Sudden Infant Death Syndrome and Local Meteorologic Temperature in North Carolina

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The association between meteorologic temperature and sudden infant death syndrome was investigated in the 1982-1983 North Carolina birth cohort. Maximum daily temperatures recorded at weather stations in the subject's county of residence for each day of the first year of life were entered into hazards models as time-dependent covariates. Risk ratios for a maximum temperature of ≤53°F (12°C) 5 days before the event compared with a maximum temperature of >53°F were 2.3 (95% confidence interval 1.6-3.3) for blacks and 1.5 (95% confidence interval 1.0-2.1) for whites. Similar results were found for minimum daily temperature. The analysis controlled for season of birth, sex, maternal age, maternal education, parity, and birth weight.

Increased mortality from sudden infant death syndrome during the winter months has long been noted as a distinguishing feature of sudden infant death syndrome epidemiology. This seasonal distribution has been observed in moderate (2) as well as colder climates (3, 4), suggesting that relative temperature or change in temperature is the important factor in sudden infant death syndrome rather than absolute temperature. The seasonal distribution could also be produced by a seasonal factor other than temperature.

Several studies have found that elevated sudden infant death syndrome rates are associated with low meteorologic temperature. These studies used temperature measurements from one central location as the exposure measure for geographically dispersed populations or did not control for confounding by season. Although these studies found statistically significant associations between temperature and sudden infant death syndrome, none of them provided estimates of the relative risk associated with low temperature.

The present study estimates the risk of sudden infant death syndrome associated with low meteorologic temperature in a demographically and climatically diverse population. More localized temperature measures are used than in earlier studies. Both daily maximum and daily minimum temperatures are examined. Hazard models are used to estimate risk ratios adjusted for competing causes of death.

MATERIALS AND METHODS

Our study population was the 1982-1983 North Carolina birth cohort, restricted to blacks and whites, singleton births, and birth weight >400 g and <6,000 g. Further details of this population have been published elsewhere. This cohort was chosen to allow comparison with an earlier, related study.
infant death syndrome deaths were those for which an
International Classification of Diseases, Ninth Revi-
sion, code 798.0 was given as the underlying cause of
death on the death certificate. Approximately 100 per-
cent of the sudden infant death syndrome deaths were
confirmed by autopsy (15).

Daily maximum and minimum temperatures as re-
corded at 120 weather stations across North Carolina
were provided by the National Climatic Data Center
(16). The daily temperatures assigned to each member
of the birth cohort for each day of the first year of life
were those temperatures measured at the weather sta-
tion in the county of residence listed on the birth
certificate. Subjects residing in counties with multiple
weather stations (27 of 100 counties) were assigned
the mean of the temperature readings from those sta-
tions. Subjects residing in counties without weather
stations (16 counties) were assigned temperature read-
ings from a selected station or stations (mean) in
adjacent counties.

Hazard models with time-dependent covariates
(temperature) were used to estimate the relative risk of
sudden infant death syndrome for low meteorologic
temperature adjusted for competing causes of death
(17, 18). Two series of models were fitted to examine
separately the effects of maximum and minimum tem-
perature. Each series consisted of eight separate mod-
els. The eight models were identical except that, in
each one, the temperature used was measured a dif-
ferent number of days (0–7 days) prior to the event
(i.e., sudden infant death syndrome death). Prelimi-
nary analysis indicated that lag periods >7 days were
not informative. Minimum daily temperature was cat-
alyzed as ≤32°F (0°C), >32°F but ≤55°F (13°C), and
>55°F (reference category). Maximum daily tem-
perature was categorized as ≤53°F (12°C), >53°F but
≤78°F (26°C), and >78°F (reference category). These
cutpoints represent the approximate 25th and 75th
percentiles of the respective temperature distribution
on the day of death among sudden infant death syn-
drome deaths. The model with the greatest effect was
chosen a priori as the final model. The final model was
validated by fitting a similar model to the 1984–1985
birth cohort.

Potential confounding was controlled for by adding
season of birth, race, sex, maternal education, maternal
age, parity, and birth weight to the final model. The
definitions and categorization of these variables have
been published elsewhere (14). Effect modification in
the final model was examined by adding interaction
terms for temperature with each of the aforementioned
variables. Confounding by season was examined in
models with two temperature dummy variables as
described above. To avoid overly cumbersome mod-
els, the additional confounders and the interaction
terms were examined in models with only one dummy
variable for temperature, i.e., the lowest temperature
category given above, with all other temperatures as
the reference category. We examined the effect of low
temperature for age <12 weeks and ≥12 weeks sep-
ately by means of a temperature × age interaction
term.

We also examined the effects of sustained low tem-
perature over a period of days, the difference in daily
high and low temperatures, and the difference in low
temperature from one day to the next. These did not
prove informative and were not examined further.

RESULTS

There were 161,727 live births and 268 sudden
infant death syndrome deaths in the 1982–1983 birth
cohort. Other population statistics are given in table 1.
The mean maximum daily temperature on the day of
death among infants who died of sudden infant death
syndrome was 65.1°F (standard deviation, 16.4).

The risk ratio for the daily maximum temperature of
≤53°F relative to >78°F increased from 1.8 (95 per-
cent confidence interval 1.3–2.6) for temperature on
the day of the event to 2.5 (95 percent confidence
interval 1.8–3.5) for temperature on the fifth day pre-
ceding the event. The risk ratio was lower for lag
periods of more than 5 days preceding the event. Daily
minimum temperature showed a slightly smaller effect
than daily maximum temperature for every lag period.
Therefore, the model of daily maximum temperature 5
days before the event was chosen as the final model.
Applying the final model to the 1984–1985 birth co-
hort yielded a risk ratio of 1.8 (95 percent confidence
interval 1.3–2.5).

Table 2 shows results for the final model. Control-
ling for season of birth (model 2) reduced the effect of
low temperature to 2.1 (95 percent confidence interval
1.4–3.0). Allowing temperature to have different ef-
fects at different seasons by including an interaction
term for temperature × season of birth showed that
temperature had the same effect at both seasons (not
shown). Controlling for several additional potential
confounders did not change the effect of low temper-
ature (models 4 and 5 compared with model 3).

Only race showed a sizable effect modification with
temperature (table 3). The risk ratio for a temperature
of ≤53°F relative to >53°F was 50 percent greater in
blacks than in whites (2.3 vs. 1.5). This relation was
not changed by including the season of birth in the
model. Effect modification by race was not found in
the 1984–1985 cohort.

The risk ratio for the effect of temperature ≤53°F
relative to >53°F was slightly greater for infants ≥12

Sudden Infant Death Syndrome and Meteorologic Temperature

We found a substantially elevated risk of sudden infant death syndrome for infants residing in areas with colder outdoor temperatures 5 days before the event. Associations with temperature could be spuriously produced if the etiologic factor were something, other than temperature, that was seasonally distributed similarly to temperature. If this were the case, one would expect the effect of temperature to be reduced by introducing a seasonal control variable into the model. Controlling for season of birth reduced the effect of temperature only slightly. Adding an interaction term for temperature \times \text{season of birth} showed that the effect of temperature was essentially the same in both seasons.

It is likely that temperature measurements among the numerous local weather stations are more variable, both geographically and temporally, than other possible seasonal etiologic factors (e.g., sunlight or precipitation). If this is the case, and our results reflect a spurious association with temperature because of the seasonal association of temperature with the true etiologic factor, one would expect our results to be weaker than those found using more general temperature measures. Comparisons with other studies are inhibited by differing statistical methods, but our results seem to be of the same order of magnitude as those of Mitchell et al. (7). They found that a lowered monthly mean minimum temperature at one central station in Auckland, New Zealand, from 12°C (53°F) to 4°C (39°F), was associated with an approximate increase in sudden infant death syndrome from two to five per 1,000 births (7, figure 3).

Our findings of a 5-day lag period between low meteorologic temperature and sudden infant death syndrome death are consistent with similar findings from other studies (5–7). This mitigates the possibility that the true association is with a seasonal factor other than temperature. It is difficult to imagine a confounder that would be associated with sudden infant death syndrome and with temperature in such a temporally precise manner across these geographically and demographically diverse populations.

The small difference we found in the effects of minimum and maximum temperature cannot support hypotheses about the relative importance of one over the other. Murph and Campbell (6) and Anderson et al. (12) also found little difference in the effects of minimum and maximum temperatures.
TABLE 2. Effect* of daily maximum meteorologic temperature on sudden Infant death syndrome in the 1982–1983 North Carolina birth cohort†

<table>
<thead>
<tr>
<th>Model and temperature</th>
<th>Risk ratio</th>
<th>95% confidence interval</th>
<th>Other variables in the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (crude)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F (12°C)</td>
<td>2.5</td>
<td>1.8–3.5</td>
<td></td>
</tr>
<tr>
<td>&gt;53°F–78°F (26°C)</td>
<td>1.7</td>
<td>1.2–2.3</td>
<td></td>
</tr>
<tr>
<td>&gt;78°F</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 (controlled)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F</td>
<td>2.1</td>
<td>1.4–3.0</td>
<td>Season of birth (August–December, January–July)</td>
</tr>
<tr>
<td>&gt;53°F–78°F</td>
<td>1.5</td>
<td>1.1–2.0</td>
<td></td>
</tr>
<tr>
<td>&gt;78°F</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (crude)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F</td>
<td>1.8</td>
<td>1.4–2.3</td>
<td></td>
</tr>
<tr>
<td>&gt;53°F</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (controlled)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F</td>
<td>1.8</td>
<td>1.4–2.4</td>
<td>Race, sex, maternal age, maternal education, parity</td>
</tr>
<tr>
<td>&gt;53°F</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 (controlled)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F</td>
<td>1.8</td>
<td>1.4–2.4</td>
<td>Race, sex, maternal age, birth weight</td>
</tr>
<tr>
<td>&gt;53°F</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* From hazard models with temperature as a time-dependent covariate.
† Restricted to blacks and whites, singleton births, and birth weight >400 g and <6,000 g.

TABLE 3. Effect* of daily maximum meteorologic temperature on sudden Infant death syndrome among black infants and white infants in the 1982–1983 North Carolina birth cohort†

<table>
<thead>
<tr>
<th>Race and temperature</th>
<th>Risk ratio</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blacks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F (12°C)</td>
<td>2.3</td>
<td>1.6–3.3</td>
</tr>
<tr>
<td>&gt;53°F</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td><strong>Whites</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤53°F (12°C)</td>
<td>1.5</td>
<td>1.0–2.1</td>
</tr>
<tr>
<td>&gt;53°F</td>
<td>Reference</td>
<td></td>
</tr>
</tbody>
</table>

* From hazard model containing temperature, race, and temperature x race covariates.
† Restricted to blacks and whites, singleton births, and birth weight >400 g and <6,000 g.

We found little difference in the effect of low temperature among infants <12 weeks old compared with older infants. This is similar to Campbell’s (5) finding.

The reduced effect of temperature in the 1982–1983 birth cohort compared with the 1984–1985 cohort may reflect warmer temperatures in the latter period. Campbell found a similar trend for death cohorts in England and Wales (8).

Smoking (19) and sleeping position (20) are two sudden infant death syndrome risk factors that were not controlled for in our analysis, because the data were not available. It seems unlikely that either of the factors could be differentially distributed with respect to temperature so as to confound our results. However, there may be important effect modification by these factors (3).

The delay of sudden infant death syndrome approximately 5 days after a low temperature reading suggests that colder weather initiates a process that leads to the infant’s death. Mage (21) has described a process composed of one or more mechanisms that cause sustained insufficient blood oxygen levels leading eventually to death. Infection and overheating are two candidate mechanisms for this process. Both of these mechanisms may be associated with sudden infant death syndrome (22-24) and with cold weather (25, 26).

Others have suggested that a fall in temperature is the relevant exposure for sudden infant death syndrome (4–6). We found no evidence for this (11, 27) nor for the importance of sustained low temperatures.

We found a greater effect for temperature among blacks than among whites. In an earlier paper, we reported a reduced effect of season among blacks as compared with whites (14). This difference is surprising, given the seasonal distribution of temperatures. It strengthens the conclusion that the effect of temperature is not confounded by a seasonal effect. Further study of race differentials in temperature effect may yield information about sudden infant death syndrome prevention and etiology.
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REFERENCES