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Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence

Marie S. O'Neill, Antonella Zanobetti, and Joel Schwartz

ABSTRACT *Daily mortality is typically higher on hot days in urban areas, and certain population groups experience disproportionate risk. Air conditioning (AC) has been recommended to mitigate heat-related illness and death. We examined whether AC prevalence explained differing heat-related mortality effects by race. Poisson regression was used to model daily mortality in Chicago, Detroit, Minneapolis, and Pittsburgh. Predictors included natural splines of time (to control seasonal patterns); mean daily apparent temperature on the day of death, and averaged over lags 1–3; barometric pressure; day of week; and a linear term for airborne particles. Separate, city-specific models were fit to death counts stratified by race (Black or White) to derive the percent change in mortality at 29 °C, relative to 15 °C (lag 0). Next, city-specific effects were regressed on city- and race-specific AC prevalence. Combined effect estimates across all cities were calculated using inverse variance-weighted averages. Prevalence of central AC among Black households was less than half that among White households in all four cities, and deaths among Blacks were more strongly associated with hot temperatures. Central AC prevalence explained some of the differences in heat effects by race, but room-unit AC did not. Efforts to reduce disparities in heat-related mortality should consider access to AC.*

KEYWORDS *Air conditioning, Climate, Ethnic groups, Heat, Mortality, Socioeconomic factors, Weather.*

INTRODUCTION

Black race, lower educational attainment, age, death outside a hospital, and lack of access to air conditioning (AC) modify associations between ambient temperatures and daily mortality.[1–5] Because AC can protect people from heat-related mortality[1,6] and access to AC and resources to use it may differ by race, we evaluated whether AC played a role in previously reported racial disparities in heat-related mortality.[5]

Dr. O'Neill is with The Robert Wood Johnson Health & Society Scholars Program, Center for Social Epidemiology and Population Health, University of Michigan, Ann Arbor, Michigan; Drs. Zanobetti and Schwartz are with the Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts; and Dr. Schwartz is with the Department of Epidemiology, Harvard School of Public Health, Boston, Massachusetts.

Correspondence: Marie S. O'Neill, PhD, The Robert Wood Johnson Health & Society Scholars Program, Center for Social Epidemiology and Population Health, University of Michigan, 1214 South University Avenue, Room 249, Ann Arbor, MI 48104-2548. (E-mail: marieo@umich.edu)

METHODS

Data Sources

Mortality and environmental data were described previously.[5] Briefly, daily, noninjury mortality counts were obtained for 1986–1993 and stratified by race (Blacks and Whites). This analysis used data for the metropolitan area (defined by county) of four cities: Chicago, Illinois; Detroit, Michigan; Minneapolis and St. Paul, Minneapolis ("Minneapolis" in this article); and Pittsburgh, Pennsylvania. Here, the term city refers to these metropolitan areas. We chose these cities because they had an adequate number of hot days for estimating heat–mortality associations, daily information on air pollution (which has been associated with daily mortality[7]), and AC prevalence data. Between 1986 and 1993, 684,847 people died in the four areas.

Weather data were from the airport station closest to each city. Apparent temperature, an index of human discomfort, was calculated from ambient temperature and dew point, as described previously.[5] Barometric pressure and concentrations of particulate matter less than 10 microns in aerodynamic diameter (PM_{10}) were also covariates for this analysis. PM_{10} can be inhaled into the lungs and has been linked with several adverse health outcomes.[8]

The American Housing Survey collects data on AC prevalence (central and one; two; three or more room units) about every 4 years, sampling 4,800 or more housing units per metropolitan area.[9] Between 1986 and 1993, two surveys were administered in each of the four cities. City-specific AC prevalence was averaged from those two surveys and applied over the entire study period. Prevalence was reported by race/ethnicity (Black, Hispanic, and total). Because we lacked Hispanic mortality data for the whole study period, we report AC prevalence statistics by Black households and "White/Other" (i.e., households not reported as being Black or Hispanic).

Statistical Methods

Robust Poisson regression was used to model daily death counts as the dependent variable in models fit individually for each city. Independent variables included a linear term for mean PM_{10} on the day of death and the previous day and natural cubic splines of mean daily barometric pressure, day of week, and day of study. Because of the nonlinear dependence of mortality on temperature and previous research showing differing lag structures for hot- and cold-weather mortality,[10] we used two cubic splines to model temperature. The cold term was temperature averaged over lags 1–3, and the heat term was temperature at lag 0. Other details of model fitting criteria are described elsewhere.[5] City-specific regressions were fit to daily death counts among Blacks and Whites, and a combined four-city effect estimate was calculated for each race by using inverse variance-weighted averages.

To evaluate the effects of AC prevalence, we performed a meta-regression with a model of the following form:

$$\beta_{ij} = C_0 + \gamma Z_{ij} + \varepsilon_{ij}$$

where β_{ij} is the coefficient for the effect of 29 °C heat, at lag 0 in city i, stratum j (Blacks or Whites), and γZ_{ij} is the AC prevalence in city i, stratum j. The expected value of ε_{ij} is assumed zero, and the variance of ε_{ij} is represented as $\sigma_{ij}^2 + \sigma$, where σ_{ij}^2 is the estimated standard error of β_{ij} within city and stratum, and σ is the heterogeneity in the β_{ij} not explained by AC prevalence. The C_0 and γ are estimated with inverse variance-weighted least squares regression, and between-city variance σs were estimated with iterative maximum likelihood estimation.[11] A random effect for city accounted for heterogeneity among the four cities.

RESULTS

Environmental variables for the four cities were reported previously.[5] They all had comparable maximum mean daily apparent temperatures (range = 34.3–36.9 °C). Mean levels of particles and other meteorological variables were also similar. About 40% of those who died in Detroit during the study period were Black; the corresponding percentages were 28 in Chicago; 11 in Pittsburgh; and 4 in Minneapolis, consistent with city demographics (Table 1).

In all four cities, central AC prevalence in the "White/Other" households was more than double the central AC prevalence in Black households (Table 2). Pittsburgh had the lowest overall prevalence of central AC, at 25%, and Minneapolis the highest, at 47%. There was less variation by race in room-unit AC prevalence and no consistent pattern of differences by race.

Table 3 summarizes city-specific heat effects by race (also reported in O'Neill et al.[5]) and the pooled effect across the four cities. In each city, heat-associated mortality was higher among Blacks, and the pooled effect showed an effect among Blacks over twice that among Whites.

TABLE 1. Demographics of four metropolitan areas, 1986–1993

	Chicago	Detroit	Minneapolis	Pittsburgh
Total population (million)	5.11	2.11	1.52	1.34
Black (%)	26	40	5	11

TABLE 2. Air conditioning (AC) prevalence by household race[9]

			AC (%)	
City	Years	Population	Central	Room unit*
Chicago	1987, 1991	Total	41	35
		Blacks	16	32
		Whites/Other†	49	35
Detroit	1989, 1993	Total	35	26
		Blacks	17	30
		Whites/Other	39	25
Minneapolis	1989, 1993	Total	47	26
		Blacks	21	19
		Whites/Other	48	27
Pittsburgh	1986, 1990	Total	25	33
		Blacks	10	46
		Whites/Other	26	33

Prevalence statistics are means of the two survey years.
*Reporting one or more room-unit air conditioners.
†All households in the survey not reported as Black or Hispanic.

TABLE 3. Percent change in daily mortality and 95% confidence intervals (CIs) associated with 29 °C apparent temperature, pooled and city specific (1988–1993 for Chicago, 1986–1993 for other cities)

	Pooled	Chicago	Detroit	Minneapolis	Pittsburgh
Total mortality	4.6 (2.6–6.7)	4.5 (2.3–6.7)	7.5 (4.2–10.8)	2.4 (–2.1 to 7.1)	3.1 (–0.5 to 6.9)
Black	9.0 (5.3–12.8)	5.9 (2.0–9.9)	12.0 (6.8–17.4)	17.0 (–7.8 to 48.4)	12.5 (1.4–24.8)
White	3.7 (1.9–5.4)	4.1 (1.5–6.7)	5.5 (1.4–9.7)	2.3 (–2.4 to 7.1)	2.0 (–1.7 to 6.0)

Estimates are relative to 15 °C apparent temperature and control for barometric pressure, PM_{10}, time trend, day of week, and apparent temperature averaged over lags 1, 2, and 3 (heat effect is expressed for apparent temperature lag 0).

In the meta-regression, for each 10% increase in central AC prevalence, heat-associated mortality, pooled across all four cities, dropped by 1.4% (95% CI=–0.1 to 2.9), a marginally significant result. The overall effect of heat on mortality (the effect of heat in a city with a 0% prevalence of central AC) was a 10.2% increase (95% CI=4.5–16.2). Applying the 1.4% estimated drop in mortality to the average difference in AC prevalence between Blacks and White/Other across all four cities (24%) suggests that differences in central AC prevalence explain no more than a 3.4% difference in heat-related mortality. Blacks had 5.3% higher heat-related mortality than Whites (Table 2); therefore, as much as 64% of this disparity is potentially attributable to central AC prevalence.

Excess heat-related mortality with 0% room-unit AC prevalence was estimated with meta-regression at 2.5% (95% CI=–13.6 to 21.7). Each 10% increase in room-unit AC prevalence was associated with a 0.95% increase in heat-associated mortality (95% CI=–4.4 to 6.5).

Because there was less of a gradient in room-unit AC prevalence and no consistent pattern of disparities by race, this variable had limited utility in this analysis. Figure shows central AC prevalence plotted against the coefficients reflecting the size of the association between heat and mortality by city and race. Higher heat and mortality associations and lower central AC prevalence were seen for Blacks. Central AC prevalence varied little among Black households across the cities.

DISCUSSION

Heat-related mortality in four US cities was reduced with increasing central AC prevalence, and substantially higher effects of heat on mortality were observed among Blacks compared with Whites. A large proportion of the disparity in heat-related mortality may be due to differences in central AC prevalence. Room-unit AC prevalence showed little effect on heat-related mortality and no consistent pattern of disparities by race.

Several previous studies showed both Black race and lack of AC as indicating vulnerability to heat-related health effects.[1–6] Heat-related mortality associations were higher in areas with lower AC prevalence, even after adjusting for latitude.[4] Access to AC has been recommended as a key component of efforts to prevent heat-related deaths.[12–14] Among 72,420 US residents, hot-weather death rates from 1980 to 1985 were 42% lower among people with central AC compared with people with no AC, and AC benefits were highest for women, the elderly, people not in the labor force, and those in dwellings of less than six rooms.[6] Comparing room-unit AC with no AC, the effect was not significantly different from zero, except among

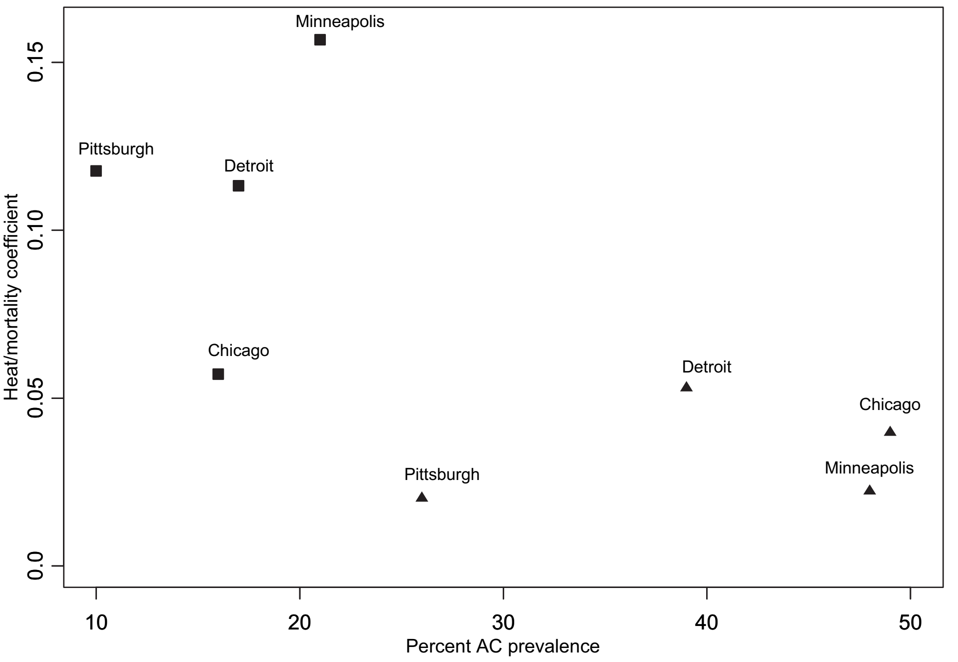

FIGURE. Coefficients for the relative risk of mortality on days at 29 °C apparent temperature compared with days at 15 °C, by prevalence of central air conditioning (AC), race, and city. ▲, Whites (and Whites/Others, for AC prevalence); ■, Blacks. Coefficients are from Poisson regression models with covariates including barometric pressure, PM_{10}, time trend, day of week, and apparent temperature averaged over lags 1, 2, and 3 (heat effect is expressed for apparent temperature lag 0). Data cover the period 1986–1993.

people whose dwellings had one to three rooms, where room-unit AC was beneficial.[6] An inverse association between expected risk of death at 30 °C and prevalence of central AC, with 33% of the variation in heat-associated mortality explained by AC prevalence, was seen in 12 US cities.[10]

Central AC prevalence is likely correlated with other area socioeconomic characteristics indicating vulnerability to mortality on extreme temperature days[15]; therefore, the explanatory power of this variable probably reflects influences of these other factors. During a 1995 heat wave in Chicago, social contacts, mobility, affordability of electricity, and sense of personal security affected whether people had adequate ventilation and cooling in their homes.[16] These factors differed across small-scale geographic areas (neighborhoods). The AC prevalence statistics used for this study were aggregated by city, limiting conclusions about smaller-scale neighborhood characteristics. Because room-unit AC prevalence patterns differed by city and race, this study design was not able to provide insights into whether these units are beneficial at the population level, though intuition would suggest that they would be. Studies examining individual-level data on AC use and ownership would be required to further evaluate this question.

Although the number of deaths occurring in the four cities was substantial, confidence intervals for the meta-regression results were wide. Additionally, Figure shows substantial scatter in the relationship between central AC prevalence and the heat and mortality effect. For heat-related mortality among Whites, Pittsburgh represented the greatest outlier in the group. The other three cities may be representative of US cities. Future analyses with more cities would help increase confidence in the results.

In spite of these limitations, the findings of this study are consistent with previous observations that central AC use is protective against heat-related mortality. They also suggest that the strong racial disparities in heat-related mortality are partially explained by central AC prevalence or other socioeconomic factors correlated with central AC prevalence that differ by race. Outreach programs to reduce heat-related mortality, which commonly include ensuring access to cool environments,[17] should take into account demographic patterns in AC prevalence to ensure equitable protection.

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