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Climate change and temperature extremes: A review of heat- and cold-related morbidity and mortality concerns of municipalities

Carina J. Gronlund[a,*], Kyle P. Sullivan[b], Yonathan Kefelegn[c], Lorraine Cameron[c], Marie S. O'Neill[b]

[a] University of Michigan Institute for Social Research, 426 Thompson St., Ann Arbor, MI 48104, United States
[b] University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109, United States
[c] Michigan Department of Health and Human Services, 333 S. Grand Avenue, Lansing, MI 48913, United States

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ABSTRACT

Cold and hot weather are associated with mortality and morbidity. Although the burden of temperature-associated mortality may shift towards high temperatures in the future, cold temperatures may represent a greater current-day problem in temperate cities. Hot and cold temperature vulnerabilities may coincide across several personal and neighborhood characteristics, suggesting opportunities for increasing present and future resilience to extreme temperatures. We present a narrative literature review encompassing the epidemiology of cold- and heat-related mortality and morbidity, related physiologic and environmental mechanisms, and municipal responses to hot and cold weather, illustrated by Detroit, Michigan, USA, a financially burdened city in an economically diverse metropolitan area. The Detroit area experiences sharp increases in mortality and hospitalizations with extreme heat, while cold temperatures are associated with more gradual increases in mortality, with no clear threshold. Interventions such as heating and cooling centers may reduce but not eliminate temperature-associated health problems. Furthermore, direct hemodynamic responses to cold, sudden exertion, poor indoor air quality and respiratory epidemics likely contribute to cold-related mortality. Short- and long-term interventions to enhance energy and housing security and housing quality may reduce temperature-related health problems. Extreme temperatures can increase morbidity and mortality in municipalities like Detroit that experience both extreme heat and prolonged cold seasons amidst large socioeconomic disparities. The similarities in physiologic and built-environment vulnerabilities to both hot and cold weather suggest prioritization of strategies that address both present-day cold and near-future heat concerns.

1. Introduction

Cold and hot weather are associated with distinct patterns of mortality and morbidity, particularly among older individuals, and can create municipal-level health burdens, which may be exacerbated by climate change. Evidence-based guidance to help city and state planners develop synergistic interventions to reduce temperature-related health effects is needed. Vulnerability to heat- and cold- morbidity and mortality has been reviewed elsewhere [1–3]. Our narrative literature review builds on this information by highlighting commonalities between heat- and cold-related vulnerabilities and co-beneficial interventions. We focus on vulnerabilities specific to Detroit, Michigan, USA and the tri-county region (Wayne, Oakland and Macomb Counties)–a region with broad economic disparities. For example, in 2016, in cities in the tri-county area, household median incomes ranged from $28,000 (Detroit—1st percentile of median household income nationally) to $96,000 (Troy—91st percentile nationally) [4]. Our findings may therefore be applicable to other cities in temperate-to-cold climates which must contend with a wide range of weather events, where residents may lack options for adequate housing and face hardships in paying for heating and cooling ("energy poverty"), and where future climate will likely be more hot and humid [5]. We reviewed literature concerning the epidemiology of temperature-related mortality and morbidity, related physiologic and environmental mechanisms, housing quality and energy use, and municipal planning for hot and cold weather.

Abbreviations: EUI, energy use intensity; HHWS, heat-health warning system

* Corresponding author.
E-mail addresses: gronlund@umich.edu (C.J. Gronlund), kpsull@umich.edu (K.P. Sullivan), kefelegny@michigan.gov (Y. Kefelegn), lcameron@michigan.gov (L. Cameron), marieo@umich.edu (M.S. O'Neill).

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2. Methods

We conducted a narrative rather than a systematic review, describing the current state of knowledge from a contextual perspective rather than more systematically identifying literature. We searched the "Web Of Science" citation indexing service in February, 2018 using search terms such as "temperature," "heat," "cold," "thermoregulation," "physiolog*," "homeless*," and "housing," identifying relevant works from all years, particularly reviews and articles studying Detroit or cities in similar climates.

3. Results

3.1. Epidemiology of temperature vulnerability

In the Detroit tri-county area from 2002 to 2016, approximately 2–3 deaths per year were classified specifically as due to hyperthermia and 16 deaths per year to hypothermia [6]. However, heat and cold likely lead to health events that are not identified as hyper- or hypothermia in medical records.

3.1.1. Temperature-associated mortality exposure-responses

Several multi-city studies have examined the associations between heat and/or cold and natural-cause mortality in the Detroit area. Associations between mortality and temperature typically take a U-shape, such that mortality risk increases both below and above a minimum mortality temperature. However, cold temperature effects increase gradually below the minimum mortality temperature without a clear threshold while heat effects increase more abruptly [7–9]. Increased heat-associated mortality risk is highest in the first 0–3 days following heat exposure [9] and may increase with more intense or longer-lasting heat waves [7]. From 1985–2012, hot temperatures were estimated to account for approximately 0.4% of deaths annually in the Detroit area (Table 1) [8]. However, as average ambient temperatures and heat waves increase, the burden of heat-associated health effects may increase substantially in many U.S. regions, including the Detroit area [10].

Cold temperatures were estimated to account for more deaths than heat–7% annually in the Detroit area (Table 1) [8]. In contrast to heat, mortality associated with cold temperatures is highest 2–3 weeks after exposure [7], suggesting a less direct mechanism of action including cardiorespiratory diseases [7,11]. Consecutive, as opposed to single, days of sustained cold temperatures do not increase mortality risk in the U.S., although both cold and heat effects are greater earlier in their respective seasons, perhaps due to lack of acclimation [12].

3.1.2. Temperature-associated morbidity exposure-responses

Among Detroit area older adults, hospitalizations for heat-related (e.g., heat exhaustion/stroke), renal, and respiratory diseases were found to increase in association with hot temperatures [13,14]. In 2014, emergency department visit rates for heat- and cold-related causes in the Midwest were 16/100,000 persons and 22/100,000 persons, respectively [15]. Although less well studied, in climates similar to Michigan's, fall-related injuries may increase on days with snow and ice [11].

For both morbidity and mortality, cities with cooler climates tend to be more sensitive to warm effects and vice versa, suggesting that populations acclimatize to the local climate [16,17].

3.2. Physiology of thermoregulation and temperature susceptibility

Humans have sophisticated physiologic mechanisms for coping with extreme heat and cold, and the health severity of extreme temperatures varies by individual and context.

3.2.1. Normal physiologic responses

A healthy body copes with both moderately high and low temperatures first by sensing changing skin and core temperatures. For heat, this triggers blood vessel widening (vasodilation), a pronounced increase in the rate at which blood is pumped (cardiac output), and sweating. This brings heat to the body's surface to dissipate, in part by sweat evaporation. In general, as a result of vasodilation and dehydration, blood pressure drops in warm temperatures [18]. However, hot temperatures may interfere with sleep, and one Detroit study found increases in blood pressure in the mornings following hot nights [19]. The drop in blood pressure from vasodilation and sweating-induced

Table 1
Characteristics related to temperature vulnerability.

Characteristic	Unit	Detroit	Tri-County Area[a]	Michigan	U.S.
Population, 2016 [4]	Persons	673,000	3,861,000	9,933,000	323,400,000
Heat-attributable deaths [8]	Percent of total annual deaths	ND	0.4%	0.4%[b]	0.3%
Cold-attributable deaths [8]	Percent of total annual deaths	ND	6.9%	7.0%[b]	5.5%
Fair or poor health [48][a]	Percent of residents	27.5%	17.5%	17.5%	17.9% [49]
Angina or coronary heart disease [48]	Percent of residents	4.6%	4.8%	5.0%	4.3% [49]
Ever had stroke	Percent of residents	6.0%	3.6%	3.4%	3.2% [49]
Diabetes [48]	Percent of residents	13.1%	10.5%	10.8%	10.8% [49]
Occupation with outdoor exposure [4][c]	Percent of residents in the labor force	26.3%	20.6%	23.7%	21.0%
Household median income [4]	Income in the past 12 months	$28,000	$57,000	$52,000	$58,000
Non-green space [50][d]	Population-weighted average percent in a ZIP code	ND	92.8%	34.2%	ND
Violent crime in cities with 500,000-999,000 residents [51]	Annual rate per 100,000 residents	1,989	NA	NA	864
Walkability [52]	WalkScore™ walkability index on a scale of 0-100	55 (Somewhat walkable)	43 (Car-dependent)	40[e] (Car-dependent)	ND
Homeless, 2016 [53]	Rate per 1000 persons [4]	3.5	0.9	1.0	1.7
No air conditioning [54]	Percent of homes	18%	10%[a]	ND	11%
Uncomfortably cold home [54]	Percent of homes	18%	14%	ND	8%

ND = Data not available. NA = not applicable

[a] Seven-county Metropolitan Statistical Area, including Livingston, Monroe, St. Clair and Washtenaw Counties in addition to the tri-county area of Wayne, Oakland and Macomb Counties.

[b] Death-weighted averages of Detroit, Flint, Grand Rapids, Lansing, and Saginaw metro areas.

[c] Natural resources, construction, maintenance, production, transportation, and material moving occupations.

[d] Cells (30 m resolution) classified as "developed, medium or high intensity.".

[e] Average WalkScore™ across 65 Michigan cities.