Associations Between Coronary Mortality and the Weather, Chicago, 1967

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STUDIES DEALING specifically with coronary mortality as related to weather are rare, even though coronary heart disease (CHD) is the leading cause of death in the United States. The few studies that have been published appear to only touch the surface. The data collected are often by season or month, only rarely by week, and almost never by day, and the numbers involved are often too small to permit any sort of statistical analysis in depth. Also, the areas chosen for study and the periods covered may be such as to completely bar investigation of certain topics. This study for Chicago overcomes some of these obstacles. It is a sequel to one of cardiovascular mortality in Memphis (*1*) and to a related study in Chicago (*2*).

In the Memphis study daily weather and mortality records for the 3 years 1959–61 were used to study associations of deaths and weather. The weather variable found to be most strongly associated with CHD deaths was the daily average temperature. An inverse relationship with temperature was found for coronary heart disease, whether or not respiratory disease was present. The general pattern observed was somewhat L-shaped, with the sharp change occurring between the 10 to 29° F days and the 30 to 39° F days.

The major aims of the Chicago study were to measure any excess in coronary deaths (by age, race, and sex of decedent) that was related to daily temperatures, snowfall, and other weather factors and to determine, by using data on multiple causes of death, whether any excess in CHD deaths could be linked to respiratory disease.

All deaths occurring in Chicago in 1967 were studied. The primary or underlying cause of death, as well as any contributory causes appearing on the death certificate, were coded. In all, there were 14,418 deaths due to coronary heart disease (category 420 in the Seventh Revision of the International Lists (*3*)).

Information obtained from the death certificate included the type of certifier (whether coroner or not); the month, day, and hour of death; decedent's sex, race, and age at death; and the interval between onset and death for the immediate cause of death.

Weather information for Chicago recorded at Midway Airport was obtained from the U.S. Weather Bureau for each day of 1967. This included daily temperatures, precipitation, snowfall, amount of snow on the ground, wind speed, hours of sunshine, and relative humidity.

Since multiple-cause coding was used, deaths could be tabulated in a number of different ways. Significant for this investigation was the presence of a respiratory disease along with coronary heart disease.

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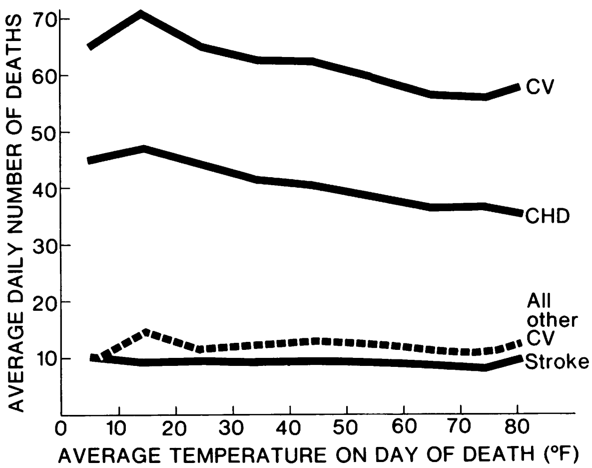
Results

By way of background, figure 1 shows the deaths from the major cardiovascular (CV) diseases according to the daily average temperature. For all CV diseases (categories 330–334, 400–468) and for coronary heart disease, clear-cut relationships to temperature of a generally inverse nature are evident; for stroke (categories 330–334) and for the remaining CV diseases, no clear-

Figure 1. Average daily deaths from cardiovascular diseases by average temperature on day of death, Chicago, 1967



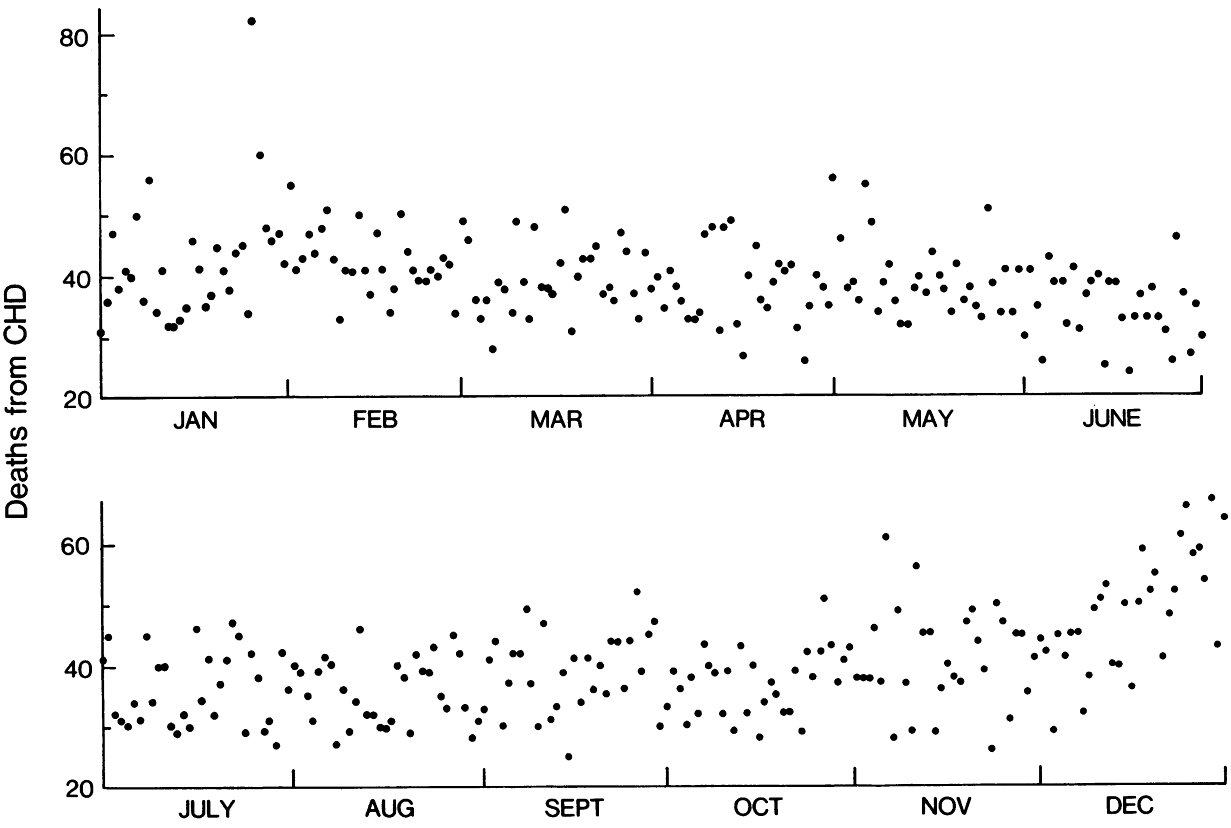
NOTE: CV—ICD (7th revision) 330–334 and 400–468; CHD—ICD (7th revision) 420; Stroke—ICD (7th revision) 330–334; All other CV—ICD (7th revision) 400–416 and 421–468.

cut relationship to the daily temperature emerges.

Unlike the earlier Memphis study (*1*), in which an L-shaped pattern was observed, the average daily number of deaths from coronary heart disease in Chicago has a straight-line relationship with daily average temperatures. Mortality was highest for days under 20° F, averaging 45–47 deaths per day, while for days with temperatures in the 80s there was a low of 35 deaths per day.

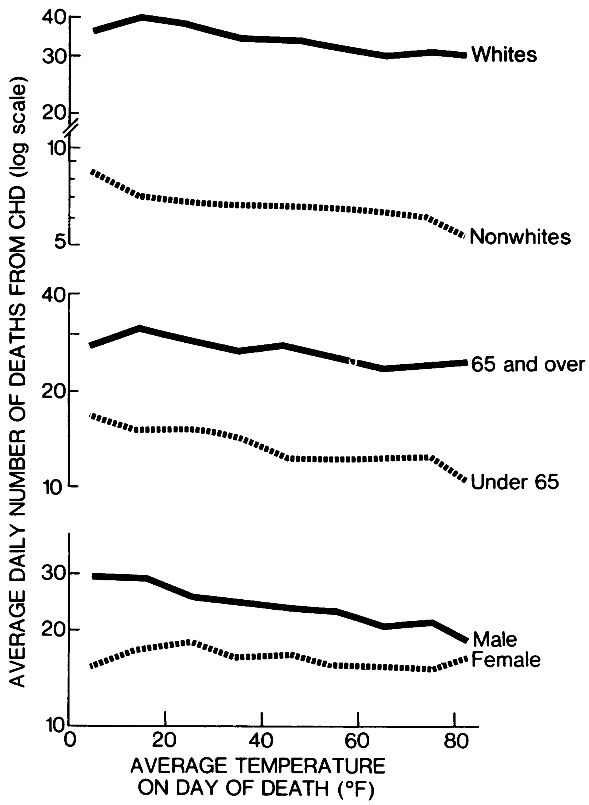
Figure 2 shows the daily deaths from coronary heart disease. There was considerable day-to-day fluctuation in the number, ranging from a low of 24 for June 18 to a high of 83 for January 26, with an average of about 39 per day. The high of 83 deaths occurred on the first day of a record blizzard and was followed by 60 deaths on the second day of the storm. There were clusters of consecutive days with high or low mortality (fig. 2), the most striking one being a succession of 15 days at the end of the year with a total of 829 coronary deaths. In this period an average of 55 deaths occurred per day, which was about 40 percent above normal.

Figure 2. Daily deaths from coronary heart disease, Chicago, chronologically for 1967



NOTE: Coronary heart disease (CHD)—ICD (7th revision) 420.

Figure 3. Average daily deaths from coronary heart disease by race and average temperature, age and average temperature, and sex and average temperature, Chicago, 1967



In figure 3 the CHD deaths by daily average temperature are shown separately by decedents' race, sex, and age. These deaths were plotted on semi-log paper in order to make a more compact set of graphs and also to facilitate comparison of the percentage changes in mortality with temperature as indicated by the slopes of the curves. The pattern for whites appears to be generally similar to that for nonwhites; also, the under 65 and 65 and over groups show essentially similar patterns. A comparison of the patterns for males and females indicates a basic difference. For males there is a strong fairly consistent inverse relationship between CHD deaths and temperature; for females no clear or consistent relationship is seen.

In table 1 the average number of deaths per day from coronary heart disease according to precipitation and average temperature is presented in the top righthand section. Here the cutoff points for the temperature groups divide the year into three nearly equal parts. For days with an average temperature under 41°F, the CHD mortality was highest for days with snowfall, next highest for days with rain, and lowest for the remaining days. For each of the other two temperature groups, the days with rain averaged somewhat more deaths than days with no rain.

FIGURE 3 NOTE: Coronary heart disease—ICD (7th revision) 420.

Table 1. Average daily coronary heart disease deaths for selected weather variables, Chicago, 1967

Weather variable	Days with average temperature Fahrenheit—			Average daily CHD deaths with average temperature Fahrenheit—		
	Under 41°	41–62°	63° or more	Under 41°	41–62°	63° or more
Precipitation:						
Snow	38	...	...	45.2	...	...
Rain	14	45	39	43.9	40.0	37.7
No rain, no snow	72	75	82	41.7	38.3	35.9
Average wind speed (miles per hour):						
Under 10	35	35	71	42.9	37.1	36.6
10–12	40	42	31	41.3	40.9	35.1
13 or more	49	43	19	44.4	38.5	38.3
Hours of sunshine:						
0–2	57	49	9	43.3	40.0	37.3
3–8	45	32	39	43.4	39.6	37.0
9–15	22	39	73	41.2	37.0	36.1
Maximum relative humidity (percent):						
Under 81	50	45	32	41.7	37.2	35.9
81–88	43	32	44	41.8	39.0	35.
89 or more	31	43	45	46.7	40.6	37.6

NOTE: Coronary heart disease (CHD)—ICD (7th revision) 420.

Table 1 also shows the mortality from coronary heart disease according to (*a*) average wind speed together with average temperature, (*b*) hours of sunshine together with average temperature, and (*c*) maximum relative humidity together with average temperature.

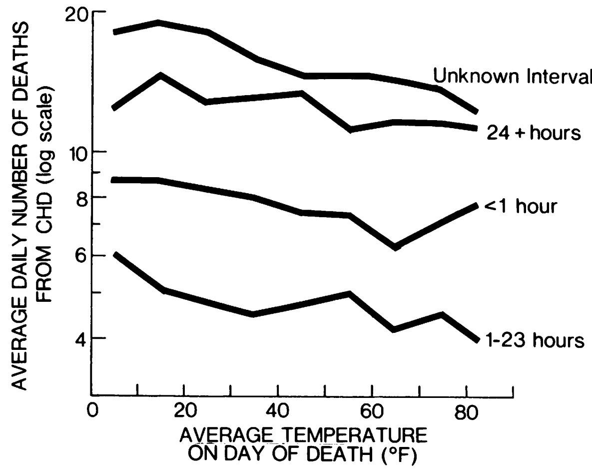
The results of controlling for the known effect of temperature upon mortality can be seen in the right half of table 1, which shows that CHD deaths vary directly with the average wind speed and the maximum relative humidity and that they also vary inversely with the hours of sunshine. In all three instances, however, the associations are only slight.

Daily CHD deaths were also studied according to the daily high and low temperatures, the amount of snow on the ground, maximum wind speed, percentage of possible sunshine, and minimum relative humidity. The results generally were similar to those already described for closely related weather variables.

In studying deaths as related to weather, "sudden" deaths from coronary heart disease may be of major importance. Here we used information taken from death certificates for the interval between the onset of illness (for the immediate cause of death) and death.

Figure 4 shows CHD mortality by average temperature separately for intervals less than 1 hour, for 1–23 hours, for 24 hours or more, and for an unknown interval. The less-than-1-hour category may be considered "sudden" CHD deaths. Although these deaths increased at higher temperatures, overall the observed patterns appeared to be fairly similar. (The last point on the line is based on only 6 days and may not be meaningful). Thus, the inverse relationship of death with temperature appears to be largely independent of the suddenness of death.

Figure 4. Average daily deaths from coronary heart disease in relation to interval from onset of immediate cause of death to death and average temperature on day of death, Chicago, 1967



NOTE: Coronary heart disease—ICD (7th revision) 420.

One aim of the investigation was to determine, by using data on multiple causes of death, whether any excess in CHD deaths could be linked to respiratory disease. In the Memphis study this question had been posed, and the answer was negative. That is, the excess in CHD deaths observed in cold weather could not be linked to the reported presence of a respiratory disease. In table

Table 2. Average daily deaths by presence or absence of coronary heart disease and of respiratory disease and by daily average temperature, Chicago, 1967

Daily average temperature (°F)	Number of days	CHD and R	CHD but no R	R but no CHD	Neither CHD nor R
1– 9	6	3.8	45.2	13.0	54.7
10–19	15	4.8	46.1	13.9	53.0
20–29	37	3.5	44.7	13.4	52.1
30–39	60	3.9	41.6	12.6	53.0
40–49	59	3.8	40.7	13.0	52.3
50–59	50	3.4	39.5	12.7	51.9
60–69	73	3.5	36.7	11.6	51.0
70–79	59	2.7	37.7	11.3	51.5
80–83	6	3.0	37.2	11.0	55.3
Total	365	3.5	40.0	12.4	52.1

NOTE: Coronary heart disease (CHD)—ICD (7th revision) 420; respiratory disease (R)—ICD (7th revision) 470–527.

Table 3. Average daily deaths from coronary heart disease by maximum relative humidity, snowfall, average temperature, and sex of decedents, Chicago, 1967

Percent maximum relative humidity	Average temperature Fahrenheit: Less than 41°, Snow	Less than 41°, No snow	41–62°	63° or more
	Average daily deaths for both sexes			
Less than 81	38.9	42.3	37.2	35.9
81–88	45.0	39.2	39.0	35.8
89 or more	50.0	44.9	40.6	37.6
	Average daily deaths for males			
Less than 81	23.1	25.2	22.1	20.8
81–88	27.7	24.2	22.4	20.7
89 or more	31.8	25.9	24.2	21.2
	Average daily deaths for females			
Less than 81	15.8	17.1	15.1	15.2
81–88	17.3	15.0	16.6	15.1
89 or more	18.2	19.0	16.4	16.4
	Number of days			
Less than 81	8	42	45	32
81–88	19	24	32	44
89 or more	11	20	43	45

NOTE: Coronary heart disease—ICD (7th revision) 420.

2 the same question is now presented for Chicago for 1967. The results confirm those for Memphis (see column labeled "CHD but no R").

Table 3 presents the average daily deaths from coronary heart disease according to sex of decedent for the categories "temperature-snowfall" and "humidity."

Overall, the results are more striking for males than for females. The range shown for males is 21 to 32 deaths per day; for females the range is only 15 to 19. Temperature, snowfall, and humidity seem to be related to CHD mortality for males, but the picture for females differs. Snowfall does not appear to be relevant; temperature and humidity may be.

A different vantage point is afforded in table 4. Here correlations are shown for combinations of these three weather variables with CHD mortality. These correlations are based on daily values, that is, 365 points. Temperature and snowfall seem to be related to deaths of males, but temperature and humidity may be the important factors for females. Save for the humidity values, the correlations are higher throughout for males than females. *R* values in this table were obtained as byproducts from a multiple linear regression program in which 10 weather variables were included. The other seven variables were: range in temperature, precipitation, inches of snow on the ground, average wind speed, hours of sunshine, percentage of possible sunshine, and change in temperature from the preceding day. It is interesting to note that when all 10 were included, the *R* values were 0.52 for both sexes—0.54 for males and 0.27 for

Table 4. Selected correlations of weather variables with daily coronary heart disease deaths, by sex of decedents, Chicago, 1967

Independent variables	*R* values: Both sexes	Males	Females
1. Average temperature (°F)	—0.36	—0.39	—0.15
2. Snowfall and sleet (inches)	.35	.40	.10
3. Maximum relative humidity (percent)	.13	.06	.15
Variables 1 and 2	.46	.50	.16
Variables 1 and 3	.44	.43	.25
Variables 2 and 3	.36	.40	.17
Variables 1, 2, and 3	.50	.52	.25

NOTE: Coronary heart disease—ICD (7th revision) 420.

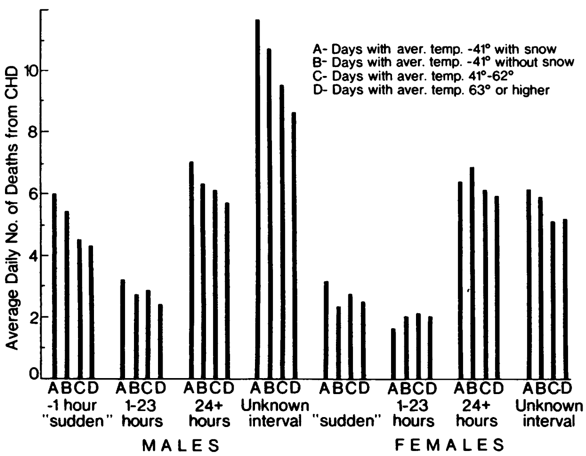
females. Thus, it appears that little is gained by adding new variables to the three with which we began.

Figure 5 presents the average daily deaths from coronary heart disease according to sex for the categories "temperature-snowfall" and "interval." As before, the patterns for males are clear cut, but those for females are not.

In figure 6 the average daily deaths from coronary heart disease are given by the categories "sex," "temperature-snowfall," and "hour of death." For the coroner-certified deaths, the time of death was not given on the death certificate. For males the observed gradient by snowfall-temperature A>B>C>D is clearly present and remarkably similar in all three groups. Also of interest here is the consistently greater number of CHD deaths occurring in the daytime as compared with nighttime. This observation holds also for females. It appears highly unlikely that the coroner-certified deaths could be so heavily biased in the direction of nighttime deaths that this result could be upset.

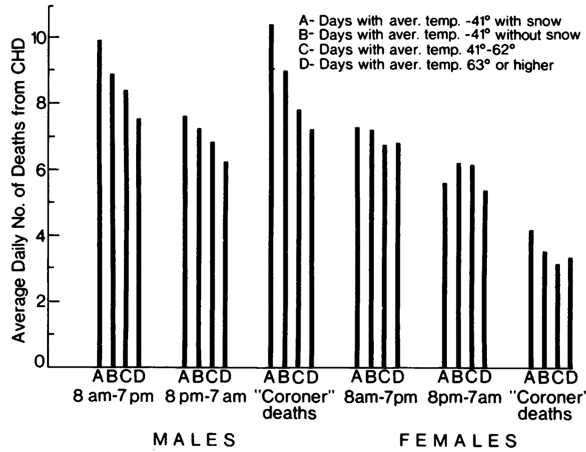
Figure 7 can now be studied in conjunction with table 5. This chart attempts to illustrate the time of "sudden" CHD deaths of males in relation to periods of snowfall for each of the 16 days with 1 inch or more of snow. For example, on January 4, 1967, according to the Weather Bureau, snow

Figure 5. Average daily deaths from coronary heart disease by interval from onset of immediate cause of death to death, average temperature on day of death, snowfall, and sex of decedents, Chicago, 1967



NOTE: Coronary heart disease—ICD (7th revision) 420.

Figure 6. Average daily deaths from coronary heart disease by hour of death, average temperature on day of death, snowfall, and sex of decedents, Chicago, 1967



NOTE: Coronary heart disease—ICD (7th revision) 420.

fell from 1:15 pm to 1:35 pm and again from 2:19 pm to past midnight. According to our mortality records taken from the death certificates, one man died of a sudden coronary attack between 2 and 3 am, one between 4 and 5 am, one between 11 am and noon, and one between 2 and 3 pm. Thus one death is counted as occurring during a snowfall period and three deaths as occurring outside a snowfall period, on January 4.

Over all of the 16 days shown in figure 7, 50 deaths were observed during snowfall periods and 41 outside such periods. This result is recorded as "50 + 's" and "41 — 's" under the heading "Observed" in the lowest panel of table 5. Now, if time of death were wholly independent of snowfall, what should be expected in the way of pluses (+'s) and minuses (—'s) for the 91 deaths shown in figure 7? We simply added the total time (in minutes) that it snowed during these 16 days and divided this figure by the total number of minutes in 16 days. This operation gives an "expected" percentage—in this case 39.6. Applying this percentage to 91 yields 36.0 expected for plus (+) and 55.0 for minus (—).

Comparing the observed values with the expected (table 5), we see little difference for most groups. It is only the "male < 1 hour" (or sudden CHD deaths) category and possibly the 1–23

Table 5. Observed and expected coronary heart disease deaths by sex, interval from onset of immediate cause of death to death, and whether death occurred during a snowfall period (+) or not (—), Chicago, 1967

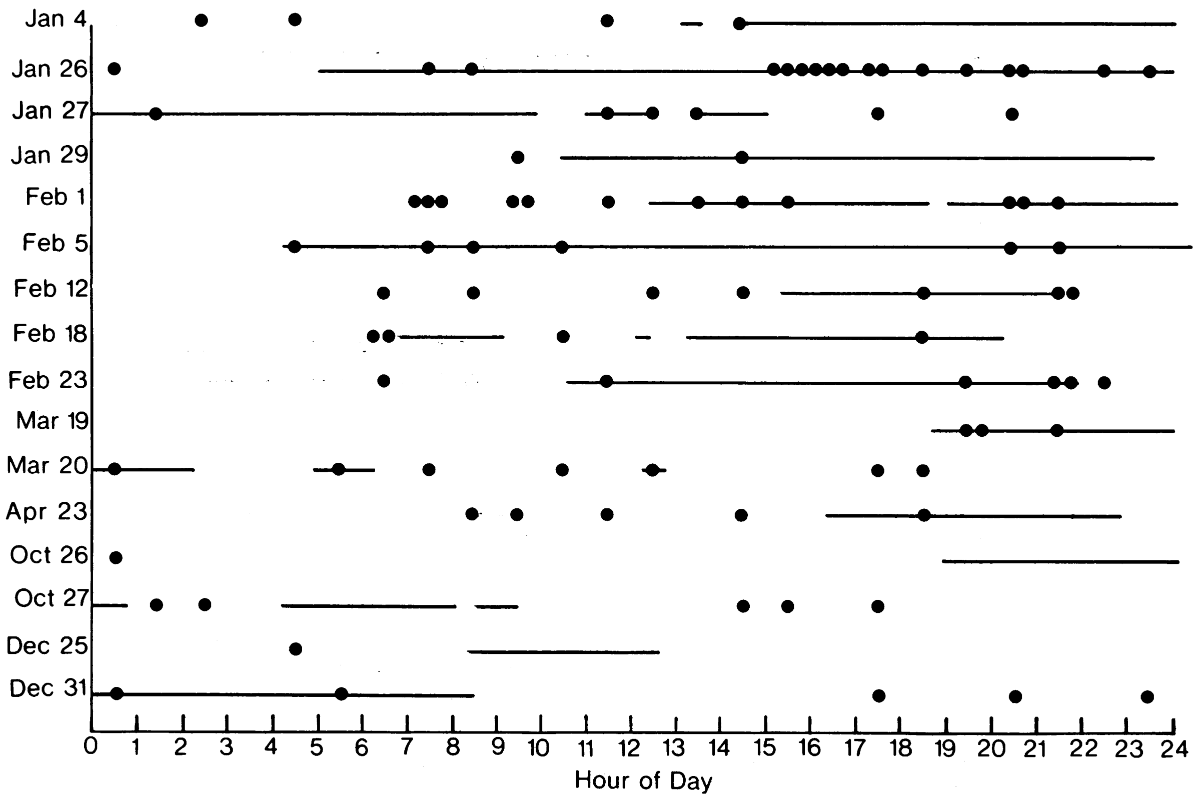
Sex of decedents and interval in hours	Observed deaths		Expected deaths [1]	
	+	−	+	−
	38 days with snowfall			
Both sexes	407	749	382.5	773.5
Less than 1	108	151	87.8	171.2
1–23	63	117	58.7	121.3
24 or more	162	344	165.7	340.3
Unknown interval	74	137	70.2	140.8
Males	242	424	219.8	446.2
Less than 1	70	94	56.1	107.9
1–23	44	77	38.9	82.1
24 or more	88	176	85.8	178.2
Unknown interval	40	77	39.0	78.0
Females	165	325	162.7	327.3
Less than 1	38	57	31.7	63.3
1–23	19	40	19.7	39.3
24 or more	74	168	80.0	162.0
Unknown interval	34	60	31.3	62.7
	22 days with less than 1 inch of snow			
Both sexes	177	445	171.0	451.0
Less than 1	38	84	33.5	88.5
1–23	27	77	28.6	75.4
24 or more	81	205	78.6	207.4
Unknown interval	31	79	[illegible]	79.8
Males	102	261	99.8	263.2
Less than 1	20	53	20.1	52.9
1–23	19	55	20.3	53.7
24 or more	45	110	42.6	112.4
Unknown interval	18	43	16.8	44.2
Females	75	184	71.2	187.8
Less than 1	18	31	13.5	35.5
1–23	8	22	8.2	21.8
24 or more	36	95	36.0	95.0
Unknown interval	13	36	13.5	35.5
	16 days with 1 or more inches of snow			
Both sexes	230	304	211.5	322.5
Less than 1	70	67	54.3	82.7
1–23	36	40	30.1	45.9
24 or more	81	139	87.1	132.9
Unknown interval	43	58	40.0	61.0
Males	140	163	120.0	183.0
Less than 1	50	41	36.0	55.0
1–23	25	22	18.6	28.4
24 or more	43	66	43.2	6 · 8
Unknown interval	22	34	22.2	33.8
Females	90	141	91.5	139.5
Less than 1	20	26	18.2	27.8
1–23	11	18	11.5	17.5
24 or more	38	73	44.0	67.0
Unknown interval	21	24	17.8	27.2

[1] Expected numbers were derived separately for the 22-day period and for the 16-day period by applying the proportion of the entire study period in which snow fell (or did not fall) to the total deaths (with known time of death) in each "sex-interval" category. Expected numbers for the 38-day period were then obtained by addition.

NOTE: Coroner-certified deaths are omitted since time of death was not recorded on the death certificate.

Coronary heart disease—ICD (7th revision) 420.

Figure 7. Hours of "sudden" coronary heart disease deaths of males in relation to 16-day periods with snowfall of 1 inch or more, Chicago, 1967



NOTE: Coronary heart disease—ICD (7th revision) 420.

hour category for the high snowfall days for which an excess of pluses (+'s) is noted. This result would tend to support the notion that actual exposure to snowfall may be the cause of the increased mortality observed for the sudden CHD group. That this result holds only for the high snowfall days seems reasonable.

Discussion

These results can be placed in perspective by considering a general framework for their interpretation. To do this, we pose a set of questions and attempt to answer them by using data from the study.

1. Is there an association between daily temperatures and deaths from coronary heart disease (CHD)? What is the nature of this association? Direct? Inverse? Linear? Exponential? Is the association independent of the well-known seasonality of respiratory disease? What of other weather factors, such as snow, rain, wind, and relative humidity?

2. Do the associations observed for coronary heart disease hold for males as well as for females? For whites and nonwhites? For young and old? Do they hold for "coroner" deaths as well as for "noncoroner" deaths?

3. How closely can we tie any observed relationship to actual exposure to the weather? For example, is there an association between daily temperatures and sudden deaths from coronary heart disease occurring outdoors? Indoors? During the day? At night?

4. Are there any specific activities related to the weather that appear to increase the mortality risk? For example, does shoveling snow increase the risk of sudden death from heart attack?

5. How do the associations found between daily temperatures and CHD mortality tie in with observed geographic differences in CHD mortality? Do areas with one kind of climate tend to have higher CHD mortality than areas with another kind?

6. What role does air pollution play?

7. Is the association of daily temperatures and CHD mortality more pronounced in the year of an influenza epidemic?

8. What inferences can be made with respect to an association between daily temperatures and the incidence of coronary heart disease? What of other weather factors?

This study has been concerned mainly with the first two questions, which may be answered as follows. Yes, there is an association between daily temperatures and deaths from coronary disease. It is an inverse linear association and appears to be independent of the well-known seasonality of respiratory disease. The pattern for coronary heart disease holds for males but not for females. It holds for whites and nonwhites and for young and old.

When temperature is controlled, the data for CHD mortality suggest that there are more deaths on days with snowfall than on days with none and that there is a small direct relationship to the daily relative humidity. The associations hold for coroner-certified deaths as well as for noncoroner-certified deaths, as may be seen in figure 6.

With respect to the third question, the analyses of sudden CHD deaths according to the hour of death and the daily average temperature showed similar patterns for deaths occurring during the day and deaths occurring at night (these data are not shown). This result is contrary to the notion that direct exposure to the weather is relevant. On the other hand, there is a hint that direct exposure is relevant in that an inverse relationship with temperature was observed for CHD deaths of males, but not for CHD deaths of females. The assumption is that males in general spend more time outdoors than do females. Of course a special study could pin down any association between daily temperatures and sudden CHD deaths occurring outdoors.

Questions 4–8 remain unanswered, although table 5 and figure 7 give some data on CHD deaths during periods of snowfall. Many attractive areas for research remain. Each requires investigation in its own right and ideally would cover a wide number of areas and a period of years.

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(*3*) World Health Organization: Manual of the international statistical classification of diseases, injuries, and causes of death. (Based on the recommendations of the Seventh Revision Conference, 1955, and adopted under the WHO nomenclature.) Geneva, 1957.

ROGOT, EUGENE (National Heart and Lung Institute): ***Associations between coronary mortality and the weather, Chicago, 1967. Public Health Reports, Vol. 89, July–August 1974, pp. 330–338.***

Daily weather and mortality records for Chicago, Ill., for 1967 were used to investigate associations of coronary heart disease (CHD) deaths and weather. The weather variable most strongly associated with CHD mortality was the daily average temperature. An inverse linear relationship was observed between temperature and CHD deaths, whether or not respiratory disease was present. This pattern held for males but not for females; similar patterns were observed for whites and nonwhites and for persons under and over 65. Sudden CHD deaths showed much the same inverse linear relationship to temperature as did other CHD deaths.

When temperature was controlled, positive associations were noted for CHD mortality and snowfall. This result held for males but not for females. Also, when the temperature was controlled, there appeared to be a weak direct relationship between CHD deaths and daily relative humidity. The association between snowfall and temperature with deaths from coronary heart disease held for coroner-certified deaths as well as for noncoroner-certified deaths.

An interesting observation was the consistently greater number of CHD deaths occurring in the daytime as compared with night-

Results of detailed examination into the time of death in relation to periods of snowfall supported the notion that actual exposure to snowfall was the cause of the increased mortality observed for the sudden CHD group.