Comparing the Relationships Between Heat Stress Indices and Mortality in North Carolina

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Overview

- Background on measures of heat stress:
  - Heat index and Wet Bulb Globe Temperature (WBGT)

- Relationships between measures of heat stress and mortality:
  1. Wet Bulb Globe Temperature (WBGT)
  2. Air Temperature
  3. Heat Index
Research Questions

How do the relationships between Mortality and WBGT compare to those between Air Temperature and Heat Index?

Are there regional differences in these relationships across North Carolina?
Heat is leading cause of weather-related death

Ability of WBGT to predict health outcomes at a population-level relative to other indices limited in understanding

Various National Weather Service (NWS) Offices are producing experimental WBGT forecast products

WBGT increasingly utilized for athletic safety in NC and other states

Source: NWS Raleigh
Heat Stress

- Exposure to environmental conditions:
  1. Air temperature
  2. Relative humidity → Heat Index
Heat Stress

• Exposure to environmental conditions:
  1. Air temperature
  2. Relative humidity
  3. Wind speed
  4. Solar Radiation
  5. Water vapor pressure

- Heat Index
- Wet-Bulb Globe Temperature

www.skcinc.com
Heat Stress: Wet-Bulb Globe Temperature

- Created for military training safety (1950s)

- Three components

\[ WBGT = 0.7NW + 0.2GT + 0.1DB \]
Methods: Mortality Data and Regionalization

- Death records for NC
  - Heat Season (May 1 - Sept. 30) for 2005 – 2015

- Counties were grouped into 5 regions

- Two Piedmont Regions
  - Urban and rural
All-Cause mortality in addition to:

1. Cardiovascular disease
   - *(ICD10 I00-I99)*

2. Renal Disease
   - *(ICD10 N00-N39)*

3. Respiratory Disease
   - *(ICD10 J00-J99)*

### Methods: Cause-Specific Mortality

<table>
<thead>
<tr>
<th>Cause</th>
<th>Statewide Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-Cause</td>
<td>133848</td>
</tr>
<tr>
<td>Cardiovascular Disease</td>
<td>110776</td>
</tr>
<tr>
<td>Renal Disease</td>
<td>9363</td>
</tr>
<tr>
<td>Respiratory Disease</td>
<td>84460</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountains</td>
<td>47,579</td>
</tr>
<tr>
<td>Rural Piedmont</td>
<td>65,181</td>
</tr>
<tr>
<td>Urban Piedmont</td>
<td>127,269</td>
</tr>
<tr>
<td>Coastal Plain</td>
<td>64,410</td>
</tr>
<tr>
<td>Coast</td>
<td>32,834</td>
</tr>
</tbody>
</table>
Methods: WBGT Estimation

• Since WBGT is not routinely measured, it was estimated using:
  • **Hourly Observations** from 36 ECONet stations:
    1. Air Temperature
    2. Dew point temperature
    3. Relative humidity
    4. Pressure
    5. Wind speed
    6. Solar radiation
    7. Zenith angle (half past the hour)

• Wind speed uncertainty
  • **Minimum threshold of 1 m/s** based on sensitivity of anemometers at ECONet weather stations

Credit: NC State Climate Office
Weather Station Data: County-Level

- Assigned each county one station based on closest station via Euclidean distance
  - If station’s daily measure was missing or failed QC, data from second closest station was used
Methods: Statistical Analysis

- Distributed lag non-linear model (0-3 day lags)
- Controls for underlying seasonality in mortality:
  - Day of year (short-term trends)
  - Year (long term trends)
  - Holidays
- Natural cubic splines of WBGT, heat index, and air temperature with 5 degrees of freedom

\[
\log(\mu) = \beta_0 + \beta_1(Temp, df = 5) + \beta_2(DOY, Year, df = c(4, 5)) + \beta_4\text{Holiday}
\]
Seasonal Mortality


Average Mortality per Day of Year (2005–2015)
Weekly Mortality

Average Mortality per Day of Week (2005–2015)

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Average Daily Mortality (per 100,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>5033</td>
</tr>
<tr>
<td>Monday</td>
<td>4943</td>
</tr>
<tr>
<td>Tuesday</td>
<td>4866</td>
</tr>
<tr>
<td>Wednesday</td>
<td>5013</td>
</tr>
<tr>
<td>Thursday</td>
<td>5044</td>
</tr>
<tr>
<td>Friday</td>
<td>5120</td>
</tr>
<tr>
<td>Saturday</td>
<td>4999</td>
</tr>
</tbody>
</table>
Methods: Threshold Determination

• Temperature thresholds were identified in which the lower 95% confidence interval of the response curve was statistically different from zero

• Results are presented as relative risk of mortality per degree compared to mortality risk at temperature threshold

• Models with air temperature, heat index, and WBGT were compared based on Akaike Information Criterion (AIC)
Regional Climate Differences

Average Mean Air Temperature (°C) per Region

Month

May June July August September October

Mean Air Temperature (°C)

Mountains
Rural Piedmont
Urban Piedmont
Coastal Plain
Coast
Relative Risk of All-Cause Mortality based on Max. WBGT

- Rural Piedmont
- Urban Piedmont
- Coastal Plain
- Coast
All-Cause Mortality: Heat Index

Relative Risk of All-Cause Mortality based on Max. Heat Index

- Rural Piedmont
- Urban Piedmont
- Coastal Plain
Cardiovascular-Related Mortality

- WBGT models strongest for cardiovascular causes of death
  - No significant relationship in Coastal Plain region
  - Strongest relationship in the Urban Piedmont and Coast region.
Renal Disease Mortality

- Heat Index most statistically robust for causes of death related to renal disease and renal failure
  - Strong relationships in all regions except Mountains
Conclusions

• WBGT outperformed heat index and air temperature overall
  • However, relationships in the Mountains were poor, with air temperature serving as the best index

• Both WBGT and Heat Index identified highest risk of death due to heat for cardiovascular-related mortality and renal disease

• This study demonstrated the overall utility of using WBGT to establish relationship between heat and mortality compared to commonly used metrics