Effects of weather on incidence of attempted suicide by carbon monoxide poisoning

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Geltzer AJ, Geltzer AMB, Dunford RG, Hampson NB. Effects of weather on incidence of attempted suicide by carbon monoxide poisoning. Undersea Hyper Med 2000; 27(1):9–14.—Depressive illness and related suicide attempts have been reported to have seasonal variation, possibly related to weather. This study sought to determine the effects of weather and time of year on suicide attempts by carbon monoxide (CO) poisoning. Cases of patients in western Washington State attempting suicide by CO poisoning and referred to a regional hyperbaric oxygen treatment center from 1981–1995 were reviewed retrospectively. Information from the National Climatic Data Center was used to compare date of treatment to local weather data on the day of attempted suicide and on each day of the preceding week. The study population consisted of 264 patients attempting suicide by CO poisoning on 251 days of the 15-yr period. Mean and total precipitation in the preceding 7 days strongly correlated with attempted suicide rate, with incident rate ratios ranging from 1.75 to 2.77 and 1.14 to 1.75, respectively (P values <0.05). A decrease in minimum daily temperature also correlated with attempted suicide rate. No other weather variables showed significant correlation with dates of CO suicide attempts. February, March, and October were seen to be separate factors related to a higher incidence of attempted suicide by CO poisoning. Precipitation in Seattle, change in minimum temperature, and month of the year correlated with the regional incidence of suicide attempts with CO poisoning.

carbon monoxide, poisoning, suicide, weather

Seasonal changes in mood and behavior have been reported to occur in the general population for centuries. Historical references range from Hippocrates who taught that "the changes of the seasons produce diseases" to Pinel in the early 19th century who described winter and summer subtypes of depression (1). In 1984, Rosenthal and coworkers (2) studied a series of patients with winter depression and first delineated the clinical features of the syndrome "Seasonal Affective Disorder" (SAD). In their studies, this type of depression was characterized by hypersomnia, overeating, and carbohydrate craving, and seemed to respond to changes in climate and latitude.

Although this seasonal variation in mood has been studied extensively, few investigations have examined the effect of the variation on suicides and attempted suicides. In 1993, Maes and colleagues (3) linked seasonal variation in mood to seasonal variation in suicides. Depressed patients admitted to a Belgian hospital were examined retrospectively. Seasonal variations in patient symptoms were found to correlate with the variation in suicide rate in Belgium between 1979 and 1987. Proposed explanations for seasonal variation in suicide rate have included changes in climate or time of the year itself. Both have been examined in a number of prior studies, with inconsistent results (4–16).

The present study was designed to determine if there is an association between either weather or time of year and the incidence of suicide attempts from carbon monoxide (CO) poisoning in western Washington State. Suicide attempts from CO poisoning were chosen for analysis for a number of reasons. Attempted suicides are 4–8 times more common than successful suicides (12), providing a larger population for study. Furthermore, poisonings account for 95% of all suicides attempted (12). Carbon monoxide is a leading cause of poisoning death in the United States, accounting for an estimated 2,500 intentional deaths annually (17). Finally, the Pacific Northwest has significant seasonal climatic change, offering sufficient variation in weather variables for analysis.

METHODS

Virginia Mason Medical Center (VMMC) in Seattle, Washington, serves as the regional referral center for hyperbaric oxygen treatment of patients with severe CO poisoning. Records of all patients referred to VMMC's Hyperbaric Department for treatment of intentional CO

poisoning from 1981 to 1995 were reviewed. Cases occurring within western Washington State, defined as that region of the state west of the Cascade mountain range, were included in the study. Weather parameters for each day in the 15-yr period were obtained from the National Climatic Data Center, United States Department of Commerce. The station in Seattle records precipitation, sunshine, and temperature (minimum, maximum, and mean). It also reports "percent possible sunshine", calculated by dividing the minutes of sunshine observed each day by the minutes of possible sunshine from sunrise to sunset. In addition to using these values as variables, the mean and total amount for each category in the 1 through 7 days preceding the dates of attempted suicide were calculated. In this way, for each episode of attempted suicide, there were weather data not only for that day but also for the preceding 1 through 7 days. The change in each weather variable from day-to-day and week-to-week was also calculated by simple subtraction. Finally, month and season of attempted suicide were examined as variables.

Because attempted suicides are a relatively rare event, they were analyzed using Poisson regression (Stata computer software, Release 5; Stata Corporation, College Station, TX). Poisson regression was chosen because it is appropriate for rare events in a large number of trials. Furthermore, it assumes independent events, each with the same probability of occurring. Finally it assumes that the total number of such events could be, though with very small probability, indefinitely large. Poisson regression allowed identification of weather variables correlating with dates of attempted suicide, as well as quantification of any correlations found. A P value less than 0.05 was accepted as significant. Each statistically significant variable was examined while holding the other variables constant to determine whether more than one factor was simultaneously contributing to suicide attempts.

RESULTS

A total of 264 patients attempting suicide with CO in western Washington were referred over 5,478 days. Attempted suicides were recorded on 251 days, with 13 days having two attempted suicides. The means, incident rate ratios, and significance for each weather variable examined were calculated. On the day of referral for attempted suicides, no variable was significantly different from non-event days. Similarly, the amount of sunshine, percent of possible sunshine, and temperature during the week preceding suicide attempts did not differ significantly from weeks in which there were no attempted suicides recorded. However, the amount of precipitation, both mean and total, before attempted suicides correlated significantly with a higher incident rate ratio on all of the preceding 1–7 days (Tables 1 and 2). The peak effect occurred after 4 days. The 4 days before an attempted suicide averaged 0.125 ± 0.201 inches of precipitation whereas the 4 days before each day where no suicide attempt was recorded averaged 0.096 ± 0.144 inches of precipitation. The incident rate ratio for these 4 days was 2.71 and was highly significant ($P < 0.005$).

The change in weather from day-to-day or week-to-week was not significant for any variables studied except for the day-to-day change in minimum temperature (Table 3). There was a mean change in minimum temperature of $-0.8° \pm 5.9°$F on attempted suicide days as compared to $+0.03° \pm 3.7°$F on non-suicide days (incident rate ratio of 0.955, $P = 0.001$). Thus, as it got colder there was an increase in attempted suicides.

With regard to temporal incidence, the month of March demonstrated the most suicide attempts, significantly more than August, the month with the least ($P < 0.05$) (Table 4). This significance remained even after controlling for monthly precipitation or minimum temperature change. While controlling for the amount of daily precipitation or minimum temperature change, February, March, and October had significantly higher incident rate ratios when compared to the month with the lowest suicide incidence. This is illustrated in Fig. 1, where the months with the most precipitation are seen to be different from those with the most attempted suicides.

The effect of the daily precipitation in the preceding 1–7 days remained after controlling for the effect of minimum temperature. When analyzing the daily precipitation in the 1–7 days preceding suicide attempts and controlling for the month effect, the mean precipitation for Days 1–4 remained significantly correlated but for Days 1–5,1–6, and 1–7 lost significance ($P = 0.055$, 0.050, and 0.116, respectively). An identical result was obtained for total precipitation. However, this loss of significance may be due to an insufficient number of suicide attempts showing the effect rather than any real covariance change being seen with month and precipitation.

With regard to minimum temperature change, this effect also remained after controlling for both precipitation and month effect. This suggests that all three variables are separate factors contributing to the incidence of attempted CO poisoning.

The season of the year (January to March, April to June, July to September, October to December) did not significantly correlate with CO suicide attempts.

Table 1: Comparison of Attempted Suicide Rate With Mean Precipitation for 7 Preceding Days

	Non-Suicide Dates (mean inches of precipitation)	Attempted Suicide Dates (mean inches of precipitation)	Incident Rate Ratio	*P* Value Using Poisson Regression
Day of	0.097	0.096	0.97	0.912
1 day before	0.095	0.139	1.75	0.003
2 days before	0.095	0.133	2.15	0.002
3 days before	0.096	0.131	2.63	0.001
4 days before	0.096	0.125	2.71	0.003
5 days before	0.096	0.118	2.47	0.017
6 days before	0.096	0.117	2.70	0.015
7 days before	0.097	0.113	2.51	0.039
Daily change	0.0005	−0.014	0.83	0.403
Weekly change	0.0005	−0.014	0.57	0.159

DISCUSSION

Time of year and weather have been previously proposed as explanations for observed seasonal variation in mood. Both suicides and attempted suicides have been reported to relate to month. An analysis of suicidal deaths occurring in upstate New York in 1966–1967 found a statistically significant effect of month, with peaks in May and October (7). A study of 9,235 people attempting suicide by poisoning in Sofia, Bulgaria, from 1978 to 1985 found a significant seasonal variation, with the highest incidence occurring in spring (especially March) and the lowest in August (12). Similarly, a 12-yr study in Australia demonstrated a "suicide season" between the dry and wet seasons (May to August) for men aged 35 yr and older in the Northern Territory, during which time there were more completed suicides than at other times of the year (13).

Several investigators have gone a step further and examined the relationship between suicide and weather parameters. In the 1930s, suicide incidence in Switzerland was found to increase with warm, dry, and windy weather as a result of the "Foehn effect" (4,6). Interestingly, another study at the same time demonstrated a relationship between falling barometric pressure and rising suicide incidence (5). In 1974, Zung and Green (8) studied all 3,672 deaths by suicides in North Carolina and all 3,258 new male admissions to the Durham Veterans Administration Hospital psychiatry service from 1965 to 1971. Although their analysis did show a seasonal relationship to depression and suicide, they failed to find a significant correlation between temperature, length of day, precipitation, or humidity with completed suicides.

In 1994, Barker and coworkers (14) examined 12,379 attempted suicides referred to a British hospital with regard to weather over a 14-yr period. Theirs is one of the few published studies that has controlled for the effect of the month of the year while examining the effects of weather on attempted suicides. They found a monthly and seasonal difference in suicide attempts, with more occurring in May and June, and a similar seasonal effect with

Table 2: Comparison of Attempted Suicide Rate With Total Precipitation Over the 7 Preceding Days

	Non-Suicide Dates (total inches of precipitation)	Attempted Suicide Dates (total inches of precipitation)	Incident Rate Ratio	*P* value using Poisson Regression
Day of	0.097	0.096	0.97	0.912
1 day before	0.095	0.139	1.75	0.003
2 days before	0.199	0.265	1.47	0.002
3 days before	0.287	0.392	1.38	0.001
4 days before	0.383	0.498	1.28	0.003
5 days before	0.481	0.588	1.20	0.017
6 days before	0.578	0.701	1.18	0.015
7 days before	0.676	0.792	1.14	0.039
Daily change	0.0005	−0.014	0.83	0.403
Weekly change	0.003	−0.096	0.92	0.159

Table 3: Comparison of Attempted Suicide Rate With Change in Weather Day-to-Day

Variable	Non-Suicide Dates	Attempted Suicide Dates	Incident Rate Ratio	*P* Value Using Poisson Regression
Precipitation, inch	+0.001	−0.014	0.826	0.403
Sunshine, min	−1.2	+23.7	1.000	0.107
Sunshine, %	−0.2	+3.6	1.003	0.075
T mean, F	+0.01	−0.3	0.975	0.177
T maximum, F	−0.01	+0.2	1.007	0.543
T minimum, F	+0.03	−0.8	0.955	0.001

increases in spring and summer. Attempted suicides by women correlated with more cloud cover, higher maximum and minimum temperatures, hot days, and a combination of hot and still weather on the day of the attempt. After controlling for month of year, the findings remained significant for cloud cover, maximum temperature, and rainfall. For men, significant correlations were found with increased rain, increased cloud cover, poorer visibility, and wind on the day of suicide attempt. However, none of these findings were significant after controlling for month of the year. When weather from the day preceding attempted suicide was analyzed, suicide attempts in women were associated with maximum and minimum temperature, temperature amplitude, and rainfall. When change in weather from day to day was examined, only increase in rainfall was significant and limited to males.

Studies performed in the United States to date have not confirmed these observations from England. The most notable examined 4,187 suicides in New York City over a 5-yr period and failed to show a correlation between weather and successful suicides (9). A more recent study examined the effect of natural disasters in the United States on suicide rates (16). Suicide rates were found to increase after severe earthquakes, floods, and hurricanes. The study failed to show an effect after severe storms. However, the focus of the investigation was psychological damage from a disaster, not the effects of specific weather variables.

Table 4: Comparison of Attempted Suicide Rate by Month

Month	Mean Attempted Suicide	Incident Rate Ratio	*P* Value Using Poisson Regression
January	0.041	1.12	0.734
February	0.064	1.75	0.072
March	0.073	2.00	0.020
April	0.056	1.52	0.183
May	0.039	1.06	0.866
June	0.044	1.22	0.554
July	0.043	1.18	0.622
August	0.037	1.00	
September	0.029	0.79	0.523
October	0.065	1.76	0.061
November	0.040	1.09	0.790
December	0.049	1.35	0.345

The current study demonstrates that greater precipitation in the 7 preceding days correlates with a higher incidence in patients referred for hyperbaric oxygen treatment of intentional CO poisoning. For every 1-inch increase in the mean daily amount of precipitation during the preceding week, there is roughly a doubling in the incidence of suicidal CO poisoning. Similarly, for every 1-inch increase in the total amount of precipitation in the preceding week, there is a 1.14 increase in the incidence of CO suicide attempts treated. In western Washington, this precipitation is usually in the form of rainfall, as only 2–3 days of snowfall occur annually.

The reason that the weather on the actual day of treatment did not significantly correlate with attempted suicide probably relates to inherent delays from time of the suicide attempt to arrival at the hyperbaric chamber. Most patients attempting suicide with CO are found unconscious in the field after variable amounts of time from initiation of the act. They are resuscitated, transported to a local emergency department, evaluated and stabilized, then sent to the regional hyperbaric referral center for treatment. Total delays of several hours are not uncommon, with the result that many patients attempting suicide in the evening are not treated until after midnight and, therefore, on a new day. Because it was frequently not possible to determine the length of each of these delays from retrospective chart review, we did not attempt to estimate time of suicide attempt and instead chose to analyze all cases uniformly from date of hyperbaric treatment.

Our study also shows an increase in the incidence of CO suicide attempts when minimum daily temperature decreases. However, a large overlap in minimum temperature

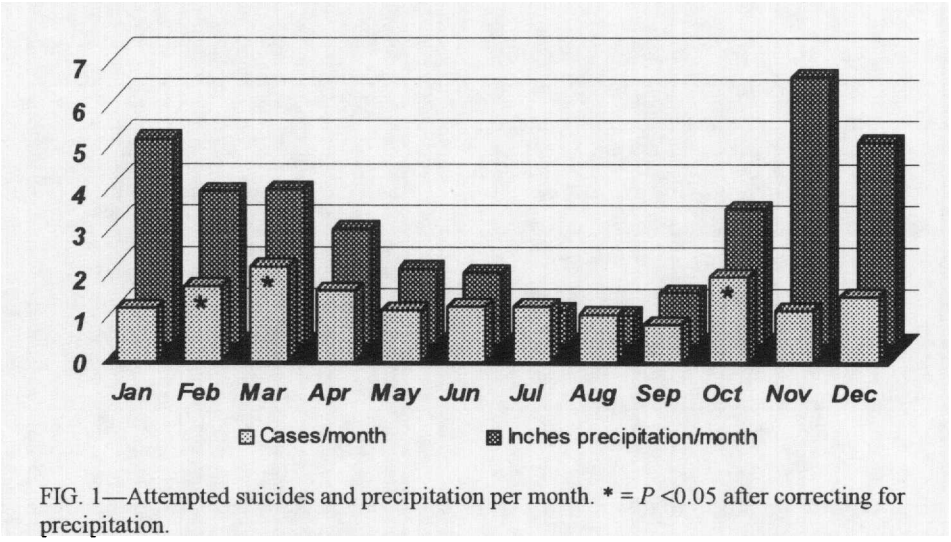

FIG. 1—Attempted suicides and precipitation per month. * = P <0.05 after correcting for precipitation.

values between attempted suicide and control days make this observation, although statistically significant, difficult to interpret clinically. It is possible that there is some as yet undetermined covariable that increases the number of patients presenting on days which become colder.

In agreement with earlier reports, certain months of the year were found to correlate with the frequency of suicide attempts. When considering the months identified in the present study (February, March, and October), it is difficult to attribute the effect to a particular holiday or other social influence. As controlling for precipitation did not negate the fact that some months have statistically higher suicide attempt rates, support is generated for the concept that month of the year is indeed a contributing factor separate from precipitation. Because relatively few months demonstrated statistically greater suicide attempts, it is not surprising that season was not found to be an independently significant variable.

It must be recognized that the group of patients reported in this study is a subset of individuals attempting suicide. All used CO and all survived at least to medical evaluation and treatment. There may be an unrecognized confounding influence in this select population that explains why individuals choose to attempt to commit suicide by CO poisoning after rainy weeks. For example, people may be using their automobiles and garages more during rainy weather, giving them increased exposure to the potential suicide method. If this were the entire explanation, however, one would expect to see the same correlation on days when there is less sunshine or colder mean temperature. Neither were observed in this study. Future investigation should examine other forms of attempted or successful suicide to see if precipitation is a factor in these as well.

The population studied resided in western Washington State, an area geographically dissimilar to much of the United States, raising the possibility that results may not apply to the national population if location plays a role. In 1991, Rosen and Rosenthal (18) postulated that latitude is a factor in SAD. They studied populations in New Hampshire, New York, District of Columbia, and Florida, concluding that factors consistent with winter SAD correlated positively with latitude, whereas factors consistent with summer SAD correlated negatively. However, their study did not control for any weather variables. As such, the latitude effect may have actually been a weather effect similar to the one demonstrated in our study. In support of this hypothesis is a study by Lester (19) demonstrating that suicide rates were highest in the South and West, but this influence disappeared when precipitation and sunshine were taken into account, suggesting that weather factors may have been the driving variables.

Of additional interest in the present study are the factors that were not significantly associated with suicide attempts. Previous investigations have demonstrated an effect of sunshine and mean temperature. Tietjen and Kripke (15) reported inhibition of suicides by sunlight in Sacramento county, but only on Days 31–35 following a period of greater than average sunshine. They also found inhibition by mean temperature on Days 26–30 following above average temperatures. Similarly, Souetre and coworkers (20) demonstrated that the regional distribution of suicides in France correlated with sunlight duration and ambient temperature. However, after controlling for socioeconomic factors, only ambient temperature remained significant. As in Lester's studies, these researchers examined suicide within regions with differing populations. These investigations were different from our study which used essentially the same population/

weather/socioeconomic variables as controls. Certainly many different factors are playing a role in suicides, depression, and SAD, and more studies examining large populations are needed before fully understanding all of the possible influences. The current study, despite its relatively long time period, failed to demonstrate correlations with other weather variables. This may relate to the subgroup of attempted suicides studied or to the fact that even 264 subjects is a relatively small population when examined over a 15-yr period.

In summary, mean and total precipitation in the preceding 7 days correlated strongly with attempted suicide rate by CO poisoning. There was also a slight effect of change in minimum daily temperature on attempted suicides. No other weather variables showed significant correlation with dates of CO suicide attempts. As in other studies, specific months were identified as separate factors contributing to a higher incidence of treated attempted CO poisoning. Although the results of previous studies examining the relationship between weather and all types of suicide attempts have revealed inconsistent results, this is the first study to examine only a single method of attempted suicide. It would be interesting to see if precipitation correlates with suicide attempts with CO poisoning in an area with a climate different from Seattle's.

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