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Seasonality and Climatic Associations with Violent and Nonviolent Suicide: A Population-Based Study

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Key Words
Violent suicide · Nonviolent suicide · Seasonality

Abstract
Background: Using 7-year population-based data on Taiwan, we examined seasonal variation in violent versus nonviolent suicide, and its association with meteorological factors: ambient temperature, relative humidity, atmospheric pressure, rainfall and daily sunshine hours. ***Methods:*** We used Taiwan's nationwide mortality data from 1997 to 2003, categorizing the sample decedents into two groups, violent (ICD-9-CM codes E953–E958) and nonviolent (E950–E952) suicide, based on the suicide method used. Seasonal autoregressive integrated moving average (SARIMA) modeling was used to detect seasonality of suicide, and the association of climate variables with violent versus nonviolent suicide. ***Results:*** The SARIMA test of seasonality was significant for both genders and the pooled sample (all $p < 0.001$) in violent suicide deaths, but not nonviolent suicides. Seasonal trends show a significant peak in March–May (early to late spring) for violent suicides. Increasing ambient temperature predicted increasing violent suicide rates. ***Conclusions:*** We conclude that seasonality exists in violent but not nonviolent suicide rates. Our findings suggest that suicide is a heterogeneous phenomenon and violent suicide may be more influenced by biochemical and chronobiological mechanisms.

Introduction

Increasing suicide rates have become a major public health concern worldwide in the past decade. In 1998, an estimated 1.8% of global deaths were caused by suicide, projected to increase to 2.4% by 2020 [1]. Past epidemiological studies have suggested many risk factors: region, age, gender [2], psychiatric history, unemployment [3], interpersonal relationships, life events [4], socioeconomic factors [5], season/climate [6], race [7], sickness absence [8] and marital status [9]. Among these risk factors, seasonal impact has drawn considerable attention since the 19th century. Although there is no scientific evidence documented, climatic variables such as temperature have been suspected to influence seasonal fluctuations in sui-

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cide rates through their impacts on brain functioning. A noted author in the classics of suicidology, Durkheim, has proposed that the disruption of social rhythm may be related with specific seasonal peaks for suicide. Since the advent of advanced statistical techniques, several studies have consistently demonstrated seasonal fluctuations in suicidal deaths in several populations [10].

Some authors, e.g. Marcinko et al. [11], have postulated that suicides cannot be considered a homogeneous group. Few authors have explored the empirical evidence regarding the heterogeneity of suicides, the etiology of suicide by type and the biochemical mediator pathways. A starting point to evaluate the heterogeneity of suicide etiology would be to investigate seasonal variations in the different methods of suicide and look for indirect evidence that violent versus nonviolent methods may have different causal pathways. Some studies have documented that seasonal variations in suicidal deaths vary by the method of suicide [12].

A study in Finland showed a peak in shooting suicides among children and adolescents in fall, but a spring peak among adults [13]. A summer peak of hanging deaths has been reported in Lithuania [14]. Maes et al. [15] could not find evidence for seasonality in nonviolent suicide in Belgium. However, Hakko et al. [16] showed a significant seasonality in violent suicides in Finland during 1980–1984. They also verified that specific violent and nonviolent methods of suicides were clustered by season, when classified by suicide method [17].

This study aims to contribute to the literature on suicide seasonality by suicide type, using 7-year population-based data on violent versus nonviolent suicide from a subtropical island nation, Taiwan. This study also adds to the literature by concurrently examining statistical associations with meteorological variables.

Methods

Suicide Data

In Taiwan, suicide has been the ninth leading cause of death since 1999, with 18.8 suicidal deaths per 100,000 in 2005 (Taiwan Department of Health, 2005). We used 1997–2003 cause of death data from Taiwan's Department of Health to examine time trends of violent and nonviolent suicides. This data file provides information on: date of birth and death, place of death (hospital, clinic, midwifery, home and others), nature of death (disease or natural death, accidental, suicidal, homicidal and other causes), underlying cause of death (ICD-9-CM code), employment status and marital status. Being an island with a natural geographical marine boundary against illegal immigration, with an extremely low legal immigration rate, Taiwan had a relatively fixed population over the study period. With mandatory registration of births, deaths, marriages/divorces and migration, its demographic and vital event statistics are accurate and complete.

Study Sample

The total 18,130 suicidal deaths in Taiwan between January 1, 1997, and December 31, 2003, were categorized into two groups by suicide method, i.e. 11,633 violent suicides (ICD-9-CM codes E953–E958) and 6,497 nonviolent suicides (ICD-9-CM codes E950–E952), as documented in past studies [18, 19]. The sample mean age at death was 49.5 years (±18.3). Annual population data from Taiwan's Population Affairs Administration of the Ministry of Interior were used to calculate monthly suicidal deaths per 100,000 population.

Meteorological Data

Meteorological data comprised: daily ambient temperature (average of minimum and maximum temperature), relative humidity, atmospheric pressure, rainfall and hours of sunshine, obtained from 19 observatories of the Central Weather Bureau, and averaged across all stations and the days of the month, to calculate monthly mean values over the 7-year period. (Of the total 26 observatories across the island, data from 7 stations in the central mountainous region with very scanty population were discarded.) Since Taiwan is a small island, with a total land mass slightly in excess of 36,188 km^2, with most of the population living along the peripheral coastal rim, a monthly mean value was judged representative of the climatic situation for the island.

Seasons in Taiwan

Located between 21°45′ N and 25°56′ N, Taiwan's weather is typically subtropical, seasons ranging from warm to hot, and humid all year round. The Central Weather Bureau defines spring as March to May, summer June to August, autumn September to November and winter December to February.

Statistical Analysis

Monthly suicide rates per 100,000 population for violent and nonviolent suicides, by gender, were calculated, across the 7-year study period (used as a single time series for analysis and discussion). First, the Q statistic test was used to assess the serial correlation within the time series. Then, violent and nonviolent suicide rates were evaluated for seasonality by using 'autoregressive integrated moving average' (ARIMA). This method, describing a univariate time series as a function of its past values and other significant independent variables, has been used in past studies of seasonality and environmental exposure impacts. The ARIMA model uses autoregressive parameters, moving average parameters and the number of differencing passes to describe a series in which a pattern is repeated over time.

We examined whether the time series have a recurring pattern by calendar month to decide upon the type of analysis to be used. If no seasonal pattern is discovered, regular ARIMA can be applied. If a seasonal pattern exists, the original time series is not stationary and requires seasonal adjustment (seasonal ARIMA, SARIMA). In evaluating the data, autocorrelation functions are used to identify the order of autoregressive and moving average of the time series.

Table 1. Mean monthly suicide rates (per 100,000 population) and mean climatic variables

Variable	Mean	SD	Minimum	Maximum
Total violent suicide deaths	0.62	0.10	0.43	0.94
Male violent suicide deaths	0.83	0.14	0.54	1.28
Female violent suicide deaths	0.41	0.08	0.24	0.60
Total nonviolent suicide deaths	0.35	0.10	0.18	0.65
Male nonviolent suicide deaths	0.46	0.15	0.20	0.91
Female nonviolent suicide deaths	0.23	0.70	0.09	0.45
Ambient temperature, °C	23.15	4.04	16.20	29.30
Relative humidity, %	78.18	2.80	70.29	83.65
Atmospheric pressure, hPa	999.62	4.89	990.65	1,007.90
Rainfall, mm	173.85	85.30	28.83	527.00
Sunshine, h	158.20	119.22	20.82	889.75
Maximum temperature, °C	26.80	4.08	19.03	33.18
Minimum temperature, °C	20.46	4.01	13.15	26.38

Since climatic factors might have a significant impact on suicide rates and confound 'seasonality', monthly mean values of temperature, relative humidity, rainfall, hours of sunshine and pressure were included in the SARIMA model to improve the accuracy of seasonality effect estimates. The final model was selected based on the lowest mean Akaike information criterion and Schwarz criterion, to choose the best model that most closely fit the data from the family of SARIMA regression models [20]. A p value of <0.05 was used for statistical significance.

Results

Suicide Rates

During the study period, the mean annual violent and nonviolent suicide death rates were 7.49 and 4.18 per 100,000, respectively. The monthly violent suicide death rate ranged between 0.43/100,000 in February 1998 and 0.94/100,000 in May 2003, with a mean monthly rate of 0.62 (SD 0.10) and, by gender, a rate of 0.83 for males and 0.41 for females (table 1). The mean monthly nonviolent suicide rate was 0.35 and for males and females 0.46 and 0.23, respectively.

Table 1 also summarizes the mean monthly values of climate parameters. Across the 7-year study period, the mean ambient temperature was 23.15°C, relative humidity 78.18%, atmospheric pressure 999.62 hPa, rainfall 173.85 mm and sunshine hours 158.20.

Seasonal Variations and SARIMA Tests of Seasonality

Seasonal variations in violent and nonviolent suicide death for males and females, and the pooled sample are illustrated in figure 1. A generally similar monthly pattern in violent suicide death rates across the pooled sample and by gender is observed in figure 1. Crude rates show a significant peak in March–May (early to late spring) and a discernible trough in September (early autumn). Figure 1 also shows an obvious peak during March for nonviolent suicides.

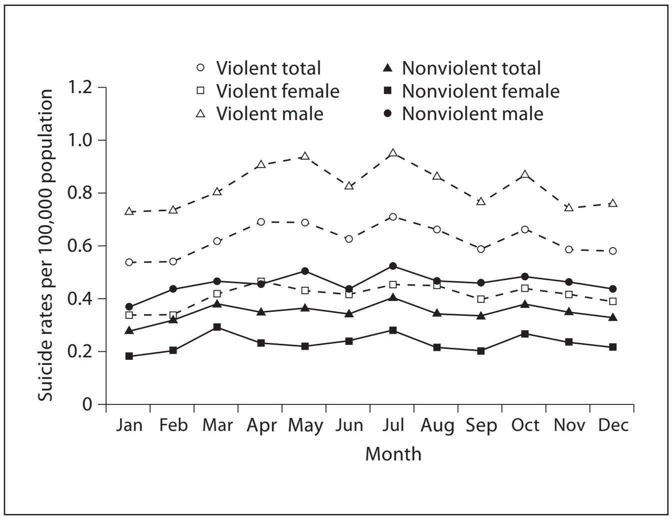

Fig. 1. Mean monthly suicide rates in Taiwan, 1997–2003.

Since the Q statistics were significant, the SARIMA model was appropriate for the time series estimation. Statistical tests for seasonality were significant for each gender and for the pooled sample in violent suicides ($p < 0.001$ for the SAR12 estimate in all models). The seasonality test among nonviolent suicides was not significant (not shown).

Table 2. SARIMA analysis results showing associations of climatic variables and seasonality with monthly suicide rates

Independent variables	Monthly suicide rates per 100,000 population					
	violent total	violent male	violent female	nonviolent total	nonviolent male	nonviolent female
Intercept	14.2213	29.7005*	1.3858	10.0724	21.1638*	–5.4316
AR1	0.6749***	0.8993***	–0.6747***	0.8486***	0.8247***	–0.0391
MA1	–0.5998***	–0.9972***	0.9974***	–0.5870**	–0.5898**	0.1789
SAR12	0.6682***	0.6278***	0.5297***	0.7150***	0.56666***	0.7986***
SMA12	–0.8821***	–0.8882***	–0.8834***	–0.8749***	–0.8848***	–0.8905***
Atmosphere pressure	–0.0133	–0.0183	–0.0013	–0.0099	–0.0108	0.0052
Ambient temperature	0.2012**	0.1989**	0.2312**	0.0110	–0.0198	0.1391
Relative humidity	0.0001	–0.0004	0.0035	–0.0005	0.0007	–0.0025
Rainfall	–0.0001	–0.0001	–0.0001	0.0001	0.0002	0.0001
Hours of sunshine	–0.0002	–0.0004	–0.0001	–0.0001	–0.0002	–0.0001
Trend	–0.0001	–0.0008	0.0016	0.0068	0.0088	0.0053
AIC	–2.0445	–1.2642	–2.1523	–2.7011	–1.8057	–2.8277
Schwarz criterion	–1.6940	–0.9132	–1.8017	–2.3506	–1.6663	–2.4772
R^2	0.6042	0.6021	0.4512	0.8271	0.8082	0.6607

* p < 0.05, ** p < 0.01, *** p < 0.001. AR1 = Autoregressive, lag 1; MA1 = moving average, lag 1; SAR12 = seasonal autoregressive, lag 12; SMA12 = seasonal moving average, lag 12. Selection of the final parameters was based upon the lowest Akaike information criterion (AIC) and Schwarz criterion.

Climatic Influences

After adjusting for seasonality and time trend, the SARIMA regression models in table 2 reveal that ambient temperature was significantly associated with violent suicide death rates ($p < 0.01$ for the pooled sample and males and females), but neither seasonality estimates nor estimates for the meteorological variables were significant for nonviolent suicide.

Discussion

This study contributes to the literature by investigating seasonality in violent versus nonviolent suicide and exploring its association with climate, using population-based data from a subtropical country. We found evidence of seasonality as well as a positive association with ambient temperature in violent suicides. There is no evidence of seasonality in nonviolent suicides.

Our finding is consistent with the literature. Seasonality was reported in violent suicides, but not in nonviolent suicides in Belgium during 1979–1987 [15]. In Finland, Hakko et al. [16] reported seasonal, April to June peaks in violent suicides during 1980–1995. Regarding nonviolent suicides, although seasonality was observed during 1980–1984, the later period (1985–1995) did not show such evidence [16]. Another study in Italy also demonstrated significant seasonal variation in violent but not nonviolent suicides [21]. Thus, the documented seasonality of suicide in various countries could have been driven by the seasonality in violent rather than nonviolent suicides [6, 22, 23].

Many authors have speculated on the factors contributing to the seasonality of violent suicide. These include seasonal variations in physiological conditions including: plasma levels of serotonin, 5-hydroxyindoleacetic acid, cerebrospinal fluid 3-methoxy-4-hydroxyphenylglycol concentrations, plasma melatonin concentration and serum cholesterol level, as well as seasonal variations in metabolic and immune disorders [24–26]. However, temporal studies of circannual variations by season of the above factors and of violent suicides are still very scarce. Large-scale prospective studies are needed to identify the concurrent roles of biochemical, metabolic and immune factors in violent suicide behavior.

Yip et al. [27] suggested that lifestyle factors relating to social contact and activities might mediate the seasonal variation in suicide rates. According to their hypothesis, suicide seasonality should become reduced or disappear with increasing technological penetration in a population or era, due to the consequent diminishing relevance of seasonal social contact and social activities, due to technological developments in telecommunications. It is possible that the lack of seasonal variation in nonviolent suicide in this study, and among nonviolent suicides of the latter years of the Finnish study by Hakko et al. [16], may lend support to this viewpoint. Plausibly, suicidal behavior of persons who chose nonviolent methods may be driven by psychosocial factors rather than biological factors.

Another major factor in type of suicide is the role of mental illness. Since we used cause of death data, there is no information on prior diagnosis of mental illness. If violent suicides are predominated by the mentally ill, then is it possible that the interactions/metabolism/concentrations of specific medications with weather conditions underlie the act of suicide? For example, a substantial proportion of serious mental illness is treated with drugs that may compromise kidney function. With possible dehydration in higher ambient temperatures, potentially accentuated among the mentally ill due to fluid intake issues, drug-related impacts may be a factor to be investigated.

We find that ambient temperature is positively associated with violent suicides, among the pooled, male and female populations, after adjusting for seasonality and trend, and that no climatic parameter is significant for nonviolent suicide. This finding is consistent with the seasonality of violent suicide attempts in Italy, suggesting a positive relationship between temperatures and violent suicide attempts [28]. Further, no climatic parameter is significant for nonviolent suicide. Consistent with this finding, Maes et al. [29] reported no significant relationship between nonviolent suicides and any weather variable in Belgium during 1979–1987. However, partially contrary to our findings, they reported that violent suicide was not only significantly related to ambient temperature, but also to sunlight duration and relative humidity. A possible explanation for the discrepancy may be their use of multiple regression modeling, rather than SARIMA models used in the present study to adjust for time trend effects. SARIMA modeling is a state-of-the-art statistical method that has been widely used to investigate the association between climate and disease incidence [30–32]. Given the reliance of past studies on univariate statistical methods including correlation analyses, it is understandable that they could not identify the key meteorological factor(s) driving the seasonal association because of high correlations between meteorological parameters in each season. This constraint of univariate analysis for seasonality studies has been noted [6]. The use of the SARIMA method therefore differentiates this study from earlier research in this area.

Our study has 3 potential limitations. First of all, misclassification of cause of death and potential underreporting of suicides in the registry could confound our results, although it is generally agreed that in Taiwan cause of death records are accurate. In addition, mixed methods of suicide are known, such as intentional overdose of sedatives prior to charcoal burning, hanging or jumping from heights. A second, more important issue is that, although we adopted the classification of violent and nonviolent suicides used in earlier studies, the classification itself is simplistic and arbitrary. It may be more relevant to explore seasonal variations in various methods of suicide, rather than using the violent/nonviolent classification. Third, there is no information on suicides associated with mental illness. This could be an important determinant of seasonal variation in violent suicide. Lastly, ecological fallacies might confound an investigation of climatic parameters impacting individual suicide deaths.

Despite these limitations, our finding of seasonality in violent but not nonviolent suicides contributes to the literature. Our findings suggest that suicides may be a homogeneous group. Violent suicides may be more influenced by biochemical and chronobiological factors. We also found that ambient temperature was significantly and positively associated with violent suicide rates after adjusting for seasonality, month and trend. Therefore, the role of serious mental illness and plausible weather-sensitive physiological or pathological conditions underlying violent suicides need to be clarified.

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