that, "When *heat index* temperature is over 37.2˚ C, fan use increases heat stress by blowing air warmer than skin temperature over the body and causing increased sweat evaporation and speeding the onset of heat exhaustion". Other sites (**6, 7, 16, 37, 40, 42**) also claim that as ambient temperature nears skin temperature (reported threshold temperatures vary from 30˚C to over 37.2˚ C) fans are not effective for preventing heat-related illness.

There appear to be inherent inconsistencies in recommendations that fans are useful for augmenting evaporative cooling of the body while at the same time countering that the evaporative process itself leads to dehydration and increased thermal stress. As compared to North American sites, evaporation as a cooling strategy was treated quite differently in several of the European websites (**31, 34**), which advised people to dampen or spray their skin with a mister and use a fan to provide evaporative heat relief.

The conditions under which evaporation of sweat helps to cool the body or harms people by causing dehydration is unclear, but the *Ottawa* and *Toronto Health Departments* feature a "Fan Facts" guideline taken from the *EPA's Excessive Heat Events Guidebook* which lists 35˚ C as the temperature at which fan use becomes ineffective or even harmful. Elsewhere in the *EPA* guidebook, 32.2˚ C is listed as a cut-off temperature at which it is not advisable to use a fan. Various levels of humidity (35%, 60%, and 80%) were given by different agencies as thresholds above which evaporation of perspiration ceases and dissipation of heat is no longer possible.

One municipal health authority in Ohio (**43**) cautions that using a fan causes sweat to evaporate too quickly and accelerates dehydration. The same site advises that older people and children may be at higher risk of overheating because they sweat less, while provincial health authorities in Ontario warn that men are more vulnerable because thy sweat more and thus, are more prone to dehydration.

We found the advice given on how and when to use electric fans during heat episodes to be highly inconsistent. Much of this advice contains caveats for fan use which are contradictory between websites, and sometimes inconsistent within the same agency. The physiological basis for either recommending or discouraging the use of a portable electric fan for prevention of heat illness or personal comfort points to both the benefit of augmenting evaporative cooling and an assumption that evaporation of sweat causes harmful levels of dehydration. Sometimes both propositions were cited by the same agency (**6**).

In addition, several municipalities distribute fans to at risk populations during heat waves despite a lack of epidemiological evidence to support their role in prevention of heat-related mortality. We set out to examine evidence as related in the medical literature to assess advice on fan use as produced by public health agencies.

Evidence for health protection measures

<u>Physiology of thermoregulation (Colon JA, Montanez RG, & Santiago HP, 2004)</u>

Humans must maintain an internal temperature in a narrow range around 37˚ C, independent from ambient temperature fluctuation. This is accomplished by controlling heat gain or loss through thermoregulatory functions. Variations of as little as 10% can result in life-threatening illness.
Methods of heat loss or gain - * *highlights those modified by use of a fan*

- *Convection - heat is exchanged through air and fluid movement and is a function of density, speed and temperature of air or fluid.
- *Evaporation - a form of heat dissipation in which water is transformed to vapour, and is a function of partial vapour pressure, skin temperature, and ambient temperature.
- Conduction - heat is exchanged through contact between bodies (that is without air or fluid as an intermediary) and is a function of conductivity, surface contact and temperature difference.
- Radiation - a form of heat exchange related to emission and reception of electromagnetic waves and temperature difference between bodies.
- Metabolism – produces heat is gain only through chemical reactions related to biological functions and muscular activity.

Under normal conditions at 21° C, at rest, body heat is lost to the air by convection, through evaporation, by conduction, and by radiation. When ambient temperature is increased, evaporation becomes the major route of heat loss. At 10°C only about 20% of the heat loss is due to evaporation, but at 30°C, it becomes about 80% (Mitchell D et al., 1976). In elderly people who may have diminished sweat responses, the proportion of evaporative cooling may also be reduced (Robinson et al., 1965).

<u>Physiologic adaptations to excess heat due to ambient temperature or increased muscle activity</u>.

- Increased heart rate and blood volume allows blood flow to the periphery to increase by as much as a factor of 10.
- Increased skin blood flow is facilitated by peripheral vasodilatation. The newly cooled blood returns to cool the core.

- Sweating is dependent on increased dermal circulation and vasodilatation. Up to 15 litres a day can be lost through perspiration in an active adult. Evaporative cooling carries away 2.4 kJ (0.58 kCal) of thermal energy for each 1g of water evaporated, the equivalent of 1.26˚degrees Celsius (Colon JA et al., 2004).
- It is believed that older people can affect some of these same adaptations to heat (see acclimatization of the elderly section).

The mechanics of a portable electric fan typically used in residences (specifications come from *bizrate online product locator*)

- Portable electric fans displace approximately 600 to 2400 cubic feet per minute (CFM). A typical box fan displaces air at 1500 to 2200 CFM.
- Ceiling fans circulate air by blowing warm air downward in hot weather, which allows cooler air to be drawn upward around the periphery of a room, and in cool weather they push cool air upward toward the ceiling, forcing warm air down away from the fan. They typically move air at 1250 to 5000 CFM.
- Some fans used for residential outdoor areas and industrial cooling use a mister or water spray in conjunction with air flow. They may deliver up to 40,000 BTUs of cooling power, in contrast to fans which merely circulate air and have no innate capacity to reduce temperature.
- "Swamp coolers" use a fan to circulate air through material (cedar chips or cellulose) saturated with cool water or ice and can actually cool a room by as much as 11˚ C. They rely on evaporation, so they are best used in dry environments (< 50% humidity).

How is heat gained or lost as mediated by air movement (as proxy for fan use) in hot ambient temperatures?

<u>Convective cooling</u>
When a fan is used to draw air into a warm interior environment from a cooler exterior environment (at night and early morning), or to exhaust hot air out of an interior (attic fans, or to vent warm air given off by appliances), fans can be effective methods for cooling a home.
<u>Convection depends on:</u>

- Temperature gradient - having an available source of cooler air either to be drawn in or to replace the air that is expelled.
- Speed of air movement - This relates to the speed and efficiency with which warm air is replaced by cooler air brought in from outside.

<u>How does air current affect apparent temperature:</u>

- Work by Steadman in the 1970's demonstrated a lowering of *apparent temperatures* by a strong wind (>2800 feet/min) compared to a light base wind (of <500 feet/min) at all levels of relative humidity (an effect that was greater with increasing humidity) up to a dry bulb temperature of 35˚C. At higher temperatures, wind increased apparent temperatures in dry conditions (Steadman RG, 1979a).

How do air currents affect evaporation of perspiration:

A 1998 report by the American Medical Association Council on Scientific Affairs declares that electric fans are not effective at reducing the risk of heat illness because the moving air currents must be cooler than body temperature in order to be helpful (Blum LN, Bresolin LB, & Williams MA, 1998). This follows a statement in the same report that claims that "as environmental temperature reaches or passes body temperature, the body becomes reliant on perspiration to dissipate heat …(which) is less effective when there is no air movement to carry saturated air away from the skin" (Blum LN et al., 1998).

A CDC analysis of heat-related deaths reports that "Although the use of fans may increase comfort at temperatures < 90F˚, they are not protective against heatstroke when temperatures reach ≥ 90F˚and humidity is >35%" (1995; Centers for Disease Control, 1995). Two articles are cited as references (Kilbourne et al., 1982; Lee DHK, 1980) which do not specify these criteria. The first, a case-control study of the 1980 heat wave found no significant inverse association between the use of electric fans and heatstroke. No relation to temperature or humidity was examined. The second paper discussed the historical development of various heat indices used for measuring heat stress. The author states that the *effective temperature* scale measurements originally indicated an augmentation of heat load with the addition of air movement when temperatures are over 100˚F, which was later refined by other researchers (Woodcock AH, Pratt RI, & Breckenridge JR, 1952).

According to Steadman, perspiration is triggered primarily by *apparent temperatures*, regardless of actual temperature. At low humidities, when the apparent temperature is *below* ambient and the skin is relatively dry, appreciable heat is transferred into the body when the air temperature exceeds skin temperature. Because wind increases this heat flow, a hot, dry wind raises body temperature. With increased humidity at the *same* ambient temperature, the increase in *apparent temperature* triggers active perspiration and evaporative heat transfer acts to cool the body (Steadman RG, 1979b).

Evaporation rate depends on:

- Water vapour pressure gradient
  Steadman claims that since the body's vapour pressure, unlike its temperature, always exceeds that of the surroundings, the sweating person derives an evaporative cooling effect as wind speed increases, even at high humidities (Steadman RG, 1979a). A simple experiment confirms this. Exhaled human breath is considered to be saturated (100% relative humidity). Breathing out in a tight stream across your hand feels cool – event though the temperature of your respired breath is 37˚C and your skin temperature is very likely to be cooler. This is due to the evaporative cooling effect on normal skin perspiration.
- Air movement (heat transfer coefficient) – as less saturated air replaces sweat saturated air at the skin surface, evaporation of sweat increases.
- Ambient temperature – warmer air has greater saturation capacity.
- Clothing – can impede evaporation by blocking air currents.

Experimental evidence

A paucity of experimental evidence exists where portable electric fans are used as an intervention arm in the study of heat stress in laboratory subjects. Most studies were done in the period between 1960 and 1980, more efficient and powerful fans may be in use today. Experiments assessing the cooling properties of fans have been almost entirely done for occupational, athletic, military and agricultural animal housing needs. Experimental subjects are predominantly young, fit men, and outcomes measured are usually associated with athletic performance in humans, or milk production in cows. No studies were found that compared fan use to other methodologies among the vulnerable populations at risk for heat-related illness during heat waves.

A 2001 study by Mitchell compared four post-exercise cooling techniques after subjecting participants to high-intensity aerobic exercise that raised core temperature to 38.5˚C. He found that the addition of using a fan with exposure to a cool (22˚C) environment (with and without a water spray) did not reduce core cooling time compared with passive exposure to a cool environment alone. He hypothesized that the more dynamic cooling methods rapidly lowered skin temperatures (24˚C for misting and fanning, 28˚C for fanning and 32˚C for exposure to a cooler environment alone), and that the lower skin temperature induced peripheral vasoconstriction which kept more of the warm blood at the core (Mitchell JB, Schiller ER, Miller JR, & Dugas JP, 2001b). This stands in contrast to 1987 Japanese study which found that localized facial fanning under conditions of hyperthermia significantly decreased skin temperature, tympanic temperature, heart rate during exercise, perceived exertion and it markedly improved performance during exercise compared with the no-fanning group (Hirata K, Nagasaka T, Nunomura T, Hirai A, & Hirashita, 1987).

Epidemiologic evidence

The few case-control studies of death related to heat exposure and failed to show a significant inverse association between the use of electric fans and heatstroke. Three American studies found no statistically significant protective odds ratio for “having a working fan” in case-control analyses of heat-related mortality in Chicago and Cincinnati (Kaiser et al., 2001; Kilbourne, Choi, Jones, & Thacker, 1982; Naughton MP et al., 2002; Semenza et al., 1996), whereas data from a meta-analysis of six case-control studies by Bouchama found a trend (OR 0.60; 95% CI 0.4 – 1.1) towards lowering risk (Bouchama et al., 2007).

Discussion

- *The assessment of evidence to support or discourage the use of electric fans under conditions of extreme heat highlights the many knowledge gaps in this field. Most physiologic studies support the use of air currents for cooling, but do not specifically address the issue of household fans. It appears that many studies were carried out during the 1950s and 60s largely to serve the needs* *of industry, and later expanded to suit the needs of athletic departments and the military training in warm climates. This does not accurately reflect the context of at-risk elderly for heat-related illness prevention programs.*

- *Certainly there is little to recommend the use of a fan when other, more effective methods, such as air conditioning or cool showers, are available. Clearly, circulating warm indoor air without the taking advantage of cooler breezes from outside should be discouraged. Alternatively, giving people the message that fan use is of no benefit may expose vulnerable people to hot, stagnant indoor spaces if they lack other cooling methods, and this may produce more harm than good. In places where with central air conditioning, a fan may have the potential to enhance the effects of a weak system or an area that is poorly ventilated.*

- *In addition, recommendations to discontinue fan use when outdoor temperatures are over 32.2˚C (or 90˚F) may be harmful given that outdoor temperatures may not accurately reflect indoor temperatures which may in fact be within the range of a fan’s effectiveness.*

- *The benefits of air movement affecting people exercising in a hot environment do emerge from the few such investigations in occupational, athletic, and military settings, but studies using vulnerable elderly have not been found, and it is unclear whether the results of studies on young, fit men can be extrapolated to this population. Laboratory conditions typically expose these fit, young subjects to short bursts of intense activity while physiologic responses are measured. In heat wave conditions in the community, the effect of prolonged heat over days will take a toll not only on acute heat responses, but will have an effect on underlying medical conditions, sleep and nutritional status, which may already be compromised in the elderly, infirmed or disabled.*

- *Adding to the confusion are conflicting messages given to the public regarding the relationship between comfort and protection from heat-related illness. Some health authorities caution that air currents from a fan may seem to lessen discomfort, but are actually harmful. This message does not appear to be supported by evidence. Other messages appear at variance with our understanding of physiology that the evaporation of sweat, such as in claims by the Toronto Health Department that increasing air movement results in increased sweating, speeding dehydration and heat illness. The evaporation of water at the skin surface is a heat-requiring endothermic reaction, and, up to a point, would result in a drop in skin temperature even if the surrounding air were hotter. It would seem that the overall heat loss or gain is dependent on a complex interaction of ambient temperature, humidity and wind speed balancing evaporative heat loss with heat gain via convection of warmer air currents.*

- *Optimal fan types, placement, and use are addressed in a small minority of websites and only in the most rudimentary fashion. Ceiling fans are commonly found throughout residences in the Southern US, but their use is addressed by only one of the sites we investigated to substitute for or assist the use of air conditioning, without advising people to direct airflow downward. While many sites cautioned that evaporative cooling was less effective in humid conditions, the usefulness of dehumidifiers was never addressed.*

- *In light of the climate changes now taking place and the recent massive electric failures that have occurred during periods of excessive heat putting unprecedented strain on the power grids of North America, it is perhaps prudent to put resources into clarifying issues surrounding the usefulness of electric fans, which use far less electricity than air conditioners. Artificially generated air currents have been used for many decades in the settings of outdoor industrial and athletic functions, as well as in animal husbandry with technological innovations that may not have existed when many of the physiologic studies on heat stress were performed. Green housing designs could make use of natural and artificial ventilation to replace or minimise the use of air conditioning, and electric dehumidifying units can lower apparent temperature, allowing for higher tolerable indoor temperatures. Scientific knowledge of the limits and constructive uses of electric fans for heat illness prevention needs to be explored using vulnerable populations.*

1. This idea is a well-known part of the culture in Korea, where there is a popular notion that being in an enclosed room overnight with a running fan is responsible for a phenomenon known as "fan death" (Surridge G, 2004).

Medication risk

What special risks does excess heat present to people taking medication?

Physiologic responses to heat exposure involve changes in the fluid volume and blood flow distribution of the body (Vanakoski J & Seppala T, 1998). These thermoregulatory mechanisms occur as an adaptive response to heat stress and may be impaired by the intake of certain medications. Both prescription and over-the-counter medications can affect hydration status, electrolyte balance, hemodynamics, thermoregulatory set-point, or the level of alertness (Albert, Proulx, & Richard, 2006). Some of these drugs can interfere with sweating as well. Heat exposure can, in turn, affect drug absorption and pharmacokinetics (Vanakoski J et al., 1998).

For our discussion, we have grouped medications of interest into three main categories. While the list of potentially dangerous medications identified by epidemiologic observations, physiologic mechanisms and experimental studies is quite lengthy, drugs affecting the cholinergic system (anti-cholinergics), anti-psychotic drugs (neuroleptics) and diuretics (which reduce build-up of excess fluids) have come under particular scrutiny because of associations with both heat stroke and heat-related mortality.

Advice given

Twenty five of the 44 sites we surveyed identify medical illness and other conditions (pregnancy, obesity, malnutrition, sleep deprivation or fever) as increasing the risk of heat illness. Twenty eight out of 44 websites mentioned medication use independently as a risk factor for heat-related illness. Of these, 24 specify certain drugs, or classes of drugs which may put one at risk. While diuretics (especially "loop" diuretics) are mentioned the most often as a potentially hazardous class of drug during high temperatures (**1, 2, 10, 12, 32, 33, 37, 38, 42**), only the American Heart Association website cautions people taking diuretics to monitor their body fluid level by weighing themselves at the same time every day, and to increase their fluid intake if they weigh two pounds less. Two sites recommend that patients review their medications (**10, 32**), however, there are no instructions given to those whose medications are on the danger list other than to consult their physician or pharmacist. A few sites provide extensive lists of medications that increase heat-related illness (**3**, **4, 12, 28**, **33**), with as many as 124 named drugs (**28**). Some sites list drugs by medical function (anti-hypertensives, anti-depressants, etc.), others classify their action in regards to heat risk (those that inhibit sweating, that promote dehydration, etc.). Curiously, no French websites provided lists of medications that put people at risk, although Switzerland, Belgium, the United Kingdom, Spain, Italy, and many U.S. and Canadian sites provided such lists. The use of recreational drugs (such as cocaine and Ecstasy) and alcohol were mentioned frequently (11 sites), but only the Belgian public health website cautioned that withdrawal from alcohol during hot weather can also be risky.

To what extent is chronic illness/ debilitation a risk factor for heat-related illness and death in general (independent of medications)?

<u>In what way does chronic illness impede heat responses/ acclimatization?</u>
Analyses of risk factors indicate that advanced age and infirmity, particularly heart disease, neurological disease, chronic respiratory disease and mental illness put people at greater risk for heat-related illness (Basu et al., 2002; Kovats RS et al., 2007; Bark, 1998). Because physiological heat adaptation is highly dependent on changes to the circulatory and nervous systems, disorders of these systems can impede heat response. Few experimental studies have looked at heat acclimatization in this population, but studies using older, healthy subjects suggest that heat acclimatization is minimized only to a minor degree by age-related changes. Limitations to heart contractility and rate can compromise vascular redistribution necessary for heat dissipation.

<u>To what extent does loss of mobility/ autonomy contribute to risk?</u>
Bouchama has found in a meta-analysis of heat-related mortality risk factors (Bouchama et al., 2007), that being confined to bed and being unable to care for oneself were associated with the highest risk of death during a heat wave. This is consistent with the

findings of Vandentorren et al. (Vandentorren et al., 2006), who analyzed deaths during the 2003 European heat wave and found that lack of mobility was strongly associated with death. This may simply be a marker for severity of chronic illness or advanced age, but it may also limit one's ability to access hydration, heat adaptive behaviours, or to get help.

Does sleep deprivation due to elevated night time temperature aggravate illness?

High night time temperatures, which may disturb sleep, were associated with elevated mortality in several studies (Ellis FP, 1978; Pengelly D et al., 2007; Smoyer KE et al., 2000). In studies of exertional heat illness among military personnel, sleep deprivation has been identified as an independent risk factor in healthy, young recruits (Carter R et al., 2005), however, information on sleeping habits has never been evaluated in case studies of heat-related mortality victims. It appears plausible that people suffering from chronic illness may have their condition aggravated by sleep deprivation.

Many epidemiologic studies show some effect of mortality displacement (medication use is associated with most vulnerable groups)

Mortality displacement (or "harvesting") refers to the phenomenon whereby people who die as the result of a stressful event or illness would have died soon afterward had no such event occurred. Patterns of mortality displacement for heat-related deaths depend on the population at risk (Hajat, Armstrong, Gouveia N, & Wilkinson P, 2005) as well as the follow-up period assessed. Heat-related deaths tend to occur in the frail, elderly population, and among people who take medication for chronic illnesses (Bouchama et al., 2006; Kilbourne et al., 1982; Kovats RS et al., 2007). For this reason, it is often difficult to separate the medication risk from the other risk factors that may cause heat vulnerability.

How might dysfunction of different body systems impair heat response?

Cardiovascular disease – the physiological responses to heat depend heavily on a well-functioning cardiovascular system. A large part of the blood volume is translocated to the periphery by means of peripheral vasodilation, heart rate is increased, as is cardiac output. Blood volume expands as a result of greater secretion of antidiuretic hormone (ADH), and there is an increase in total body water. Heart disease may limit cardiac contractility, making it impossible to increase cardiac output. Increased cardiac demands for oxygen due to increased heart rate may put a strain on narrowed coronary arteries, and increased blood viscosity secondary to dehydration raise the danger of clotting, especially in those with pre-existing risk factors for a stroke or heart attack.

Pulmonary disease – during episodes of high environmental heat, there is an increase in minute ventilation to meet increased oxygen demands of heart. Elevated levels of respiratory irritants found in air pollution (ozone and particulate matter) often accompany hot weather, further affecting disease.

Renal disease – several mechanisms of heat response are affected by the renal system. In response to lowered renal blood flow, the renin-angiotensin system is activated, which constricts renal efferent tubules to preserve glomerular blood pressure and maintain glomerular filtration. ADH secretion is triggered, which acts on the kidney to inhibit sodium excretion in order to replace salt lost in sweat and meet the needs of increased total body water. If renal disease inhibits the smooth operation of these responses, there is a risk of dehydration, as well as hyponatremia from inability to retain salt. Reduced renal blood flow as a result of dehydration can decrease the clearance of toxins and medications, and lead to highly concentrated urine which may lead to the formation of kidney stones.

Neurologic disease – thermoregulatory responses to heat are highly dependent on autonomic changes from central nervous system inputs (vasodilation, increased heart rate, sweating etc). Autonomic dysfunction due to diabetes or other diseases affecting autonomic regulation may impair heat response. Heat has been known to aggravate multiple sclerosis, and cerebrovascular events increase from increased viscosity.

Psychiatric disease – has been identified as far back as the 1950s as a risk factor for both direct (heat stroke) and indirect heat-related illness (cardiac and respiratory disease) (Bark, 1982). Due to the effect of severe mental illnesses (such as psychosis) on judgement, patients often fail to recognize the danger and take heat-protective actions. Living with mental illness may also predispose to low socio-economic status, independently associated with heat illness risk (Stafoggia et al., 2006). The disease or its treatment may lead to being overweight (side effect of medication and/or lifestyle), again increasing risk of heat illness. Increased metabolic heat production as a result of agitation has also been cited as a danger (Bark, 1998).

Epidemiologic evidence supports the hypothesis that psychiatric patients had twice the risk of dying during a heat wave even before the introduction of neuroleptic medication (Bark, 1998). Bark claims that psychiatric patients in New York state hospitals were at highest risk of death during the 1970s, when antipsychotic medication was used in high dosages, and the risk sharply declined in the 1980s, when preventative measures were put in place (lower dosages, air conditioning in psychiatric hospitals) (Bark, 1998). Unlike the demographic profile of the heat-vulnerable sector in the general population, psychiatric heat victims are more likely to be female (higher among younger female patients), and patients over age 60 were not at significantly greater risk. Caroff (Caroff, Mann, & Campbell, 2000) has observed that there is a continuing risk of fatal heatstroke after discharge from a psychiatric facility, which he attributes to reinstitution of antipsychotic medication which patients may not have been taking before hospitalization, as well as de-conditioning and loss of heat acclimatization from a long confinement. He adds that patients recently discharged may resume illicit drug or alcohol abuse, or suddenly become more physically active with their disease under control.

Malignant hyperthermia (MH), an often fatal condition associated with the use of certain medications (neuroleptic drugs, general anaesthesia, succinylcholine) manifests as a hypermetabolic condition causing muscle rigidity, muscle breakdown (rhabdomyolysis) and rapid elevated of temperature (Capacchione JF, 2007). It is felt to be caused by a defect in a gene responsible for calcium regulation in muscle cells, allowing the cells to become flooded with calcium when exposed to certain medications, which then destroys the energy metabolizing mechanism of the cell (mitochondria). Researchers have noted that although it is a rare condition, occasionally people who have survived have later gone on to develop exertional heat stroke (Muldoon, Deuster, Brandom, & Bunger, 2004). Further, people taking neuroleptic drugs during heat waves have been found to have a dramatically elevated risk of heat-related illness (Kwok & Chan, 2005; Kao & Kelly, 2007). No epidemiologic studies to verify an association are available because both events are vanishingly rare.

Diabetes – diabetics are at particular risk in heat waves for several reasons. They are more likely to have cardiac, renal or neurological dysfunctions (mentioned above), as well as difficulty concentrating urine if their glucose level is not well controlled. This can lead to a state of chronic dehydration, and acute illness or heat stress can precipitate a severe dehydration leading to ketoacidosis or hyperosmolar hyperglycaemic coma.

To what extent can medications hinder the adaptive physiologic response to heat?

Documentation of the effects of heat exposure on the pharmacokinetics of drugs in humans is very limited (Vanakoski J et al., 1998). It remains unclear to what extent heat-related mortality is due to medication usage and not to the underlying disease being treated. We can hypothesize that there may be elevated risks associated with the actions of certain medications which may interfere with adaptive heat responses, and epidemiologic studies have identified others as posing risks. The few heat-related experimental studies on absorption, metabolism and elimination of drugs has generally taken place under short, intense heat exposures (sometimes in saunas), conditions which do not replicate those of an urban heat wave (Kukkonen-Harjula K et al., 2006; Vanakoski J et al., 1998). Here we will discuss how certain medications can potentially add to the heat burden, and what medications have been linked to excess mortality during hot days.

<u>Mode of action for risk increase</u>

- Causes dehydration (diuretics, ACE inhibitors) which may also reduce visceral blood flow to the liver and kidneys, reducing clearance of drugs and toxins. Moderate to severe dehydration poses a risk of hypovolemia and orthostatic hypotension, causing falls and increasing hear rate.
- Decrease heart rate or contractility (anti-anginal drugs, beta-blockers).
- Disrupt electrolyte balance (any drug that antagonizes water retention, has a laxative effect, or that causes vomiting or diarrhoea, such as colchicine, lactulose, or morphine) can lead to electrolyte disturbances by shifting fluid balance.
- Reduces sweating by decreasing autonomic input to parasympathetic system – this effect may be magnified in psychiatric patients taking antipsychotic medications where there is a risk of medication-induced movement disorders. These patients are often given anti-Parkinson's medications to combat side effects which may act synergistically with anti-psychotics (anticholinergics, tricyclics).
- Interferes with thermoregulation (dopamine antagonists elevate set point of hypothalamus, neuroleptics, serotonin agonists)
- Vasoconstriction – peripheral blood flow reduction leads to modification in sweat gland activity (sympathetomimetics, antihistamines, particularly H1 antagonists – even over the-counter).
- Increase metabolic heat production (sympathetomimetics, thyroxine)

- Reduce alertness/ judgement/ perception of heat (sedatives, painkillers, drugs of abuse)
- Reduces renal function (NSAID's, ACE, ARB, sulphonamides, indinivir) (NSAID's, aspirin and acetaminophen contraindicated for heat stroke treatment)
- Drugs whose concentration can increase as a result of dehydration (lithium, digoxin)

Particular high-risk drugs

Diuretics

Diuretics relieve pulmonary congestion and peripheral oedema by decreasing plasma volume and subsequently decrease venous return to the heart (preload) (Mycek, Harvey, & Champe, 2000). Usually prescribed for people with congestive heart failure or hypertension, they decrease cardiac workload and oxygen demand and help to decrease blood pressure (Mycek et al., 2000). ACE inhibitors, by reducing the amount of circulating angiotensin II levels, decrease the secretion of aldosterone, resulting in decreased sodium and water retention (Mycek et al., 2000). Some diuretics increase the excretion of sodium (particularly furosemide), promoting a state of dehydration, and replenishment by drinking plain water can lead to hyponatremia, a potentially life-threatening complication. ACE Inhibitors can increase the concentration of potassium, and in a volume-depleted state, this can cause a dangerously high level potentially causing fatal arrhythmias.

Anticholinergics

In humans, the cutaneous circulation plays a major role in maintaining thermoregulatory stability. During periods of heat exposure, increases in body temperature are minimized by increases in skin blood flow and sweating. Skin blood flow responses to heat are mediated by increased activity of cutaneous cholinergic sympathetic nerves that innervate sweat glands and blood vessels. Whether the same cholinergic nerves are common to blood vessels and sweat glands is not settled. This system of nerves, sweat glands, and blood vessels is collectively known as the cutaneous active vasodilator system (Kellogg et al., 2007). Medications that antagonize this system reduce sweating and impair thermoregulation. Some drugs, such as antihistamines, have been grouped under this category because of their vasoactive effects. In this class of drugs, H1 blockers have been shown to significantly impede peripheral vasodilation as a response to heat (Vanakoski J et al., 1998).

Neuroleptics

Neuroleptics are a wide category of drugs with antipsychotic effects mainly attributed to dopamine blockade. The phenothiazine class of neuroleptics has been most implicated in heat related illness. Phenothiazines also have combined anticholinergic and central thermoregulatory effects. They inhibit afferent neuronal input to the hypothalamus, which decreases the hypothalamus' normal compensatory effect of increasing cutaneous blood flow to aid in heat dissipation) (Kao et al., 2007).

To what extent does heat modify the absorption, distribution, activity and clearance of medications?

Route of administration
Subcutaneous and transdermal routes have increased absorption when skin blood flow is increased, warm, and damp with sweat. This may have consequences for angina patients who use a nitroglycerin patch. Studies show that heat-related increased concentration in nitroglycerin resulted in a drop in arterial pressure, increasing heart rate (Vanakoski J et al., 1998). Diabetics on subcutaneous insulin likewise may have increased absorption, leading to a hypoglycaemic state (Koivisto, 1980). No significant heat-related effect is seen with gastrointestinal or intravenous absorption (Vanakoski J et al., 1998).

Distribution
In the limited studies examining how heat exposure affects the distribution of certain drugs, little consistency of results were observed. Variations were thought to be due to the fluid shifts resulting from the state of relative dehydration (Vanakoski J et al., 1998).

Elimination
Drug clearance is slowed by heat exposure in both hepatically and renally excreted drugs due to reduction in renal and hepatic circulations (Vanakoski J et al., 1998).

Epidemiologic evidence for certain medications as risk factors for heat mortality

Medications implicated in heat-related deaths in epidemiologic studies – In assessments of demographic, regional, and behavioural risk factors for heat-related mortality, few studies have looked specifically at medication usage. Even in studies where specific illnesses were identified (schizophrenia, depression, cardiovascular disease, diabetes), no mention of medication taken were recorded (Curriero F et al., 2002; Kilbourne, 1997; Mirabelli & Richardson, 2005; Naughton MP et al., 2002; Schuman, 1972; Stafoggia et al., 2006), likely because this information is not readily available from death certificates. In one of the few available epidemiologic case-control studies of hot day deaths related to medications use, the Insitut de Veille Sanitaire examined risk factors among elderly dying at home during the 2003 French heat wave (Ledrans, 2003). Investigators found that taking diuretic medication gave a non-significant odds ratio for heat-related mortality of 1.33 ($p < 0.41$), anti-depressant medication had the highest risk (OR = 3.98, $p < 0.07$), and anti-Parkinson medications had an OR of 3.08 ($p< 0.33$). Odds ratio for neuroleptics was not calculated due to small sample size. Bouchama looked at psychotropic medication use in a meta-analysis heat-related mortality covering four studies (Bouchama et al., 2007), and estimated an odds ratio of 1.9; no individual study showed statistical significance. Kilbourne's case-control study of heat stroke victims in St. Louis and Kansas City, Missouri found that taking major tranquilizers (antipsychotics) and anticholinergics was a risk factor for heatstroke death (Kilbourne et al., 1982).

Few studies look at medication compliance issues – Michenot et al. (Michenot F, Sommet A, Bagheri H, Lapeyre-Mestre M, & Montastruc JL, 2006) evaluated adverse drug reactions (ADR) in elderly patients among hospitalized patients during the 2003 European heat wave (as reported to the French Pharmaco Vigilance Database) and found that, compared to a summer without a heat wave, "serious" ADR's were similar, but fatal reactions in 2003 were four times higher. Diuretic medications were the most commonly associated with ADR's, followed by angiotensin converting enzyme inhibitors, antidepressants, proton pump inhibitors, digoxin, benzodiazepines, oral hypoglycemics and angiotensin receptor blockers (ARBs). The most common reactions were mainly metabolic (dehydration, electrolyte disturbances) and general (confusion, disorientation) (Michenot F et al., 2006). Bark conducted an analysis of deaths during heat waves in New York State between 1950 and 1984 (Bark, 1998), comparing the death rates of hospitalized psychiatric patients and those of the general public. He found that hospitalized psychiatric patents had twice the risk of dying during a heat wave as the general population, including the period before the introduction of anti-psychotic medication. In a 1999 Cincinnati heat wave (Kaiser et al., 2001), toxicology screening was performed on a small proportion of 17 fatal heat stroke cases (47.1 % of which had mental illness), and researchers found that in all cases where patients had prescriptions for psychotropic medication, both quantitative and qualitative tests for drugs were negative.

Sauna and medication studies

Anecdotal reports of medication use among regular users of sweat lodges and sauna baths fail to turn up any particular dangers (Berger LR & Rounds JE, 1998; Kukkonen-Harjula K et al., 2006; Tavakoli & Yates, 2003). Traditional saunas expose bathers to temperatures of 80 – 90˚ C and between 15 – 30% relative humidity, with sweat lodge conditions considerably more variable. Bathers in saunas typically repeat cycles of exposure to heat and cold, with five to 20 minutes spent in the hot sauna, followed by a cool shower. Kukkonen-Harjula (Kukkonen-Harjula K et al., 2006) examined scientific literature concerning both therapeutic uses and contra-indications to sauna bathing. She concludes that "people with cardiovascular disorders in a stable state with medication may safely take their sauna baths". Fewer patients with recent myocardial infarctions displayed cardiac dysrhythmias during bathing, compared to during submaximal exercise (Kukkonen-Harjula K et al., 2006). Tavakoli reports that a study involving 16 patients in a psychiatric hospital in Finland showed that moderate sauna bathing is safe for somatically healthy patients taking neuroleptics (Tavakoli et al., 2003). Psychiatric inpatients in Finland are typically provided with at least one sauna per week, as it is a vital part of the culture (Tavakoli et al., 2003).

Experimental studies

Gonzalez created a heat exchange model to predict the anticholinergic drug response in a group of healthy male subjects (Gonzalez & Kolka, 2000). By injecting his subjects with 2 mg of atropine sulphate, a powerful anticholinergic drug which acts to suppress activity of eccrine sweat glands, he was able to then measure physiologic strain (an effective temperature index composed of thermoregulatory parameters) when exposing his subjects to exercise in both dry and humid high temperatures. By repeatedly exposing his subjects to high temperature, he was able to show an improvement in effective temperature paralleling heat acclimatization, despite reduction in sweat rate due to anticholinergic action. He hypothesizes that potentiation of dry, non-evaporative heat loss by acclimatization would offset any imbalances in evaporative heat loss.

Hermesh et al. compared a group of schizophrenic male outpatients maintained on depot antipsychotic medication (haloperidol or fluphenazine) against a group of healthy controls. Both groups were exposed to exercise tolerance tests in a hot thermal chamber (40˚ C and 40% relative humidity). (Hermesh et al., 2000). The researchers found a significantly higher rise in rectal and skin temperatures in the patient group, although no differences in sweat rate, heart rate, or blood pressure were seen. The authors conclude that this impaired heat tolerance may be due to the medication effects, a dysfunction associated with schizophrenia, or both.

Conclusions and recommendations

What to tell the public

- *Dedicating a large section of heat advice to providing a lengthy list of potentially dangerous medications is likely to make messaging less effective. Unless the agency providing the advice can offer practical recommendations (other than "check with your doctor"), is appears unnecessary to take space away from more helpful messaging.*
- *Some sites caution all users of psychiatric drugs to check with their doctor to make sure their treatment is safe in the heat. Not all psychiatric drugs present similar risks; anti-psychotics seem particularly dangerous, although from available evidence it may be impossible to know how much risk is attributable to the medication and how much to the underlying disease.*

What to tell health care providers

- *Patients on medications that can potentially impede heat loss should be given pre-seasonal recommendations by their physicians on how to monitor themselves (weigh yourself to monitor hydration status), or taper their drug regimens.*
- *Mental health care providers should evaluate their patients' drug treatments at the start of the summer season and caution patients on neuroleptic drugs to avoid extreme heat exposure or strenuous activity in the heat.*
- *Some case reports on heat-related deaths find that victims were on several medications that may act synergistically to hamper physiologic heat responses. Clinicians should exercise caution when treating people who may have existing vulnerability to heat (old age, obesity, etc.) to avoid polypharmacy, especially with psychiatric medications.*

Knowledge gaps exist

It is apparent that little objective evidence exists to quantify the risk of heat-related mortality attributable to medication usage. Neuroleptic drugs are frequently cited as known risk factors in epidemiologic studies and case reports, and this is explained by their negative impact of the mechanisms of heat dissipation. One study of heat-related mortality risk in psychiatric patients finds this population to be at particularly high risk, however, before the introduction of neuroleptic drugs (Bark, 1998), and a small study which examined drug compliance found fatal heatstroke victims may not have been taking their medication on the day they died (Kaiser et al., 2001). Similarly, we know that patients with cardiovascular diseases are at increased risk for heat-related death, but how much of this risk may be blamed on their medications, or to what extent tapering their medications would augment risk of dying from their disease, is still unclear. Studies evaluating medication usage in heat-related mortality victims, along with an evaluation of medication compliance is needed to address these issues.

Optimal hydration in the heat

The importance of optimal hydration for prevention of heat-related illness

Inadequate fluid status has been cited as an important precipitating factor for the development of life-threatening heat stroke, as well as minor heat illnesses, such as muscle cramps and heat exhaustion (Coris EE, Ramirez AM, & Van Durme DJ, 2004; Sawka MN, Francesconi RP, Young AJ, & Pandolf KB, 1984). Further, dehydration has been blamed for negative effects on performance of athletes, soldiers and workers doing strenuous tasks in the heat (Coris EE et al., 2004). Thermoregulatory compensation for high ambient temperatures depends heavily on replenishment of fluids lost due to perspiration and through exhaled breath (Johnson, 1993). The loss of electrolytes, primarily sodium in sweat, must be replenished to maintain physiologic function (O'Brien et al., 2001). Replacing water without sodium has been blamed for causing hyponatremia, an imbalance of body electrolytes, which can lead to serous illness and has been blamed for the deaths of a small number of athletes and soldiers (Almond CS, Shin AY, Fortescue EB, & et al, 2005; O'Brien et al., 2001). This finding has led military physicians to review fluid replacement protocols for soldiers training in the heat (O'Brien et al., 2001).

Studies, both observational and experimental, have been carried out on exercising subjects exposed to heat stress in attempts to quantify the optimal amounts of water, minerals, and carbohydrates in beverages recommended to people at risk for heat stress (Scott, Rycroft, Aspen, Chapman, & Brown, 2004; Shirreffs, 2003; Strydom & Holdsworth, 1968; Wyndham CH et al., 1973). The extent to which the results can be extrapolated to infants, the ill, and the elderly whose personal susceptibility makes them especially vulnerable to heat is unclear. Further, many people with diagnosed heart or renal failure must keep tight control on their fluid intake, either by limiting consumption, or by taking medication that augments urinary fluid excretion (diuretics) in order to manage their conditions. How this balance is affected by high ambient temperature has been given little attention. We describe the hydration advice which is targeted to the general public (including elderly and other vulnerable groups), the evidence to support this advice as pertains to the high-risk population, and recommendations for optimal hydration in this group.

Advice given

More than two thirds of the websites that we consulted stress increasing the amount of beverages consumed during hot weather. Nearly all of these same sites emphasized the need to drink without waiting for the sensation of thirst. Ten advised to first consult a doctor if one is following a fluid restricted regimen. None of the U.S. health department sites consulted provided this caveat.

Only seven sites specified to restrict extra fluid consumption to water, a few included fruit juices or other non-alcoholic drinks. The Italian Health Department warns to avoid mineral water, stressing that tap water is better suited to replacing minerals. Sport drinks were recommended in the websites of the Ottawa Health Department and the Health Department of Belgium, while a more detailed guide to hydration provided by Texas A & M University cautioned that sports drinks should contain no more than 6 – 8% glucose. Six sites warned against drinking very cold drinks (the WHO, CDC, Environment Canada and the California Department of Health Services which cautions that cold drinks may cause stomach cramps), and the French Health Department which suggests that frozen drinks will diminish the sensation of thirst too quickly.

Beverages to avoid consuming received a lot of attention, with 77% of consulted sites warning to avoid beverages containing alcohol (the most commonly repeated piece of advice). None specified a particular concentration of alcohol, or cautioned against “hard drinks”, in fact, the Texas A & M University site singled out beer as being particularly dangerous. A few sites gave diuretic effects as being the reason for avoiding alcohol, while a few others attributed its effect of diminishing judgement as the rationale. Caffeinated drinks and beverages sweetened with sugar were listed as “to be avoided” by half of the sites, with coffee, tea and cola mentioned specifically by several. None of the sites cautioned specifically against hot drinks.

Some sites provided very detailed recommendations for fluid consumption (the French Health Department suggests drinking an extra half litre for every degree over 37˚C body temperature, for example), others recommended a range or absolute amount. This varies considerably, however, with “more than one litre per day” suggested by the Italian Health Department, and 2.5 to 5 litres per day by the Laboratoire de Santé Publique in Marseilles. Others agencies ask people to gauge their own needs, with two California health sites suggesting if one urinates less, to drink more, and several sites recommending drinking no more than is lost in sweat. Methods on how to measure fluid lost in sweat or urine are not elaborated. One site (Texas A & M University) advises people to check the colour of their urine: if it is dark yellow, they need to drink more.

The issue of mineral replacement is emphasized to a lesser degree, with ten sites cautioning against the use, or limiting the use, of salt tablets to replenish sodium lost in sweat. Seven sites suggest replacing minerals by consuming food or a sport beverage. However, people are cautioned to avoid heavy meals in hot weather by nine sites, and six warn against protein-rich foods. Another three sites recommend staying away from hard-to-digest or fatty meals, and eight recommend eating small, well-balanced or light meals.

Ten sites give recommendations targeted to people exercising in the heat. Most of this advice includes drinking before and during exercise (usually along the order of 0.5 to 1 litre per hour), with the French Health Department advising people to weigh themselves before and after activity to estimate fluid loss. Taking one’s weight is also recommended by the American Heart Association, but for a different target population. They advise patients with heart failure to record their weight every morning, and if they weigh two or more pounds less, they are likely dehydrated and need to increase their fluid consumption. People taking diuretic medications, or who follow a fluid restricted diet are advised by ten sites to consult their doctor to learn how much fluid to consume. People with difficulty swallowing liquids are advised by the French Health Department to increase foods rich in water (fruits and vegetables) or Jell-o.

Evidence to support these recommendations

Physiologic principles behind heat-related changes in fluid status and dehydration

Fluid loss can be divided into insensible and sensible losses. Insensible losses are continuous evaporative losses from the respiratory tract and diffusion through the skin, which together make up about 600 ml per day under normal conditions (Colon JA et al., 2004). The insensible water loss through the skin occurs independently of sweating. Sensible losses occur through excretion of sweat, urine and the feces. The amount of fluid lost in sweat is highly variable, depending on activity level and ambient temperature. The volume can vary anywhere from the normal 100 ml per day to 1 to 2 litres per hour (Folk, 1991). Between 600 and 1800 ml is excreted per day as urine, and only 100 ml of fluid is lost in the feces per day under normal circumstances (Gagge AP, Fobelets AP, & Berglund LG, 1986; Painter P, Cope J, & Smith J, 1999).

Many physiological factors contribute to thermoregulation, and when uncompensated heat gain occurs, heat illness ensues. Heat is dissipated by radiation from the body to a cooler environment. Convection and conduction contribute to a lesser degree, but can become important sources of cooling depending on the temperature gradient between the body and environment (Keim SM et al., 2002). During periods of high ambient temperature, a large portion of blood volume is redistributed to the periphery and skin surface, normally 5 -7˚C cooler than body core temperature, driven by a pressure gradient caused by cutaneous vasodilation. Skin blood flow helps to augment the output of sweat glands, thus promoting evaporative heat loss. Blood is cooled by heat transfer to the skin surface, then the cooler blood is re-circulated to body core(Kamijo & Nose, 2006).

Evaporative cooling is a mechanism which can dissipate heat even in an environment which is warmer than skin temperature, providing sweat or other fluids can be evaporated from the skin. This depends on the wettness of the skin, air currents, and relative humidity, as well as ambient temperature. Water lost during sweating comes from both intra-and extra-cellular fluid compartments. A large decrease in plasma volume may cause a reduction in sweat rate and thus increase core temperature (Hogarth, Noth, & Glace, 2001).

With increased environmental heat, sweating is augmented and additional fluid intake is required to maintain fluid balance (Hogarth et al., 2001). Marked vasodilation in the vascular bed of the skin redistributes blood flow from the renal and splanchnic (gastric and intestinal) circulation, which normally contains 25-30% of total blood volume, causing a fall in blood flow to these areas. Cardiac output must increase to maintain blood pressure regulation and to meet metabolic demands. However, cardiac output and skin blood flow cannot be driven upwards without limits in response to extreme ambient heat to meet demands for heat loss (Rowell LB, 1983). If fluid volume is insufficient, metabolic demands are too high, or the heart cannot meet the demands of increased cardiac output, thermoregulation can fail.

Schedules for drinking during hot weather

Many factors contribute to the individual requirements for fluid supplementation in hot weather. There is great variability in the amount of heat production resulting from activity, sensible and insensible fluid losses, as well individual characteristics such as age, gender, body mass, smoking, heat acclimatization, and health status. Under average conditions, according to the National Research Council’s Recommended Dietary Allowances (National Research Council, 1989), the recommended water intake for adults is 1 mL/kcal energy expenditure. For the prevention of heat illness in the general population, Barrow et al. (Barrow MW & Clark, 1998) suggest that for each pound of weight lost, the individual should consume 0.473 litres (16 oz) of fluid and then continue to drink 236 mL (8 oz) of fluid every 20 min during activity and void light yellow urine at least four times daily. According to Strydom et al. (Strydom et al., 1968) who studied the effects of different levels of water deficit on physiological responses during ambient heat exposure, humans can maintain water balance by replacing all fluids lost in sweat and urine by drinking water in small amounts every15 minutes, while Kamijo suggests the elderly should drink a given amount of beverage every 20 to 30 minutes even though they do not feel thirsty (Kamijo et al., 2006).

Is thirst perception a poor indicator of hydration status?

Maintaining adequate fluid status is considered to be essential in preventing a rise in core body temperature (Coris EE et al., 2004; Kamijo et al., 2006; Johnson, 1993). It is commonly advised to drink without waiting for thirst in a large majority of the websites we consulted. This advice has been integrated into the training protocols of military and athletic programs, where regularly scheduling fluid breaks have become common practice (Binkley HM, Beckett J, Casa DJ, Kleiner DM, & Plummer PE, 2002; O'Brien et al., 2001). Indicators such as urine output, urine osmolarity and the ability to maintain body mass are considered better measures of dehydration than thirst (Kamijo et al., 2006).

The elderly may have a low fluid intake as a consequence of a decreased sense of thirst (Ham RJ, 1992; Strydom et al., 1968). Mack et al.(Mack GW et al., 1994) compared osmotic control of thirst and free water clearance in the elderly with those in the young. They found that perceived thirst was lower in the elderly subjects. One reason for this may be that sodium retention mechanisms are reduced in the elderly (Mack GW et al., 1994). The older body secretes anti-diuretic hormone (ADH) despite decreased blood tonicity (the syndrome of inappropriate ADH secretion) especially in persons with increased chronic cardiac, hepatic and renal disease. Increased ADH secretion and concentration increases the risk of hyponatremia when fluid intake increases (Maresh CM et al., 2006). Further, persons with cognitive difficulties may have a diminished sense of thirst as well (Feinsod et al., 2004).

Although it is generally believed that dehydration (defined as a loss of 2% or greater pre-exercise body weight) adversely affects athletic and work performance, recent studies have examined the danger of overhydration, leading to severe hyponatremia, which has been identified as a risk factor for mortality among soldiers and distance runners

(Almond CS et al., 2005; O'Brien et al., 2001). O'Brien examined a series of hyponatremia hospitalizations associated with heat-related injuries and apparent overhydration in the U.S. military, undertaken as a result of the death of a young soldier from complications of hyponatremia after he attempted to drink 10 quarts of water while vomiting repeatedly. He had been encouraged to drink by his supervisor officer who believed he was suffering from a heat-related illness (O'Brien et al., 2001). A prospective study of marathon runners in the 2002 Boston marathon found that upon completion of the race, 13% of study participants were found to have hyponatremia (defined as a serum sodium level of 135 mmol per litre or less) and 0.6% had potentially life-threatening critical hyponatremia (defined as a serum sodium of 120 mmol per litre or less) (Almond CS et al., 2005). Hyponatremia was strongly correlated with weight gain during the race. Medical advisors to the race have suggested runners write their weight on their bibs at the start of the race, and if they subsequently collapse, a quick weight check can determine if their problem is dehydration or hyponatremia from too much water intake (Kolata, 2005).

Barriers to access to fluids

Bedridden people as well as those with decreased mobility often have increased difficulty of obtaining fluids (Barrow MW et al., 1998; Feinsod et al., 2004). In the same context, young children and infants are vulnerable as they have impaired adaptation abilities.

Rehydration fluids (versus plain water), electrolyte replacement, sweet drinks, caffeine, and alcohol

Kamijo et al. (Kamijo et al., 2006) studied the advantage of restitution from dehydration by supplementation of carbohydrate-electrolyte solution. Carbohydrate depletion often causes fatigue as muscle glycogen is utilized in exercise. In high ambient heat, there is an elevated catabolic rate associated with an increase in muscle temperature, as well as a higher plasma adrenaline concentration (Johnson, 1993). Dehydration is thought to hasten muscle glycogen utilization (Johnson, 1993). Water absorption increases 6-10 fold when 2-6% carbohydrate (CHO) is added to saline. An advantage of flavoured beverages containing carbohydrates is that the taste may encourage drinking more than just plain water (Johnson, 1993). However, high carbohydrate concentrations will delay gastric emptying, thus reducing the amount of fluid that is available for absorption; very high concentrations will also result in secretion of water into the intestine and thus temporarily increase the danger of dehydration (Merson SJ & Shirreffs, 2002). Perhaps because of this effect, high sugar concentrations (>10%) may result in an increased risk of gastro-intestinal disturbances.

The majority of sports drinks have a carbohydrate content of 6-9% weight per volume and contain small amounts of electrolytes, primarily sodium. In addition to flavouring and colouring, the traditional ingredients are water, carbohydrate, sodium, and potassium. Sodium stimulates glucose absorption in the small intestine. The active co-transport of sodium and glucose creates an osmotic gradient that facilitates net water absorption (Salkin, 2007). Sodium is the major ion in the extra-cellular fluid but potassium is the major ion in the intra-cellular fluid. Potassium has been suggested to be important in enhancing rehydration by promoting intracellular rehydration but further studies are needed to provide conclusive evidence (Rao SSC et al., 2006; Schamadan & Snively, Jr., 1967; Schamadan, Godfrey, & Snively, 1968; Shirreffs, 2003).

Caffeinated beverages are consumed by much of the American population, with an estimated 20 – 30% of the adult population drinking more than five cups of coffee daily (equivalent to approximately 600mg of caffeine) and 10% consuming over 1000 mg of caffeine per day (Stookey JD, 1999). Half our selected sites cautioned against drinking caffeinated beverages during hot weather, because it is widely believed that they may cause dehydration due to a diuretic effect. This effect appears to be modified by habituation, caffeine content, and hydration status (Grandjean AC, Reimers KJ, Bannick KE, & Haven MC, 2000; Scott et al., 2004; Stookey JD, 1999). The diuretic effect of caffeine is not linear, according to Grandjean (Grandjean AC et al., 2000), and depends on the amount ingested. Her team studied free-living young men who did not engage in strenuous activity and, in a crossover manner, assigned them to groups based on fluid intake of a standard volume in the form of water-only, or beverages with mild (average 114 mg/d) or moderate amounts (average 253 mg/d) of caffeine. No significant differences in hydration status were observed between the different groups on the basis of body weight, urine and blood assays (Grandjean AC et al., 2000). Neither Stookey nor Scott were able to detect changes in hydration status of people consuming caffeinated beverages (Scott et al., 2004; Stookey JD, 1999). Stookey studied the “bioavailability” of water in caffeinated and alcoholic drinks. He concluded that on average, the diuretic effects of caffeine and alcohol appeared responsible for an 8% decrease in water bioavailability (Stookey JD, 1999). Scott exposed 13 mountain climbers to two different ad librium fluid consumption protocols while on base camp at Mount Everest (water-only or water and tea) and found no difference in urinary measures of hydration status (urine volume or specific gravity) or amount of beverage consumed (Scott et al., 2004). The average amount of tea consumed per day was 1.8 litres (about seven cups). The amount of caffeine in black tea is about 47 mg per cup (Mayo Clinic, 2008), making for an average of about 340 mg per day caffeine consumption.. The diuretic effect of caffeine is observed when the dose exceeds 300 mg (Maughan R & Griffin J, 2003). Granjean finds that an acute ingestion of such an amount in people deprived of caffeine for several days or weeks will have a short-term diuretic effect (Grandjean AC et al., 2000), however, Stookey claims that diuretic effects of alcoholic and caffeinated beverages are mediated by the hydration state, and that in a dehydrated state (defined by increased osmolarity of blood serum), the diuretic effect can be attenuated by as much as 32% (Stookey JD, 1999).

There have recently been introduced new high-caffeine beverages, or “energy drinks” whose caffeine content exceeds that of coffee (Red Bull, Rockstar, Sobe). While these drinks generally contain between 50 – 160 mg caffeine per serving (Mayo Clinic, 2008), even given an 8% decline in the bioavailablilty of the fluid content, these drinks should not be a cause of dehydration. However, caffeine also has stimulant properties on the sympathetic nervous system and can increase heart rate which is harmful in a situation of high ambient heat because this places an increased strain on the heart (Folk, 1991).

Drinking alcohol in a heat wave is to be avoided for several reasons. Alcohol has a diuretic effect which varies according to the alcohol content of the drink. Urinary output increases by 10 ml for each gram of alcohol consumed (Stookey JD, 1999). While this does not present a cause for concern in drinks with a large fluid-to-alcohol content (such as beer), in hard drinks (like whiskey), the bioavailability of the fluid content can be attenuated by nearly half (Stookey JD, 1999). Consuming a great deal of alcohol, in addition to having a negative effect on judgement which can be dangerous in extreme heat, diminishes the contractility of the heart and causes peripheral vasodilation which in turn decreases the blood pressure and limits the necessary compensatory increase in cardiac output. Furthermore, a large consumption of alcohol inhibits the secretion of ADH (antidiuretic hormone). (5) It is beyond the scope of this paper to discuss the condition of alcoholism as an independent risk factor for heat-related illness, but epidemiologic studies have found that heavy alcohol use is associated with a higher risk of heat-related mortality (Kilbourne et al., 1982). Further, withdrawal from alcohol can cause a hyper-metabolic state which can negatively impact thermoregulation (Bayard, McIntyre, Hill, & Woodside, 2004).

<u>Fluid restriction and diuretic use</u>

For people who must limit fluid intake to control blood pressure, or manage heart or renal failure, individual monitoring in conditions of heat stress is critical (Feinsod et al., 2004). While no experimental studies are available in this vulnerable population to provide standard guidelines, the Canadian Heart and Stroke Foundation, as well as the Kidney Foundation of Canada advise fluid restricted patients to weigh themselves at the same time every day after voiding, and that a significant decease (1 kg or more) may indicate dehydration and the need to increase fluid intake (2004; 2008).

For those on diuretic medication, general clinical evaluation remains a mainstay in monitoring hydration status. The goal of diuretic dosage is to achieve dry weight, i.e., the patient is oedema free and has a normal jugular venous pressure (JVP). Over-treatment with a diuretic can lead to dehydration in hot weather, or when there is poor fluid intake, or vomiting and diarrhoea. In these circumstances, the person will show a significant (i.e., more than 1 kg) and sustained decrease in weight below dry weight (Blue L & McMurray J, 2005). If there are signs of volume depletion and hypoperfusion, such as symptoms of dizziness (postural hypotension), or a rising blood urea (more than 5 mmol per L), then the diuretic dose should be decreased (Feinsod et al., 2004).

<u>What to advise?</u>

- *For the general population, increasing fluid intake during periods of extreme hot weather is advised. Drinking frequently without waiting for thirst may be beneficial for the elderly, and being alert to fluid status in those who are unable to care for themselves (bedridden patients, children, cognitively impaired) appears self-evident.*
- *Fluid consumption over and above the amount consumed voluntarily may improve performance in athletics and strenuous labour, but care must be taken to avoid over-hydration with the risk of causing hyponatremia.*

- *Advice on avoiding alcohol is likely over-emphasized, and advice should distinguish between moderate consumption of low-alcohol beverages (evidence does not strongly support a diuretic effect) and spirits, which should be avoided.*
- *Likewise, cautioning people to avoid coffee, tea, and other caffeinated drinks is not well supported and should probably be discarded.*
- *For those who must control their fluid intake for medical reasons, health care professionals must individualize their treatment regimens, and people in this category should be monitored more closely in periods of heat stress.*

Evidence gaps needing to be filled

Experimental studies looking at optimal hydration under conditions of heat stress typically use outcomes having to do with performance enhancement using young, fit subjects. Few studies have used older or infirm subjects, whose hydration needs may differ drastically from active, healthy people. Similarly, most of the information we have on how environmental heat affects medication users is largely theoretical. Controlled studies are needed that use older subjects to evaluate how various hydration protocols can mitigate the adverse effects of heat. Studies examining how fluid status is affected by some common medications (notable diuretics), and medical conditions, such as diabetes and heart failure are also needed.

Recommended level of activity in the heat

Intro – what changes to activity level should be implemented in hot weather?

The risk of heat illness is often compounded by physical activity, and in persons who are very active (soldiers in training, college athletes, etc.) heat stroke may occur at mild to moderate ambient temperatures (Epstein, Moran, Shapiro, Sohar, & Shemer, 1999). Typically, people who begin athletic activity in the summer experience exertional heat-related illness more often than people who train year-round (Binkley HM et al., 2002). Epidemiologic studies of heat-illness deaths and hospitalizations in the US and Israeli military find the highest incidence among new recruits who may be unaccustomed to vigorous exercise and/or hot climates (Carter R et al., 2005; Epstein et al., 1999). Athletic governing bodies, occupational health specialists, and military services have made efforts to assess risks of heat illness and death and have adopted rigid training standards to lessen heat risk.

Public and inter-governmental health agencies (World Health Organization, Centers for Disease Control, Department of Health (United Kingdom), etc.) caution the public through “hot weather advice” websites to reduce or limit physical activity, sports, and strenuous tasks or activities, such as gardening, or at least to displace such activities to the cooler hours of the day. Beyond that advice, there are few guidelines to follow for the general public concerning how to taper their activities, which activities are likely to put them more at risk, and preventative measures to make activity in the heat safe.

Here we describe what advice is given to the public, the evidence for such advice, and what insights can be gained from sources, such as military training manuals, sports governing bodies and occupational hygiene organizations that oversee and do research into preventing heat illness. Of particular relevance to public health messaging is: 1) who is most affected by activities that increase metabolic heat production, and 2) what bearing does activity have in relation to the elderly and infirm?

Advice given

We found that out of the 44 websites consulted, 18 advise the public to avoid or reduce physical activities (**1,2,3,4,5,7,21,22,24,25,26,32,33,36,38,40,41,42**) and an additional ten specify "in the sun", "during the hottest part of the day", "outside" or "in a building without air conditioning" (**9,12,13,18,23,29,30,31,37,44**). Fourteen sites advise to "take plenty of rest breaks", "slow down", "rest in a cool area" (**1,4,7,13,14,21,22,23,28,29,32,35,36,42**), and several of these recommend drinking during exercise or bringing water when venturing outside. Various hydration regimens are suggested by sources (see hydration section), but most recommend small, but frequent water or sports beverage breaks.

Similar recommendations are given by agencies dealing with elderly people (American Association of retired People, California Department of Aging) which caution elders to "relax", "put off chores" and "schedule outdoor activities" before noon or in the evening (**19, 39**).

What are the consequences of overheating because of over activity?

An overview of the physiology of exercise under heat stress involves first reviewing mechanisms of heat loss and gain. Human thermoregulation dictates that core temperature must be kept at 37˚C, and as that little as 3˚C variation can threaten life (Keim SM et al., 2002). Many mechanical as well as physiological factors contribute to thermoregulation, and when uncompensated heat gain occurs, heat illness ensues. One of the most variable of these factors is metabolic heat production. Because conversion of stored chemical potential energy into of kinetic energy is highly inefficient, as much as 80% of muscle energy can take the form of heat production (Taylor N, 2006). Energy from sunlight or other radiant sources (fire, ovens, etc.) can contribute to heat gain, and radiation from the body to a cooler environment can dissipate heat. Evaporative cooling is a mechanism which can dissipate heat even in an environment which is warmer than skin temperature, providing sweat or other fluids can be evaporated from the skin. This depends on the wettness of the skin, air currents, and relative humidity, ambient temperature. Convection and conduction contribute to a lesser degree, but can become important sources of heating or cooling depending on the temperature gradient between the body and environment (Keim SM et al., 2002).

Pathophysiological consequences of overheating secondary to over-activity can be as simple as heat-related cramps to life-threatening heat stroke (Binkley HM et al., 2002). Other direct heat-related illnesses include heat syncope, dehydration, and heat exhaustion. There is speculation that these categories of illnesses follow a continuum, with major pathologies occurring only after more minor complaints are ignored or under treated (Binkley HM et al., 2002). Case histories from heat stroke fatalities suggest that this is sometimes the situation, but there is evidence that decline is quite rapid in certain cases, making it unlikely that a recognizable more benign condition preceded the fatal illness

Who is vulnerable?

Personal factors leading to higher levels of retained heat include demographic characteristics like age (Lind et al., 1970; Robinson et al., 1965), ethnicity (Carter R et al., 2005), gender (Carter R et al., 2005), possible undiagnosed afflictions such as Sickle cell trait (Carter R et al., 2005), RyR1 mutation, a gene thought to be responsible for causing such conditions as malignant hyperthermia and rhabdomyolysis, (Capacchione JF, 2007; Davis et al., 2002), as well as taking medications (diuretics, neuroleptics, anti-cholinergics, weight-loss drugs), using alcohol or illicit drugs, a history of prior heat illness, individual body type and level of conditioning. In the British military, Booker and Bricknell have identified such personal risk factors for heat illness as lack of sleep, concurrent illness, muscle injury and deep burns (Booker RJ & Bricknell MCM, 2002; Bricknell, 1995). The culture of the setting of exercise can also endanger health, particularly in situations where people suffering the effects of heat are motivated to keep going due to fear of reprisal or rejection (occupational settings, sports, military).

Certain types of activity have been linked to increased heat illness risk. Intermittent exercise produces more heat than continuous exercise (Mitchell JB et al., 2001a), and high intensity aerobic exercise has been associated with a high risk as well. Heat capture in confined spaces can be a problem in certain occupations (plumbing) or military actions (beneath decks on cargo ships) (Ellis FP, 1976). In sports, military and occupational settings, wearing heavy equipment can add to heat load, and clothing that is meant to act as a barrier to radiant heat or fluids can retard evaporative cooling. Finlay points out that canoeing and kayaking can be potentially dangerous in the heat, not only due to reflected radiation from the surface of the water, but also related to the false sense of security that is given by being surrounded by cool water (Finlay, 2008).

Evidence from studies of heat illness in military recruits suggests that undiagnosed innate susceptibility to rapid onset of hyperthermia may be found among the general population, however, it may be seen less frequently among athletes and manual labourers due to self-selection for heat tolerance (Capacchione JF, 2007).

Epidemiologic evidence of activity-related heat illness

Few large-scale epidemiologic studies have been conducted on exercise-related heat illness. In the field of athletics, heat illness is the third leading cause of death in US high school athletes (Coris EE, Walz SM, Duncanson R, Ramirez AM, & Roetzheim RG, 2006). Exercising children do not adapt as effectively as adults to a high climatic heat stress and the adaptation of adolescents falls in between. Reasons for this include a greater surface area-to-body mass ratio than adults which causes a higher heat gain from the environment, an increase in metabolic heat production during physical activities, and a diminished sweating capacity (Anderson et al., 2000). Among professional athletes heat fatalities are rare and make headline news when it occurs (Roberts S, 2003). This may be partly due to weeding out of heat-intolerant athletes, but more stringent work-rest cycles and hydration regimens in professional sports may be partly responsible. In 2007, the October Chicago marathon claimed the life of one participant and sent 300 others to hospital with heat related illness due to unseasonably high temperatures (Davey, 2007). Even in cool climates, such as Britain and Canada, it has been speculated that heat stroke is occurring with increasing frequency among distance runners (Hart, Egier, Shimizu, Tandan, & Sutton, 1980; Nicholson, 1981).

One large epidemiologic study assessing risk factors for heat illness in the US military during a 22-year period found a large reduction in heat exhaustion hospitalizations, but a nearly fivefold increase in heat stroke cases (Carter R et al., 2005). Some of the reduction in heat-related hospitalization may be explained by diagnostic shifts, or improvements in out-patient treatments precluding hospital admission. Some surprising findings were a relative risk of 40 times in exercise-related deaths during basic training among those with sickle cell trait compared to those without (Kark, Martin, Canik, & Hicks, 1989). In the Chinese military, an increase of 3.5 times in heat-related illness was associated with a body mass index (BMI) > 27 (Chung, 1996), and in Israel, heat stroke was associated with morning runs in new recruits on days with what was considered a mild heat load, leading the author to speculate that metabolic heat production, rather than ambient air temperature, was a greater factor in the onset of the condition (Epstein et al., 1999).

From 1980 to 1994, the number of deaths which met the NTOF (National Traumatic Occupational Fatalities) surveillance system criteria for “excessive heat exposure” was 260 (Adelakun, Schwartz, & Blais, 1999). In 1984, the Bureau of Labor Statistics reported 2199 non-fatal heat-related injuries (Adelakun et al., 1999). Heat illnesses were most often associated with the service sector (657), manufacturing (529), construction(398) transportation (206), retail trades (157) and agriculture (102) (Adelakun et al., 1999).

What is the advice from professional agencies involved in research?

Novel strategies for coping with exercising in the heat taken from the athletic setting include pre-exercise cooling of the body, which is a method for lowering body heat content prior to heat exposure by having the subject immerse himself in a water bath of 28 - 29˚C which is gradually lowered to 23 – 24˚C and terminated at the first signs of shivering (Taylor N, 2006). It is thought to enhance subsequent heat tolerance and delay onset of fatigue. Keeping a record of heat illness symptoms has been described by Coris (Coris EE et al., 2006), as a means to identify milder forms of heat illness and dehydration before more serious syndromes occur. The National Athletic Trainers’ Association recommends enforcing hydration and rest regimens, as well as weighing athletes before and after training (Binkley HM et al., 2002). Other methods of lowering heat risk for athletes have included various localized cooling methods targeting areas of the body with a higher density of thermal receptors (such as the hands and face) (Ciabattoni E, 2005; Hirata K et al., 1987).

Military training uses acclimatization methods which include two weeks of heat exposure prior to deployment to hot regions, adjustment of training schedules by heat load categories, and educating instructors and soldiers on the symptoms of heat illness (Epstein, Shani, Moran DS, & Shapiro Y, 2000). A simple screening test to identify those at risk of heat illness has been proposed by Gardner (Gardner JW, Kark JA, & Karnei K, 1996). High risk personnel are identified with a BMI > 22 and a 1.5 mile run-time ≥ 12 minutes. Recruits identified by such a test would be prohibited from strenuous activity until they improved their fitness and lost weight.

Occupational hygienists use threshold limit values which are based on wet globe dry temperature (WGBT), a reading of ambient temperature, radiant thermal energy and a humidity index and specify exertional job stress categories to limit risk of heat illness. As threshold limit values for WGBT temperatures are based on a healthy male younger than 40 who is acclimatized to the weather, this standard may put women and older workers at risk.

What is the role of acclimatization?

The benefit of active acclimatization to heat as a protective factor for all people who are physically active during hot weather has been discussed in the acclimatization section.

What recommendations should be made for safe activity in the heat?

- *We found that the recommendation to reduce normal activity level during extremely hot weather to be sensible advice for the public in general, but more needs to be known about the activity level of heat-vulnerable persons, and whether their normal activity puts them at risk of heat-related death or illness. From epidemiologic studies, many of those most at risk appear to be bed-bound or shut-ins, with a separate population of people engaging in strenuous activity who are observed to be at risk for succumbing to exertional heat-stroke (Basu et al., 2002; Kovats RS et al., 2007). The extent to which people not falling into either of those groups are known to be vulnerable to heat-related illness if they do not reduce their daily activities remains unknown. However, it would be prudent for people to be aware of the inherent risks of activity in the heat and the symptoms of heat exhaustion and heat stroke, to avoid beginning new activities during extreme heat, and to reduce activities to a comfortable level, making sure they have easy access to cool areas to rest and can obtain proper hydration.*

- *Experimental evidence from organizations whose members must perform critical tasks under thermal stress suggests that there are techniques to make activity safer, such as pre-cooling the body prior to activity.*

- *Epidemiologic evidence from large-scale military databases have identified several factors associated with heat illness in otherwise fit, young people* *(acute illness, fever, muscle injury, sleep deprivation) (Booker RJ et al., 2002; Bricknell, 1995). It may be advisable to caution the general public to avoid exercise under these conditions.*

- *Special precautions should be taken by parents, teachers, and coaches when temperatures are high to ensure that children and adolescents limit the intensity and duration of sports and that they have access to hydration and cool areas to rest.*

Discussion

Limits of site search

Our review was limited to websites that were available (i.e., on line) during our search period (March 2007 to July 2007). We had hoped to capture seasonal advice during the summer: a consequence of the choice of study period was that our Australian site was searched out-of-season. Further, we were not able to include post-summer updates to our search sites.

It was not always clear which advice was targeted to the general public, and which to health care providers and other specialists. For example, the *Toronto Public Health Department* had advice targeted towards landlords to protect community-dwelling vulnerable people, while the United Kingdom *Department of Health* web-site linked to advice for managers of care homes. We included the former site, but not the latter. Some sites appeared redundant; i.e., *NOAA*, *FEMA*, and the *American Red Cross* had a common heat advice webpage that was found as a link from each agency; in such cases, we referenced the common page only once. In other cases a single agency had several sites giving recommendations with differing emphases; i.e., a public health education organization under the rubric of the *French Health Department* had a site for heat illness prevention, as did the *French Health Department* itself; we used both sites since the advice differed somewhat between them. It became clear that the recommendations given by different agencies (sometimes in different countries) were reproduced by other sites, sometimes word for word (for example, the *Ottawa Public Health Department* published a guide for using electric fans that was nearly identical to that of the *EPA*), however we counted them as two different sites.

We searched patient advocacy group websites and used material directed to patients, but not recommendations geared towards health care professionals. It was not always clear to whom the site was directed, for instance, the *World Health Organization* offers advice on preventing harmful effects of heat waves which was written to appeal to a broad public, but it is doubtful that members of the general public would chose that site when looking for local advice.

To better serve the purpose of comparing website advice, we made efforts to standardize the language that was used; i.e., if a website gave advice to drink more, we grouped it together with other pieces of hydration advice recommending to drink more often, to drink a large quantity, or to drink frequently. Likewise we characterized advice that recommended seeking shelter from the sun with those that recommended seeking shade, avoiding sun exposure, etc. Standardizing advice also necessitated using loose translations of foreign languages; i.e., the use of a "brumisatuer" in French was classified with "misting", "spraying oneself with water", or "dampening the skin with a sponge".

Our web-site search, despite limitations, resulted in a comprehensive assessment of the public health heat messaging available online. We believe we have conducted an exhaustive survey covering the breadth of web-based information provided, as well as extracting the oddities found in some sites (i.e., the *Italian Health Department* recommends drinking tap water rather than mineral water for proper hydration). Sites were searched with no a priori bias, and although we deliberately included in our sample sites in jurisdictions that had experienced high-mortality heat waves, they were not represented out of proportion to regions not known for these events. While the exact counts of messages may vary in a repeated site search, we have confidence that our rankings of frequency of messages is a fair representation of the existing messaging.

<u>Characterization of sites</u>
Our search turned up heat protective advice from intergovernmental organizations (*World Health Organization, Centers for Disease Control and Prevention*), disaster relief organizations(*FEMA, American Red Cross*), weather and environmental services (*Météo-France, Environment Canada, Environmental Protection Administration, National Oceanographic and Atmospheric Administration*), and national public health ministries (Italy, Spain, France, Health Canada, U.K., Belgium, Switzerland), private and university-affiliated health agencies (*Harvard Health Letter, American Association of Retired People*, *Texas A & M University Health Hints*), and state, provincial and municipal health departments in Australia, Canada, the U.S., and care provider websites (American Academy of Family Physicians), and patient advocacy groups (*American Heart Association*).

Health Departments in jurisdictions with past experience of heat waves having high mortality differed between each other significantly in their web-based prevention efforts. The *Health Department of France* had extensive advice on heat-related illness prevention and addressed various at-risk groups (elderly, infants, workers), as well as providing access to reports giving advice on hot weather food storage, medication safety and air-conditioning installation. The *New York City Department of Health and Mental Hygiene* posts concise pre-seasonal advice along with recommendations for what to do during a heat wave. In contrast, the *Philadelphia Health Department*, which has created a state-of-the-art Heat Health Warning System in response to high-mortality heat waves, had no web-available heat advice.

<u>Populations targeted</u>
While most of the prevention advice given has relevance for the general public, it may not always be pertinent to groups most at risk. The degree to which elderly and other heat-vulnerable people need to reduce their activity level (which may be minimal already) to protect their health, or whether their acclimatizing slowly to heat can afford a degree of protection as it does in young, fit people, remains to be seen. While older adults

and people living with chronic illness are mentioned as being at high risk in most sites, only about 20 percent of all the sites consulted give practical heat protective advice to the elderly or infirm (two of these are sites are provided by agencies for the elderly and one is the offering of a cardiac patient group), and about 11 percent of sites give heat-specific advice for children aimed at their caregivers.

What is the nature is the advice being given

Websites differed greatly in terms of the comprehensiveness of recommendations. Pre-seasonal advice on keeping the home cool was offered by only four sites (the health departments of France and Milwaukee, the *National Oceanographic and Atmospheric Administration, and Texas A & M University*). The *American Red Cross* provided a link to a separate site entitled "Family Disaster Plan" for pre-seasonal preparation, but this site did not offer heat-specific advice.

Many sites recommended being aware of the characteristics that render people vulnerable to heat in advance of the summer season, as well as medical illnesses and medication that are associated with heat illness risks. Nearly two thirds of sampled sites listed being elderly (six sites said "over 65", two sites gave "over 75 years old) as a prime risk factor for heat illness, and nearly half the sites listed infants as a risk group. Twenty-eight out of 44 websites mentioned medication use independently as a risk factor for heat-related illness. Of these, 24 specify certain drugs, or classes of drugs which may put one at risk. Nineteen sites recommend asking a doctor or pharmacist for advice about medication usage, but only the *American Heart Association* (AHA) website gives practical tips for those who take medication. For people who take diuretics to control their fluid volume, the AHA advises that they weigh themselves daily during extreme hot weather, and that a loss of two or more pounds indicates possible dehydration.

About half of the websites devoted space to definitions and treatment of heat-related illnesses, with most of them identifying the symptoms of heat cramps, heat exhaustion and heat stroke. Health awareness advice included providing the telephone numbers of heat health lines and knowing whom to contact in case of heat –related health emergencies. More than one third of the sites recommended checking in on vulnerable people, and an equal number reminded people never to leave children, or anyone, alone in a parked car during hot weather. Among the most common pieces of heat protection advice (listed earlier), avoiding alcohol and wearing light coloured clothing were the most frequently cited.

Problematic areas

It was not always apparent that areas emphasized by the sites reflect issues of greatest concern. If criteria for public acceptability and effectiveness of health messaging is simplicity and conciseness, it was surprising to see many sites devoting valuable space to unimportant items, such as the treatment of muscle cramps, avoiding alcohol, and how to dress to keep cool. Some preventive campaigns were well-structured (France gave five top heat tips – drink often, don't go out in the hottest part of the day, dampen the skin several times a day, spend 2-3 hours in a cool place if possible, and help vulnerable people), while others had quite a bit of redundancy and waste of web-space (more than two thirds of the *American Red Cross*’s page is taken up with descriptions and definitions of heat illnesses, heat index and heat wave, leaving just a third for actual useful prevention messaging).

Little referencing was found for the advice given, even in the more detailed websites. The *Texas A & M University* website frequently used articles from the popular press, such as *Healthday* and *Texas Coach*, and cited other health tip websites as references for their information.

Seen altogether, the websites in our survey did not always give a clear, consistent picture of what people should do to prevent heat illness. A cursory review indicates that advice may not be coherent with the epidemiology of heat-related illness and physiological principles.
Dehydration is often found as a contributing factor to both direct heat illness (heat exhaustion and heat stroke), yet the most frequently cited piece of heat advice was to avoid drinking beverages containing alcohol. There is little evidence that moderate consumption of low-alcohol drinks (beer, wine spritzers, etc.) have harmful diuretic effects and their ubiquitous presence at summer activities (barbeques, sports events) may alienate the public consulting these websites. Similarly, recommendations to not use a fan during extreme hot weather may be viewed with suspicion among people who have relied on a fan evaporating water from dampened skin as a way to keep cool.

How we conducted the evidence review

We chose six ubiquitous pieces of advice to explore in more detail and searched for evidence to support, refute, and contextualize the recommendations given (acclimatization, air-conditioning, fan use, medications, hydration, and activity reduction). By reviewing the relevant epidemiological, physiological, and experimental studies in each area, we were able to draw conclusions and highlight areas where more research needs to be done. We searched within the limits of medical and biological databases until we exhausted all sources. Due to limitations of space and time, however, we did have to limit our evidence section on medications. We assessed the physiological and pharmacological theoretical risks of most classes of drugs as identified by websites as causing an elevation of heat illness risk, but we concentrated our efforts on three classes of medication which presented a very widely recognized risk, either in epidemiological risk factor studies, or because of physiological effects on thermoregulation or fluid balance (diuretics, neuroleptics, and anti-cholinergics). Our review was less than comprehensive in areas outside the strictly medical or biological fields (indoor air engineering, for example) due to lack of expertise. Lack of pertinence of experimental studies limited the conclusions we were able to draw: most experimental study subjects were fit, young, healthy individuals and the thermal conditions for exposure were brief and intense. It was necessary to relate the evidence from these studies to prolonged heat episodes, and to vulnerable populations whose responses may differ greatly.

Evidence paper insights:

What advice is practical

- Acclimatization to heat appears to be protective in both experimental and geographic epidemiologic studies. Several websites target this advice to people exercising or playing sports in the heat, however ways to effect heat adaptations in vulnerable people remains unclear. Experiments on men as old as 60 suggest that training in thermal chambers can promote physiologic changes which indicate an improvement in cardiovascular and endocrine mechanisms to lower heat strain.
- Advice for vulnerable people to stay in a cool or air-conditioned environment during episodes of extreme or unusual heat seems well supported by evidence. Our review of epidemiologic evidence supports more time spent there being better, but it may limit acclimatization.
- Use fans to substitute for or boost the effectiveness of air conditioning, since "still air" feels hotter given the same ambient temperature. When using ceiling fans it is important to make sure to direct airflow downward in hot weather.
- Patients on medications that can potentially impede heat loss should be given pre-seasonal recommendations by their physicians on how to monitor themselves (weigh yourself to monitor hydration status), or taper their drug regimens.
- Mental health care providers should evaluate their patients' drug treatments at the start of the summer season and caution patients on neuroleptic drugs to avoid extreme heat exposure or strenuous activity in the heat.
- Clinicians should exercise caution when treating people who may have existing vulnerability to heat (old age, obesity, etc.) to avoid polypharmacy, especially with psychiatric medications.
- For the general population, increasing fluid intake during periods of extreme hot weather is advised. Drinking frequently without waiting for thirst may be beneficial for the elderly, and being alert to fluid status in those who are unable to care for themselves (bedridden patients, children, cognitively impaired) appears self-evident.
- For those who must control their fluid intake for medical reasons, health care professionals must individualize their treatment regimens, and people in this category should have their hydration status monitored more closely in periods of heat stress.
- Recommendations to reduce normal activity level during extremely hot weather are well supported by physiologic evidence. Metabolic heat production varies with fitness level, acclimatization, age, body type. People should be aware of the inherent risks of activity in the heat and the symptoms of heat exhaustion and heat stroke. They should avoid beginning new activities during extreme heat and to reduce activities to a comfortable level, making sure they have easy access to cool areas to rest and can obtain proper hydration.
- Special precautions should be taken by parents, teachers, and coaches when temperatures are high to ensure that children and adolescents limit the intensity and duration of sports and that they have access to hydration and cool areas to rest.

What advice does not appear to be well supported by scientific evidence

- One of the most frequent recommendations given for heat protection among the websites we reviewed, is to stay in a cool or air-conditioned environment. This advice seems well supported by evidence to protect vulnerable people from episodes of extreme or unusual heat, but when temperatures are not so extreme, avoiding outdoor temperatures may deprive elders of the opportunity to acclimatize to heat by some degree of heat exposure.
- Advice to keep air conditioning units set to 5˚C below ambient temperature may be impractical, as it requires daily outdoor temperature monitoring, and many home air conditioning units cannot be set to a specific temperature. This recommended setting may also be insufficient during periods of extreme heat,
- The reason cited for not recommending electric fans, given by several health departments, is that they increase the rate of dehydration. There is no physiologic evidence in our review that supports the hypothesis that increasing air movement results in increased sweating, speeding dehydration and heat illness.
- Recommendations to discontinue fan use when outdoor temperatures are over 32.2˚C (or 90˚F) may be harmful given that outdoor temperatures may not accurately reflect indoor temperatures which may in fact be within the range of a fan's effectiveness.
- Dedicating a large section of heat advice to providing a lengthy list of medications potentially dangerous in hot weather is likely to make messaging less effective. Unless the agency providing the advice can offer practical recommendations (other than "check with your doctor"), is appears unnecessary to take space away from more helpful messaging.
- Fluid consumption over and above the amount consumed voluntarily may improve performance in athletics and strenuous labour, but care must be taken to advise frail and elderly people to avoid over-hydration to avoid the risk of causing hyponatremia.
- Advice on avoiding alcohol is likely over-emphasized, and advice should distinguish between moderate consumption of low-alcohol beverages, and spirits, which should be avoided.
- Cautioning people to avoid coffee, tea, and other caffeinated drinks because of possible diuretic effects is not well supported and should probably be discarded.

<u>Area where more study is needed</u>

- Research into the benefits and limits of heat acclimatization in vulnerable populations is extremely limited. We still do not know to what extent these changes can be attained by people in their 70s and 80s, people who do not engage in strenuous exercise, or those with chronic medical conditions. More research needs to be done to answer these questions.
- In areas without widespread use of air conditioning, ways to make air conditioning more available to those who need it has been problematic. Evaluations of the use of cooling shelters suggests that they are underused by the most vulnerable populations.
- Evidence regarding the benefits of using air conditioning to cool only a bedroom at night, as is a widespread practice, is lacking. Evidence against a protective effect of sleeping in an air conditioned room comes from an analysis of the 1980

heat wave in St. Louis and Kansas City, where a strong inverse relationship between daily hours of home air conditioning and heatstroke was observed, and other investigators have found little benefit from single-room units except in very small apartments.

- To mitigate effects on power systems and contribution of greenhouse gasses to the environment, the possibility of supplementing air conditioning with apparatuses to augment air movement (ceiling or standing fans) and reduce the synergistic effect of humidity (dehumidifying units) allowing for higher tolerable indoor temperatures should be explored.

- Not all psychiatric drugs present similar risks; anti-psychotics seem particularly dangerous, although from available evidence it may be impossible to know how much risk is attributable to the medication and how much to the underlying disease. Epidemiologic studies evaluating medication usage in heat-related mortality victims, along with an evaluation of medication compliance is needed to address these issues.
- Experimental studies looking at optimal hydration under conditions of heat stress typically use outcomes having to do with performance enhancement using young, fit subjects. Few studies have used older or infirm subjects, whose hydration needs may differ drastically from active, healthy people. Controlled studies are needed that use older subjects to evaluate how various hydration protocols can mitigate the adverse effects of heat. Studies examining how fluid status is affected by some common medications (notable diuretics), and medical conditions, such as diabetes and heart failure are also needed.
- More needs to be known about the activity level of heat-vulnerable persons, and whether their normal activity puts them at risk of heat-related death or illness. From epidemiologic studies, many of those most at risk appear to be bed-bound or shut-ins, with a separate population of people engaging in strenuous activity who are observed to be at risk for succumbing to exertional heat-stroke. The extent to which people not falling into either of those groups are known to be vulnerable to heat-related illness if they do not reduce their daily activities remains unknown.

Helpful advice from other domains

- Innovative ways to reduce heat risk for those who must perform active duties in high temperatures has been explored in the realms of civil protection services (firemen, emergency crews), occupational fields (workers near industrial radiant heat sources, wearing protective equipment), military training, and athletics.
- A technique has been introduced to increase heat illness symptom awareness in athletes by having them periodically complete a questionnaire.
- Pre-cooling and localized cooling techniques have also been used in the realm of sports and occupational medicine. It is thought that pre-cooling reduces rate of rise of core body temperature when exposed to extreme heat for short periods. Localized cooling takes advantage of the greater density of cutaneous thermal receptors in the hands and face, and with techniques that increase blood flow to these areas, such as applying a mild vacuum, returning greater volumes of cooler blood to reduce core temperatures.

- Unlike the fields of sports and physically demanding occupations where workers and athletes are to some degree self-selected, the military recruits a diverse range of people who may not easily withstand the rigors of basic training. Experience with hundreds of fatalities in young recruits has prompted military officials to consider methods for screening out people with inherent exercise or heat-illness risks. Research into this field has identified markers associated with increased risk, such as for sickle cell trait, RyR1 mutation, and a high body mass index.

References

1. *Heat-related illnesses and deaths - United States, 1994 - 1995* (1995). (Rep. No. MMWR 44). Centers for Disease Control and Prevention.
2. Quick Kidney Quips (2004). Kidney Foundation of Canada [On-line]. Available: http://www.kidney.sk.ca/services/newsletters/QKQ/documents/2004/August%202004%20QKQ.pdf
3. Heart & Stroke Foundation (2008). Heart & Stroke Foundation [On-line]. Available: http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.2796497/k.F922/Heart_Disease_Stroke_and_Healthy_Living.htm
4. Adelakun, A., Schwartz, E., & Blais, L. (1999). Occupational Heat Exposure. *Applied Occupational and Environmental Hygiene, 14,* 153-154.
5. AFSSE (2007). *Impacts sanitaire des installations de climatisation: domimile des particuliers*.
6. Albert, C., Proulx, R., & Richard, P. (2006). Chaleaur accablante et usage de médicament: étude exploratoire en Estrie. *Bulletin d`Information en Santé Publique du Québec, 17,* 5-8.
7. Almond CS, Shin AY, Fortescue EB, & et al (2005). Hyponatremia among runners in the Boston marathon. *New England Journal of Medicine, 352,* 1550-1556.
8. Anderson, S. J., Griesemer, B. A., Johnson, M. D., American Academy of Pediatrics, & Committee on Sports Medicine and Fitness (2000). Climatic Heat Stress and the Exercising Child and Adolescent. *Pediatrics, 106,* 158-159.
9. Bark, N. M. (1982). The prevention and treatment of heatstroke in psychiatric patients 2. *Hospital and Community Psychiatry, 33,* 474-476.
10. Bark, N. M. (1998). Deaths of psychiatric patients during heat waves. *Psychiatric Service, 49,* 1088-1090.
11. Barnett AG (2007). Temperature and cardiovascular deaths in the US elderly: changes over time. *Epidemiology, 18,* 369-372.
12. Barrow MW & Clark, K. (1998). Heat-Related Illnesses. *Am Fam Physician, 58*.
13. Bass DE (1963). Thermoregulatory and circulatory adjustments during acclimatization to heat in man. In E.M.Hertzfeld (Ed.), *Temperature: Its measurement and Control in Science and Industry* (3 ed., pp. 299-305). New York: Reinhold.
14. Basu, R. & Samet, J. M. (2002). Relation between ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiologic Reviews, 24,* 190-202s.
15. Bayard, M., McIntyre, J., Hill, K. R., & Woodside, J. (2004). Alcohol Withdrawal Syndrome. *American Family Physician, 69*.
16. Belmin, J., Auffray, J.-C., Berbezier, C., Boirin, P., & Mercier, S. (2007). Level of dependency: a simple marker associated with mortality during the 2003 heatwave among French dependent elderly people living in the community or in institutions. *Age and Ageing, 36,* 298-303.
17. Berger LR & Rounds JE (1998). Sweat lodges: a medical view. *The IHS Primary Care Provider, 23,* 69-75.

18. Binkley HM, Beckett J, Casa DJ, Kleiner DM, & Plummer PE (2002). National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses. *J Athl Train, 37,* 329-343.
19. Blue L & McMurray J (2005). How much responsibility should heart failure nurses take? *European Journal of Heart Failure, 7,* 351-361.
20. Blum LN, Bresolin LB, & Williams MA (1998). Heat-related illness during extreme weather emergencies. *JAMA, 279,* 1514.
21. Booker RJ & Bricknell MCM (2002). Heat illness - recent developments. *Journal of the Army Medical Corps, 148,* 11-18.
22. Bouchama, A., Dehbi, M., Mohamed, G., Matties, F., Shoukri, M., & Menne B (2007). Prognostic factors in heat wave-related deaths; a meta-analysis. *Archives of Internal Medicine, 167,* 2170-2176.
23. Bouchama, A., Dehbi, M., Mohamed, G., Matties, F., Shoukri, M., & Menne, B. (2006). Risk and protective factors in heat-related death during heat waves: a meta-analysis of case-control studies. *JAMA.*
24. Bricknell, M. (1995). Heat illness - a review of military experience. *Journal of the Royal Army Medical Corps, 141,* 157-166.
25. Capacchione JF (2007). Rhabdomyolysis, heat stress and malignant hyperthermia in the military. *American Society of Anaesthesiologists Newsletter, 71.*
26. Caroff, S. N., Mann, S. C., & Campbell, E. C. (2000). Risk of fatal heatstroke after hospitalization. *Psychiatric Services, 51,* 938.
27. Carter R, Cheuvront SN, Williams JO, Kolka MA, Stephenson LA, Sawka MN et al. (2005). Epidemiology of hospitalizations and deaths from heat illness in soldiers. *Medicine and Science in Sports and Exercise,* 1338-1344.
28. CDC (2002). Heat-related deaths—Four states, July–August 2001, and United States, 1979 –1999. *Morbid.Mortal.Week Rep., 51,* 567-570.
29. Centers for Disease Control (1995). Heat-related mortality: Chicago, July 1995. *Mortality and Morbidity Weekly Report, 44,* 577-579.
30. Chestnut, L. G., Breffle, W. S., Smith, J. B., & Kalkstein, L. S. (1998). Analysis of differences in hot-weather-related mortality across 44 U.S. metropolitan areas. *Environmental Science & Policy, 1,* 59-70.
31. Chung, N. K. (1996). Obesity and the occurrence of heat disorders. *Military Medicine, 161,* 739-742.
32. Ciabattoni E (2005). Just cool it. *Stamford Magazine.*
33. Colon JA, Montanez RG, & Santiago HP (2004). *Biomass transfer in the human body system* (Rep. No. Congress on biofluid dynamics of human body systems of University of Puerto Rico, Mayaguez).
34. Coris EE, Ramirez AM, & Van Durme DJ (2004). Heat illness in athletes; the dangerous combination of heat, humidity, and exercise. *Sports Medicine, 34,* 9-16.
35. Coris EE, Walz SM, Duncanson R, Ramirez AM, & Roetzheim RG (2006). Heat illness symptom index (HISI): a novel instrument for the assessment of heat illness in athletes. *Southern Medical Journal, 99,* 340-345.
36. Crabbe, C. (2003). France caught cold by heatwave. *Bulletin of the World Health Organization, 81,* 773-774.
37. Curriero F, Heiner KS, Samet, J. M., Zeger S, Strug L, & Patz JA (2002). Temperature and mortality in 11 cities of the Eastern United States. *American Journal of Epidemiology, 155,* 80-87.
38. Davey, Monica (2007). Death, havoc and heat mar Chicago race. *New York Times.*
39. Davido, A., Patzak, A., Dart, T., Sadier, M. P., Méraud, P., Masmoudi, R. et al. (2006). Risk factors for heat related death during the August 2003 heat wave in Paris, France, in patients evaluated at the emergency department of the Hopital Euroéan Georges Pompidou. *Emergency Medicine, 23,* 515-518.
40. Davis RE, Knappenberger PC, Michaels PJ, & Novicoff WM (2003). Changing heat-related mortality in the United States. *Environmental Health Perspectives, 11,* 1712-1718.

41. Davis, M., Brown, R., Dickson, A., Horton, H., James, D., Laing, N. et al. (2002). Malignant hyperthermia associated with exercise-induced rhabdomyolysis or congenital abnormalities and a novel RYR1 mutation in New Zealand and Australian pedigrees. *British Journal of Anaesthesia, 88,* 508-515.
42. de Dear RJ, Ring JW, & Fanger PO (1993). Thermal sensations resulting from sudden ambient temperature changes. *Indoor Air, 3,* 181-192.
43. Dixsaut G (2005). *Vague de chaleur et climatisation: revue bibliographique* (Rep. No. 16,3). Institut National de Sante Publique du Quebec.
44. Donaldson GC, Keatinge WR, & Nayha S (2003). Changes in summer temperature and heat-related mortality since 1971 in North Carolina, South Finland, and Southeast England. *Environ Res, 91,* 1-7.
45. Edholm OG (1969a). The effect of heat on acclimatized and unacclimatized groups of very fit men. *Proceedings of the Royal Society of Medicine, 62,* 1175-1179.
46. Edholm OG (1969b). The effect of heat on acclimatized and unacclimatized groups of very fit men. *Proc.roy.Soc.Med., 62,* 175-1179.
47. Ellis FP (1976). Heat Illness: III. Acclimatization. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 70,* 419-425.
48. Ellis FP (1978). Mortality in the elderly in a heat wave in New York City, August, 1975. *Environmental Research, 15,* 504-512.
49. Ellis FP, Exton-Smith AN, Foster KG, & Weiner JS (1976). Eccrine sweating and mortality during heat waves in very young and very old persons. *Irish Journal of Medical Science, 12,* 815-817.
50. Ellis, F. P. (1972). Mortality from heat illness and heat-aggravated illness in the United States. *Environmental Research, 5,* 1-58.
51. Ellis, F. P. & Nelson, F. (1978). Mortality in the elderly in a heat wave in New York City, August 1975. *Environmental Research, 15,* 504-512.
52. Epstein, Y., Moran, D. S., Shapiro, Y., Sohar, E., & Shemer, J. (1999). Exertional heat stroke: a case series. *Medicine & Science in Sports & Exercise, 31,* 224-228.
53. Epstein, Y., Shani, Y., Moran DS, & Shapiro Y (2000). Exertional heat stroke: the prevention and management of a medical emergency. *Journal of Basic and Clinical Physiology and Pharmacology, 11,* 395-401.
54. Feinsod, F., Levenson, S. A., Rapp, K., Rapp, M. P., Beechinor, E., & Liebmann, L. (2004). Dehydration in Frail, Older Residents in Long-Term Care Facilities. *Journal of the American Medical Directors Association, 5,* s36-s41.
55. Finlay, R. (2008). Hot weather part I and II: Adventure racing, kayaking, hyperthermia, desert survival. Kayak Lake Mead [On-line]. Available: http://www.kayaklakemead.com/dehydration-heat-exhaustion-stroke.html
56. Flynn A, McGreevy C, & Mulkerrin EC (2005). Why do older patients die in a heatwave? *Q J Med, 98,* 227-229.
57. Folk, G. (1991). The evolution of sweat glands. *International Journal of Biometeorology, 35,* 180-186.
58. Fouillet A, Rey G, Laurent F, Pavillon G, Bellec S, Clavel J et al. (2006). Excess mortality related to the August 2003 heat wave in France. *Int Arch Occup Environ Health, 1,* 16-24.
59. Gagge AP, Fobelets AP, & Berglund LG (1986). *A standard predictive index of human response to the thermal environment* (Rep. No. 92:2 B).
60. Gardner JW, Kark JA, & Karnei K (1996). Risk factors predicting exertional heat illness in male Marine Corps recruits. *Medicine and Science in Sports and Exercise, 28,* 939-944.
61. Gonzalez, R. R. & Kolka, M. A. (2000). Prediction of anticholinergic drug response using a thermoregulatory exchange index. *Journal of Thermal Biology, 25,* 157-163.
62. Gover M (1938). Mortality during periods of excessive temperature. *Public Health Report, 53,* 1122-1143.
63. Grandjean AC, Reimers KJ, Bannick KE, & Haven MC (2000). The Effect of Caffeinated, Non-Caffeinated, Caloric and Non-Caloric Beverages on Hydration. *Journal of the American College of Nutrition, 19,* 591-600.

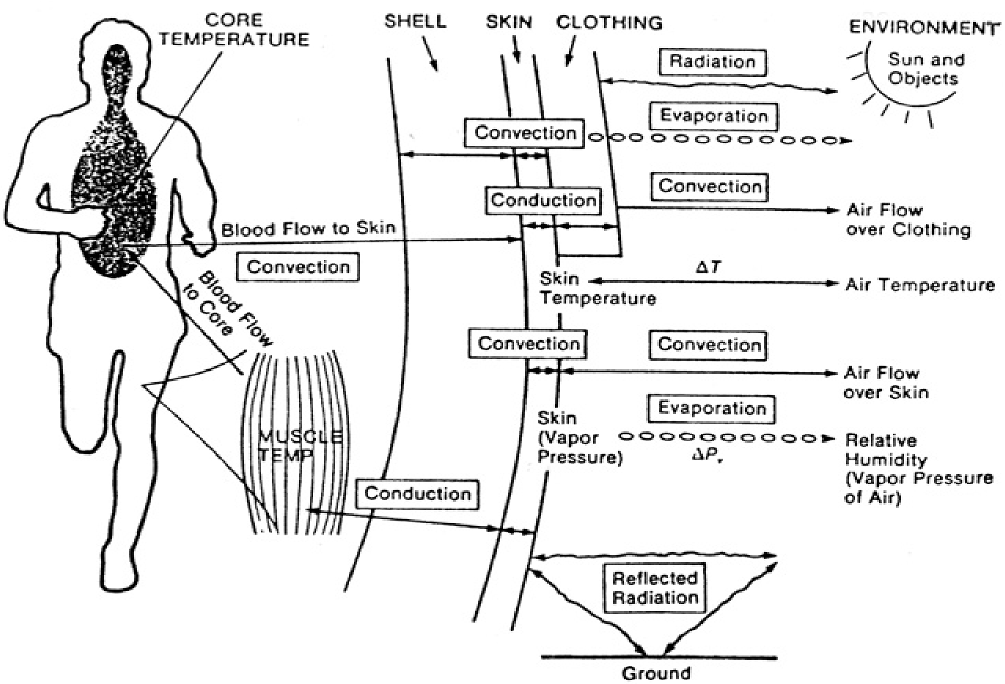
64. Green JS & Kalkstein LS (1996). Quantitative analysis of summer air masses in the eastern United states and an application to human mortality. *Climate Research, 7,* 53.
65. Hajat, S., Armstrong, B., Gouveia N, & Wilkinson P (2005). Mortality displacement of heat-related deaths. *Epidemiology, 16,* 613-620.
66. Hajat, S., Kovats RS, Atkinson RW, & Haines A (2002). Impact of hot temperatures on death in London: a time series approach. *J Epidemiol.Community Health, 56,* 367-372.
67. Ham RJ (1992). Characteristics of the ill elderly patient. In Ham RJ & Sloane PD (Eds.), *Primary Care Geriatrics.* (2nd ed., pp. 40-63.). St. Louis: Mosby Year Book.
68. Hart, L. E., Egier, B. P., Shimizu, A. G., Tandan, P. J., & Sutton, J. R. (1980). Exertional heat stroke: the runner's nemesis
1. *Canadian Medical Association Journal, 122,* 1144-1150.
69. Hermesh, H., Shiloh, R., Epstein, Y., Maniam, H., Weizman, A., & Munitz, H. (2000). Heat intolerance in patients with chronic schizophrenia maintained with antipsychotic drugs. *The American Journal of Psychiatry, 157,* 1327-1329.
70. Hirata K, Nagasaka T, Nunomura T, Hirai A, & Hirashita (1987). Effects of facial fanning on local exercise performance and thermoregulatory responses during hypothermia. *European Journal of Applied Physiology, 56,* 43-48.
71. Hogarth, K. D., Noth, I., & Glace, B. (2001). Hydration and the athlete. *Sports Medicine Update, American Orthopaedic Society for Sports Medicine, Fall*.
72. Hukmani NS (2004). Review of inside design conditions in air conditioned spaces. *Air Conditioning and Refrigeration Journal, Jan-Mar 2004*.
73. IPCC Working Group II & Intergovernmental Panel on Climate Change (1997). *The Regional Impacts of Climate Change: An Assessment of Vulnerability*.
74. Johnson, S. J. (1993). Fluid loss can lead to heat stress, though replenishment offsets effects
1. *Occup.Health Saf, 62,* 62, 65.
75. Kaiser, R., Rubin, C. H., Henderson, A. K., Wolfe, M. I., Kieszak, S., Parrott, C. L. et al. (2001). Heat-related death and mental illness during the 1999 Cincinnati heat wave. *American Journal of Forensic Medicine and Pathology, 22,* 303-307.
76. Kalkstein LS (1998). Climate and Human Mortality: relationships and mitigating measures. In (Advances in Bioclimatology: Human Bioclimatology ed., pp. 161-177).
77. Kalkstein LS & Valimont KM (1987). *Climate effects on human health* (Rep. No. 25389). EPA Science and Advisory Committee.
78. Kamijo, Y. & Nose, H. (2006). Heat illness during working and preventive considerations from body fluid homeostasis. *Industrial Health, 44,* 345-358.
79. Kao, R. L. & Kelly, L. M. (2007). Fatal Exertional Heat Stroke in a Patient Receiving Zuclopenthixol, , Quetiapine and Benztropine. *Can J Clin Pharmacol, 14,* e322-e325.
80. Kark, J. A., Martin, S. K., Canik, J. J., & Hicks, C. U. (1989). Sickle Cell Trait as an Age-Dependent Risk Factor for Sudden Death in Basic Training. *Annals of the New York Academy of Sciences, 565,* 074-408.
81. Keim SM, Guisto JA, & Sullivan JB (2002). Environmental thermal stress. *Ann Agric Environ Med, 9,* 1-15.
82. Kellogg, D., Hodges, G., Orozco, C., Phillips, T., Zhao, J., & Johnson, J. (2007). Cholinergic mechanisms of cutaneous active vasodilation during heat stress in cystic fibrosis. *J Appl Physiol, 103,* 963-968.
83. Kenney, W. L. & Thayne A (2003). Invited Review: Aging and human temperature regulation. *J Appl Physiol, 95,* 2598-2603.
84. Kilbourne, E. M. (1997). Heat Waves and Hot Environments. In K Naji (Ed.), *The Public Health Consequences of Disasters* (pp. 245-269).
85. Kilbourne, E. M. (2002). Heat-related illness: current status of prevention efforts. *American Journal of Preventive Medicine, 22,* 328-329.
86. Kilbourne, E. M., Choi, K., Jones, S., & Thacker, S. B. (1982). Risk factors for heatstroke: a case-control study. *Journal of the American Medical Association, 247,* 3332-3336.

89. Knowlton K, Lynn B, Goldberg RA, Rosenzweig C, Hogrefe C, Rosenthal JK et al. (2007). Projecting heat-related mortality impacts under a changing climate in the New York City region. *Am J Public Health, 97,* 2028-2034.
90. Koivisto, V. (1980). Sauna induced acceleration in insulin absorption from subcutaneous injection site. *British Medical Journal, 280,* 1411-1413.
91. Kolata, G. (2005). Study cautions runners to limit their water intake. *New York Times*.
92. Kosatsky T, Henry B, & King N (2005). How Toronto and Montreal (Canada) respond to heat. In Kirch W, Menne B, & Bertollini (Eds.), *Extreme Weather Events and Public Health Responses* (pp. 167-171). Berlin: Springer.
93. Kovats RS & Hajat, S. (2007). Heat stress and public health: a critical review. *Annu.Rev.Public Health 2008, 29,* 9.1-9.15.
94. Kukkonen-Harjula K & Kauppinen K (2006). Health effects and risks of sauna bathing. *International Journal of Circumpolar Health, 65,* 195-205.
95. Kwok, J. S. & Chan, T. Y. (2005). Recurrent heat-related illnesses during antipsychotic treatment. *Annals of Pharmacotherapy, 39,* 1940-1942.
96. Ledrans, M. (2003). *Étude des facteurs de risque de décès des personnes âgées résidant à domicile durant la vague de chaleur d'août 2003* Institut de veille sanitaire.
97. Lee DHK (1980). Seventy-five years of searching for a heat index. *Environmental Research, 222,* 356.
98. Lind, A., Humphreys PW, Collins KJ, Foster K, & Sweetland KF (1970). Influence of age and daily duration of exposure on responses of men to work in heat. *Journal of Applied Physiology, 28,* 50-56.
99. Mack GW, Weseman CA, Langhans GW, Scherzer H, Gillen CM, & Nadel ER (1994). Body fluid balance in dehydrated healthy older men: thirst and renal osmoregulation. *J Appl Physiol, 76,* 1615-1623.
100. Maresh CM, Gabaree-Boulant CL, Armstrong LE, Judelson DA, Hoffman JR, Castellani JW et al. (2006). Effect of hydration status on thirst, drinking, and related hormonal responses during low-intensity exercise in the heat. *J Appl Physiol, 97,* 39-44.
101. Marmor, M. (1975). Heat wave mortality in New York City, 1949 to 1970 1. *Archives of Environmental Health, 30,* 130-136.
102. Maughan R & Griffin J (2003). Caffeinated beverages and fluid balance: a review. *J Hum Nutr Diet, 16,* 411-420.
103. Mayo Clinic (2008). Food and nutrition: how much caffeine is in your daily habit? Mayoclinic.com [On-line]. Available: http://www.mayoclinic.com/health/caffeine/AN01211
104. McGregor G, Pelling M, Wolf T, & Gosling S (2007). *The social impacts of heat waves* (Rep. No. SC20061/SR6). Environment Agency.
105. Merson SJ & Shirreffs, S. M. (2002). Changes in blood, plasma, and red cell volume after the ingestion of hypotonic and hypertonic solutions. *Proceedings of the Nutrition Society, 61*.
106. Michenot F, Sommet A, Bagheri H, Lapeyre-Mestre M, & Montastruc JL (2006). Adverse drug reactions in patients older than 70 years during the heat wave occurred in France in summer 2003: a study from the French Pharmaco Vigilance Database. *Pharmacoepidemiology and drug safety, 15,* 735-740.
107. Minson, C. T., Holowatz, L. A., Wong, B. J., Kenney, W. L., & Wilkins, B. W. (2002). Decreased nitric oxide- and axon reflex-mediated cutaneous vasodilation with age during local heating. *J Appl Physiol, 93,* 1644-1649.
108. Mirabelli, M. C. & Richardson, D. B. (2005). Heat-related fatalities in North Carolina. *American Journal of Public Health, 95,* 635-637.
109. Mitchell D, Senay LC, Wyndham CH, van Rensburg AJ, Rogers GG, & Strydom NB (1976). Acclimatization in a hot, humid environment: energy exchange, body temperature, and sweating. *J Appl Physiol, 40,* 768-778.
1109. Mitchell JB, Schiller ER, Miller JR, & Dugas JP (2001b). The Influence of different external cooling methods on thermoregulatory responses before and after intense intermittent exercise in the heat. *Journal of Strength and Conditioning Research, 15,* 247-254.

111. Mitchell JB, Schiller ER, Miller JR, & Dugas JP (2001a). The Influence of different external cooling methods on thermoregulatory responses before and after intense intermittent exercise in the heat. *Journal of Strength and Conditioning Research, 15,* 247-254.
112. Muldoon, S., Deuster, P., Brandom, B., & Bunger, R. (2004). Is there a link between malignant hyperthermia and exertional heat illness? *Exercise and Sport Sciences Reviews, 32*, 174-179.
113. Mycek, M. J., Harvey, R. A., & Champe, P. C. (2000). *Pharmacology*. (2nd ed.) Philadelphia: Lippincott, Williams & Wilkins.
114. National Research Council (1989). *Recommended dietary allowances* (Rep. No. 249). Washington, D.C.: Nationa; Academy Press.
115. Naughton MP, Henderson, A., Mirabelli MC, Kaiser, R., Wilhelm JL, Kieszak, S. et al. (2002). Heat-related mortality during a 1999 heat wave in Chicago. *Am J Prev Med, 22,* 221-227.
116. Nicholson, M. R. (1981). Heat stroke and community runs
1. *Br.Med.J.(Clin.Res.Ed), 282,* 1544-1545.
117. O'Brien, K. K., Montain, S. J., Corr, W. P., Sawka, M. N., Knapik, J. J., & Craig, S. C. (2001). Hyponatremia associated with overhydration in U.S. army trainees. *Military Medicine, 166,* 405-410.
118. O'Neill, M. S., Zanobetti, A., & Schwartz, J. (2005). Disparities by race in heat-related mortality in four US cities: the role of air conditioning prevalence. *J.Urban.Health, 82,* 191-197.
119. Painter P, Cope J, & Smith J (1999). Reference information for the clinical laboratory. In Burtis C & Ashwood E (Eds.), *Tietz Textbook of Clinical Chemistry* (3rd ed., pp. 1788-1846). Philadelphia: W.B. Saunders Company.
120. Paldy A, Bobvos VJ, & Vamos A (2005). The effect of temperature and heat waves on daily mortality in Budapest, Hungary 1970-2000. In (Extreme Weather Events and Public Health Responses ed., Springer.
121. Pengelly D, Campbell M, Cheng C, Fu C, Gingrich SE, & Macfarlane R (2007). Anatomy of Heat Waves and Mortality in Toronto. *Canadian Journal of Public Health, 98,* 364-368.
122. Perez-Pena, Richard (2006). Heat Wave Was a Factor in 140 Deaths, New York Says. *New York Times*.
123. Rao SSC, Summers RW, Rao GRS, Ramana S, Devi U, Zimmerman B et al. (2006). Oral Rehydration for Viral Gastroenteritis in Adults: A Randomized, Controlled Trial of 3 Solutions. *Journal of Parenteral and Enteral Nutrition, 30,* 433-439.
124. Roberts S (2003). Sports of the times; N.F.L.'s pernicious culture of obesity. *The New York Times*.
125. Robinson, S., Belding HS, Consolazio FC, & Turrell ES (1965). Acclimatization of older men to work in heat. *J Appl Physiol, 20,* 583-586.
126. Rogot E, Sortie PD, & Backlund E (1992). Air Conditioning and mortality in hot weather. *American Journal of Epidemiology, 136,* 106-116.
127. Rowell LB (1983). Cardiovascular aspects of human thermoregulation. *Circulation Research, 52,* 367-379.
128. Salkin, Allen (2007). Three yards and a drink that tastes like dust. *New York Times*.
129. Sardon J-P (2007). The 2003 heat wave. *Eurosuveillance, 12*.
130. Sato K (1993). The mechanism of eccrine sweat secretion. In Gisolfi CV, Lamb DR, & Nadel ER (Eds.), *Perspectives in Exercise Science and Sports Medicine,* (pp. 85-117). Dubuque, IA: Brown & Benchmark.
131. Sawka MN, Francesconi RP, Young AJ, & Pandolf KB (1984). Influence of hydration level and body fluids on exercise performance in the heat. *Journal of the American Medical Association, 252,* 1165-1169.
132. Schamadan, J. L., Godfrey, W. R., & Snively, W. D. (1968). Preliminary communication: evaluation of potassium-rich solutions as oral prophylaxis for heat stress disease. *Industrial Medicine & Surgery,* 677-684.

133. Schamadan, J. L. & Snively, W. D., Jr. (1967). The role of potassium in heat stress disease
1. *Industrial Medicine and Surgery, 36,* 785-788.
134. Schuman, S. H. (1972). Patterns of urban heat-wave deaths and implications for prevention: data from New York and St. Louis during July, 1966. *Environmental Research, 5,* 59-75.
135. Scott, D., Rycroft, J. A., Aspen, J., Chapman, C., & Brown, B. (2004). The effect of drinking tea at high altitude on hydration status and mood. *Eur J Appl Physiol, 91,* 493-498.
136. Semenza, J. C., McCullough JE, Flanders D, McGeehin MA, & Lumpkin JR (1999). Excess hospital admissions during the July 1995 heat wave in Chicago. *Am J Prev Med, 16,* 269-277.
137. Semenza, J. C., Rubin, C. H., Falter, K. H., Selanikio, J. D., Flanders, W. D., Howe, H. L. et al. (1996). Heat-related deaths during the July 1995 heat wave in Chicago. *New England Journal of Medicine, 335,* 84-90.
138. Senay LC (1972). Changes in plasma volume and protein content during exposures of working men to various temperatures before and after acclimatisation to heat : separation of the roles of cutaneous and skeletal muscle circulation. *J.Physiol.London, 224,* 61-81.
139. Shapiro Y, Pandolf KB, & Goldman RF (1982). Predicting sweat loss response to exercise, environment and clothing. *Eur J Appl Physiol, 48,* 83-96.
140. Shirreffs, S. M. (2003). The optimal sports drink. *Sportmedizin nd Sportraumatologie, 51,* 25-29.
141. Silviero-Graudenz S, Landgraf RG, Jancar S, Tribess A, Fonseca SG, Christhina-Fae K et al. (2006). The role of allergic rhinitis in nasal responses to sudden temperature changes. *Journal of Allergy and Clinical Immunology, 118,* 1126-1132.
142. Smoyer KE, Rainham DGC, & Hewko JN (2000). Heat-stress-related mortality in five cities in Southern Ontario: 1980 - 1996. *International Journal of Biometeorology, 44,* 190-197.
143. Stafoggia, M., Forastiere, F., Agostini, D., Biggeri, A., Bisanti, L., Cadum, E. et al. (2006). Vulnerability to heat-related mortality: a multicity, population-based, case-crossover analysis. *Epidemiology, 17,* 315-323.
144.
Steadman RG. (1979a). The Assessment of Sultriness. Parts I and II. Journal of Applied Meteorology 18, 861-884.
Ref Type: Generic
145.
Steadman RG. (1979b). The Assessment of Sultriness. Parts I and II
323. Journal of Applied Meteorology 18, 861-884.
Ref Type: Generic
146. Stookey JD (1999). The diuretic effects of alcohol and caffeine and total water intake miscalculation. *European Journal of Epidemiology, 15,* 181-188.
147. Stoops, J. L. (2008). *A possible connection between thermal comfort and health* U.S. Department of Energy.
148. Strydom, N. B. & Holdsworth, L. D. (1968). The effects of different levels of water deficit on physiological responses during heat stress
1. *Int.Z.Angew.Physiol, 26,* 95-102.
149. Sullivan-Bolyai JZ, Lumish RM, Smith EWP, Howell JT, Bregman DJ, Lund M et al. (1979). Hyperpyrexia due to air-conditioning failure in a nursing home. *Public Health Reports, 94,* 466-470.
150. Surridge G (2004, September 22). Newspapers fan belief in urban myth. *JoonAng Daily*.
151. Tavakoli, S. & Yates, W. (2003). Sauna and hot tub warnings. *Psychosomatics, 44,* 261-262.
152. Taylor N (2006). Challenges to temperature regulation when working in hot environments. *Industrial Health, 44,* 331-344.
153. Vanakoski J & Seppala T (1998). Heat exposure and drugs: A review of the effects of hyperthermia on pharmacokinetics. *Clin.Pharmacokinet, 34,* 311-322.

154. Vandentorren, S., Bretin, P., Zeghnoun, A., Mandereau-Bruno, L., Croisier, A., Cochet et al. (2006). Heat-related mortality: August 2003 heat wave in France: risk factors for death of elderly people living at home. *European Journal of Public Health, 16,* 583-591.
155. Weiss M, Milman B, Rosen B, Eisenstein Z, & Zimlichman R (1991). Analysis of the diminished skin perfusion in elderly people by laser Doppler flowmetry. *Age and Ageing, 21,* 237-241.
156. Woodcock AH, Pratt RI, & Breckenridge JR (1952). Heat exchange in hot environments. *Environ.Protec.Br.Rep., 183*.
157. Worfolk, J. B. (2000). Heat waves: their impact on the health of Elders. *Geriatric Nursing, 21,* 70-77.
158. Wyndham CH, Strydom NB, Benade AJS, & Van Der Walt WH (1973). The effect on acclimatization of various water and salt replacement regimens. *South African Medical Journal, October 6,* 1773-1779.
159. Wyndham, C. H. (1973). The physiology of exercise under heat stress. *Ann.Rev.Physiol., 35,* 193-220.
160. Wyndham, C. H., Benade, A. J., Williams, C. G., Strydom, N. B., Goldin, A., & Heyns, A. J. (1968a). Changes in central circulation and body fluid spaces during acclimatization to heat. *J.Appl.Physiol, 25,* 586-593.
161. Wyndham, C. H., Williams, C. G., Morrison, J. F., Heyns, A. J., & Siebert, J. (1968b). Tolerance of very hot humid environments by highly acclimatized Bantu at rest
11. *British Journal of Industrial Medicine, 25,* 22-39.



Appendix A

Sites accessed: seasonal recommendations and advice related to discrete extreme heat episodes

I. Intergovernmental organizations:
  a. World Health Organization/ Regional Office for Europe (1)
  b. Centers for Disease Control and Prevention (7)

II. Disaster relief organizations:
  a. Federal Emergency Management Agency (FEMA) (14)
  b. American Red Cross (5)

III. Weather services
  a. Météo-France (34)
  b. Environment Canada (35)
  c. Environmental Protection Administration/ Office of Atmospheric Programs (6)
  d. National Oceanographic and Atmospheric Administration (26)
  e. Illinois State Climatologist Office (USA) (24)

II. Private agencies
  a. Harvard Health Letter (10)
  b. American Association of Retired People (19)
  c. Laboratoire de Santé Publique (Faculté de médecine de Marseille) (31)
  d. Texas A & M University/ Texas Cooperative Extension Health Hints (42)

III. Public health authorities:
  a. Federal
    i. Health Canada (8)
      1. Public Health Agency of Canada, Canada Health Network (11)
    ii. Department of Health, UK (3)
    iii. Direction général de Santé, France (21)
      1. Insitut national de prevention et d`éducation pour la santé, France (18)
    iv. Santé publique, Sécurité de la Chaîne alimentaire et Environment (Belgique) (32)
    v. Office federal de la santé publique/ Plan d´Action environment et santé (Suisse) (33)
    vi. Ministerio de Sanidad é Consumo (España) (37)
    vii. Ministero della salute (Italia) (38)
  b. State and Provincial
    i. Ministère de la Santé et des Services sociaux, Québec (2)
    ii. British Columbia Ministry of Health (16)
    iii. Ontario Ministry of Health and Long Term Care (30)
      1. Santé Ontario (29)
    iv. Illinois Department of Public Health (20)
    v. Texas Department of State Health Services (23)
    vi. Wisconsin State Government/Department of Health and Family Services (27)
    vii. California Department of Health Services (40)
      1. California Department of Aging (39)
    viii. Department of Human Services, Victoria, Australia (22)
  c. Municipal
    i. Toronto Public Health Department (4)
    ii. Direction de la santé publique de Montréal (12)
    iii. Vancouver Health Department (15)
    iv. Ottawa Public Health (25)
    v. New York City Department of Health and Mental Hygiene (17)
    vi. Maricopa County Department of Health Services (Phoenix, Arizona) (36)
    vii. Milwaukee Health Department (28)
    viii. Chicago Department of Public Health (41)
    ix. City of Columbus – Columbus Public Health (43)
    x. Los Angeles County Health Department (44)

IV. Care providers:
  a. Primary care physicians

i. American Academy of Family Physicians (13)

V. Patient advocacy groups, and patient information services

a. American Heart Association (9)

Websites:

1. WHO Regional Office for Europe
2. Ministère de la Santé et Services sociaux, Québec
3. The Department of Health, United Kingdom
4. Toronto Public Health Department
5. The American Red Cross
6. United States Environmental Protection Agency, Office of Atmospheric Programs
7. Centers for Disease Control and Prevention
8. Health Canada
9. American Heart Association (extremely hot weather defined as humidity >70% AND T˚F >70˚F)
10. Harvard Health Letter
11. Public Health Agency of Canada, Canada Health Network (part of # 8?)
12. Direction de la Santé publique de Montréal
13. American Academy of Family Physicians
14. Federal Emergency Management Agency (FEMA)
15. Vancouver Health Department
16. British Columbia Ministry of Health
17. New York City Department of Health and Mental Hygiene
18. Insititut National de Prévention et d`Éducation pour la Santé, France
19. American Association of Retired People
20. Illinois Department of Public Health
21. Direction générale de Santé, France
22. Department of Human Services, Victoria, Australia
23. Texas Department of State Health Services (DSHS)
24. Illinois State Climatologist Office
25. Ottawa Public Health
26. National Oceanographic and Atmospheric Administration
27. Wisconsin State Government/Department of Health and Family Services
28. City of Milwaukee Health Department
29. Santé Ontario
30. Ontario - Ministry of Health and Long-term Care
31. Laboratoire de Santé publique (Faculté de médecine de Marseille)
32. Service public fédéral (SPF) Santé publique, Sécurité de la Chaîne alimentaire et Environnement (Belgique)
33. Office fédéral de la Santé publique - Plan d’Action environnement et santé (Suisse)
34. Météo-France
35. Environnement Canada
36. Maricopa County Department of Emergency Management (Phoenix, Arizona)
37. Ministerio de Sanidad e Consumo (Spain)
38. Ministero della Salute (Italy)
39. California Department of Aging

40. California Department of Health Services
41. Chicago Department of Public Health
42. Texas A & M University – Texas Cooperative Extension Health Hints
43. City of Columbus, Ohio – Columbus Public Health
44. Los Angeles County Health Department

Appendix B - Advice by topic

Fan Advice

Safe Fan Use:

- It is useful to have a fan available at the start of summer (**33**)
  - under certain circumstances (**21**)
- Make sure older adults have access to an electric fan whenever possible (**7**)
- Use a portable electric fan if necessary (**4, 38, 39, 44**)
  - to substitute for or assist air conditioning (**39**)
  - in or next to a window (**4, 6, 25**)
    - box fans are best (**6, 25**)
  - plugged directly into wall (**4, 6, 25**)
    - if you need extension cord, be sure it is UL approved (**6, 25**)
  - To exhaust hot air from rooms or draw in cooler air (**4, 6, 25**)
- To conserve energy, use a fan instead of AC, remembering to turn it off when you leave the room (**30**)

Circulating air:

- Fans can increase the circulation of hot air which increases thermal stress and thereby increases health risks during excessive heat events (**6**)
- Fans offer little protection when the temperature is elevated as they just move hot air (**4, 5, 6, 25, 32, 42**)
- Circulating air can cool the body by increasing the perspiration rate of evaporation (**14**)
- Keep windows and doors open with at least one fan moving air throughout the room (targeted to teachers for schoolrooms) (**20**)
- Use cross-ventilation and fans to cool rooms if air conditioning is not available (**23**)
- Use a ceiling fan to substitute for or assist air conditioning (**39**)
- Don’t use a fan in a <u>closed room</u> without windows or doors open to the outside (**4, 6, 12, 25, 42**) because:
  - A person who sits inside a closed room with no air conditioning and a fan blowing on them can have increased dehydration, and when the room is hot, actually increase thermal stress (**42**)
- Use a fan only to bring cooler air in or exhaust hot air out (**4, 6, 22, 25**)
- Use attic fans to vent warm air out of the attic (**5**)

Evaporative Cooling:

- Evaporation of sweat becomes the principle effective means of maintaining a constant body temperature as environmental temperature reaches skin temperature (**42**)
- Fans keep you cool by evaporating your sweat (**5, 6, 25, 42**)
- High humidity makes it more difficult to sweat (**32**)
- When environmental humidity approaches 80%, evaporation of perspiration ceases and dissipation of heat is no longer possible (**20**)
- Lack of wind blocks perspiration (**31**)
- Men are more at risk of heat-related illness because they sweat more and are more prone to dehydration (**29**)
- Children are less well adapted to heat because they produce more metabolic heat than adults and sweat less (**42**)
- Older people should not use fans as the only protection against the heat because they sweat less and fans work only when we sweat (**42**)
- A fan can be cooling, especially if one regularly wets the skin (**21, 31, 33, 39**)
    - avoid overdoing it, it creates exhaustion (**33**)
    - use a hand-held battery operated fan and mister (**39**)

Unsafe Fan Use:

- Don’t use a fan:
    - to blow hot air on yourself (**4, 6, 25**):
        - this can cause heat exhaustion to happen faster (**6, 25**)
        - If you need a fan to stay cool in hot weather, don’t sit directly in front of the fan, and always open a window for ventilation when running a fan (**42**)
    - to blow air on a young child (**31**)
        - this can cause him to become cold if he is sweating (**31**)
    - when room temperature is hotter than 32.2˚ C (**6**)
    - to substitute for spending time in an air-conditioned facility (**6**)
- Fans are not effective:
    - when temperature is over 35˚C, they move air only and don’t cool it (**37**)
    - when the temperature is over 30˚C fans are not as effective (as air conditioning) at preventing heat-related illness (**16**)
    - when the temperature is between 35 and 37.8˚ C, fans will not prevent heat-related illness (**6, 7, 40, 42**)
    - fans increase heat stress at temperature › 32.2˚ C with humidity › 35% - avoid using when ambient temp › 37.8˚ C (**27**)
    - When heat index temperature is over 37.2˚ C, fan use increases heat stress by blowing air warmer than skin temperature over the body and causing increased sweat evaporation and speeding the onset of heat exhaustion (**6**)
    - They can cause sweat to evaporate too quickly and accelerate dehydration (**42**)

Other:

- If your afraid to open your window to use a fan, choose other ways to keep cool (**6, 25**)
- A better way to stay cool (then a fan) is to take a cool bath or shower, spray the body with water to get cooling from evaporation, or get to a place that has air conditioning during the hottest part of the day (**6, 7**)

Physical activity and acclimatization advice

Activities:

- Reduce or avoid physical activities/strenuous activities/ sports/ gardening/ crafts (**1, 2, 3, 4, 5, 7, 21, 22, 24, 25, 26, 32, 33, 36, 38, 40, 41**)
  - in the sun/ hottest part of the day/ outside (**1, 2, 3, 5, 9, 12, 13, 18, 21, 23, 26, 29, 30, 31, 36. 37, 44**)
    - between the hours of 10:00AM and 6:00PM (**13**)
  - avoid stressful activities during the hot season (April – October) (**36**)
- Take plenty of rest breaks/ slow down/ rest in cool area (**1, 4, 7, 13, 14, 21, 22, 23, 28, 29, 32, 35, 36, 42**)
- Unacclimatized people should not start a new activity during extreme heat (**21**)
- Sprinkle water on the face and neck regularly (**21**)
- Use a buddy system when working in the heat (**7**)
- For conditioned people, do not participate in a competition (**21**)
- Drink before and during exercise (**4, 13, 21, 31**)
- Avoid activities that require you to wear a helmet (**13**)
- Try to acclimatize slowly to the heat (**1, 7, 13, 23**)

Medication Advice

Vulnerable people are those who:

- Anyone/ elderly people having chronic illnesses/ disabilities (**1, 2, 3, 4, 5, 6, 7, 11, 21, 23, 26, 29, 40, 41, 42, 43**)
  - Endocrine disorders (**1**)
    - Diabetes (**2, 3, 4, 12, 16, 17, 37, 42**)
    - Hyperthyroid (**12, 16**)
    - Diabetes insipidus (**42**)
    - Adrenal disorders (**42**)
  - Cardiovascular/ heart disease (**1, 2, 3, 4, 7, 8, 12, 17, 21, 22, 27, 28, 32, 37, 38, 40, 42**)
    - Peripheral vascular disease (**3, 12**)
    - Poor circulation (**5, 23, 42**)
    - Heart failure (**42**)
  - Neurologic disease (**1, 2, 32, 37, 38**)
    - Cerebrovascular (**2, 12, 37**)

        - Parkinson's disease (**3, 12, 32**)
        - Alzheimer's or related (**3, 12, 32**)
        - Autonomic disorder (**12**)
    - Psychological disorders/ mental illness/ impairment (**1, 2, 3, 6, 7, 8, 11, 12, 21, 37, 38, 40, 42**)
        - Dementia (**3, 32**)
        - Memory, behavioural, comprehension and orientation problems or fail to recognize danger (**21**)
    - Respiratory diseases (**1, 2, 3, 4, 8, 12, 21, 27, 28, 32, 37, 38, 42**)
        - Cystic fibrosis (**12, 16**)
    - Liver disease (**1, 42**)
    - Kidney problems (**1, 2, 3, 8, 12, 17, 27, 32, 37, 42**)
    - High blood pressure (**1, 7, 8, 12, 16, 22, 40, 42**)
    - Skin ulcers (**12**)
    - Sickle cell anaemia (**12**)
    - Obesity/ overweight (**3, 6, 12, 16, 23, 26, 27, 28, 32, 37, 42**)
    - Malnutrition/ underweight/ eating disorders (**3, 12, 16, 42**)
    - Loss of autonomy (**3, 4, 12, 21**)
    - Dehydration (**16, 27**)
    - Sleep deprivation (**16**)
    - People with acute illness or fever (**11, 12, 16, 21, 42**)
        - Diarrhoea (**12**)
        - Infection (**12**)
        - Gastroenteritis (**32, 42**)
    - Menopause (**42**)
    - Pregnant (**42**)

Medications that increase risk are:

- Grouped by function, those:
    - That aggravate dehydration, heat exhaustion and electrolyte balance (**1, 3, 12, 32**)
        - Diuretics (esp. loop) (**1, 2, 10, 12, 32, 33, 37, 38, 42**)
        - Laxatives (**10**)
        - Causing vomiting or diarrhoea (colchicines, antibiotics, codeine) (**3**)
    - Affect renal function (**3, 32**)
        - NSAID's (**1, 3, 12, 32, 33**)
        - Sulfonamides (**1 ,3, 12**)
        - Indinavir (**1, 3, 12**)
        - Cyclosporin (**3**)
    - Affect thermoregulation (**3**)
        - By central action:
            - Neuroleptics (also interfere with sweating) (**3, 4, 12, 27, 28, 31**)
                - Psychiatric drugs (**4, 22, 33, 37, 42**)
                - Phenothiazines (**37**)
            - Serotoninergic agonists (**3, 12**)

        - By interfering with sweating: **(3**)
            - Anti-cholinergics: (**2, 4, 26, 27, 37**)
                - Atropine (**3, 31**)
                - Tricyclics (**3, 12, 17**)
                - Anti-histamines (H1 antagonists -first generation)(**3, 12, 17, 37, 38, 42**)
                - Certain anti-Parkinson drugs (**3, 4, 12, 17**)
                - Certain anti-spasmotics (**3**)
                - Diisopyramide (**3, 12**)
                - Anti-migraine agents (**3**)
                    - pizotifene-**12**
            - Vasoconstrictors (**3, 12**)
                - Sympathomimetics (**12**)
                    - Amptetamines (**1, 17, 33, 37**)
                - Anti-migraine-ergot derivatives, triptans (**12**)
        - By modifying basal metabolic rate:
            - Thyroxine (**3**)
    - Drugs which exacerbate the effects of heat:
        - By reducing arterial pressure:
            - All anti-hypertensives (**3, 12, 33, 38, 42**)
            - All anti-anginal drugs (**3, 12, 33, 42**)
    - Drugs that reduce alertness (section 4.4 in British National Formulary) (**3**)
        - Painkillers (**1, 10**)
        - Major tranquilizers/ sedatives (**2, 17, 26, 27, 34, 42**)
        - Benzodiazepines (**1**)
    - Whose levels are affected by dehydration:
        - Lithium (esp. with alcohol **– 27**) (**3, 12, 27**)
        - Digoxin (**3, 12**)
        - Anti-epileptics (**3, 12**)
        - Biguanides (**3, 12, 33**)
        - Statins (**3, 12, 33**)
        - Fibrates (**12**)
        - Anti-arrythmics (**12, 33**)
    - Facilitate sunburn:
        - Chlorpromazine (**4**)
        - Thoridazine (**4**)
        - Perphenazine (**4)**
        - Fluphenazine (**4**)
        - Thiothixene (**4**)
- Certain types of meds unspecified (**3, 4, 5, 16, 26, 40**)
    - Without regular medical follow-up (**21**)
    - Medications for cardiovascular disease, respiratory disease or renal disease can cause dehydration (**27**)
    - Meds for movement disorders, allergies, depression and heart or circulatory problems (**28**)

  - Meds that provoke hyperthermia or lower blood pressure (**32**)
- Antidepressants (**1, 4, 38**)
- Beta blockers (**1, 12, 37**)
- ACE inhibitors (**1**)
- Anti-emetics (**27**)
- Alcohol/ illicit drugs (**3, 11, 12, 17, 21, 23, 26, 27, 32, 33, 42**)
  - Cocaine (**17, 33**)
  - Ecstasy (**17**)
  - In withdrawal from alcohol (**32**)
- Over-the-counter meds:
    - Anti-histamines (**4**)
    - Sleeping pills (**4**)
    - Anti-diarrhoea (**4**)
  - Aspirin is contra-indicated in heat stroke (**21**)
  - Respect instructions on medicine bottles to keep at appropriate temperature (**21**)

Health awareness:

- Review your medications/ keep a list handy (10, 32)
- Ask a doctor/pharmacist if you have a question about your health/medication (**2, 3, 5, 6, 8, 18, 19, 21, 23, 25, 27, 28, 32, 34, 35, 37, 38, 40, 44**)
  - Especially if you have:
    - Heart failure (**2**)
    - On dialysis (**2**)
    - Loss of fluids due to GI problems (**2**)
    - Unusual symptoms (**3, 18, 25, 34**)
    - A chronic medical condition (**19**)
    - A prescription for diuretics or antihistamines (**23**)
    - Dementia, nausea or vomiting, Parkinson's, psychiatric disorders (depression or schizophrenia, anxiety), seizures, stomach or bladder spasms (**28**)
  - Monitor body fluid level by weighing yourself every morning. If you weigh two pounds less than normal in the morning, you are likely dehydrated and need to drink more before doing vigorous activity (**9**)

Hydration advice

Drinking in general:

- Drink regularly/a lot/sufficiently/more than normally/ regardless of your activity level/plenty (**1 ,2, 3, 4, 5, 7, 12, 14, 16, 17, 18, 21, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33, , 35, 36, 37, 38, 40, 42, 43, 44**)
- Without waiting for thirst (**1, 2, 3, 4, 5, 7, 12, 16, 17, 18, 21, 22, 23, 24, 26, 27, 28, 29, 32, 33, 35, 36, 37, 38, 40, 42, 43, 44**)
- Unless contraindicated by a doctor (**2, 18, 21, 22, 26, 37**)
- To replenish loss of liquid due to sweat and respiration (**34)**

- If you are urinating less, drink more water (**40, 44**)
- Producing lots of clear, dilute urine is a good indication that you are well hydrated (**42**)
- Do not ration your water (targeted to desert hikers) (**36**)

What to drink:

Water only

- Drink water (**5, 14, 25, 31, 35, 42, 44**)

Water plus others

- Drink water regularly or other non-alcoholic liquids (**6**)
- Drink lots of water and natural juices (**29, 30, 41**)
- Drinking of liquids can be aided if they are slightly sweet (**12**)
- Syrups and fruit juices are preferred to heavily sugared liquids, such as sodas (**31**)
- Water, fruit juices, ice cream, popsicles, sport drinks, cold soup/broth, fruits and vegetables high in water content (e.g. melon, strawberries, peaches) (**25**)
- Mineral water or lightly carbonated drinks containing salt, fruit juices, or energy sport drinks (**32**)
- Sport drinks should contain not more than 6-8% glucose or be high in fructose (**42**)
  - higher sugar content slows water absorption (**42**)

Temperature

- Drink regularly sufficient quantities of cool liquid (**31**)
- Cold fluids seem to be absorbed more rapidly from the stomach than those that are warm or room temperature (**42**)
- Avoid very cold drinks (**1, 7, 21, 35, 38, 40**)
  - they may cause stomach cramps (**1, 7, 35, 40**)
  - frozen drinks will diminish the sensation of thirst too quickly (**21**)

Avoid consuming:

- Alcohol (**1, 2, 3, 4, 5, 6, 7, 12, 13, 14, 16, 17, 18, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43**)
  - it has a diuretic effect (**42**)
  - especially beer, which dehydrates the body (**5, 42**)
- Carbonated beverages (**25, 38**)
- Caffeine (**2, 3, 5, 13, 16, 24, 25, 30, 33, 35, 40, 42, 43**)
  - coffee (**25, 29, 30, 32, 38, 41**)
  - tea (**25, 29, 30, 32**)
  - cola (**29, 30, 41**)
  - because of the diuretic effect (**42**)
- Sweet/sugary/very sweet drinks (**2, 12, 16, 43, 33, 35, 40**)
- Both sugar or caffeine (**1, 4, 7, 17, 18, 21, 23, 24, 28, 37**)
- Soft drinks and energy drinks (**42**)
  - they contain high levels of sugar (**42**)
- Mineral water **(38**)
  - tap water is better suited to replacing minerals (**38**)

Quantities:

- 0.5 litres per day extra for every degree over 37˚C of body temperature (**21**)
- ≥ 1 litre per day (**38**)
- ≥ 1.5 litres per day (**18, 32**)
- 1.5 -2.0 litres per day (**21**)
- 1.9 – 4.3 litres per day (**25**)
- ≥2 litres per day (**42**)
- ≥ 2.5 – 5.0 litres per day (**31**)
- Consult your physician if you are on a fluid restricted diet (**5, 32, 33, 42**)
  - for people who have epilepsy or heart, kidney, or liver disease (**5, 42**)
- Do not drink more fluids than you lose in sweat (**16, 40, 42**)
  - risk of hyponatremia (**42**)

Mineral replacement:

- Do not take salt tablets (**3, 5, 6, 14, 26, 36, 42**)
  - if you are on a low salt diet, consult a doctor before taking (**1, 5, 7**)
  - unless instructed to do so by a physician (**5, 24, 42**)
- Replace minerals lost in sweat by consuming (**33, 35, 42**):
  - solid food in small amounts to replace minerals (**21**)
  - a sport beverage (**1, 7, 35, 40**)
    - consult a doctor before drinking a sport drink if you are on a low salt diet (**1, 7, 35, 40**)

What to eat:

Quantities:

- Eat well-balanced small/ light meals (**14, 17, 23, 24, 25, 38, 42, 43**)
  - more often (**5, 24, 29, 38,42**)
  - Regularly **(3, 14**)

Types of food and temperature of food:

- Eat more cold food, salads and fruit (gazpacho,– **37**) (**3, 37, 38**)
- Eat foods that replace lost salt (**12**)
- Eat light, cool, easy to digest foods/ fresh foods such as fruits or salads (**6, 34**)
- Eat foods cool and rich in water: fruits, salads, vegetables, and milk products (**33**)

Do not consume:

- Avoid heavy meals (**4, 6, 7, 24, 26, 28, 34, 38, 41)**
- Avoid protein-rich foods (**5, 24, 26, 29, 35, 42**)
- Avoid hard-to-digest meals (**6**)
- Avoid hot meals (**7, 26, 28**)
- Avoid fatty meals (fried food, fatty meat) (**34, 38**)
- Avoid using cooking ovens (**41**)
- Avoid sugar (**34**)

Other

- In heat waves, food rots more quickly (**32**)
    - thus, avoid perishable items such as cold cuts and prepared salads unless you are certain they are prepared and served fresh (**32**)
    - also avoid milk, butter, fresh cheeses, and cream pastries that are not eaten immediately or that you are not certain are conserved at a cool temperature (<8C) (**32**).
- Do not eat if sufficient water is not available as this will hasten dehydration (**36**).
- For people with difficulty swallowing liquids, eat foods rich in water (fruits and vegetables) or Jell-O (**21).**
- If one eats less than usual, drink more to compensate (**21**).
- 20% of total water intake is through foods (**42**).
- Many fruits and vegetables, such as watermelon and cucumbers, are nearly 100% water by weight. When considering healthy nutrition, fruits and vegetables are always a good choice, including for hydration (**42**)
- Conserve perishables in the refrigerator (**33**)

<u>Air Conditioner Advice</u>

Home Use of air conditioning during hot weather:

- Choose to stay indoors in an environment with air conditioning (**2, 5, 6, 7, 12, 13, 14, 16, 17, 19, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 35, 37, 38, 40, 41, 42, 43**)
    - Only:
        - If you are elderly/vulnerable (**30**)
        - If you become overheated use an air conditioner (**44**)
        - During the hottest times of the day (**44**)
        - In certain (unspecified) circumstances (**21**)

Adjust air conditioning:

- Keep air conditioning 5˚C less than ambient temperature during extreme heat (**21, 31**)
- Between 25˚ to 26˚C (**21**)
- At 25.5˚C (78˚F) (**17**)
- Around 25.6˚C to 26.7˚C (78˚F to 80˚F) when home, 29.4˚C (85˚F) when away (**26**)
- If you have central air conditioning, cool only the rooms you use, but don't close all the vents – it reduces efficiency (**26**)
- Don't switch air conditioning to a colder setting when turning it on, avoid setting at extremes (**26**)

Visiting air-conditioned areas:

- If you have no air conditioning at home, try to spend time in an air conditioned or cool (basement, church, shopping mall, park, beach, or library) environment (**1, 2, 4, 5, 6, 7, 12, 14, 17, 18, 21, 23, 24, 25, 26, 27, 28, 29, 32, 33, 35, 37, 38, 39, 40, 41, 42, 44**)
    - Only if you are ≥ age 60 or have been sick lately (**26**)

Time suggested:

- A few/several hours a day (**2, 5, 7, 12, 18, 21, 24, 26, 27, 31, 32, 40**)
- At least two hours a day (**5, 24, 25, 29, 34, 37**)
- At least two to three hours per day (**18**)
- At least three hours a day (**21, 42**)
- Spending 15-20 minute intervals in air conditioning can help (**26**)

Adverse health effects of cooling off too fast/too much due to air conditioning use:

- Respiratory problems (**21, 38**)
    - Viral or bacterial (**21**)
- Torticollis (**21**)
- Legionnaire's disease – only with central units (**21**)
- Aspergillosis - only among immunocompromised (**21**)

If air conditioning is not available/ If no electricity (blackout):

- Take a cold shower or dip in the pool to cool your body temperature (**44**)
- If air conditioning is not available, stay on the lowest floor, out of the sunshine (**5, 19, 42**)

Physical activity:

- Avoid unnecessary physical activity if you are in a building without air conditioning (**44**)
- Practice physical activity in the shade, indoors in an air-conditioned area, or in a well-ventilated space (**4, 21, 31**)
- Take lots of rest breaks, preferably in the shade or air-conditioned areas (**1, 4, 7, 8, 13, 22, 23, 28, 36**)

Electric appliances:

- Minimise the use of electric appliances (**4, 5, 7, 21, 24, 37**)
    - To reduce the chance of a community wide outage (**5**)
- To conserve energy, use a fan instead of air conditioning (**30**)
- Use fans to substitute or assist air conditioning (**39**)

Obtaining and maintaining an air conditioner:

- Call Human Development Corporation to determine if you are eligible for a free air conditioner (based on income and medical need) (**26**)
- Acquire a fan or even an air conditioner (**21, 26, 28**)
- Keep the air conditioner itself in the shade or build a covering (**26**)

- Install window air conditioner snugly and insulate if necessary (**5, 42**)
- Clean/vacuum air conditioner filters regularly (**21, 26, 33**)
    - at least every 15 days (**21**)
    - weekly during periods of high use (**5**)