



Research report

Temperature change dominates the suicidal seasonality in Taiwan: A time-series analysis

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ARTICLE INFO

Article history:

Received 1 July 2011

Received in revised form 11 November 2011

Accepted 11 November 2011

Available online 6 December 2011

Keywords:

Climate

Economic factor

Seasonality

Suicide

Temperature increase

ABSTRACT

Objective: The arguments between bioclimatic and sociodemographic hypotheses for the suicidal seasonality continue. The present study aimed to examine the relationships between suicidal seasonality and the climate as well as the economic factors.

Methods: The monthly suicide death rates of the total, male and female populations in Taiwan during January 1991–December 2010 were obtained from the population-based database. Autoregressive integrated moving average (ARIMA)/seasonal ARIMA (SARIMA) was used to analyze suicidal seasonality, with monthly ambient temperature, temperature increase, rainfall, sunlight, unemployment and labor force participation rates as the independent inputs.

Results: The models revealed that monthly temperature increase was strongly positively associated with seasonality of suicide rates of all populations ($\beta = 0.0184$, $P < 0.001$; $\beta = 0.0234$, $P = 0.001$; $\beta = 0.0145$, $P < 0.001$, respectively). Rainfall was significantly negatively associated with the total and male suicide rates ($\beta = -0.0001$, $P = 0.012$; $\beta = -0.0002$, $P = 0.043$, respectively), but not with female. Unemployment and labor force participation rates were not significantly related to their corresponding suicide rates.

Limitations: Socio-demographic data, individual major events, and subgroups by suicide methods were not taken into account.

Conclusions: The results indicate that, as far as suicidal seasonality is concerned, monthly temperature increase is the most influential factor, and climatic factors have more significant effect than the economic factors.

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1. Introduction

The seasonality of suicide with a peak in spring has been widely recognized (Postolache et al., 2010; Rocchi et al., 2007a; Sun et al., 2011; Tsai and Cho, 2011), but arguments between bioclimatic and sociodemographic hypotheses as the underlying mechanism for the suicidal seasonality continue. Bioclimatic hypothesis attributed suicidal seasonality to biological influence resulting from the weather conditions, and sociodemographic hypothesis to the annual ebb of the

social life (Chew and McCleary, 1995). A better understanding of this phenomenon could provide more effective strategies for suicide intervention. At the first glance, seasonality should be surely related to the climatic factors, which have obvious seasonality. Many previous studies on the seasonality of suicide explored the impact of climatic factors. A bioclimatic theory suggested that temperature had a direct influence on the tendency to suicide. Lin et al. (2008) explored seasonality by seasonal autoregression integrated moving average (SARIMA) model and found that increasing ambient temperature predicted increasing violent suicide rates. Preti and Miotto (1998) also confirmed the positive association between suicide seasonality and temperature. Further, Page et al. (2007) found that an increase in suicide by 46.9% during the 1995 heatwave, and each 1 °C increase in

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mean temperature was associated with a 3.8% rise in suicide. Besides temperature, sunlight was also found to be positively related to the suicide seasonality, while rainfall negatively related (Preti, 1997). However, seasonal variation existed not only in the climatic variables, but also the socioeconomic variables. Durkheim attributed the suicidal seasonality to the annual ebb and flow of social life (Chew and McCleary, 1995). Souetre et al. (1987) addressed that covariation between the main seasonal component of suicides and socio-logical factors existed in addition to the climatic factors. Rocchi et al. (2007b) also found economic reason to be significant for seasonal unevenness of suicide. Preti and Miotto (1998) concluded that work aimed at suicide prevention should therefore take into account the complex influence of seasonal climate both on human biological rhythms and on socio-relational habits. Nonetheless, the study on suicidal seasonality taking both climatic and socioeconomic factors into account at the same time has been spared. Although Chew and McCleary (1995) tried to evaluate the relative influence of social versus bioclimatic factors on cross-national variation in the magnitude of spring suicide peaks, they used the latitude of each nation's capital city, rather than the genuine meteorological parameters including temperature, rainfall, and sunlight hours, as the independent variables. However, as Chew and McCleary also recognized, latitude may be a problematic indicator of seasonal temperature change, the question "is the seasonality of suicide associated more with the climatic or economic factors" remained unanswered.

The aim of the present study was to examine the suicidal seasonality taking both the meteorological as well as economic parameters into account at the same time.

2. Method

The monthly suicide death numbers and rates of the total, male, and female populations in Taiwan during January 1991–December 2010 were obtained from population-based database (ICD-9 classification E950–959) of the Department of Health of Taiwan (http://www.doh.gov.tw/CHT2006/DM/DM2_2_p02.aspx?class_no=440&now_fod_list_no=11468&level_no=1&doc_no=77184. Retrieved July 30, 2011). Year 1991 was chosen to be the starting year because the suicide data was comprehensively and readily available thereafter. Hakko et al. (2002) addressed that the calendar effect should be taken into account in analyses of seasonality because uneven days in months could cause deviation, and affected the statistical significance for the seasonality effect. The suicide death rates in the present study were adjusted based on a 30-day duration for months.

Four meteorological parameters (monthly mean ambient temperature, temperature increase compared against the previous month, rainfall, sunlight) were collected from the database of the Central Weather Bureau in Taiwan (<http://www.cwb.gov.tw/>. Retrieved July 30, 2011). Data from six weather stations (Taipei, Taichung, Tainan, Yilan, Hualien and Taitung representing northwest, mid-west, southwest, northeast, mid-east and southeast of Taiwan, respectively) were averaged to represent the monthly meteorological parameters of Taiwan.

Two economic factors (monthly unemployment and labor force participation rates) were gathered from Directorate-General of Budget, Accounting and Statistics, Executive Yuan of Taiwan (<http://www.stat.gov.tw/ct.asp?xItem=17144&ctNode=517>. Retrieved July 30, 2011).

The mean monthly total, male and female suicide rates were analyzed for seasonality, with the above four climatic and two economic factors as independent inputs, by using 'autoregressive integrated moving average (ARIMA)/seasonal ARIMA (SARIMA)'. This method has been used in the studies involving seasonality including suicide. It utilized the past values and moving average of a time series variable to explore the pattern repeated annually and to predict the future values. The model would be specified as $(p,d,q)/(P,D,Q)^S$, with p and P representing the autoregressive and seasonal autoregressive; d and D representing the non-seasonal differences and seasonal differencing; and q and Q the moving average parameters and seasonal moving average parameters, respectively (Wangdi et al., 2010). SARIMA model equation:

$$y_t = [\Theta_q(B)\Theta_Q(B^S)a_t\Phi_p(B^S)] / [\Phi_p(B^S)\Phi_P(B)(1-B)^d(1-B^S)^D]$$

where $\Phi_p(B)$ is the autoregressive (AR) operator, $\Phi_P(B^S)$ the seasonal AR (SAR) operator, $\Theta_q(B)$ the moving average (MA) operator, $\Theta_Q(B^S)$ the seasonal MR (SMA) operator, $(1-B)^d$ and $(1-B^S)^D$ the ordinary and seasonal difference components, a_t the white noise, and y_t the dependant variable. The length of the seasonal period S was 12 for month-based data. Because the goal of the present study was to explore the potential affecting climatic and economic variables on suicide seasonality, monthly averaged values of temperature, rainfall, hours of sunshine, unemployment and labor force participation rates were included in the ARIMA/SARIMA model as independent inputs. The selection of the final models was based upon the minimum Akaike information criterion (AIC). $P < 0.05$ was considered statistically significant.

3. Results

The suicide death numbers of total, male, and female populations in Taiwan during 1991–2010 were 55362, 37566, and 17796, respectively. The average monthly suicide rates for total, male, female populations, ambient temperature, temperature increase, rainfall, sunlight, unemployment and labor force participation rates were as shown in Fig. 1. The average monthly suicide rates for total, male and female populations ranged from 0.88 to 1.12, 1.17 to 1.51 and 0.58 to 0.73 per 100,000 populations, respectively. The average monthly ambient temperatures were as low as 17.6 °C, and as high as 29.0 °C. The monthly temperature increase had a minimum of −3.1 °C, and maximum of 2.9 °C. The average monthly rainfalls were as little as 61.2 mm, and as much as 311.5 mm. The average sunlight hours were as little as 101.7 h a month, and as much as 217.3 h a month. The average monthly unemployment rates for total, male and female populations ranged from 3.18% to 3.69%, 3.49% to 3.79% and 2.73% to 3.56%, respectively. The average monthly labor force participation rates of total, male and female populations ranged from 57.9% to 58.5%, 69.3% to 70.0% and 46.3% to 47.3%,

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