Winter Weather and Cardiovascular Mortality In Minneapolis-St. Paul

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Abstract: A study of vital statistics data from five Minneapolis-St. Paul winters indicates cardiovascular mortality is influenced by winter temperatures and snow. Although air temperature was not statistically implicated in triggering cardiovascular mortality in four of the five study winters, during the winter of 1976–77, about 15 per cent of the variance in daily cardiovascular mortality could be attributed to fluctuations in the daily minimum air temperature. Snow influenced mortality on the day of occurrence as well as the two days following a snowfall.

There appear to be some differences in the ability of winter weather to influence mortality from acute myocardial infarction (ICD 410) and old myocardial infarction (ICD 412). The variance in daily ICD 410 mortality attributable to the influence of snow is somewhat less than that in daily ICD 412 mortality. The greatest variance in daily ICD 412 mortality that could be ascribed to snow occurred during the winter of 1974–75, and was 13 per cent. It is likely that rain intermixed with snow may also trigger increased mortality from cardiovascular disease. A combination of rain and snow can produce dramatic increases in mortality from ICD 410. Study of mortality data from five winters indicates that snow is somewhat more important in triggering deaths from heart disease than is air temperature. (*Am J Public Health* 1982; 72:261–265.)

Introduction

Winter weather has been presumed to exert deleterious stress on human health by both the scientific community and the general public. However, this presumption has been made largely on the basis of qualitative rather than quantitative studies. The Minneapolis-St. Paul area is noted for its harsh winters, and if winter weather does produce noticeable health effects, such effects should be discernible from a quantitative study over a five-winter period.

Snowfall may cause people to perform unusually heavy physical activity in snow clearance tasks. It may also cause stress in people walking through wet, heavy snow and drifts; it may be the cause of falls on slippery pavements.

Cold air temperatures have been shown to alter heart rate and increase systolic and diastolic pressures.[1] Cold weather and snow have been shown to be statistically related to deaths from stroke and heart attack.[2] Cold snaps in Toronto increased sudden deaths from ischemic heart disease among men under 65 years of age.[3] Deaths from ischemic heart disease in Boston increased 22 per cent in the week following a blizzard.[4] In Toronto, ischemic heart disease deaths increased on the day of a 10.2 cm (4") or greater snowfall, and remained elevated for the following three days.[3]

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Materials and Methods

To investigate the possible role of air temperature, precipitation, and snow in heart mortality, I studied daily mortality and daily weather conditions in the Minneapolis-St. Paul Standard Metropolitan Statistical Area (SMSA) for five winters. The winters ran from January 1, 1973 to March 31, 1973, December 1, 1973–March 31, 1974, December 1, 1974–March 31, 1975, December 1, 1975–March 31, 1976, and December 1, 1976–March 31, 1977.

Daily mortality for the SMSA was obtained from the National Center for Health Statistics Detailed Mortality Tapes, which codes daily deaths by the International Classification for Diseases (ICD) system (Eighth Revision). Heart disease, comprising ICD codes 390–398, 402, 404, and 410–429, was studied as a unit, but separate statistical computations were also performed for ICD 410 (acute myocardial infarction) and ICD 412 (old myocardial infarction), the two major categories of cardiovascular mortality.

Air temperature data were modified by the subtraction of long-term average daily minimum temperatures from the observed daily minimum temperatures. This was done to eliminate the bias caused by the annual seasonal swing in temperatures. (It eliminated low frequency noise in the temperature spectrum.) Anderson and Rochard found that a similar subtraction did not change their results.[3]

Computations were performed on the University of Michigan Amdahl 470v8 computer using the MIDAS statistical package. Single and multiple correlation coefficients were computed using the method outlined by Snedecor and Cochran.[5] Time series analysis was done using the BMD3T

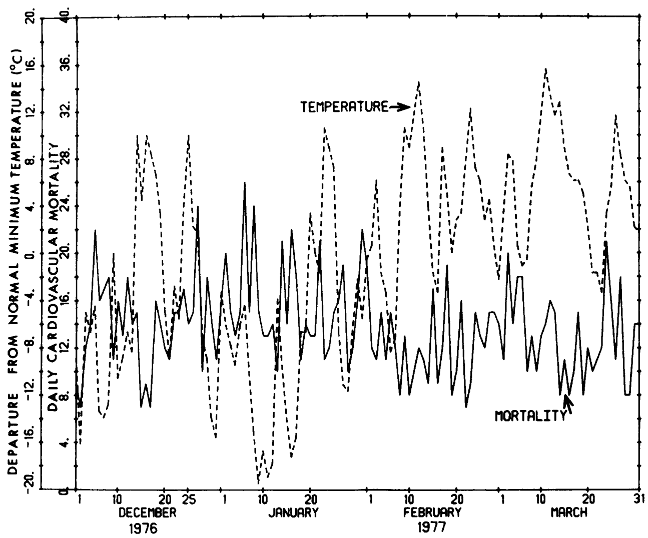

FIGURE 1—Time Series Plots of Cardiovascular Mortality (solid line) and Departures from Normal Minimum Air Temperature (dashed line) for Minneapolis-St. Paul SMSA for the Winter December 1, 1976–March 31, 1977

program.[6] Limiting values of coherence were calculated using the equation suggested by Panofsky and Brier.[7]

Results

Minimum Temperature and Cardiovascular Mortality in Minneapolis-St. Paul SMSA

Minimum temperature appeared to play no role in cardiovascular mortality in four of the five study winters; only in the winter of 1976–77 was there a statistically significant relationship. Figure 1 shows the time series plot of departure from normal daily minimum air temperature and daily cardiovascular mortality during the 1976–77 winter. During this winter, minimum air temperatures from six days preceding death to minimum temperature on the day of death were strongly related to cardiovascular mortality (Table 1). About 13 per cent of the variance (the square of the correlation coefficient) in daily cardiovascular mortality can be attributed to minimum air temperatures on the day of death and on the third day preceding death, and about 15 per cent overall.

The unusual importance of minimum daily air temperature in heart mortality during the winter of 1976–77 may be due to the prolonged period of below normal temperatures in December 1976, and January 1977, followed by the prolonged period of above normal minimum daily temperatures in February and March 1977. The winter was one of extreme temperatures for much of the four-month period, and these extreme temperatures enhanced the statistical effects of minimum temperature on cardiovascular mortality.*

The good correlation between minimum air temperature and cardiovascular mortality for long time periods during this winter indicated that a more elaborate investigation of the relationship between the two series using cross-spectrum analysis should be attempted. At a frequency of 0.375 (corresponding to a period of 2.7 days), the spectrum of cardiovascular mortality was 88.10 out of phase from the spectrum of minimum air temperature, with a coherence (serial correlation) of 0.447, significant at the 95 per cent level. At a period of 15.8 days, the spectra were 179.60 out of phase, with a coherence of 0.443. However, the largest contribution to the cross spectrum is at periods greater than 16 days, with a coherence of 0.753, indicating the importance of the long-term temperature fluctuation during this winter. These high coherences suggest that a strong relationship between minimum air temperature and cardiovascular mortality existed over the course of the winter, and indicate that the two series are indeed correlated at both short and long periods.

Winter Precipitation and Cardiovascular Mortality in Minneapolis-St. Paul SMSA

The traditional medical view of winter weather suggests that cardiovascular mortality is enhanced by snow. The importance of snow in winter cardiovascular mortality was relatively variable in the Minneapolis-St. Paul SMSA during the five study winters, with snow having no statistically

*It is possible that a Canadian study of winter air temperature and its impact of myocardial infarction in Ontario[8] failed to detect any relationship because of the relatively normal winter temperatures during the study period.

TABLE 1—Correlation between Cardiovascular Mortality and Departures from Normal Minimum Air Temperature in the Minneapolis-St. Paul SMSA during the Winter of 1976–77

	Day Preceding Death						
	0	1	2	3	4	5	6
Correlation coefficient between cardiovascular mortality and departures from normal temperatures	−0.28	−0.22	−0.24	−0.28	−0.27	−0.28	−0.22
Significance	0.01	0.05	0.01	0.01	0.01	0.01	0.05

TABLE 2—Correlation between Snowfall on the Two Days Preceding Death and on the Day of Death with Mortality from Grouped Cardiovascular Mortality, from Acute Myocardial Infarction, and Old Myocardial Infarction in the Minneapolis-St. Paul SMSA

	Winter				
Cause	1973	1973–74	1974–75	1975–76	1976–77
Grouped Cardiovascular Mortality	0.24	0.29	0.07	0.16	0.13
	(0.05)	(0.01)	(N.S.)	(N.S.)	(N.S.)
ICD 410	0.24	0.23	0.12	0.22	0.19
	(0.05)	(0.05)	(N.S.)	(0.05)	(0.05)
ICD 412	0.21	0.22	0.36	0.20	0.18
	(0.05)	(0.05)	(0.01)	(0.05)	(0.05)

determinable influence on cardiovascular mortality as a whole in three winters, to the winter of 1973–74, where about 8 per cent of the variance in daily heart deaths could be attributed to snow (Table 2).

In the winter of 1974–75, total precipitation (the liquid equivalent of snow and all other forms of precipitation including rain and hail) played a more significant role than snow in daily cardiovascular mortality, and could explain 14 per cent of the variance in daily cardiovascular mortality. The stronger correlation of mortality with precipitation may reflect the influence of winter rainstorms and glaze storms on cardiovascular mortality. A time series plot of snow and cardiovascular mortality for this winter is shown in Figure 2. The cardiovascular mortality maximum (peaking with 35 deaths on January 12) in early January 1975 follows a snow and rain event (including thundershowers) with an accumulation of 10.2 cm (4″) of snow on January 10th. (Rain interspersed with snow will change the nature of snow, creating a wet, often mushy layer. When air temperatures

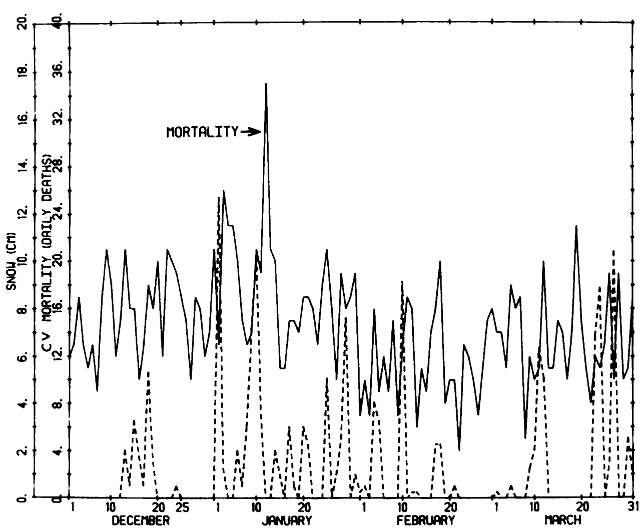

FIGURE 2—Time Series Plot of Cardiovascular Mortality (solid line) and Snow Occurrences (dashed lines) for the Minneapolis-St. Paul SMSA for the Winter December 1, 1974–March 31, 1975

fall, this wet, compacted mass will freeze to ice.) Total cardiovascular mortality during early January 1975 is shown in Table 3. Despite the poor correlation between snow and cardiovascular mortality during this winter, Figure 2 shows that cardiovascular mortality increased following snowfalls of 6 cm or more, not only after the two snowfalls in early January, but also after the snowfalls in late January, early February, and the three events in March.

Pooled mortality data for all five winters indicate that ICD 410 mortality is elevated primarily on the day of a snowfall and also on the following day. The strongest influence of snow on ICD 410 mortality in the five study years occurred in the winter of 1973 (January-March 1973), when about 6 per cent of the variance in daily ICD 410 deaths could be attributed to snow on the day preceding death and on the day of death (Figure 3). Figure 3 shows the time series plot of snow and ICD 410 mortality for the period January 1–March 31, 1973. Mortality peaked on January 3, when more than 17 cm of snow fell. It is somewhat surprising that 6 per cent of the variance in daily ICD 410 mortality during this winter could be attributed to a relatively few snowfalls.

There was no statistically significant relationship between ICD 410 mortality and snow during the winter of 1974–75. However, ICD 410 mortality did peak on January 12, two days following a blizzard and thunderstorm. While 10.2 cm of snow fell, the total precipitation for the day was 2.9 cm. On this day, there were 17 deaths from ICD 410, and unusually high number (Table 3 shows daily ICD 410 mortality for January 1-15, 1975). The lack of correlation between snow and ICD 410 mortality in this winter indicates the profound effect of the January 10 snow and rain storm on enhancing ICD 410 mortality.

The strongest relationship (R = 0.36) between snow and ICD 412 mortality among the five study winters occurred in the winter of 1974–75, when about 13 per cent of the variance in daily ICD 412 mortality could be attributed to snow on the day of death or on the two preceding days (Table 2). Figure 4 shows the time series plot of snow and ICD 412 for this winter. As is evident, there were nine days having snowfalls of 5 cm or more. Major peaks in ICD 412 appear to follow or occur on days with heavy snow. Mortal-

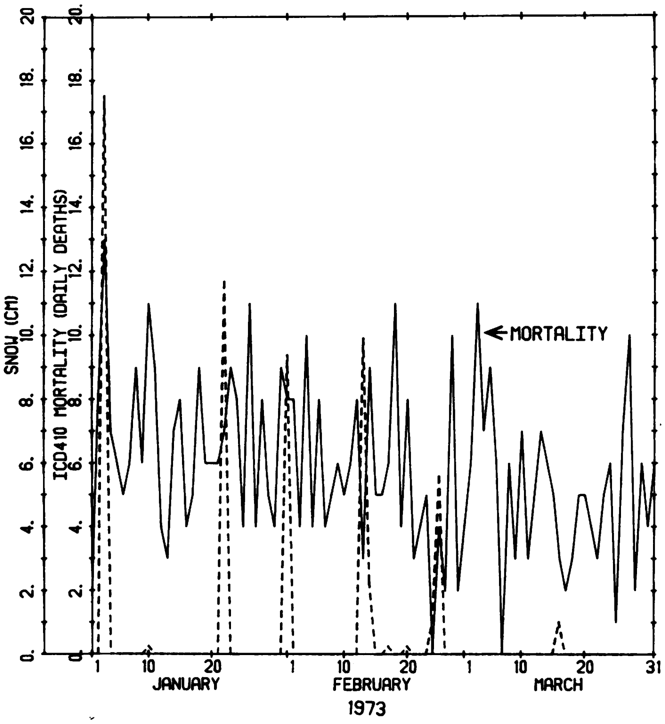

FIGURE 3—Time Series Plot of Acute Myocardial Infarction Mortality (solid line) and Snow Occurrences (dashed lines) for the Minneapolis-St. Paul SMSA for the Winter January 1, 1973–March 31, 1973

ity from ICD 412 tends to rise most rapidly on the day following a snow event, with peaks of 17 deaths occurring on January 3 (after a 12.7 cm snow on the 2nd), and on January 11, following a 10 cm snow intermixed with rain. Table 3 shows the daily mortality from ICD 412 during the first half of January 1975.

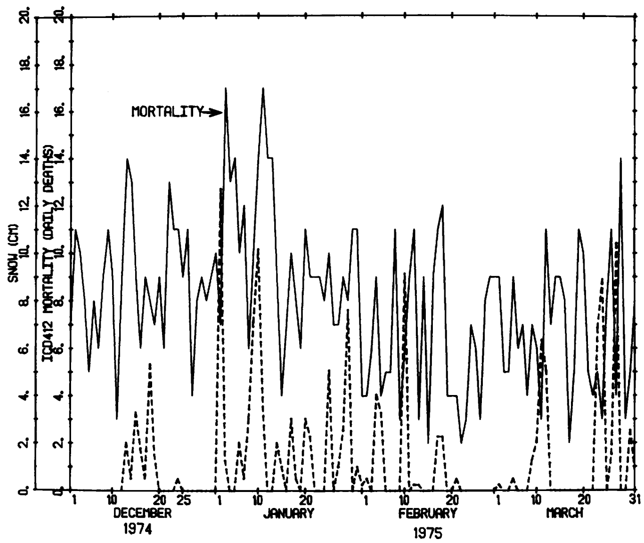

FIGURE 4—Time Series Plot of Old Myocardial Infarction Mortality (solid line) and Snow Occurrences (dashed lines) for the Minneapolis-St. Paul SMSA for the Winter December 1, 1974–March 31, 1975

Discussion

From this study, it appears that weather parameters have had a small but significant effect on cardiovascular mortality in Minneapolis-St. Paul. Temperature appeared to have an effect only in the winter of 1976–77, when unusually cold conditions in December and January were followed by large numbers of deaths, and unusually warm conditions in February and March were followed by fewer deaths. Also, the first half of the winter was the unusually cold period, and many of the more susceptible individuals may have succumbed, leaving a more resistant population by the time air

TABLE 3—Daily Mortality from Grouped Cardiovascular (ICD 390–398, 402, 404, and 410–429), ICD 410, and ICD 412 and Snowfall during early January 1975 in the Minneapolis-St. Paul SMSA

Date	Snow (cm)	Grouped Cardiovascular	ICD 410	ICD 412
Jan. 1	0	21	9	10
Jan. 2	12.7	13	4	7
Jan. 3	1.3	26	8	17
Jan. 4	0	23	7	13
Jan. 5	trace	23	7	14
Jan. 6	2.0	20	10	10
Jan. 7	0.5	15	3	12
Jan. 8	3.0	13	7	6
Jan. 9	7.1	14	3	10
Jan. 10	10.2	21	4	14
Jan. 11	3.6	19	1	17
Jan. 12	trace	35	17	14
Jan. 13	0	21	6	14
Jan. 14	2.0	20	9	9
Jan. 15	1.0	11	5	4

temperatures rose to above normal later in the winter. This culling of the susceptible population may have enhanced the statistical analysis; isolated extreme cold snaps or warm conditions during any particular winter may have an effect on cardiovascular mortality that would not be statistically significant when examining data for the entire winter.

Precipitation is a more complex factor in cardiovascular mortality, and it appears that snow and winter rainstorms interspersed with snow may also contribute to increased cardiovascular mortality. Snow is the more important form of precipitation in causing increased cardiovascular mortality, particularily in ICD 412 over the course of a winter. The worst case for increased mortality from ICD 410 as seen in this study is a new snow of about 10 cm on top of preexisting snow, followed by a considerable rainfall. Relatively warm air temperatures, near 0°C, during and after the rain, may mask the risk of physical activity. Facial exposure to air temperatures near 0°C can produce bradycardia, leading to possible anoxia in a heart already ischemic.[1]

During the winter of 1974–75, mortality from ICD 410 and from ICD 412 responded differently to snow and precipitation. Mortality from ICD 410 peaked at 17 on January 12, 1975, following a rain and snow event on the 10th. Mortality for ICD 412 peaked at 17 on both January 3, 1975, and January 11, 1975, suggesting that the snow and rain event on the 10th did not provoke the unusual increase in ICD 412 mortality that it did in ICD 410 mortality.

This study was done with a minimum of funds, and was therefore relegated to using only mortality data. The public health implications of winter weather could be further clarified by a study of hospital admission data, which would more accurately represent the total morbidity and allow for better identification of the age, race, and sex of victims of winter weather.

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