

Suicides in California (1968-1977): Absence of Seasonality in Los Angeles and Sacramento Counties

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Abstract. Since the turn of the century, there have been numerous publications on the seasonality of suicide. Rarely has the duration of sunlight exposure or any other weather parameter been quantitated in studies of suicide seasonality. To explore the relationships between sunlight and suicide, we examined California weather and suicide data from 1968 to 1977. Los Angeles County and Sacramento County were well-suited to the investigation, as complete data were available for these large population centers. There was no evidence of seasonality to suicides in L.A. County or Sacramento, despite a pronounced seasonality to weather. To investigate the acute temporal effects of weather on suicides, all occurrences of 10 successive above- or below-average sunshine days were identified. Suicides for intervals of 5 days were then compared by Mann-Whitney analyses for 25 days after the selected intervals. For L.A. County, there were no significant findings. For Sacramento County, however, there was evidence for sunlight inhibition of suicides at days 21-25 after the above-average sunshine. Suicides after 10 days of below-average sunshine were increased as much as 70% about the 10-year average. Further replication studies with larger data sets are needed for an adequate examination of the correspondences of suicide data and weather measurements.

Key Words. Seasonality, weather, seasonal affective disorder, epidemiology.

The seasonality of suicides has been thoroughly reviewed (Kevan, 1980; Aschoff, 1981; McCleary et al., 1991), with the peak incidence of suicides being found to occur in late spring and early summer in the northern hemisphere. The peak occurs in the late spring and early summer in Australia as well, although 6 months later than in the northern hemisphere. In U.S. data, peak incidence consistently occurred in May (Dublin, 1963; Lester, 1979; Lester and Frank, 1988, 1990a, 1990b). As described by Kevan (1980), the seasonality of suicide had been demonstrated in so many studies by the turn of the century that debate among social scientists was focused on the cause rather than the occurrence of seasonality. There have been two broad explanations of seasonality in suicides: the biometeorological and the socio-economic. Though considerable controversy and conflicting reports exist, it could be that sociological variables interact with an underlying annual biometeorological source to produce suicide seasonality.

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Seasonality of depressive disorders was described about 400 B.C. by Hippocrates (Rosenthal et al., 1985). Most investigators have found that the peak incidence of depressive episodes occurs during spring and fall, with some studies demonstrating dual peaks in the same population (Rosenthal et al., 1983). Using specialized diagnostic criteria, Rosenthal et al. (1985) defined a unique population of patients with atypical depressive symptoms that occurred on a regular seasonal basis. Seasonal affective disorder (SAD), as this disorder has been called, is "atypical" because a large percentage of these patients have symptoms such as hypersomnia and fatigue, increased appetite, carbohydrate craving, and weight gain in the winter (Wirz-Justice, 1986). Of interest, patients with SAD respond to bright light therapy with an improvement in symptoms (Rosenthal et al., 1985). Rosenthal et al. (1985) found that patients with SAD who traveled or lived at different latitudes had milder symptoms when they were nearer the equator. Moreover, Potkin et al. (1986) have shown that U.S. patients with SAD are more common in northern latitudes.

Descriptions of SAD imply that deficient sunshine could be a crucial factor in seasonality of suicides. Since studies investigating suicide and its relationship to psychiatric diagnosis demonstrate that 45-70% of suicides have an affective disorder (Roy, 1989), it might be supposed that the seasonality of suicides demonstrated in the U.S. occurs as a result of decreased sunlight, which might act in a manner similar to that proposed for SAD to induce a depressed state susceptible to increased suicidality. An apparent problem with this hypothesis is that SAD has its peak incidence in winter (Wehr, 1989), whereas suicides tend to peak in spring (Kevan, 1980; Aschoff, 1981).

To explore relationships between sunlight and suicide, we analyzed daily California data from 1968 to 1977. Los Angeles County and Sacramento County were studied, as sufficient data were available for only these specific population centers. In addition to examining the overall seasonal trends, we looked at the short-term effects of 10 consecutive days of above-average or below-average sunshine, cloud cover, minimum temperature, and maximum temperature on suicides during a subsequent 25-day interval.

Methods

Computer tapes of death certificate data were obtained from the California Bureau of Vital Statistics. A subset of completed suicide data was computed from the death certificate data. Computer tapes of weather data, including total daily minutes of sunshine (TSUN), proportion of sky cover from sunrise to sunset in tenths (SCSS), maximum temperature (TMAX), and minimum temperature (TMIN), were obtained from the National Oceanic and Atmospheric Administration (NOAA). The California weather data obtained were a subset of NOAA data tape TD-3210. Data were complete for 1968 to 1977. Sacramento County and Los Angeles County both had large populations that could be related to specific weather stations, and were thus chosen as the foci of this investigation. All data were processed on a Digital Equipment Corporation VAX computer using the SPSS-X statistical program (SPSS, Inc., Chicago, IL).

The initial investigation was performed for Los Angeles County and was then partially repeated for Sacramento County. Daily means and standard deviations were computed for all weather variables. To investigate relationships between weather variables, correlation analyses between all weather variables were performed. Mean daily suicides from 1968 to 1977 were

graphically plotted. A 5-day moving average smoothing function was used to assess seasonality of suicides. Weather variables were graphically plotted in a similar manner. Seasonality was assessed statistically through the calculation of mean 10-year daily suicide rates for each day of the year; these rates were then subjected to Rayleigh test analysis (Batschelet, 1981), an appropriate statistical test for cyclical data such as these. To evaluate the constancy of weather and suicide events, autocorrelation analyses were performed on raw data for TSUN, SCSS, and suicides. If weather or suicide trends remain relatively constant over extended seasons, then significant positive lagged correlations should be obtained over relatively long intervals.

In the final stage of the analysis, the seasonal pattern was removed from all data by computing the mean value (1968-1977) for each day of the year for TSUN, SCSS, TMAX, TMIN, and suicides. For each of four separate analyses (with TSUN, SCSS, TMAX, and TMIN), the daily mean value for each variable was subtracted from each actual daily value to yield seasonally adjusted values. All occurrences of 10 consecutive days of above-seasonal-average weather data were then selected. All occurrences of 10 consecutive days of below-seasonal-average data were likewise selected. The selection procedure was programmed so that there was no overlap between occurrences selected. That is, after the first 10 days of above- or below-average weather, no additional selection would begin until after day 10 of the previous period. Suicide events were examined for a total of 35 days after the first day of each 10-day weather occurrence. The mean daily numbers of suicides (NUMSUI) were then calculated for intervals of 5 days beginning from the first day of each selection. That yielded seven intervals, each representing suicides during 5 days, with the first two intervals occurring during the weather event and the latter five groups occurring after the weather event. The Mann-Whitney test (2-tailed) was used to contrast total NUMSUI between above-average and below-average weather intervals for each 5-day interval. To assess whether cases selected were randomly distributed over the year, the start days of each 10-day occurrence selected were graphically analyzed for the four weather variables. These data were assessed by the Rayleigh test (Batschelet, 1981) to determine randomness of distribution of selected events.

A similar analysis was performed on data from Sacramento County. Suicides were graphically analyzed for seasonal patterns, and statistically assessed by Rayleigh test as already described for Los Angeles. Data were then seasonally adjusted as above, and 10-day intervals of consecutive above-average (and below-average) weather were selected. Mean NUMSUI were computed for the seven intervals of 5 days beginning with day 1 of the 10-day selection, and NUMSUI were compared for above- and below-average weather occurrences for each of the four weather variables with the Mann-Whitney test (as above). To assess the actual magnitude effect of each of the weather variables on suicides during the 5-day intervals described above, seasonally adjusted mean daily suicides were reconverted to actual mean daily suicides for each of the above- and below-average weather variables. For each weather variable, those values were tabulated, and percent-differences between NUMSUI were calculated for each of the seven intervals.

Results

For the weather station located at the L.A. Civic Center, the 10-year means and standard deviations for L.A. County weather variables were as follows: TSUN = 529 ± 3.4 minutes, SCSS = 4.0 ± 0.05 tenths, TMAX = 75.2 ± 0.1 °F, TMIN = 57.0 ± 0.08 °F. Table 1a presents correlations between daily weather variables over 1968-1977. Of note was the relationship between SCSS and TSUN, with a correlation coefficient of -0.78, an indication that only 61% of variability in sunshine was attributable to percentage sky cover. Fig. 1a shows mean daily suicides for L.A. County (1968-1977). Suicides ranged on average from three to four per day (mean = 3.56), with no statistically significant seasonal trends (Rayleigh

Table 1. Correlations of daily weather parameters**A. Los Angeles County**

	SCSS	TMAX	TMIN
TSUN	-0.78	0.53	0.20
SCSS		-0.46	-0.03
TMAX			0.74

B. Sacramento County

	SCSS	TMAX	TMIN
TSUN	-0.77	0.77	0.47
SCSS		-0.63	-0.31
TMAX			0.83

Note. TSUN = total daily minutes of sunshine. SCSS = proportion of sky cover from sunrise to sunset in tenths. TMAX = maximum temperature. TMIN = minimum temperature.

$z = 1.229$, $p > 0.05$). Figs. 2a-c illustrate mean daily weather data for TSUN, SCSS, TMAX, and TMIN. TSUN (Fig. 2a), TMIN and TMAX (Fig. 2c) all reached maxima in July-August, and minima in December-January. There were secondary May-June minima for TSUN (Fig. 2a) that appeared to be attributable to very high sky cover (SCSS; Fig. 2b); none of these seasonal weather trends, however, had obvious relationships to seasonal suicides (Fig. 1a). Autocorrelations $\geq r = 0.30$ were found through a lag of 5 days for TSUN and 1 day for SCSS, but there was virtually no day-to-day correlation in suicides, and no significant positive autocorrelation at 7 days (which excludes a weekly cycle).

As described in the **Methods** section, the final analysis for L.A. County involved contrasting occurrences of 10 consecutive days of above-average weather and below-average weather. There were no significant differences between 5-day NUMSUI data for high versus low TSUN occurrences, high versus low SCSS occurrences, or high versus low TMAX occurrences. For TMIN, mean NUMSUI significantly differed only at days 11-15, with higher numbers of suicides being associated with lower minimum temperatures ($p < 0.01$). However, the trend was not consistent for adjacent 5-day intervals.

The distribution of selected 10-day intervals with respect to month of year was statistically assessed for randomness for both above- and below-average weather from L.A. County. There was a trend toward selection of extreme intervals from the middle of the year (May-June-July). Of the eight distributions analyzed, however, only two (below-average TSUN and below-average TMIN) had significant annual selection trends indicated by the Rayleigh test ($p < 0.05$).

For the Sacramento weather station, the 10-year means and standard deviations for weather variables were as follows: TSUN = 592 ± 2.9 minutes, SCSS = 4.2 ± 0.04 tenths, TMAX = 73.3 ± 0.17 °F, TMIN = 48.1 ± 0.09 °F. Table 1b presents the correlation analyses for Sacramento weather variables. As with L.A. County, only about 60% of variability in sunshine was attributable to sky cover. Fig. 1b shows there was no statistically significant seasonality in suicides in Sacramento County from 1968 to 1977 (Rayleigh $z = 1.044$, $p > 0.05$). Aside from subtle

Fig. 1a. Mean daily suicides in Los Angeles County (1968-1977)

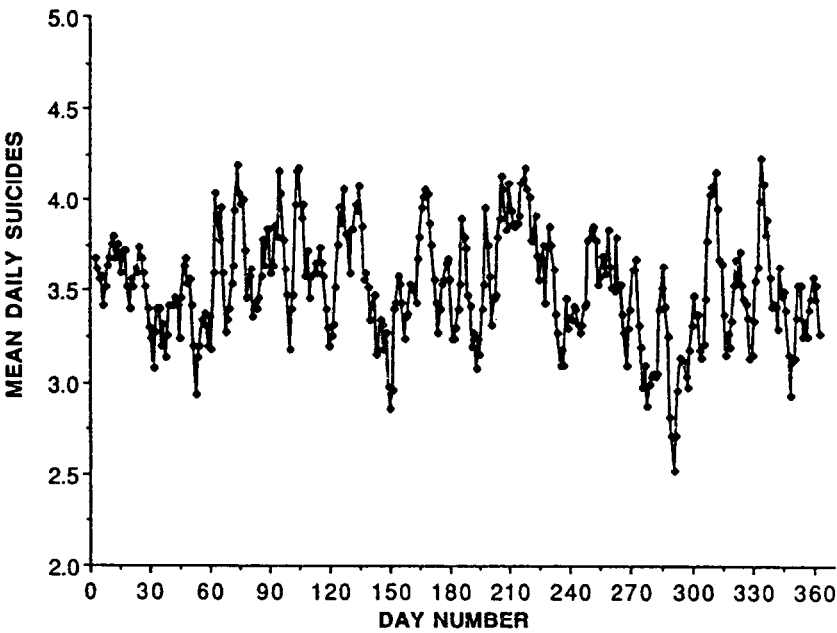


Fig. 1b. Mean daily suicides in Sacramento County (1968-1977)

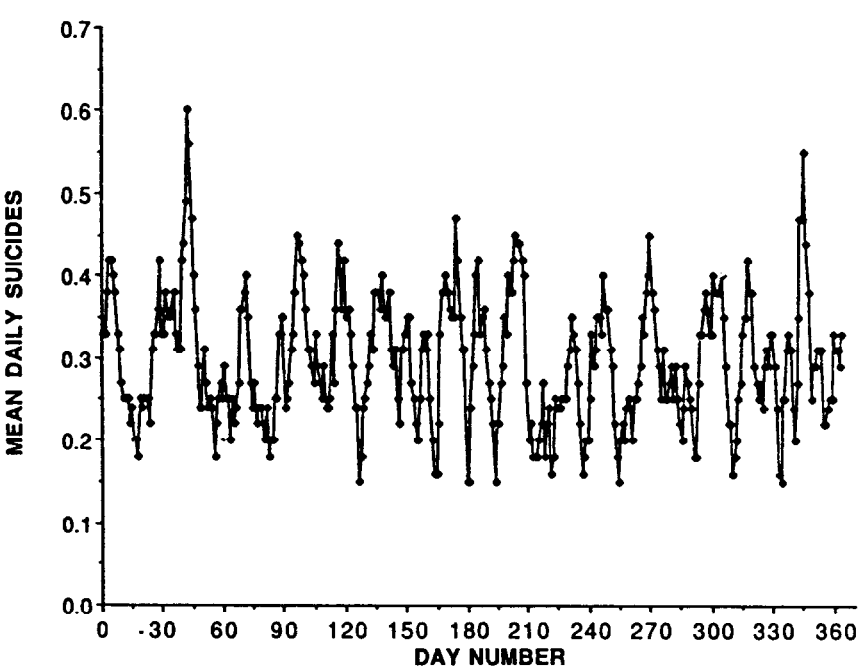


Fig. 2a. Mean daily sunshine for Los Angeles County (1968-1977)

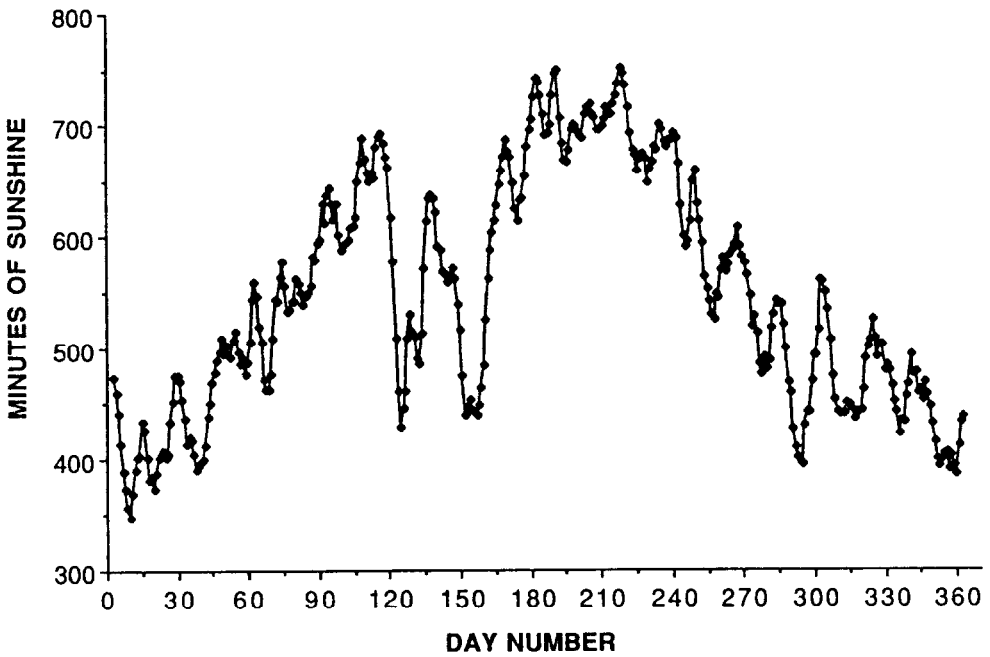


Fig. 2b. Mean daily sky cover for Los Angeles County (1968-1977)

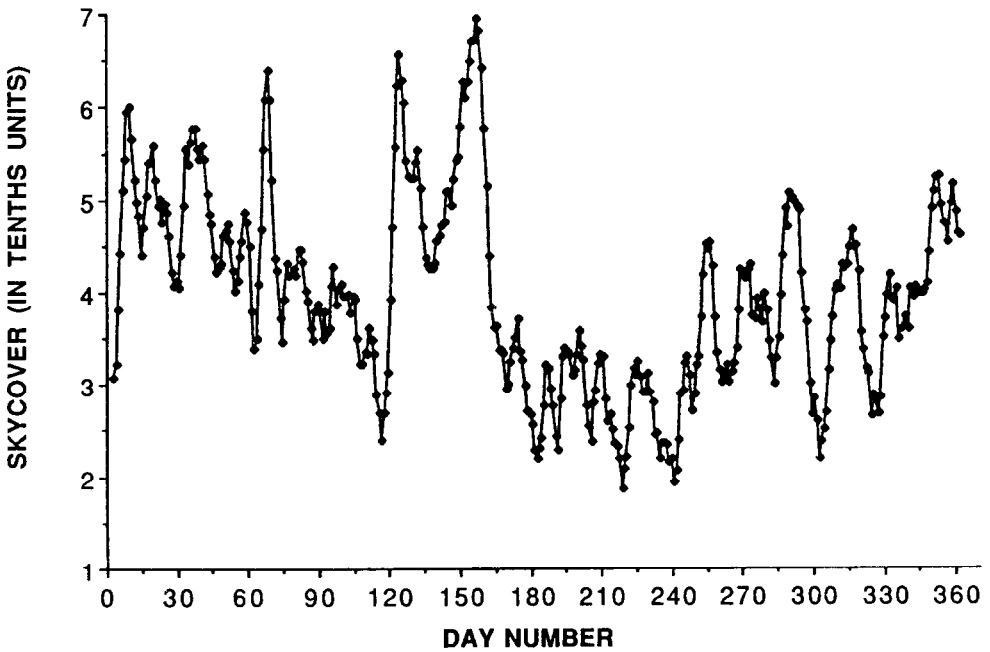
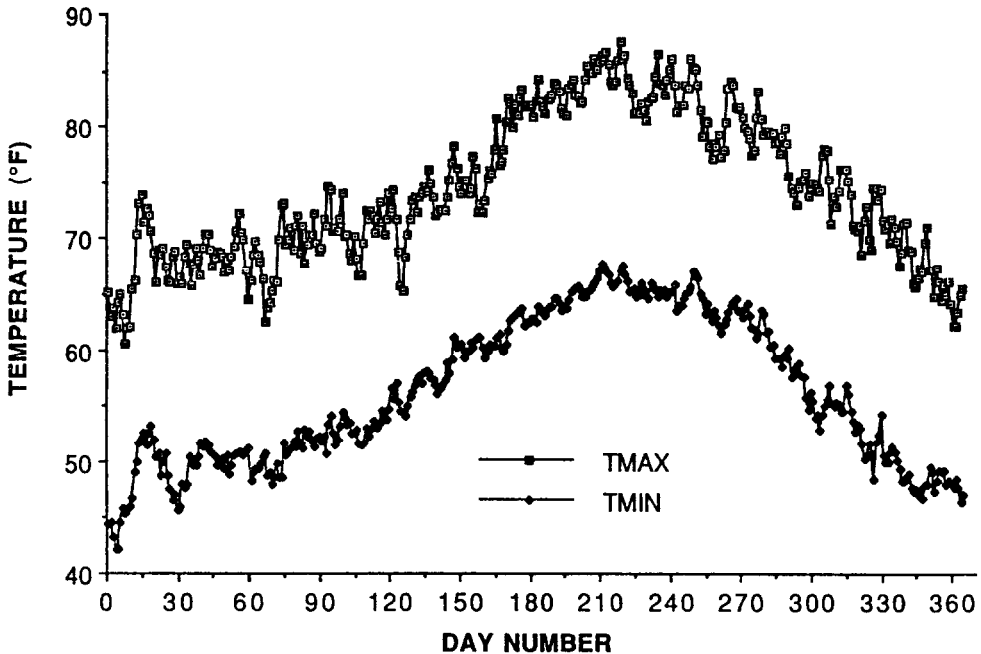


Fig. 2c. Mean daily temperature for Los Angeles County (1968-1977)

differences, seasonal weather trends in Sacramento were rather similar to those in L.A. (e.g., Fig. 2).

Table 2 presents the results of the Mann-Whitney analyses of suicides related to 10-day occurrences of extreme weather in Sacramento County. For TSUN (Table 2a), the mean rank NUMSUI differed significantly only for days 31-35 (i.e., 21-25 days after the 10-day weather interval). There were more suicides for 5-day periods following below-average TSUN intervals. Note there were far more 10-day intervals of consistently high TSUN ($n = 63$) than 10-day intervals of consistently low TSUN ($n = 6$). For SCSS (Table 2b), there were no significant differences in suicides between periods of consistently high or low sky cover and no persuasive trends. For TMAX (Table 2c), there was no consistent pattern in suicides with respect to high and low TMAX; for days 26-30, however, suicides were significantly lower after above-average TMAX ($p < 0.05$). For TMIN (Table 2d), there were no significant differences, but the trend was toward more suicides following 10 consecutive days of above-average TMIN.

For Sacramento County, Table 3 shows actual mean suicides (i.e., not seasonally adjusted) relative to each of the weather conditions, as well as the percent difference between actual suicide rates related to extreme conditions. The mean 10-year daily suicide rate for Sacramento County (1968-1977) was 0.30 suicides per day.

Discussion

In two California locations, suicides were not notably seasonal even though there

Table 2. Sacramento County suicides in below- and above-average intervals

TSUN	Below average	Above average	Mann-Whitney	2-tailed
	(n = 6)	(n = 63)	U	p
	Mean rank	Mean rank	value	value
Days 1-5	29.42	35.53	155.5	0.48
Days 6-10	27.17	35.75	142.0	0.32
Days 11-15	38.42	34.67	168.5	0.66
Days 16-20	47.17	33.84	116.0	0.12
Days 21-25	43.75	34.17	136.5	0.26
Days 26-30	41.08	34.42	152.5	0.44
Days 31-35	50.67	33.51	95.0	0.05
SCSS	Below average	Above average	Mann-Whitney	2-tailed
	(n = 32)	(n = 12)	U	p
	Mean rank	Mean rank	value	value
Days 1-5	22.86	21.54	180.5	0.76
Days 6-10	23.44	20.00	162.0	0.43
Days 11-15	22.19	23.33	182.0	0.79
Days 16-20	22.66	22.08	187.0	0.90
Days 21-25	22.09	23.58	179.0	0.73
Days 26-30	22.84	21.58	181.0	0.77
Days 31-35	21.30	25.71	153.5	0.31
TMAX	Below average	Above average	Mann-Whitney	2-tailed
	(n = 48)	(n = 36)	U	p
	Mean rank	Mean rank	value	value
Days 1-5	38.82	47.40	687.5	0.11
Days 6-10	41.24	44.18	803.5	0.58
Days 11-15	42.47	42.54	862.5	0.99
Days 16-20	39.81	46.08	735.0	0.24
Days 21-25	39.52	46.47	721.0	0.20
Days 26-30	47.07	36.40	644.5	0.05
Days 31-35	44.72	39.54	757.5	0.34
TMIN	Below average	Above average	Mann-Whitney	2-tailed
	(n = 38)	(n = 29)	U	p
	Mean rank	Mean rank	value	value
Days 1-5	32.82	35.55	506.0	0.57
Days 6-10	35.89	31.52	479.0	0.36
Days 11-15	32.66	35.76	500.0	0.52
Days 16-20	31.75	36.95	465.5	0.28
Days 21-25	31.38	37.43	451.5	0.21
Days 26-30	31.08	37.83	440.0	0.16
Days 31-35	32.30	36.22	486.5	0.41

Note. TSUN = total daily minutes of sunshine. SCSS = proportion of sky cover from sunrise to sunset in tenths. TMAX = maximum temperature. TMIN = minimum temperature.

Table 3. Actual mean daily suicides at 5-day intervals during and after above- or below-average weather in Sacramento County

Days	TSUN			SCSS			TMAX			TMIN		
	BA	AA	% diff	BA	AA	% diff	BA	AA	% diff	BA	AA	% diff
0-5	0.27	0.33	-19.5	0.29	0.25	14.6	0.27	0.39	-29.9	0.30	0.32	-6.2
6-10	0.21	0.31	-32.7	0.27	0.20	35.3	0.26	0.29	-10.0	0.28	0.24	18.8
11-15	0.32	0.28	14.1	0.28	0.26	9.0	0.29	0.28	2.48	0.27	0.32	-16.4
16-20	0.51	0.35	47.6	0.29	0.29	-1.0	0.27	0.33	-17.6	0.31	0.34	-10.0
21-25	0.37	0.27	37.2	0.29	0.31	-5.8	0.32	0.38	-15.4	0.23	0.28	-18.5
26-30	0.37	0.29	27.4	0.31	0.21	45.0	0.31	0.21	51.7	0.25	0.32	-21.3
31-35	0.39	0.24	65.0	0.28	0.39	-28.6	0.32	0.24	34.0	0.30	0.31	-3.3

Note. TSUN = total daily minutes of sunshine. SCSS = proportion of sky cover from sunrise to sunset in tenths. TMAX = maximum temperature. TMIN = minimum temperature. BA = below average. AA = above average. diff = difference.

was seasonality in weather variables. In light of the numerous reports documenting seasonality to suicides in other United States data (Dublin, 1963; Lester, 1979; Lester and Frank, 1988, 1990*a*, 1990*b*; McCleary et al., 1991), it was surprising that there was no evidence of seasonality to suicides in Los Angeles or Sacramento County from 1968 to 1977 (Fig. 1).

The explanation for the absence of seasonality in these data is unclear, but some sociological explanations have been proposed by others. In his comprehensive analysis of suicides in Japan from 1900-1941, and from 1947-1982, Abe (1987) showed that seasonality of suicides, though still present, has decreased. Moreover, he showed that the decrease in seasonality was correlated with rising per-capita gross domestic product. In a less detailed analysis in the same article, Abe (1987) showed that the same trend is occurring elsewhere in the world. In an analysis of suicides in Italy from 1969 to 1984, Micciolo et al. (1991) showed that seasonality was greater in rural than in urban settings. If both of these factors (gross domestic product and urban vs. rural setting) contribute markedly to seasonality of suicides, then one might expect little seasonality in these prosperous urban settings in modern times. In addition to sociological explanations, it remains possible that weather exposures such as to sunshine do exert an effect on behaviors such as suicide, but that sociological variables now predominate.

At this point in human history, urban people may simply spend so little time outdoors that weather effects are minimized. This explanation finds some support in the work of Savides et al. (1986). On average, subjects experienced bright light approaching sunlight intensity for only 90 minutes per day. This could conceivably explain both temporal differences and differences in urban/rural suicides found by Micciolo et al. (1991), if persons in modern urban locales are spending less time outdoors.

Though numerous studies have investigated relationships between weather variables and suicides, few have carefully examined details of weather data. The weather data for L.A. County (Fig. 2) revealed a fairly typical pattern for coastal regions of California. TSUN reached a maximum in July-August (Fig. 2a). Although SCSS was maximal in December-January, there was a secondary May-June peak attributable to coastal fog (Fig. 2b). TMAX and TMIN essentially followed TSUN (Fig. 2c). With the exception of less May-June SCSS (reflected in TSUN), due to distance from the ocean, Sacramento weather patterns had similar seasonality to that found in L.A. County. As shown in Table 1, there were highly significant correlations between weather variables.

Autocorrelation analyses for TSUN and SCSS revealed that in these two California locations, much of the weather variance was short-term rather than seasonal, suggesting that short-term effects between weather and suicides might be of greater relative importance in California. This finding supports the graphic representations of mean daily NUMSUI (Fig. 1), showing an absence of seasonality.

Although there have been numerous studies of the seasonality of suicides, none of them have examined short-term temporal effects of weather on suicides (for reviews, see Kevan, 1980; Aschoff, 1981). In one of the more thorough investigations of suicides and sunlight duration, Sou  tre et al. (1987) examined mean monthly

temperature and day length from 1925-1982, but they did not investigate the effects of short-term alterations in weather parameters. Data on light therapy responses of SAD and no-treatment relapses suggested that bright light responses might be seen over a course of 1 or a few weeks (Rosenthal et al., 1985). Extrapolating these data to suicidality, we compared the effects of 10 consecutive days of above-average weather on suicides with the effects of 10 consecutive days of below-average weather. For L.A. County, there were no significant differences in suicides following above- or below-average TSUN, SCSS, and TMAX. For TMIN, there was one significant difference at days 11-15 ($p < 0.01$). However, the pattern was not consistent even for adjacent intervals, so this finding was most likely anomalous. To summarize, for L.A. County, there was no evidence of seasonality in suicides; nor was there persuasive evidence to support any acute effect of 10 consecutive days of below (or above) average weather on suicides.

After possible confounders were removed from seasonal weather trends, Sacramento data showed consistently increased suicides after low TSUN intervals, as might be predicted from the SAD phenomenon (Table 2a). For TSUN, mean rank NUMSUI differed significantly only at days 31-35, but the pattern was completely consistent over days 11-35. This consistency, as much as the statistical significance, suggests that the effect might be real. Ten consecutive days of below-average sunshine may produce an increase in depression that results in a real increase in suicides, regardless of time of year. The observed number of suicides after 10 days of low TSUN was as much as 70% above the 10-year average (see Table 3, 0.51/day vs. 0.30/day average). In Sacramento, there were no significant differences between suicides in the comparisons for the SCSS condition (Table 2b) or for the TMIN condition (Table 2d). Mean suicides were higher at days 26-30 after lower TMAX. However, since there was no consistent trend for TMAX, and this effect was not like any seen in L.A., this was perhaps also an anomalous finding. It is conceivable that TMAX and TMIN modify suicide less by direct temperature effects than by modifying time spent outdoors. However, current data do not permit us to explore this form of behavioral mediation.

It was surprising that the Sacramento results appeared to demonstrate real sunshine inhibition of suicide, but the Los Angeles results did not achieve significance, despite the larger number of L.A. suicides, which allowed greater statistical sensitivity in the L.A. analyses. The explanation may be that weather reports for the Sacramento weather station would be well-correlated with weather over the entire county. In Los Angeles, a single weather station may not properly reflect the coastal weather micro-climates, since in coastal regions, there is a rapid change in temperature and sunlight exposure as one moves inland (a phenomenon due in large part to coastal fog).

Given that the observed Sacramento relationship of low sunlight to subsequently increased suicides is neither statistically robust nor supported by L.A. data, further study is needed. As Table 3 reflects, the numbers of suicides analyzed (particularly in Sacramento data) were rather small for high statistical sensitivity. Weather effects on suicide did not achieve statistical significance until they reached 20-30% changes in rate or more. Thus, although this analysis required extensive computational efforts,

still larger data sets must be studied in geographical areas that have more of a weather change compared with California, if correspondences of suicide data and weather measurements are to be examined definitively.

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