Effects of the Summer Heat Wave of 1988 on Daily Mortality in Allegheny County, PA

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Synopsis

The authors studied total mortality in Allegheny County, PA, during the summer of 1988. A heat wave occurred in July of 1988, with daily maximum temperatures near or above 90 degrees Fahrenheit on 15 consecutive days. During that period there were a total of 694 deaths from all causes in the county, compared with an expected 587 deaths (P < .01). All 107 excess deaths were of persons ages 65 or older, with the majority (78) occurring to persons older than age 75. Daily mortality was most closely correlated with average temperature from the previous day (R = .49, P < .01), suggesting the cumulative effects of successive high daytime and night-time temperatures on susceptible persons. Evaluation of a possible effect on mortality of high ambient ozone levels detected in early July suggested that ozone did not contribute to excess mortality during the heat wave.

Comparison of the 1988 heat wave with a less intense hot spell of 1973 indicated that excess mortality was less than would have been expected in 1988. The authors speculate that increased public awareness and the wider use of air conditioning over the years may have reduced the lethality of periods of extreme summer temperatures in urban areas. Further research is needed to evaluate this hypothesis completely. Public health officials should continue to monitor weather forecasts for predictions of extended periods of unusual heat and should warn the public to take suitable precautions during such periods.

THE SUMMER of 1988 was unusually hot and dry in much of the United States, setting records for high temperatures and low rainfall in many areas. These conditions also prevailed in Allegheny County, PA, surrounding the city of Pittsburgh, where the summer was the hottest in the last 100 years (*1*). Daily average temperatures exceeded the expected normal on 63 of 92 days in June, July, and August, and a heat wave with 15 consecutive daily maximums above or near 90 degrees (°) Fahrenheit (F) occurred during the first half of July.

The effects of unusual environmental heat, and heat waves in particular, on human morbidity and mortality have been studied sporadically since the early 1900s. Studies conducted since World War II have consistently described substantial but variable increases in total mortality during heat waves, with the greatest impact falling on elderly city dwellers (*2–9*). Excess mortality exceeding 400 percent among the oldest age groups was reported during severe hot spells before the widespread use of air conditioning in this country (*4*). Heat-related mortality, while sometimes attributed directly to heat stroke or heat exhaustion, most often occurs as an exacerbation of an existing chronic illness, particularly cardiovascular, cerebrovascular, and severe pulmonary illnesses (*10*).

Other factors consistently associated with heat-related mortality are low socioeconomic status, poor quality housing, and use of certain medications. All of these conditions are prevalent among the urban elderly, further increasing their risk during heat waves. Access to an air conditioned environment during at least part of the day during a hot spell is believed to be a strong protective factor (*9, 11*). Unfortunately, air conditioning is probably not available to many poor elderly persons who cannot afford its cost and, further, the elderly may be unable to seek refuge from the heat in air conditioned public facilities.

Allegheny County is mostly urbanized, with a large population (1,362,198 total, 387,490 in the city of Pittsburgh alone) and a high proportion of elderly residents (16 percent ages 65 or more years). County residents enjoy comparatively mild summer weather in most years. The extreme environmental conditions of the summer of 1988 prompted this investigation; its primary goals were to determine (*a*) whether any excess mortality occurred during the summer and (*b*) if excess mortality did occur, which groups of county residents were at increased risk.

A secondary goal was to examine the possible effects on mortality of high ambient ozone levels detected during the first few days of the July heat wave. These lev-

Table 1. Days with temperatures above normal in June–August 1988 (observed) compared with the average for 1983-87 (expected)

Characteristic	*June*	*July*	*August*
Days with maximum temperature above 90° F.:			
Expected	1	3	2
Observed	8	17	13
Days with maximum temperature above 100° F.:			
Expected	0	0	0
Observed	0	2	1
Days with average temperature at least 5 degrees above normal:			
Expected	8	8	6
Observed	9	16	17
Consecutive days above 90° F.:			
Expected	0	2	0
Observed	3	13	8

Table 2. All-case, all-ages mortality for Allegheny County, PA, June-August 1988 (observed), compared with the 5-year average for 1983-87 (expected)

Period	*Number of deaths*
June 1988	1,141
June 1983–87	1,240
July 1988	1,270
July 1983–87	1,260
August 1988	1,263
August 1983–87	1,207
Heat wave, July 4–18, 1988	694
July 4–18, 1983–87	587
Total summer 1988	3,674
Total summers, 1983–87	3,707

els caused the issuance of an air pollution advisory in the county, cautioning persons with chronic respiratory or cardiovascular disease to reduce outdoor activity and requesting citizens to reduce automobile driving (*12*). Episodes of intense air pollution have caused substantially increased mortality in several notorious incidents in the past, such as the London fog of 1952 and in this area, Donora, PA, in 1948. In these episodes, the pollution consisted primarily of particulates (coal smoke) and sulfur dioxide rather than ozone (*13*). To our knowledge episodic high levels of ozone have never been shown to result in excess mortality in a defined population.

A final objective was to compare mortality data for July 1988 with similar data for 1973, when a 10-day heat wave occurred in late August and early September. This comparison was planned as a preliminary test of an hypothesis that use of air conditioning, which is assumed to have become more widely available over the years, has tended to reduce the lethality of extreme summer weather. If heat wave-associated excess mortality in 1988 could be shown to be less than expected, on the basis of the 1973 heat wave data, then the air conditioning hypothesis would be supported, at least from an ecologic perspective.

Methods

Weather data for the county are collected by the National Weather Service (NWS) at the Greater Pittsburgh International Airport, approximately 15 miles outside the city limits. Temperature readings taken at the airport are usually 2–5 degrees lower than informal readings taken in the city itself, especially at night. NWS weather data are routinely obtained by the Bureau of Air Pollution Control of the Allegheny County Health Department, which made them available for this investigation, along with air quality monitoring data.

Specific weather parameters considered in this study were daily maximum, minimum, and average temperatures, normal daily average temperature and deviation of the observed from the normal, dewpoint, windspeed, and percent total sunshine. Air quality measurements used were daily maximum and daily average ozone levels, computed as county-average measurements derived from readings taken at four permanent monitoring sites within the county. Product moment correlations of individual weather and air quality parameters with daily mortality tallies were calculated using the SPSS^x statistical software package (*14*).

Death certificates for Allegheny County residents were reviewed for the period June 1–August 31, 1988, in the Allegheny County Health Department's Health Data Center. For this study date of death, age, race, sex, municipality of residence, census tract of residence, and place of death were abstracted. Expected mortality for the months of June, July, and August and the period of the July heat wave was determined using data from the 5-year period 1983-87, when no heat waves occurred. The 1987 county population estimates also provided by the Health Data Center were used to calculate mortality rates.

Expected weekly death rates over the 3 summer months were calculated using the procedure described by Weiner (*15*). Under this procedure, the expected rate is calculated as a 5-year, 5-week moving average and is plotted with 95 percent confidence bands over the period of interest. Observed rates are plotted with the expected to provide graphic evidence of the occurrence of excess (or unusually low) mortality.

Age-, sex-, race-, and other category-specific death counts were considered as Poisson variables, with the 5-year data base average values as their means. Ninetyfive percent confidence limits were calculated for these means (*16*). Observed counts from the summer period were considered significantly different if they fell outside the 95 percent confidence limits.

Mortality during the heat wave of August 27–September 5, 1973, was evaluated in the same way, using data from the nonheat wave years 1970–72 and 1974–75 to provide expected numbers of deaths. The duration and intensity of the heat wave were combined into a single quantitative expression by adding the number of cooling degree-days (equal to the daily average temperature minus 65, a measure used by the National Weather Service to describe the intensity of warm weather) across all 10 days of the hot spell. The same calculation was performed for the 15-day 1988 heat wave. Age-specific excess mortality rates observed during the 1973 heat wave were then expressed as the number of excess deaths observed per 100,000 persons in the specific age group per cooling degree-day. Using these rates, predicted numbers of deaths could be calculated for 1988, after taking into account the greater duration and intensity of the 1988 heat wave.

Results

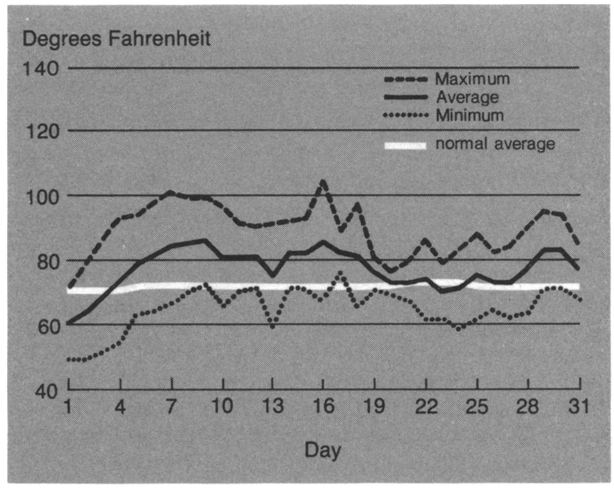
Temperatures, 1988. June, July, and August 1988 were clearly extreme in comparison to the previous 5 years, as shown in table 1, especially in the category of consecutive hot days. Unusually warm days occurred in each month. There was also a heat wave, consisting of 15 consecutive days with daily maximum temperatures above 90 degrees F, from July 4 through July 18. During the heat wave there were 2 days, one record-setting, with daily maximum above 100°.

Figure 1 displays recorded temperature data for the month of July, during which the heat wave occurred. This was the period of the most extreme summer weather, regarded by residents as most oppressive, and the mortality analysis therefore focused specifically on this event. As seen in the figure, the daily maximum temperature rose above 90° at the airport on July 4, reached peaks of 100° on July 7 and 103° on July 16 and did not fall substantially below 90 until the 19th. This period also saw daily average temperatures well above normal and, therefore, high daily minimums as well. Again, these temperatures were recorded at the airport; overnight low temperatures were most likely higher in urban areas of the county due to the so-called heat island effect (*10*).

Mortality, 1988. Table 2 displays all-cause, all-ages mortality for specified periods. Tallies for 1988 are compared with expected values based on the previous 5 years. Only two comparisons show statistically significant differences: a deficit of 99 deaths for June and an excess of 107 deaths for the heat wave period of July 4–18. The apparent excesses for July and August were not statistically significant and probably represent normal random fluctuation, and there was no difference at all in total mortality over the summer months.

Weekly mortality rates for the summer are shown in figure 2. This figure clearly indicates (*a*) the peak in mortality coinciding with the heat wave in early July, (*b*) the pattern of unexpectedly low mortality in June, and (*c*) the varied pattern for August, when a lower sec-

Figure 1. Daily temperature readings, Allegheny County, PA, July 1988



SOURCE: National Weather Service, Greater Pittsburgh International Airport

Figure 2. Observed and expected weekly mortality, all ages, Allegheny County, PA, June-August 1988

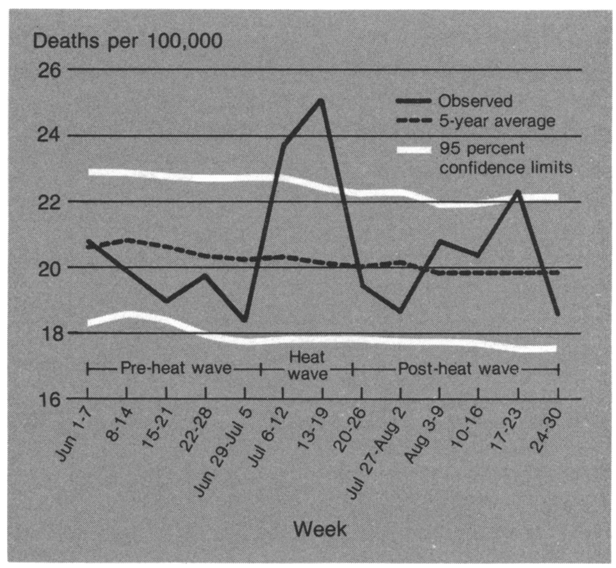


Figure 3. Daily mortality and daily maximum temperatures, Allegheny County, PA, July, 1988

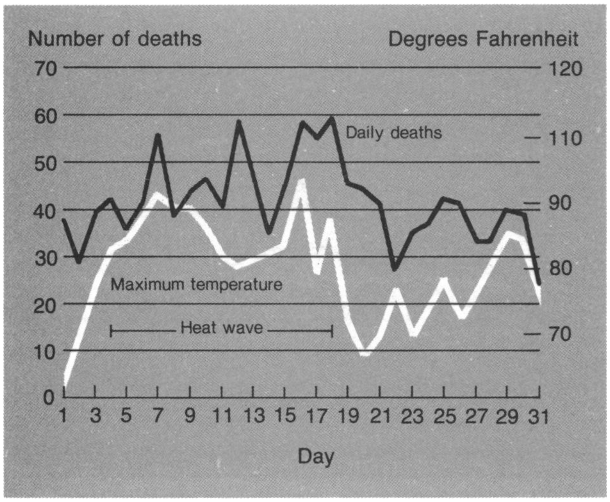
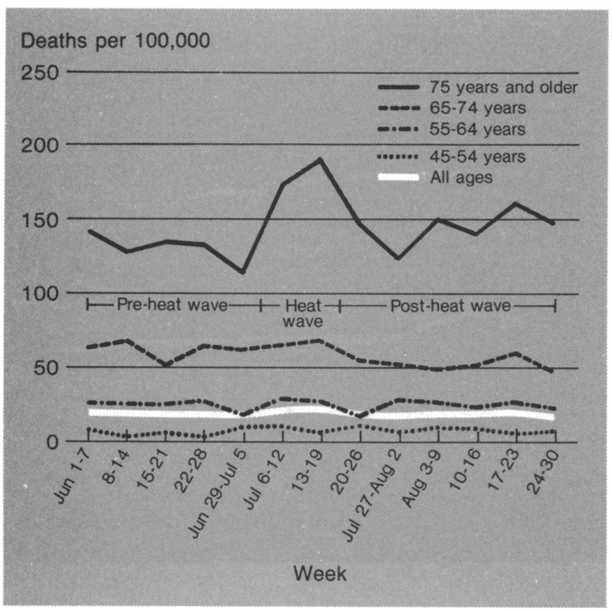


Figure 4. Age-specific weekly mortality rates, Allegheny County, PA, June-August 1988



ondary peak appeared after the return of seasonal temperatures in the second half of the month. Overall, the pattern suggests a typical common-source epidemic in which nearly all people at risk are affected over a short period, producing a temporary increase in the mortality rate followed by a temporary decrease, but no general increase over the entire period under consideration. A number of possible determinants of mortality were evaluated to understand better the dynamics of this apparent epidemic.

Mortality determinants, 1988. Information on temperature and ambient ozone and on the decedents' age, sex, race, residence, and place of death was examined in seeking determinants of the death rate for the 1988 heat wave.

Temperature. Daily mortality figures for July were plotted with daily maximum temperatures to show the pattern of death tallies with changing temperature. Figure 3 clearly shows the peaks in daily mortality, well above the monthly average of 41, during the heat wave. Typically, these coincided with temperature peaks, as on July 7 and 16. Overall, there was a fairly clear pattern of a direct relationship between maximum temperature and number of deaths (R = .44, $P < .01$) during July. The observed relationship of deaths with daily average temperature was equally strong (R = .46, $P < .01$), as was the correlation with the average temperature recorded on the previous day (R = .49, $P < .01$), suggesting the importance of successive high maximum temperatures coupled with high overnight temperatures. This combination is believed to cause the most severe stress to chronically ill elderly persons whose capacity to adapt to such unrelieved heat is greatly limited by impaired cardiovascular function.

For July, all of the temperature measures correlated significantly with daily deaths (not surprisingly, given their collinearity). Measures of dewpoint, windspeed, and percent sunshine did not correlate well, however. This finding supports previous analyses of heat wave mortality that consistently suggest that it is the temperature that matters most, rather than the humidity or lack of cloud cover. Presence of moving air might conceivably have mitigated the effects of heat, but this would have been a much more variable factor from area to area and not well summarized by as single measurement of windspeed taken at the airport.

Surprisingly, daily deaths also correlated well with maximum temperature in June (R = .37, $P = .02$), when there were fewer deaths than expected. This pattern for June might be explained by the fact that temperature varied widely over the month. Thus, even though the daily counts tended to increase when temperatures were increasing, as expected since these were the first unusually warm days of the year, there were a large number of days on which temperatures were actually below normal, and these were the days on which below-average numbers of deaths occurred.

In contrast, daily deaths did not correlate well with temperature in August, when a somewhat greater number of deaths than expected occurred. This observation is based on the occurrence of above-average numbers of deaths both on hot days in the first half of the month and on cooler days in the second half. The pattern for

August probably represents the exhaustion of the most susceptible population groups, followed by a return to normal random fluctuation in mortality. We are not aware of any specific events or conditions during the second half of August that might explain this inconsistency (for example, the occurrence of an outbreak of acute respiratory disease).

Table 3. Observed and expected mortality for Allegheny County, PA, July 14-18, 1988

Category	*Number of deaths*		*Excess (rate per 100,000)*	*P value*
	Expected	*Observed*		
Ages 65–74 years..	146	183	29.6	<.01
Men	84	91	13.5	NS
Women	62	92	40.7	<.01
Whites..........	132	166	29.3	<.01
Nonwhites.......	14	17	31.4	NS
Pittsburgh	49	69	54.3	<.01
Other county.....	97	114	19.2	NS
Ages 75 and older..	280	358	82.6	<.01
Men	118	145	82.7	<.05
Women	162	213	82.5	<.01
Whites..........	254	328	85.3	<.01
Nonwhites.......	26	30	51.5	NS
Pittsburgh	93	131	133.0	<.01
Other county.....	187	227	60.7	<.01
All ages.......	587	694	7.8	<.05

NOTE: NS = not significant.

Age. Weekly mortality rates in several age strata over the summer are presented in figure 4. There was no obvious variation in rates for age groups under 65, some variation in the 65–74 category, and marked variation in the 75 and older category. The peak in the oldest age category coincided with the heat wave in early July, demonstrating that elderly residents of the county were at greatest risk of heat-related mortality. The observed and expected counts in table 3 indicate that there were 78 excess deaths among the 75 and older age group during the heat wave, an increase of 28 percent above the expected. There were 37 excess deaths among the 65–74 age group, an increase of 25 percent above expected. For all ages combined, there were 107 excess deaths for the heat wave period. The total of 115 in the two oldest age strata was offset slightly by a nonsignificant deficit of 8 deaths among all younger groups, to produce the total of 107.

There were excess deaths in the two oldest age categories during the month of August, which was also unusually warm. Unexpectedly high numbers of deaths in July and August were again offset by unexpectedly low numbers in June; thus, for the entire 3-month period excess mortality among persons 65 and older was only 4 percent.

Sex. Weekly mortality rates per 100,000 were greater for males than the rates for females in all age categories, although there were more deaths among females than among males over the summer (reflecting the preponderance of women in the elderly population). Examination of the weekly rates by sex in the 65–74 and 75 and older age categories revealed that both sexes experienced increased mortality during the heat wave, but the effect was apparently somewhat greater on women, as seen in table 3. Excess mortality rates were highest among women and men ages 75 and older (51 and 27 excess deaths, respectively), somewhat lower among women ages 65–74 (30 excess deaths) and nonsignificant among 65–74-year-old men (7 excess deaths).

Race. Greater than expected numbers of deaths were observed for both whites and nonwhites in both susceptible age strata for the heat wave period, but the small excesses were not statistically significant for nonwhites in either. This observation suggests that nonwhites were not at increased risk of heat-related mortality relative to whites. Previous heat wave analyses have tended to find higher risk among nonwhites, although not uniformly so (*5–8*). In past studies this association has probably been confounded by socioeconomic status and quality of housing, however (*9*). White-nonwhite income and housing disparities in Allegheny County may be so small that no risk differential could appear between race groups in this area.

Residence. Rates of excess mortality were about twice as great in both susceptible age categories in the city of Pittsburgh as in the remainder of Allegheny County. This observation was somewhat surprising, since much of the rest of the county is urban. The county does include large suburban and semi-rural residential areas as well, however, where the effects of high daytime temperatures may have been mitigated by appreciable overnight cooling, leading to decreased risk of heat-related mortality. Many of these areas outside the central city are also more affluent, and their residents may have been at lower risk because of their favorable socioeconomic status.

Place of death. Concern about the possible relationship between availability of air conditioning in health care institutions prompted us to examine the place of death for deaths occurring during the heat wave. Among county residents ages 65–74, two-thirds (67 percent) occurred in a hospital during 1983–87, 10 percent in nursing homes, and 23 percent at home or in a public place; in the 75 and older age category, 56 percent of deaths occurred in hospitals, 24 percent in nursing homes, and 20 percent outside of an institution. During the heat wave of July 1988, these proportions did not change significantly in either age group, suggesting that there may not have been an increase in risk for residents of nursing homes, which currently are not required to have air conditioning.

Ambient ozone. An air pollution advisory was issued by the health department on July 6, at the beginning of the heat wave, because ozone levels exceeded the Federal standards (.12 ppm at any hourly reading). Ozone levels subsequently fell and remained below Federal standards.

When ozone levels and daily mortality for July were plotted (data not shown) there was a fairly strong relationship between mortality and both maximum ozone ($R = .36$, $P < .05$) and average ozone ($R = .41$, $P < .05$). Both ozone measures were positively correlated with mortality for June, when no excess deaths occurred, but they were not at all correlated with mortality for August, when excess deaths did occur. This is the same pattern that was observed between daily maximum temperature and mortality over the summer, and most likely it reflects the contributory role played by high temperatures in the formation of ambient ozone, rather than a direct effect of ozone on mortality. As noted before, excessively high ambient ozone levels were not observed after the first few days of the heat wave, but high daily mortality counts continued during the remainder of the heat wave. These findings tend to support those of Oechsli and Buechley, who found that air pollution had no additional effects on daily mortality among the elderly during a heat wave in Los Angeles (*4*).

Comparison with 1973 heat wave. The heat wave of 1973 consisted of 10 consecutive days on which the maximum temperature exceeded 90° F. During this period there were a total of 583 deaths, compared with the expected 420 ($P < .001$).

Age-specific death counts during the 1973 heat wave demonstrated a somewhat different pattern of susceptibility than those in the 1988 episode. There were no excess deaths among persons under 55 years of age. Among persons 55–64 years, 100 deaths were observed compared with 74 expected ($P < .01$); among persons 65–74 there were 114 deaths observed compared with 95 expected ($P < .05$); and among persons 75 and older there were 286 deaths observed compared with 165 expected ($P < .01$). There were a total of 166 unexpected, excess deaths, then, all of them occurring among persons 55 or older. In 1988 excess deaths during the heat wave were confined to the over-64 age categories.

The 1973 heat wave produced a total of 152 cooling degree-days. Using the age-specific excess death estimates and 1973 estimated county population data, there were then 1.15 excess deaths per degree-day per 100,000 in the 75 and older age category, 0.11 in the 65–74 age category, and 0.10 in the 55–64 age category.

The 1988 heat wave was both longer and more intense than the 1973 episode, producing 244 cooling degree-days. If the same rates of excess deaths per degree-day observed for 1973 had occurred in 1988, there would have been 190 excess deaths in the 75 and older age group (78 observed, $P < .01$), 34 in the 65–74 age category (37 observed, $P > .05$), and 38 in the 55–64 age category (none observed, $P < .01$). It appears that risk of mortality during a heat wave did decrease significantly from 1973 to 1988 in the oldest age category and among 55–64-year-olds, while remaining unchanged among 65–74-year-olds. These results are consistent with the hypothesis that the overall lethality of heat waves in Allegheny County decreased from 1973 to 1988.

Discussion

The Centers for Disease Control issued a warning of the possible effects of unusually hot weather fairly early in the summer of 1988, emphasizing the risk of heat stroke and heat exhaustion among the chronically ill elderly (*17*). The Allegheny County Health Department also issued hot weather health recommendations at the same time that an air pollution advisory was announced because of high ozone levels. Sales of home air conditioners were said to have exhausted available supplies early in the summer season in the Pittsburgh area, and at least one voluntary agency, the American Lung Association, was lending air conditioners to eligible clients with chronic lung diseases (*18, 19*). These factors may have prevented the hot summer of 1988 from taking a greater toll in excess mortality than it did by increasing awareness of the dangers of high temperatures and by providing substantial numbers of citizens with relief from the heat.

The relative preparedness of the county's population and sources of health information might explain our finding of (*a*) no overall mortality excess during the summer, despite transient increases in daily mortality during the hottest 2 weeks of July and the first part of August and (*b*) heat-wave associated excess mortality that was smaller than expected when compared with the excess observed during the milder heat wave of 1973.

The age and sex pattern of excess mortality observed during the July heat wave was consistent with previous reports in the literature. Risk was entirely confined to persons ages 65 or older and appeared to be somewhat greater among elderly women than among elderly men, perhaps because of physiologic differences in adaptability to high temperatures or selective survival of less-susceptible men to these advanced ages (*6*).

There was no substantial overall difference in risk between whites and nonwhites during the heat wave, unlike conditions observed in recent heat wave studies in St. Louis and Memphis, where black residents were at a decided disadvantage relative to whites (*7, 8*). If anything, Allegheny County data indicate that nonwhites may have fared somewhat better than whites. Among those older than 64, mortality of nonwhites during the heat wave period was 17.9 percent greater than expected in the city of Pittsburgh and 30.8 percent less than expected in the reminder of the county. Mortality of whites of the same ages was 40.7 percent greater than in the rest of the county. Schuman found a similar pattern for New York City in 1966 (*5*). His suggestion was that any effect of race on heat wave mortality would need to be adjusted for housing and income, and this is probably correct. Given the few deaths of nonwhites in our study, it seems most reasonable to assume that there was no significant difference between whites and nonwhites in mortality during the summer of 1988.

Overall, these results should be encouraging to observers of trends in heat wave mortality, particularly if predictions of generally hotter and drier conditions in many areas turn out to be correct over the next several seasons. Public health officials in urban areas should be able to monitor long- and short-range weather forecasts and issue appropriate environmental health warnings when extended periods of unusually hot weather appear likely. The Allegheny County data from the summer of 1988 suggest that public awareness of the importance of protecting the susceptible elderly, coupled with wider availability of air conditioning, may help to minimize the effects of extreme summer weather. These suggestions constitute an ecologic hypothesis at this point, and further research in this area is needed to measure the effects of health education of the general public and air conditioning upon other defined populations exposed to periods of unusually hot weather.

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