Heat-Related Morbidity and Mortality: What we know and how we can prevent it

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National Center for Environmental Health
Centers for Disease Control and Prevention
Presentation Outline

• An overview of the health effects of heat exposure and the epidemiology of heat waves

• A review of current and future drivers of heat morbidity and mortality

• Adaptation and mitigation actions for heat resilience.
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Overview of Heat-Related Illness

- **Heat Cramps**: Is a milder form of heat illness that affect people who sweat heavily during strenuous activity depleting the body's salt and fluids.

- **Heat Exhaustion**: A milder form of heat-related illness that can develop after several days of exposure to high temperatures.
  - Characterized by paleness, fatigue, muscle cramps, dizziness, headache, nausea or vomiting, and fainting. The skin is typically cool and moist.

- **Heat Stroke**: A severe form of hyperthermia where the body is unable to regulate its temperature.
  - The sweating mechanism fails, and the body is unable to cool down.
  - Characterized by red, hot, and dry skin (no sweating); rapid, strong pulse; throbbing headache; dizziness; nausea; confusion; and unconsciousness.
Heat Waves

- **High mortality**
  - More deaths than hurricanes, lightning, tornadoes, floods, and earthquakes combined
  - From 1999–2003, total of 3,442 reported heat-related deaths. Annual mean of 688 (MMWR 2006)

- **Lack of public recognition**
  - No damage to infrastructure (silent killer)
  - Many deaths go unreported or unattributed

- **Every death is preventable**
Heat Wave Studies

1980  St. Louis
- 1st to highlight the magnitude of mortality from heat waves
- All cause mortality increased 57%

1993  Philadelphia
- Identified cardiovascular mortality as a major cause of death associated with extreme heat

1995  Chicago
- Redefined heat-related death as used by medical examiners
- Assisted with the development of a Heat Wave Response Plan


Heat Related Deaths in Chicago in July 1995

2 day lag
Some Extreme Events will be well beyond historical experience

European Heat Wave of 2003

Confirmed Mortality

<table>
<thead>
<tr>
<th>Country</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>2,091</td>
</tr>
<tr>
<td>Italy</td>
<td>3,134</td>
</tr>
<tr>
<td>France</td>
<td>14,802</td>
</tr>
<tr>
<td>Portugal</td>
<td>1,854</td>
</tr>
<tr>
<td>Spain</td>
<td>4,151</td>
</tr>
<tr>
<td>Switzerland</td>
<td>975</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1,400-2,200</td>
</tr>
<tr>
<td>Germany</td>
<td>1,410</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29,817-30,617</td>
</tr>
</tbody>
</table>

Haines et al. *Public Health* 2006;120:585-96.
Lessons Learned

Risk factors for hyperthermia:

Individual
- Age
- Underlying medical conditions / mental illness
- Income and poverty status
- Homelessness
- Social isolation
- Access to health care and cooling facilities
- Neighborhood characteristics: land use/land cover, crime rate, housing type, urban heat island

Community Characteristics
Risk Factor: Age / Gender

FIGURE. Number of heat-related deaths,* by sex and age group — United States, 1999–2003

*Exposure to extreme heat is reported as the underlying cause of or a contributing factor to death (N = 3,442).

Risk Factor: Underlying Medical Conditions

<table>
<thead>
<tr>
<th>Variables</th>
<th>Case patients</th>
<th>Control subjects</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medical/psychiatric conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart condition</td>
<td>30 (62.5)</td>
<td>11 (15.5)</td>
<td>7.2 (2.5–20.8)*</td>
</tr>
<tr>
<td>Psychiatric illness^b</td>
<td>23 (51.1)</td>
<td>13 (18.3)</td>
<td>5.7 (1.9–16.8)*</td>
</tr>
<tr>
<td>Depression</td>
<td>17 (40.5)</td>
<td>12 (17.1)</td>
<td>4.1 (1.3–12.5)*</td>
</tr>
<tr>
<td>Other mental problem</td>
<td>11 (26.8)</td>
<td>2 (2.9)</td>
<td>11.7 (1.5–92.2)**c</td>
</tr>
<tr>
<td><strong>Living conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lived alone</td>
<td>35 (56.5)</td>
<td>23 (30.3)</td>
<td>5.4 (1.8–15.9)*</td>
</tr>
<tr>
<td>Did not leave home daily^d</td>
<td>39 (67.2)</td>
<td>25 (33.8)</td>
<td>4.5 (1.7–11.7)*</td>
</tr>
<tr>
<td>Lived on top floor</td>
<td>31 (50.0)</td>
<td>15 (19.5)</td>
<td>4.0 (1.7–9.3)*</td>
</tr>
<tr>
<td>Had annual income &lt;$10,000</td>
<td>26 (72.2)</td>
<td>25 (42.4)</td>
<td>3.1 (1.0–9.7)**c</td>
</tr>
<tr>
<td>Had working fan</td>
<td>56 (90.3)</td>
<td>67 (88.2)</td>
<td>0.71 (0.2–2.3)</td>
</tr>
<tr>
<td>Had working air conditioner</td>
<td>10 (15.9)</td>
<td>44 (57.9)</td>
<td>0.12 (0.0–0.3)*</td>
</tr>
</tbody>
</table>


Drugs that may increase risk of heat-related illness:
- Psychotropics (e.g. haloperidol or chlorpromazine)
- Medications for Parkinson’s disease
- Tranquilizers (e.g. phenothiazines, butyrophenones, and thiozanthenes)
- Diuretic medications ("water pills")
## Important Co-Morbidities

<table>
<thead>
<tr>
<th>Condition</th>
<th>Main ICD³ chapters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes mellitus, other endocrine disorders</td>
<td>E10–E14</td>
</tr>
<tr>
<td>Organic or mental disorders, dementia, Alzheimer’s (mild, moderate, severe)</td>
<td>F00–F09</td>
</tr>
<tr>
<td>Mental and behavioural disorders due to psychoactive substance use, alcoholism</td>
<td>F10–F19</td>
</tr>
<tr>
<td>Schizophrenia, schizotypal and delusional disorders</td>
<td>F20–F29</td>
</tr>
<tr>
<td>Extrapyramidal and movement disorders (e.g. Parkinson’s disease)</td>
<td>G20–G26</td>
</tr>
<tr>
<td>Cardiovascular disease, hypertension, coronary artery disease, heart conduction disorders</td>
<td>I00–I99</td>
</tr>
<tr>
<td>Diseases of the respiratory system, chronic lower respiratory disease (COPD, bronchitis)</td>
<td>J00–J99</td>
</tr>
<tr>
<td>Diseases of the renal system, renal failure, kidney stones</td>
<td>N00–N39</td>
</tr>
</tbody>
</table>

### Risk Factor: Social Isolation

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<tr>
<th>Variable</th>
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</thead>
<tbody>
<tr>
<td>Social contacts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participated in group activities</td>
<td>26 (47.3%)</td>
<td>55 (73.3%)</td>
<td>0.3 (0.1–0.7)*</td>
</tr>
<tr>
<td>(clubs, religious or support)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friends in Chicago</td>
<td>52 (85.3%)</td>
<td>67 (87.0%)</td>
<td>0.9 (0.4–2.3)</td>
</tr>
<tr>
<td>Relatives in Chicago</td>
<td>52 (88.1%)</td>
<td>66 (85.7%)</td>
<td>1.3 (0.4–3.7)</td>
</tr>
<tr>
<td>Pet in home</td>
<td>11 (17.5%)</td>
<td>28 (36.4%)</td>
<td>0.3 (0.1–0.8)*</td>
</tr>
<tr>
<td>Behaviors during heat wave*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took extra baths/showerways</td>
<td>11 (37.9%)</td>
<td>48 (64.0%)</td>
<td>0.3 (0.1–0.9)*</td>
</tr>
<tr>
<td>Visited cooling center(s)</td>
<td>1 (1.9%)</td>
<td>7 (9.2%)</td>
<td>0.2 (0.0–1.5)</td>
</tr>
</tbody>
</table>

Risk Factor: Crime
Risk Factor: Building Type
Location Matters:

Curriero et al. 2002
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Future Drivers of Heat-Related Morbidity and Mortality

• **Climate Change**
  - Climate Variability: Frequency of extreme events

• **Demographic change**
  - Aging population
  - Urbanization

• **Built environments**
  - Urban heat island
  - Stagnant air masses
Climate Change Science: Key Findings

- Climate change is altering both the average (mean) global temperature and the global frequency of extremely hot temperatures (variance).

- The impacts of climate change will vary significantly by region; some places are warming faster than others.
Global Average Temperatures have been increasing.
Global Average Temperatures have been increasing.

Source: http://www.climate-lab-book.ac.uk/2016/spiralling-global-temperatures/
Warming has varied significantly by region (observed record)

Rising Temperatures
1991-2012 average temperature compared with 1901-1960 average

Source: National Climatic Data Center
Summer Temperatures Have Shifted
1951 – 1980

Summer Temperatures Have Shifted 1981 – 1991

Summer Temperatures Have Shifted 1991 – 2001

Frequency of Occurrence

Baseline (1951 - 1980) mean

Cooler than average
Average
Warmer than average
Extremely hot

Deviation from Mean

0
0.1
0.2
0.3
0.4
0.5

0
-1
-2
-3
-4
-5

The frequency of occurrence of summer temperatures has increased from 0.1% to 10%. The “extreme” temperature events used to cover 0.1% of the Earth. Now they cover 10%.

Demographic Shifts and Urban “Built” Environments

• Cities and climate are coevolving in a manner that will place more populations at risk.

• Increase in vulnerable populations:
  – Today, more than half of the world’s population lives in cities, up from 30% in 1950.
  – By 2100 there will be 100 million more people > 65 years old (relative to 2000) (Ebi et al. 2006).

• Urban heat islands
Population Pyramids of the U.S. 2000 and 2050 (Interim Projections from 2000 Census)

Data source: Census Population Projections
http://www.census.gov/ipc/www/usinterimproj/
World Median Age, 1950 - 2050

Median Age

Year

Adapted from: United Nations World Urbanization Prospects, 2008
Figure I
Proportion of population 60 years or over: world, 1950-2050

In 2008, for the first time in history, the proportion of the population living in urban areas reached 50%.

Thermal Satellite Image of Phoenix, AZ Night Surface Temperature

Urban heat island can add 7°–12° F

Thermal Satellite Image of Phoenix, AZ Night Surface Temperature
How Rapidly Are Large Cities Warming?

**URBAN**

- Airport as “first-order” meteorological station for each urban center
- Night light ranking of C (bright)

**RURAL**

- Three stations selected for each city based on:
  1. Night light ranking of A (dark) or B (dim)
  2. Population < 4,000 per square kilometer
  3. Located within 50 to 250 km of urban station

Rural areas have warmed by about 0.7 °C over 50 years.

The Urban Heat Island Effect (UHI)

Urban areas, on average, are about 0.8 °C warmer than rural areas.

Most of the temperature anomaly in cities is attributable to UHI.

Urban areas are warming more rapidly over time than rural areas.

Neighborhood Microclimates within the UHI

Harlan et al 2006

Mean Summertime Temp (°F)
- 106°F
- 99°F

Heat Wave Temp (°F)
- 118°F
- 104°F

City Center

Each concentric circle is a distance of 8 km

Harlan et al 2006
Extreme heat, minorities

- Minorities more likely to live in heat islands
  - Black, African American (52%)
  - Asians (32%)
  - Hispanic (21%)

Jesdale et al. (2013)
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Adaptation to Heat

• Short-Term (acclimatization)

• Seasonal to multi-year: Heat response plans

• Decadal and longer: UHI reduction and mitigating climate change
Short-Term Adaptation: Acclimatization to Heat

Positive adaptations that occur include reductions in:

- Heart rate
- Body temperature responses
- Skin temperature responses
- Perceived exertion
- Decreased salt losses in urine

As well as increases in:

- Sweat rate
- Sweat onset (sweating starts earlier)
- Heart function/blood distribution
- Overall ability to perform in the heat

Seasonal Adaptation: Development of Heat Response Plans

- City-specific heat response plans are essential
- The EPA guidebook:
  - EPA, NOAA, CDC, FEMA collaboration
  - Options for defining EHE conditions
  - How to assess local vulnerability
  - EHE notification and response actions that work
EXTREME HEAT CAN IMPACT OUR HEALTH IN MANY WAYS

Climate change poses many risks to human health. Some health impacts of climate change are already being felt in the United States.

We need to safeguard our communities by protecting people’s health, well-being, and quality of life from climate change impacts. Many communities are already taking steps to address these public health issues and reduce the risk of harm.

BACKGROUND

When we burn fossil fuels, such as coal and gas, we release carbon dioxide (CO₂). CO₂ builds up in the atmosphere and causes Earth’s temperature to rise, much like a blanket traps in heat. This extra trapped heat disrupts many of the interconnected systems in our environment.

Climate change also affects human health by increasing the frequency and intensity of extreme heat events. Increases in the overall temperature of the atmosphere and oceans associated with climate change cause changes in wind, moisture, and heat circulation patterns. These changes contribute to shifts in extreme weather events, including extreme heat events.

THE CLIMATE-HEALTH CONNECTION

Extreme heat events can be dangerous to health – even fatal. These events result in increased hospital admissions for heat-related illness, as well as cardiovascular and respiratory disorders.

- Extreme heat events can trigger a variety of heat stress conditions, such as heat stroke. Heat stroke is the most serious heat-related disorder. It occurs when the body becomes unable to control its temperature. Body temperature rises rapidly, the sweating mechanism fails, and the body cannot cool down. This condition can cause death or permanent disability if emergency treatment is not given. Small children, the elderly, and certain other groups including people with chronic diseases, low-income populations, and outdoor workers have higher risk for heat-related illness.

- Higher temperatures and respiratory problems are also linked. One reason is because higher temperatures contribute to the build-up of harmful air pollutants.

- Many cities across the United States, including St. Louis, Philadelphia, Chicago, and Cincinnati, have seen large increases in death rates during heat waves.

New CDC Guidance (forthcoming)
Cooling Center Technical Guidance Document

- Widely used extreme heat intervention
- Can be housed in a variety of places:
  - Libraries
  - Public pools
  - Movie theatres
  - Etc.

National Center for Environmental Health
Signs for free water at a cooling center in Maricopa County, Arizona. Photo credit: Travis L Williams Family Service Center.
Effectiveness Summary and Barriers

- Common themes from the literature that showed effective use were:
  - Communication strategies
  - Community outreach
  - Large group of diverse stakeholders

- Barriers to implementation were:
  - Limited access to transportation
  - High cost of A/C
  - Fear of leaving home/inability to leave home
  - Stigma of cooling centers
CDC’s National Environmental Public Health Tracking Network

Includes data on climate change and heat:

- Historic temperature distribution and extreme heat days
- Projected extreme heat days
- Heat vulnerability
- Heat ER visits, hospitalizations and deaths
Historic temperature data (EPHTN)
Future modeled temperature data (EPHTN)

Projected number of extreme heat days above the 98th percentile based on a high emissions scenario (A2)

Source: NOAA, National Climate Assessment 2014
Projected number of extreme heat days (>98 percentile) in 2084 in Maryland. A2 (high emissions) scenario.
### Mitigation: What actions are cities taking?

<table>
<thead>
<tr>
<th>Management Strategy</th>
<th>Common Components</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albedo Enhancement</td>
<td>Installation of highly reflective roofing or paving materials</td>
<td>Albedo Enhancement</td>
</tr>
<tr>
<td>Building Energy Efficiency</td>
<td>Minimum insulation values in building codes; efficient light fixtures and appliances</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>Green Roofs</td>
<td>Installation of vegetative roofing materials</td>
<td>Vegetation Enhancement</td>
</tr>
<tr>
<td>Regional Forest Management</td>
<td>Requirements for the protection of regional forest cover in proximity to urbanized areas</td>
<td>Vegetation Enhancement</td>
</tr>
<tr>
<td>Renewable Energy Programs</td>
<td>Requirements for wind, solar, geothermal, or other renewable energy sources</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>Urban Tree Management</td>
<td>Municipal tree planting programs; requirements for tree protection ordinances</td>
<td>Vegetation Enhancement</td>
</tr>
<tr>
<td>Vehicle Energy Efficiency</td>
<td>Minimum fuel efficiency standards for municipal fleets; acquisition of alternatively fueled vehicles</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>Vehicle Travel Demand Management</td>
<td>Ride sharing programs; transit investments; provision of pedestrian and cycling facilities</td>
<td>Energy Efficiency</td>
</tr>
</tbody>
</table>

Stone B, Hess JJ, Frumkin H. 2010. [Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities?](https://environhealthperspect.ae.iom.us/article/118(10)/1425-8)
Management Strategy 1: Sunscreening

http://inhabitat.com/vertical-gardens-by-patrick-blanc/
Management Strategy 2: Greenbelting
Management Strategy 3: Carbon cooling
For more information please contact Centers for Disease Control and Prevention

1600 Clifton Road NE, Atlanta, GA 30333
Telephone: 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov  Web: http://www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.