



Heat health planning: The importance of social and community factors

Jane Yardley^{a,b}, Ronald J. Sigal^{b,c}, Glen P. Kenny^{a,b,*}

^a Human and Environmental Physiology Research Unit, Faculty of Health Sciences, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5

^b Institute of Population Health, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5

^c Departments of Medicine, Cardiac Sciences and Community Health Sciences, Faculties of Medicine and Kinesiology, University of Calgary, Alberta, Canada T2N 2T9

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ABSTRACT

Extreme heat events frequently have adverse effects on population health. Within every population certain groups and individuals are at a greater risk of heat-related morbidity and mortality than others. While certain physiological characteristics (advanced age, chronic conditions, etc.) are known to increase the risk of illness and/or death during periods of extreme heat, the role of social and community level factors in aggravating or mitigating this risk is poorly understood. This paper reviews the literature on the social and community level factors that affect heat-related morbidity and mortality in order to identify shortfalls in current heat health response plans so that new approaches can be recommended. While social isolation, ethnicity, socioeconomic status, and neighborhood characteristics have all been identified as potential factors affecting the risk of heat-related illness and mortality, these are rarely, if ever, identified as heat health research priorities and are thus often neglected in heat emergency planning. Current research and programming practices are often prioritized from the top down where decisions are made at the federal level and research priorities are determined by national research bodies. This, unfortunately, may not allow enough flexibility to meet the needs of physically, socially and culturally diverse communities. A more socio-ecological approach to heat health research and planning would better allow for the identification of community level vulnerabilities and available resources and would encourage communities to work with regional or national partners to adapt response plans accordingly. The development of future plans should involve more partnerships at the community level so that social and community level factors that are currently overlooked may be included in heat health response strategies.

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1. Introduction

In recent years, increases in environmental awareness have led to a focus on climate change and its potential effects on population health. Lately, we have seen an increase in environmental pollutants, changes in severe weather patterns, and altered distributions of infectious diseases (Portier et al., 2010). Average temperatures, as well as the number of extreme heat events experienced on a yearly basis, have both increased in recent history (Gaffen and Ross, 1998; Sheridan et al., 2009; United Nations, 2006).

In spite of the knowledge that our climate is changing, the full extent to which human health will be affected is still relatively unknown. To address these shortfalls in knowledge, a report by the Interagency Working Group on Climate Change and Health

(IWGCCCH) in the United States recently released a report outlining the research needed to address the human health effects of climate change (Portier et al., 2010). While this report is very thorough in identifying shortfalls in research with respect to environmental sciences, meteorology, physiology, and health administration to name a few, it may not place sufficient emphasis on a few key areas of community level research that could be essential in guiding those responsible for designing and implementing adaptation and mitigation strategies.

Extreme heat, especially if it lasts for consecutive days, can lead to substantial heat-related illness and excess mortality within the population. Some recent studies have shown that heat-related mortality has decreased in recent decades, possibly as a result of technological advancements (i.e., more widespread use of air conditioning, improved urban planning), better access to health care, and the implementation of heat alert systems (Davis et al., 2003; Donaldson et al., 2003; Tan et al., 2007). These decreases, however, seem to have leveled out in recent years, especially in North America (Sheridan et al., 2009), where air conditioning availability is relatively high (US Census, 2008), but the number of susceptible individuals (i.e., older individuals and those with

* Corresponding author at: University of Ottawa, School of Human Kinetics, 125 University, Room 367, Montpetit Hall, Ottawa, Ontario, Canada K1N 6N5.
Tel.: +1 613 562 5800x4282; fax: +1 613 562 5149.

E-mail address: gkenny@uottawa.ca (G.P. Kenny).

chronic diseases) is increasing annually (Kenny et al., 2010; Sheridan et al., 2009). In spite of greater climate control within most buildings, excess mortality during extreme heat events is still being reported, and certain communities as well as certain groups within the population remain both more susceptible and more vulnerable than others (Sheridan et al., 2009; Harlan et al., 2006).

Health-related research in recent decades has increasingly focused on the interplay of the social and physical environments and their synergistic effects on human health (Harlan et al., 2006; Grzywacz and Fuqua, 2000). Models for health and disease now include demographic factors (age, gender, ethnicity), socioeconomic characteristics (income, education), neighborhood features (physical environment, poverty, property ownership) as well as individual beliefs and behaviors (Grzywacz and Fuqua, 2000; Berkman and Glass, 2000). Where the effects of extreme heat events on human health are concerned a complex interplay of physical features (housing quality, urban design), population composition (socioeconomic status, ethnicity, demography) and social characteristics (culture, beliefs and behaviors) will determine the vulnerability and susceptibility of local populations (O'Neill and Ebi, 2007). Thus, the use of a socio-ecological approach may be the most effective way to assess and identify vulnerability through research, and to promote adaptation and mitigation strategies. To fully understand and address the disparities in heat-related morbidity and mortality it will be essential to study not only the geography, air quality, technology and physiology, but also to examine the individual and community social environments that can have a protective or aggravating effect during extended periods of extreme heat.

To find information on this topic, we searched the following bibliographic databases: PubMed from 1966 to October 2010 and Scholars Portal from 1924 to October 2010. Keywords included heat illness; heat stroke; heat injury; heat wave; heat event; heat emergency; socioeconomic status; income; education; ethnicity; poverty; heat health; neighborhood; housing; urban heat island; emergency response and emergency planning. Retained publications included epidemiological studies; case control studies; ecological time-series studies; reviews and commentaries. We also examined reference lists of relevant articles for other appropriate material.

2. Facts about heat waves: the physical variables

Based on the epidemiological literature, some facts are known about how the physical environment affects the outcome of extreme heat events on population health in industrialized nations. Whether or not these trends are the same in developing countries is relatively unknown, as reliable weather and mortality data are often unavailable, life expectancy is much lower, and infectious diseases play a greater role in mortality than they do in developed nations (Hajat et al., 2005). In terms of geography, the minimum mortality temperature (i.e., the threshold value at which heat-related mortality begins to occur) in industrialized countries is generally lower in northern regions or higher elevations resulting in greater mortality at lower temperatures in these areas (Baccini et al., 2008; Kalkstein and Davis, 1989; Medina-Ramon and Schwartz, 2007; Curriero et al., 2002). It is often surmised that this is due to ambient temperatures generally being cooler (thereby precluding physiological adaptation to the heat) and a general lack of city infrastructure designed to provide protection from the heat (Medina-Ramon and Schwartz, 2007). In addition, high temperatures encountered earlier in the summer season, before appropriate physiological adaptations and behavioural responses can be made, tend to result in high rates of heat-related illness and mortality (Diaz et al., 2002; Kalkstein and Davis, 1989).

The built environment can play an especially large role in increasing the risk of heat-related morbidity and mortality. In urban areas, the “Urban Heat Island” effect, produced by a combination of high rise buildings that lower wind speed, construction materials that retain and radiate heat, and waste heat generated by energy usage, leads to higher daytime and nighttime temperatures, resulting in greater rates of heat-related morbidity and mortality in the city than in nearby suburban and rural areas (Fouillet et al., 2006; Gaffen and Ross, 1998; Henschel et al., 1969). In addition to having an increased number of people living in cities, cities are also beginning to spread out more, replacing green space (trees, grass, etc.) with man-made structures. Recent evidence seems to indicate that such increases in urban sprawl may be related to increases in exposure to extreme heat (Stone et al., 2010). Even within individual cities variations in urban development, vegetation and building materials can lead to microclimates which may differentially affect the risk of heat-related morbidity and mortality (Silva et al., 2010; Harlan et al., 2006).

Recent experiences with severe heat events in both Europe and the United States have shown that certain sub-groups within the population are more greatly affected during prolonged exposure to high temperature. The elderly (over 65 years) are the most susceptible, with almost twice as many excess deaths as their younger counterparts (Greenberg et al., 1983; Borrell et al., 2006; Fouillet et al., 2006; Canoui-Poitine et al., 2006; Belmin et al., 2007; Diaz et al., 2002; Ishigami et al., 2008; Kenny et al., 2010; Smoyer et al., 2000; Yu et al., 2010). Underlying health conditions such as cardiovascular diseases, diabetes, and pulmonary diseases are also associated with a much greater risk of morbidity or mortality during heat events, regardless of the age of the individual (Bouchama et al., 2007). While there is still a great deal to learn, the known physiological explanation for the increase in heat-related mortality risk with these physical conditions has recently been reviewed elsewhere (Kenny et al., 2010). What is often neglected is an examination of how social and economic conditions, as well as the neighborhood environments in which people live, may also affect individual health in the face of both short and extended periods of elevated temperature.

3. Social factors affecting heat-related mortality – the current state of research

In recent decades, studies have found spatial trends within the distribution of heat-related excess mortality (Canoui-Poitine et al., 2006; Martinez et al., 1989), indicating that heat-related mortality is affected by more than just temperature and physiology. This has led to an examination of why clusters of deaths should be found in certain cities, census tracts, or neighborhoods. This question can probably best be answered within the context of a social ecological framework that examines not only the individual physiological risk factors of those inhabiting places where morbidity and mortality are high, but also scrutinizes the physical, social and economic characteristics of the places in which they live.

3.1. Social isolation

It has been argued that one of the reasons why heat waves receive less attention than other natural disasters in spite of claiming more lives is that many of the victims of extreme heat live isolated lives on the fringes of society (Klinenberg, 2002). The few studies that have examined the impact of social isolation as a risk factor in heat-related death may even underestimate the strength of this variable: the most isolated deceased individuals are often excluded from analyses out of necessity when investigators cannot

find an appropriate surrogate to provide information (Semenza et al., 1996). Poverty, ethnicity, mental illness, and increasing awareness of violent crime are among the myriad factors contributing to the growing number of individuals living in social isolation (Klinenberg, 2002).

Lack of social contact has been recognized by several studies as a major risk factor for heat-related mortality (Bouchama et al., 2007; Klinenberg, 2002; Naughton et al., 2002; Semenza et al., 1996). In a meta-analysis of observational studies examining both the risk and protective factors in heat-wave related deaths, not leaving home daily was associated with a significantly increased risk of dying during periods of extreme heat (OR 3.35; CI 1.6–6.9) while higher levels of social contact provided a protective effect (OR 0.4; CI 0.2–0.8) (Bouchama et al., 2007) (Table 1). Three separate examinations of the Chicago 1995 heat wave listed living alone as one of the main risk factors for mortality (Semenza et al., 1996; Naughton et al., 2002; Klinenberg, 2002), while being involved in group activities and having friends in the city (or even a pet in the household) were both determined to have protective effects (Semenza et al., 1996; Naughton et al., 2002). Not being married, which was used as a proxy of living alone, was also found to be a contributing risk factor for mortality during the 2003 heat wave in France (Canoui-Poittrine et al., 2006).

While living alone should not be equated with social isolation, changes in the social and built environments may have led to an increase in the number of people living alone, who are also socially isolated. There has been an increase in recent years in the number of individuals, especially seniors, who live alone (Kramarow, 1995). Higher perceived rates of violent crime due to media coverage may have created an atmosphere of fear where many people do not feel comfortable leaving their homes, especially if they must do so on their own (Klinenberg, 2002). There has also been a trend towards the decreasing availability of safe public spaces and supported housing arrangements, thereby decreasing the availability of social contact for many vulnerable individuals (e.g., senior citizens, individuals with mental illness) (Klinenberg, 2002).

3.2. Ethnicity

There are very few recent studies that examine ethnicity as a risk factor when examining heat related death. Several available sources are quite dated making it difficult to assess whether or not trends that have been found in past literature still hold today. In addition, several authors note that differences in mortality are probably due to social and economic disparity (which will be discussed in Section 3.3), rather than to ethnicity itself.

Ethnicity has been examined as a risk factor for heat-related morbidity and mortality only in the United States (Greenberg et al., 1983; Jones et al., 1982; Ellis, 1972; Martinez et al., 1989; Henschel et al., 1969; Schuman, 1972; Schwartz, 2005). For the most part, these studies have shown that white individuals fare better than non-white individuals when exposed to extreme heat. The size of the disparity, however, has varied among studies. An analysis of longitudinal temperature and mortality data from the 1950s and 1960s indicated that the incidence of heat deaths in non-white people was roughly twice that of white people in the United States (Ellis, 1972). In examining several years of American temperature and mortality data where only “deaths due to excessive heat” were included in the analysis, one study found that the death rate for white individuals from heat-related ailments was 2.42 per 100,000, while those classified as non-white had a death rate of 20.25 per 100,000, just over eight times higher than their white counterparts (Martinez et al., 1989). It should be noted, however,

that poverty rates were also higher among the non-white groups in the studied areas.

When individual heat events were studied, relationships between ethnicity and heat-related mortality were also found. Age-adjusted death rates among heavy laborers during a 1980 heat wave in Texas, for example, were found to be 0.8 per 100,000 for white and Hispanic individuals, approximately one third of the rate of 2.1 per 100,000 found for black individuals (Greenberg et al., 1983). The same study noted that a comparison group showed a similar rate of non-heat related deaths for black individuals performing heavy labor during the same year, leading the authors to question whether socioeconomic status may have been more of a factor than ethnicity. Meanwhile, during a heat wave in St. Louis and Kansas City, Missouri that same year, age-adjusted heat stroke rates were found to be up to six times higher for non-white individuals than they were for white individuals (Jones et al., 1982). Similar to the Texas study, this analysis concluded that socioeconomic status was probably a significant factor in the differences between groups. Where the opposite outcome has been found, such as during the Chicago heat wave of 1995 where a mortality rate of 17 per 100,000 was calculated for white individuals, and only 11 per 100,000 for those who were black (Klinenberg, 2002), the community social environment, which will be discussed in more detail in Section 3.4, seems to have played an important protective role.

When comparisons are made among census tracts within a city, or between cities, a great deal of variation is found. During the July 1966 heat wave in St. Louis, predominantly white (less than 25% of the population was non-white) census-tracts had an incidence of heat deaths of 25 per 100,000, while the incidence in the tracts housing a greater percentage of black individuals (>50%) was 32 per 100,000 (Henschel et al., 1969). It is also noted by the authors that the higher death rates in these areas are more likely due to overcrowding, poorer housing conditions, lower economic status and poorer general health of the individuals inhabiting them, rather than being evidence that nonwhite individuals may be less tolerant to heat.

More recently, an analysis of temperature related-mortality in California found that while the death rate among black individuals was higher than that of white and Hispanic individuals, the differences were not statistically significant (Basu and Ostro, 2008). Significant differences were found in data comparing heat-related mortality in 7 different U.S. cities showing that at temperatures over 29 °C, the percentage change in daily mortality for black individuals was twice that for white individuals when data were pooled (O'Neill et al., 2003). It is interesting to note that when cities were examined individually in the same study, black individuals had a lower percentage change in mortality than white individuals in New Haven, Connecticut (6.8% for black individuals vs. 7.9% for white individuals), but saw almost eight times more deaths in Minneapolis, Minnesota (17.0% vs. 2.3%) (O'Neill et al., 2003). This seems to provide evidence that local characteristics (both physical and social) could be confounding the analysis of heat-related mortality data where ethnicity is concerned.

There is no evidence to indicate that white individuals have any different physiological heat loss responses than black individuals that would provide them with an advantage when exposed to extreme heat. This, combined with the fact that the presence and size of ethnic disparity in heat-related mortality varies from city to city, seems to indicate that the higher mortality rates associated with being non-white are related to other social and environmental factors. When included in multi-level analyses, income and education tended to have stronger effects than race, indicating that socioeconomic factors probably play a more important role than ethnic ones (O'Neill et al., 2003; Jones et al., 1982).

Table 1

Social risk factors for heat-related morbidity and mortality.

Social factor	Source	Type of study	Risk	Comments
Social isolation	Semenza et al. (1996)	Case-control	OR: 2.3 (95% CI: 1.4 to 3.5)	Compared people who died during the 1995 Chicago heat wave (cases) to age- and neighborhood-matched controls who did not die
	Kaiser et al. (2001)	Case-control	OR: 7.6 (95% CI: 0.9 to 355)	17 residents of Cincinnati, OH who died during the 1999 heat wave (cases) and 34 neighborhood-matched controls
	Naughton et al. (2002)	Case-control	OR: 8.1 (95% CI: 1.4 to 48.1)	Compared 63 people who died in the 1999 Chicago heat wave with 77 neighborhood-and-age-matched controls
	Canoui-Poitaine et al. (2006)	Case-control	OR: 1.63 (95% CI: 1.23 to 2.15)	Compared characteristics of individuals ($n=961$) dying at home during the 2003 heat wave in France to those who died at home during the same time frame in non-heat wave years. Not being married used as a proxy for social isolation. Adjusted for age, sex, nationality, and activity level
Low income	Bouchama et al. (2007)	Meta-analysis	OR: 3.35 (95% CI: 1.6 to 6.9)	Meta-analysis of case-control studies. Social isolation defined as not leaving home daily
	Naughton et al. (2002)	Case-control	OR: 3.1 (95% CI: 1.0 to 9.7)	Compared 63 people who died in the 1999 Chicago heat wave with 77 neighborhood-and-age-matched controls
	Kaiser et al. (2001)	Case-control	OR: 8.2 (95% CI: 0.9 to 393)	Low Income was defined as <\$10,000 US 17 residents of Cincinnati, OH who died during the 1999 heat wave (cases) and 34 neighborhood-matched controls. Low income defined as household income <\$10,000
Low education	O'Neill et al. (2003)	Poisson regression modeling study	Excess risk ^a on hot days High school or less: 6.9% (95% CI: 1.2 to 12.9) More than high school: 2.9% (95% CI: -3.0 to 9.3)	Daily death count across 7 major US metropolitan areas was the dependent variable in Poisson modeling study regression, with daily "apparent temperature" and other risk factors entered as independent variables in order to determine excess risk on hot days
Socio-economic status	Jones et al. (1982)	Case-control	Heat stroke risk on hot days by SES: High: 8.1/100,000(SL), 6.5/100,000(KC) High middle: 19.6/100,000 (SL), 6.3/100,000 (KC) Low middle: 44.5/100,000 (SL), 23/100,000 (KC) Low: 55.8/100,000 (SL), 36.5/100,000 (KC)	Compared heat stroke rates in St Louis (SL) and Kansas City (KC) during 1980 heat wave to same (SES) period in 1978 and 1979 where there was no heat wave. Socioeconomic status defined by census tract based on median school years completed, proportion of housing units with > 1.01 persons/room, and proportion of families living below poverty level
Ethnicity	O'Neill et al. (2003)	Poisson regression modeling study (Kaiser et al., 2001)	Excess risk on hot days: Black: 14.0% (95% CI: 10.7 to 17.3) White: 9.9% (95% CI: 6.6 to 13.6)	Daily death count across 7 major US metropolitan areas was the dependent variable in Poisson regression, with daily "apparent temperature" and other risk factors entered as independent variables
	Greenberg et al. (1983)	Observational	Mortality rate during heat wave: Black: 2.1/100,000 White: 0.8/100,000	Observational analysis based on death certificate information
	Jones et al. (1982)	Case-control	Heat stroke risk on hot days: Non-white: 43.2/100,000 White: 15.1/100,000	Compared heat stroke rates in St Louis (SL) and Kansas City (KC) during 1980 heat wave to same period in 1978 and 1979 where there was no heat wave
	Henschel et al. (1969)	Observational	Mortality rate during heat wave: Black: 32/100,000 White: 25/100,000	Observational data compiled from hospital records and death certificates
	Schuman (1972)	Ecological time series	% increase in mortality (NY) Nonwhite: 20% White: 39% (SL) Nonwhite: 119% White: 41%	Comparison of patterns of heat wave mortality in New York (NY) and St. Louis (SL) during 1966 heat wave as versus a comparable non-heat wave period
	Schwartz (2005)	Case-only	Non-white OR: 1.22 (95% CI: 1.09 to 1.37)	Compared odds of dying on a hot day (temperature in top 1%) versus other days, among people over age 65 in Detroit, MI with non-white origin and previous cardiac or pulmonary admissions
Air conditioning	Naughton et al. (2002)	Case-control	OR: 0.2 (95% CI: 0.1 to 0.7)	Compared 63 people who died in the 1999 Chicago heat wave with 77 neighborhood-and-age-matched controls
	Semenza et al. (1996)	Case-control	OR: 0.2 (95% CI: 0.2 to 0.4)	Compared people who died during the 1995 Chicago heat wave (cases) to age- and neighborhood-matched controls who did not die
	Kaiser et al. (2001)	Case-control	OR: 0.03 (95% CI: 0 to 0.2)	17 residents of Cincinnati, OH who died during the 1999 heat wave (cases) and 34 neighborhood-matched controls
Housing	Bouchama et al. (2007)	Meta-Analysis	OR: 0.23 (95% CI: 0.1 to 0.6)	Meta-analysis of case-control studies
	Naughton et al. (2002)	Case-control	Living on top floor: OR: 4 (95% CI: 1.7 to 9.3)	Compared 63 people who died in the 1999 Chicago heat wave with 77 neighborhood-and-age-matched controls

Table 1 (Continued)

Social factor	Source	Type of study	Risk	Comments
	Semenza et al. (1996)	Case-control	Living in a dwelling with 2 rooms or less: OR: 3.4 (95% CI: 1.5 to 7.9)	Compared people who died during the 1995 Chicago heat wave (cases) to age- and neighborhood-matched controls who did not die
Access to transportation	Semenza et al. (1996)	Case-control	OR: 0.4 (95% CI: 0.2 to 0.6)	Compared people who died during the 1995 Chicago heat wave (cases) to age- and neighborhood-matched controls who did not die

CI, confidence interval; OR, odds ratio.

^a Excess risk: observed cases during heat wave minus expected cases in same population during non-heat-wave comparison periods, expressed as a percentage of expected cases during non heat-wave comparison periods.

3.3. Socioeconomic status

In examining mortality rates from various heat events in industrialized countries in recent decades, it has been noted that individuals of lower socioeconomic status (SES) may be at greater risk of morbidity and mortality (Naughton et al., 2002; Schuman, 1972; Greenberg et al., 1983; Jones et al., 1982; Borrell et al., 2006; Chestnut et al., 1998; Curriero et al., 2002; Medina-Ramon et al., 2006; O'Neill et al., 2003; Michelozzi et al., 2005). These studies have used various proxies for SES including income (Naughton et al., 2002; Smoyer et al., 2000; Curriero et al., 2002), education (Borrell et al., 2006; Michelozzi et al., 2005; O'Neill et al., 2003; Chestnut et al., 1998; Medina-Ramon et al., 2006), population density and/or crowding and various deprivation indices (either by neighborhood or by census tract) that attempt to include all of these factors (Jones et al., 1982; Schuman, 1972; Canoui-Poittrine et al., 2006). The fact that SES is represented in so many different ways can make it difficult to compare across studies. While the strength of the relationship varies between studies and among cities or neighborhoods within studies, the link between low SES and heat-related mortality is generally present.

The IWGCCH report on the health impacts of climate change identifies poverty as a crosscutting issue for climate change and health (Portier et al., 2010), although identifying why this is the case, or how the risk in this group can be mitigated receives minimal attention in the description of the research needs. Indeed, studies examining the distribution of heat-wave morbidity and mortality within various cities have noted that there is often a greater concentration of hospital admission and excess deaths in lower income areas (Jones et al., 1982; Schuman, 1972; Canoui-Poittrine et al., 2006). Data from the 1980 heat wave in St. Louis and Kansas City, MO show that age-adjusted heat stroke rates were six times higher for those living in the lowest SES census tracts (ranked according to income, education and crowding) compared to those in high SES areas (Jones et al., 1982). A similar relationship was also found in Paris during the 2003 heat wave, where a gradient of excess deaths was seen to increase from the economically favored zones of the city to the more deprived neighborhoods (Canoui-Poittrine et al., 2006).

At the household and individual level, several studies using income as a marker of low SES have found an inverse relationship between income and the risk of heat-related mortality (Curriero et al., 2002; Naughton et al., 2002; Smoyer et al., 2000). Using a combination of census and weather data in random-effects linear regression models, one study estimated that, in the United States, every 10% increase in poverty is associated with approximately a 4.3% increase in mortality risk for every 10 degree Fahrenheit increase above the minimum mortality temperature for each region (Curriero et al., 2002). An assessment of mortality data from the Chicago heat wave in 1995 also showed that those living below the poverty level (i.e., annual income of less than \$10,000) were indeed at a greater risk of dying than those of similar age living in the same neighborhood [Odds Ratio 3.1 (CI 1.0–9.7)] (Naughton et al., 2002).

Where education was used as an indicator of SES, the same relationships were often found (Borrell et al., 2006; Michelozzi et al., 2005; O'Neill et al., 2003; Chestnut et al., 1998; Medina-Ramon et al., 2006). During the European heat wave of 2003, low educational attainment was associated with greater excess heat-related mortality in two separate studies (Borrell et al., 2006; Michelozzi et al., 2005). The same trend was found in many U.S. cities when longitudinal temperature and mortality data were examined: greater heat-related mortality was found among those with lower levels of education (i.e., high school or less), while more years of schooling seemed to provide a protective effect (Medina-Ramon et al., 2006; Chestnut et al., 1998; O'Neill et al., 2003; Curriero et al., 2002).

In interpreting these findings, most authors agree that the protective effects of both income and education are probably related to the location and quality of housing that these individuals or groups can afford. In many instances, the urban poor, including the homeless, are clustered in developed areas within the city, where the built environment of concrete and asphalt lead to higher daytime and night-time temperatures (the Urban Heat Island Effect) than in the surrounding, often more densely vegetated, suburbs (Clarke, 1972; Smoyer et al., 2000; Jones et al., 1982; Henschel et al., 1969). Inner city housing often consists of multi-unit buildings and greater population density, both of which are thought to increase the risk of heat-related mortality (Chestnut et al., 1998; Jones et al., 1982; Clarke, 1972). Living in an older house, a lower quality house, or on the upper levels of a multi-unit building have also been associated with greater mortality during hot weather (Chestnut et al., 1998; Naughton et al., 2002).

The inability to afford air conditioning may be a major factor that impacts low income individuals and groups during periods of extreme heat. Air conditioning has long been recognized as one of the greatest protective factors against heat-related mortality (Kaiser et al., 2001; Naughton et al., 2002; Rogot et al., 1992; Semenza et al., 1996). Having a working home air conditioner, or access to an air-conditioned environment for part of the day during extreme heat events, can significantly reduce the risk of heat-related morbidity and mortality [Odds ratio 0.23 (CI 0.1 to 0.6)] (Bouchama et al., 2007). One study concluded that more than half of the race-related differences in heat mortality (from 1986 to 1993 in four different cities) could be attributed to the greater prevalence of air conditioning among the white population in comparison to the black population (O'Neill et al., 2005). It has been estimated that every percentage increase in home air conditioning availability could lead to a decrease of at least 1.14 heat-related deaths per year (Davis et al., 2003). Unfortunately, the most socially and economically disfavored group, the homeless, often have limited or no access to shelter from the sun, let alone to air conditioned environments.

While the prevalence of air conditioners has increased (especially in the United States) (US Census, 2008), so has the cost of the electricity required to run them (Kovats and Hajat, 2008). The simple fact of owning an air conditioning unit does not mean that running the unit will be affordable. A study of elderly

adults in Canada and the United States concluded that income was a limiting factor in whether or not home air conditioning units were actually used during periods of extreme heat (Sheridan, 2007). Where senior citizens are at a greater risk for heat-related mortality and are often on a fixed income, the rising cost of electricity (and therefore home air conditioning), should be a cause for concern.

Another interesting finding is that lower SES has been strongly associated with dying outside of a hospital during extreme heat events (Medina-Ramon et al., 2006; Kovats et al., 2004). One possibility suggested by the authors of these studies is that many people delay seeking medical attention when experiencing heat stress. In some countries, this may simply be due to the prohibitive costs associated with health care. An alternate explanation is that access to transportation may be limited for low income individuals, thereby preventing them from accessing health care. There is also evidence to indicate that more affluent individuals and groups may have better access to health care services than those who are less privileged (Lasser et al., 2006). Cardiovascular disease, an important cause of out-of-hospital death during heat waves due to its sudden onset (Linares and Diaz, 2008), has also been found to be more common among individuals in the lower socioeconomic strata (Karlamangla et al., 2010). Finally, as has already been mentioned, those who live alone and who are socially isolated may not recognize the need for medical attention until it is too late for them to seek treatment without assistance, where assistance is generally unavailable to them (Klinenberg, 2002).

Many of these studies must be interpreted with caution. If heat-related mortality (as assessed by cause of death in coroner's reports) is used in the analysis instead of excess mortality, the effect of the heat may be severely underestimated, as many deaths will be attributed to the underlying chronic diseases that can exacerbate heat illness rather than the heat itself (Ellis, 1972). While some studies control for activity levels and underlying health conditions, many do not, and therefore overlook several confounding factors: in North America and many Western European countries, several studies have shown that socioeconomic status is related to overall health, where those having relatively higher income and social standings have better overall physical and mental health (Wilkinson, 1996). Individuals in the lower socioeconomic strata often have greater rates of obesity (Mclaren, 2007) as well as chronic diseases (Marmot et al., 1991; Loucks et al., 2009) which will increase their risk of morbidity and mortality in the face of extreme heat exposure (Kenny et al., 2010). Rates of physical activity and general levels of physical fitness are known to provide protection against heat-related ailments and are also directly correlated to socioeconomic position throughout the life course (Cleland et al., 2009).

Some studies, however, have not found a significant relationship between socioeconomic status and the risk of heat-related mortality (Ishigami et al., 2008; Basu and Ostro, 2008). A study examining temperature-related mortality in London, Milan, and Budapest found that deprivation (a proxy for socioeconomic status determined using the Multiple Deprivation Index for each Census Area Statistic Ward) did not seem to increase the risk of death due to heat exposure (Ishigami et al., 2008). A recent study of temperature-related mortality in Brisbane, Australia found that the relationship between mean daily temperature and all-cause mortality was modified by age and gender, but not by socioeconomic status (Yu et al., 2010). The authors do suggest, however, that the combination of greater social homogeneity in Australia than in other countries previously studied as well as the heterogeneous composition of the statistical local areas being examined may have contributed to the lack of effect modification by SES (Yu et al., 2010). It is also interesting to note that some low-income neighborhoods within census tracts may fare better than

nearby neighborhoods of similar socioeconomic and ethnic composition (Klinenberg, 2002). The presence of heterogeneity in the risk of heat-related death among similar communities and cities experiencing the same environmental stresses indicates that community level factors play an important role, and should be looked at more closely.

3.4. Neighborhood characteristics

Some of the inconsistent findings with respect to the influence of income, education, and race on the risk of mortality during extreme heat may be related to community and neighborhood level factors (both physical and social) that can either alleviate or exacerbate hot weather effects (Smoyer, 1998; Klinenberg, 2002). An examination of microclimates in eight different neighborhoods of the same city showed that lower SES groups and ethnic minority groups were more likely to live in neighborhoods where high settlement density, sparse vegetation, and limited open space created higher temperatures (Harlan et al., 2006). Conversely, where studies have found decreases in heat-related mortality in recent years, credit has often been given to improvements in urban planning, including increasing access to water, creating more shaded public areas and enhancing the levels of vegetation in the urban environment (Davis et al., 2003).

Aside from community infrastructure, several social characteristics that often defy quantification (knowing one's neighbors, formal and informal social clubs, population turnover, community safety and walkability) may also play a role in determining mortality rates during hot weather (Klinenberg, 2002; Smoyer, 1998). An in-depth social analysis of heat-related mortality performed after the 1995 heat wave in Chicago compared neighboring communities having similar residential concentration, poverty levels, and number of individuals living alone, in order to determine why one community had ten times the death rate than its neighbor during the heat wave. There were some ethnic differences in the community composition (the high risk community was composed predominantly of black residents, while the low risk community's inhabitants were mostly Latino) but the proximity to friends and family, which is known to be a protective factor during heat waves (Semenza et al., 1996), was similar for both groups (Klinenberg, 2002).

The answer seemed to lie in how the communities themselves differed in their commercial and economic development, which in turn affected the social environment (Klinenberg, 2002). The high risk community had slowly lost many of its businesses over the years and had also lost many of its residents, leaving several abandoned buildings and empty lots. With few or no local amenities, as well as crumbling infrastructure, fewer people ventured out into the streets. Vacant lots with dense weed coverage also proved to be an ideal setting for gangs and drug dealers, leading to an increase in crime in the neighborhood. Residents admitted to being afraid for their safety and, as a result, left home rarely. Several elderly residents also claimed that living on higher (and therefore hotter) floors felt safer than living on ground floors and expressed anxiety at the thought of leaving windows open, for fear of being robbed. Even during the heat wave, many individuals did not leave home daily, resulting in a high rate of heat-related casualties (Klinenberg, 2002).

In the neighboring low-risk community the main street was lined with a multitude of businesses, and was generally teeming with people, providing both commercial and social outlets for the residents of the community. The proximity of amenities encouraged people (even the very elderly) to leave home daily and to feel safe running errands on foot. The constant presence of people on the street may have contributed to the lower crime rates in the area, and consequently a greater feeling of security among the

residents. During the heat wave, many of the elderly residents, who were already in the habit of leaving their homes daily, simply stayed longer in local air-conditioned businesses or sat outside in shaded areas to take refuge from the heat (Klinenberg, 2002).

While very few studies have qualitatively examined how community social structure affects heat-related mortality, some similar trends were found for summer mortality over a four year period in St. Louis (Smoey, 1998). Lower mortality rates were found for neighborhoods where the population was stable (few people moving in or moving out), fewer units were vacant, and where more of the housing units were owner occupied (Smoey, 1998). It has been surmised that similar factors (i.e., a large proportion of public housing, a small proportion of owner-occupied dwellings, a greater number of households living in apartments) may have contributed to substantially greater excess mortality in London, when compared to the rest of England and Wales, during a 1995 heat wave, in spite of the fact that the average age of Londoners was younger.

3.5. Significance to public health

It is apparent from the literature that the effects of heat events on human health are dependent on the interaction of several factors. The physical environment in which individuals live (in terms of both geography and urban development) will have an effect on the temperature or microclimate to which they may be exposed. Environmental exposures may in turn be related to individual socioeconomic factors, as the type of community in which individuals dwell (housing quality, vegetation, etc.) is often related to their income and education. Social, cultural and economic characteristics of the community in which they reside can also affect individual behaviour in terms of social contact, leaving home, visiting air conditioned environments, or even opening windows. As a result, to fully understand the complex interaction of factors affecting heat-related morbidity and mortality, an interdisciplinary, multi-level approach to research will be essential to provide the information necessary for effective heat health planning and community adaptation.

4. The current state of planning and prevention

As a result of past heat events, in particular the experiences of Chicago in 1995 and Europe in 2003, a number of countries, regions and communities both in North America and in Europe have implemented heat health watch systems and emergency response plans in order to prevent further heat-related disasters. For the most part these have several things in common. All plans involve a threshold temperature at which the emergency response is initiated (Kalkstein et al., 1996; Koppe et al., 2004; Kosatsky et al., 2005; Fouillet et al., 2008). There is widespread use of television and radio to announce the heat warnings, and to provide practical advice on how to stay safe during hot weather (Kalkstein et al., 1996; Koppe et al., 2004; Kosatsky et al., 2005; Fouillet et al., 2008). Several plans also involve a telephone hotline individuals can call for information or assistance (Kalkstein et al., 1996; Kosatsky et al., 2005), cooling centres where the public can access air conditioning (Kalkstein et al., 1996; Koppe et al., 2004; Kosatsky et al., 2005) and an increase in the availability of emergency responders on days where the temperature is predicted to exceed the pre-determined threshold (Kalkstein et al., 1996; Koppe et al., 2004). It is also commonly recognized that the elderly are extremely susceptible to heat-related ailments, and measures are taken to ensure that institutions for the elderly and the medical personnel who care for them are adequately prepared (Koppe et al., 2004; Kalkstein et al., 1996; Fouillet et al., 2008; Kosatsky et al., 2005).

Meanwhile, several at-risk regions and cities still have not developed or implemented heat health emergency response plans. A 2004 study in the United States showed that of 18 cities identified as “at risk” one third had no stand-alone heat response plan, and at least one third of the 10 plans that existed were deemed to be cursory (Bernard and Mcgeehin, 2004). Similarly, a report released by the World Health Organization in Europe found that only 15 of the 45 countries approached with questionnaires declared that they had a heat health warning system or emergency plan in place (Koppe et al., 2004). More recently, O'Neill et al. found that when 70 of 285 communities responded to a survey about local government programs to prevent heat-related health problems in the United States, only 30 communities had established prevention programs (O'Neill et al., 2010). The authors identified the need for new partnerships and financial resources so that local action to prevent adverse health consequences of climate change could be better supported.

There are several common criticisms of existing warning systems and emergency plans. The first of these generally involves the choice of the temperature threshold at which a heat emergency should be announced. In many instances the thresholds are arbitrary, and are applied across numerous cities in spite of the fact that the response to heat may vary across regions, between cities within the same region (Kalkstein and Sheridan, 2007) or even within the same city (Harlan et al., 2006). In Europe, it was found that of the 15 countries who have warnings systems in place, eight use temperature alone and do not consider humidity, and most plans are concerned only with the daily maximum temperature (Koppe et al., 2004), when elevated night-time temperature has been shown to be as great a risk factor (Kalkstein and Davis, 1989).

Bassil and Cole (2010) examined the effectiveness of several current heat health response plans in North America and Western Europe by reviewing peer-reviewed literature, grey literature, and non-published sources including conference proceedings, government documents, theses, working papers and reports (Bassil and Cole, 2010). They reported that several common themes emerged as a result of this process. The first of these is that the general public surveyed currently seems to be aware of heat events and alerts when they occur, but these reports often do not include the most vulnerable groups (homeless, isolated elderly, etc.), making it difficult to assess whether or not these groups are actually being reached. They also noted that awareness of heat events has generally not led to changes in behaviour, possibly due to at risk groups, such as the elderly, not having an appropriate awareness of their vulnerability. The review concluded that heat related interventions are, for the most part, underdeveloped, and that a greater investment is needed to improve program and policy development and evaluation (Bassil and Cole, 2010).

For the most part, heat emergency plans continue to neglect the poor and the socially isolated (Bassil and Cole, 2010). In an examination of European heat health warning systems, Kovats and Ebi (2006) found that while media announcements, telephone help lines and cooling centres were often widespread, outreach visits to homebound vulnerable persons or the homeless, as well as evacuation of these individuals to cooling centres, was rarely practiced. The same trends were found with North American response plans, where the homeless, the disabled and those with chronic conditions were generally overlooked in the majority of heat wave response plans that were examined (Bernard and Mcgeehin, 2004). Bernard et al. (Bernard and Mcgeehin, 2004) also noted the limited benefit of cooling centres for the most vulnerable individuals who had neither assistance nor transportation available in order to gain access to them. Notable exceptions to this described in the literature include the Philadelphia heat response plan which incorporates daytime outreach to the homeless (Kalkstein et al., 1996), the Arizona Department of

Health Services Heat Health Plan, which includes provisions to increase outreach to the homeless (especially in the downtown core) as well as to provide transportation and cooling shelters during extended heat events, (Arizona Department of Health Services, 2006) and the Toronto plan where street patrols provide the homeless with bottled water and subway tokens in order to access the available cooling shelters (Kosatsky et al., 2005).

4.1. Recommendations for Improvement

4.1.1. Research

The need for evidence-based health protection advice and programming during periods of extreme heat has been identified by many (Hajat et al., 2010; Ebi and Semenza, 2008; O'Neill and Ebi, 2009). To date, a great deal of the research has tended to take a hard science, top-down approach, which is necessary for certain aspects of heat-related public health, including the development of predictive climate models, pathogen surveillance, land use policies, water supply, air quality and electricity availability. This approach, however, has a tendency to overlook the socioeconomic and community level factors that are known to influence health and may play major roles in either increasing or alleviating the risk of heat-related injury and illness.

There is sufficient evidence to indicate that a social ecological approach to heat health research is necessary, as a variety of physical, physiological, social and environmental factors play roles in heat-related morbidity and mortality, leading to a great deal of variability in health outcomes among communities. With this in mind, it would seem reasonable that more resources should be dedicated to researching how community level factors (both social and physical) affect local populations during heat events. This will necessitate community level collaboration, as services and groups within the smaller geographic areas are better placed to evaluate the needs of those living nearby and are better able to understand the constraints of providing services within their particular community.

The recent IWGCC report does indeed identify the need to determine community characteristics that may make their residents either more vulnerable or more resilient to the adverse health impacts of heat waves, among its research priorities for heat-related morbidity and mortality (Portier et al., 2010). What it fails to do, however, is clarify how community level research efforts can and should be supported through the variety of agencies tasked with this type of research including the Centers for Disease Control and Prevention, the National Institutes of Health and the Environmental Protection Agency. It will be necessary for these agencies to establish and implement a standard definition of heat-related health outcomes as well as methodologies for surveillance and program evaluation (Portier et al., 2010), while at the same time collaborating with communities to develop population-specific plans adapted to their particular physical and social environments. Such a multi-level interdisciplinary approach is not a new idea and has already been successfully applied in other areas of public health (One Health Initiative, 2008).

Communities will also evolve in terms of economic and commercial development, modifying both the social and physical environments over time. These changes, combined with shifts in demographics, have the potential to alter the vulnerable and susceptible components of both neighborhoods and cities. For this reason, research priorities should also include plans not only to develop, implement and evaluate heat health response plans at the community level, but also to re-evaluate community needs on a regular basis.

4.1.2. Community adaptation programming

As cities and neighborhoods vary in the composition of their population, their built environments, and their physical and social

amenities, so too should the heat-related emergency response plans that are put in place to protect their residents. The World Health Organization's "Report on Heat Wave Risks and Responses" recommends that plans reflect local needs and make use of local available infrastructure (Koppe et al., 2004). Planning and programming for heat-health protection will likely be most effective if performed in a bottom-up and community-specific manner.

Similar to the research, heat health adaptation programming should be a collaborative effort among multiple levels of government and various community stake holders. Federal and regional involvement will be necessary both in terms of funding, as well as in the implementation of strategies involving air and water quality as well urban development and land use. In developing community-specific action plans, municipal governments should be charged with engaging local stakeholders (community centres, health centres, hospitals, clinics, volunteer groups, transit officials, schools, emergency services, etc.) so that accurate needs assessments can be performed by those living and working in the communities themselves. This approach will allow each community to assess its own assets and vulnerabilities in order to produce an adaptation plan that addresses these.

A more community-oriented, social ecological approach to heat emergency planning would have several advantages. The most evident of these would be to recognize the interaction of multiple factors that create vulnerability, and to adapt the plan to the social, physical and economic circumstances of the residents: an inner city community with high rates of homelessness, poverty, overcrowding, and substandard housing where daytime temperatures are likely to be increased by the Urban Heat Island effect will have very different needs from those residing in an affluent, verdant suburb where temperatures may actually be lower, air quality better, and air conditioning far more widespread. Local variability among the response plans will allow specific vulnerable groups within each area to be targeted, with assistance being provided by those who already live and work in the same community. Collaboration among the various levels of government will be necessary in order to ensure that the needs of residents in diverse communities are met. Evaluation of the programs will also be facilitated, as those in the community responsible for planning and implementing the emergency response will most likely be involved in the service deliveries, giving them a perspective on their effectiveness as well as on which areas to improve.

5. Conclusions

With so many factors influencing the risk of heat-related illness, injury and mortality, it is difficult to know which ones play the greatest roles or to predict how these will interact to affect human health. As such, it is also difficult to assess where an intervention will be most effective. The inconsistency of the findings in heat-related mortality across cities, census tracts and neighborhoods would seem to indicate that community level economic, physical and social factors may play a role in mediating the effects of heat on human health. A more social-ecological approach to heat health research and planning recognizes the interaction of multiple factors that can alleviate or aggravate heat-related morbidity and mortality. Having groups and services within individual communities assess the needs of their local residents as well as tools available to them will allow for the production of the most effective emergency plans for responding to extreme heat events.

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Competing interests

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