

# Climate Change in Relation to Suicide Rates in Taiwan: A Ten-Year Trend Study

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**Background:** Climate change has greatly affected the environment, ecology, and economy. However, little is known about whether and how climate change influences mental health. This study used datasets to examine the relationships among various meteorological factors and suicide rates in Taiwan over a 10-year period.

**Methods:** Four sets of data were linked in this study. Descriptive statistics were used to determine distributions of meteorological variables and suicide rates. Multiple logistic regression analyses were conducted annually to examine whether meteorological variables can predict concurrent suicide. Time series analyses were performed to verify whether suicide rate is associated with climate change trends.

**Results:** During the period 1999-2008, there was an increase in the suicide rate in Taiwan, especially among males. The pressure, temperature, relative humidity, and sunshine hours remained relatively stable during this 10-year period, while the frequencies of heavy rainfall, defined as over 500 mm within a single month, increased dramatically after 2004. The concurrent effect of heavy rainfall on suicide rate was significant after 2004. A similar pattern was found on time series analysis. When stratified by sex, the effect was especially salient among females ( $\hat{b}=0.002$ ,  $p<0.05$ ). Pressure also had a significant effect on suicide rate ( $\hat{b}=-0.191$ ,  $p<0.001$  for males;  $\hat{b}=-0.097$ ,  $p<0.0001$  for females).

**Conclusions:** With respect to the risk factors of suicide, not only individual level factors, but also macro level factors, such as climate change, have played a role in the increasing suicide rate during the past decade in Taiwan.

**Keywords.** climate change, time series, suicide

## Introduction

Suicide has been ranked among the 10 leading causes of death in Taiwan. According to Taiwan's

Department of Health, the suicide rate ranged from 13.6 per 100,000 to 16.8 per 100,000 from 2004 to 2008<sup>[1]</sup>. The world population has grown 132%<sup>[2]</sup>, and suicide deaths have risen 60% over the past 50 years. Therefore, suicide has become an important public health problem all over the world.

Suicide is a complex outcome involving more than one factor. Sufficient research has indicated that suicide is associated with biological (e.g., hormone and heredity)<sup>[3, 4]</sup>, psychological (e.g., depression

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and personality)<sup>[5]</sup> and social (e.g., pressure and industrialization)<sup>[6]</sup> variables. Recently, the relation between the impact of environmental changes and individual health has gained attention. Climatic factors have become important when it comes to their effects on suicide rates.

Some studies have pointed out that suicides peak in late spring or early summer<sup>[7, 8]</sup>. The same result has been found in Taiwan, with suicides peaking in spring<sup>[9]</sup>. Higher temperatures may raise the risk of suicide<sup>[10]</sup>. A study in Finland indicated that the death rate from suicide is highly correlated with ambient temperature, especially among females<sup>[11]</sup>. However, there are no particular conditions that can be termed suicide weather, with contradictory results reported in different countries. For example, in Italy, lower precipitation increases the risk of suicide after controlling for sunshine hours and relative humidity<sup>[12]</sup>. Findings from an Australian study have also indicated that the rate of suicide rises about 8% when precipitation decreases 300mm<sup>[13]</sup>. But, negative results have been reported as well, such as an increasing suicide rate after a thunderstorm<sup>[10]</sup>.

Different meteorological conditions may have different effects on suicide rate, but studies that include systematic analyses of climate data and which discuss the association between climatic parameters and suicide rate are rare. Taiwan is a small island with large meteorological variations. With well-established weather reporting system and database, Taiwan is well suited to investigating the relation between meteorological factors and suicide.

Furthermore, Taiwan has suffered from natural disasters which have impacted on the economy during the period 1999-2008. Such losses could affect individuals' ability to adapt or mental status, leading to a rise in the suicide rate. Similar research has focused on seasonal effect. Little is known about how meteorological factors affect mental health after controlling for economic indicators and important events. In addition, climate change follows the regular pattern of seasons, but its influences on individuals may be revealed after a period of time. The aim of this study is to use 10-year data to examine the relationships among various meteorological factors and suicide rates in Taiwan.

## Methods

### Database

Monthly suicide data was provided by the Department of Health, Executive Yuan, for the period 1999 to 2008. According to the International Classification of Diseases, deaths coded E950-E958 were defined as suicide and included in the study. The total number of suicides was 33989.

Climate data, comprised of pressure, temperature, rainfall, relative humidity and sunshine hours, was derived from 14 meteorological stations of the Central Weather Bureau of Taiwan, from 1999 to 2008. There are 31 meteorological stations in Taiwan. Seventeen meteorological stations located in the mountains or sparsely populated areas, were excluded.

Population data was released by the Department of Household Registration, Ministry of the Interior, Taiwan. This study used suicide data and population data to calculate the monthly suicide rates, based on the following formula:

$$\text{Monthly suicide rate} = \frac{\text{total monthly suicidal deaths}}{\text{mid-year population}}$$

Economic indicators included Industrial Production Index and Unemployment Rate obtained from the Taiwan Economic Journal. The study period was as described above.

Three important events occurred during the study period: 921 Earthquake, media reporting of Korean actress Lee Eun-ju's suicide and bankruptcy of Lehman Brothers. According to a study by Chou in 2003<sup>[14]</sup>, the risk of suicide rose over the 14 months following the 921 Earthquake. Therefore, the time period from October 1999 to December 2000 was controlled for by dummy variables in the analysis. There was heavy reporting of Lee Eun-ju's suicide, with marked increase in the number of suicide deaths over the following 4-week period<sup>[15]</sup>. Therefore, suicide deaths in March 2005 were controlled for in this study. The impact of the bankruptcy of Lehman Brothers was also considered in the time series analysis from September 2008.

### Data analysis

Descriptive statistics, multivariable analysis

and time series analysis were used in this study. Descriptive statistics were obtained to determine the distributions of meteorological variables and suicide rate. Poisson regression was employed to explore the relationships among 10-year suicide rates in both sexes and meteorological variables. To understand how meteorological variables affect suicide rates over time, time series analysis was conducted using Eviews 7 software for data in time series pattern. The model is as follows:

$$\text{Suicide rate} = C_t + \hat{b}_1 \text{Pressure}_{t-1} + \hat{b}_2 \text{Rainfall}_{t-1} + \hat{b}_3 \text{Rh}_{t-1} + \hat{e}_1 \text{IPI}_{t-1} + \hat{e}_2 \text{Unemployment rate}_{t-1}$$

Where  $C_t$  is the intercept at time  $t$ , and  $i$  is the lag period(month).

## Results

### Suicide rates

Figure 1 shows the suicide trend in Taiwan during the period 1999-2008. In general, the suicide rates of males were higher than those of females. There were upward trends in suicides among both sexes from 1999, with the increase more obvious among males. From 2004 to 2008, suicide rate was high among males.

### Climatic factors

During the study period, pressure had an effect on suicide rate, which was most obvious among males ( $\hat{b}=0.164, p=0.037$ )(Figure 2). Distribution of rainfall is presented in Figure 3. During the 10-year period, the frequency of heavy rainfall, defined as over 500 mm within a single month, increased after 2004, and was most marked in

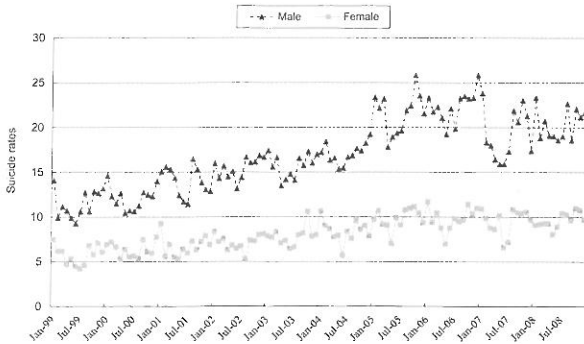


Fig. 1 Monthly suicide rates in both sexes, 1999-2008

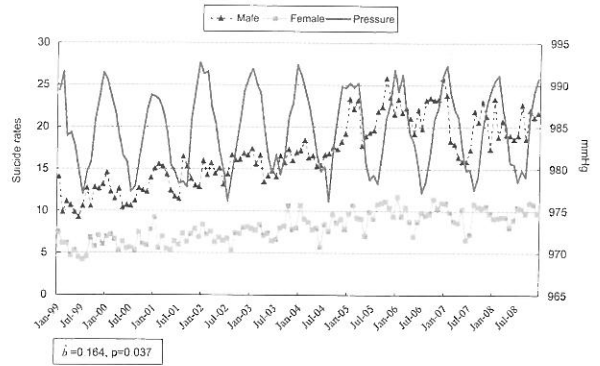


Fig. 2 Monthly suicide rates by sex and pressure in Taiwan, 1999-2008

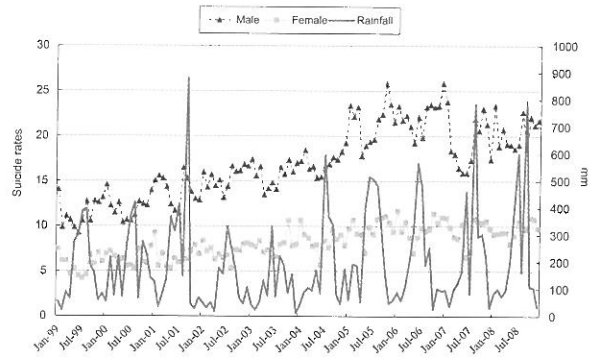


Fig. 3 Monthly suicide rates by sex and rainfall in Taiwan, 1999-2008

2007. However, temperature, relative humidity, and sunshine hours remained relatively stable over the observed decade. Poisson regression in Table 1 revealed that pressure and rainfall are significantly associated with suicide rates in both sexes. Positive association was also found between temperature and male suicide rate ( $\hat{b}=0.0113, p<0.05$ ).

### Climatic influence

Tables 2a and 2b show the estimates of climatic factors, economic factors and important events in relation to suicide rates across the 10-year study period. After controlling for three different important events, male suicides in the current month were affected by factors that could be traced back several months, such as pressure 5 months ago ( $\hat{b}_1=-2.203, p<0.001$ ), rainfall 2 months ago ( $\hat{b}_2=0.003, p<0.05$ ), industrial production index 4 months ago, and unemployment rate 5 months ago. Similarly, pressure from 5 months ago ( $\hat{b}_1=-0.108, p<0.0001$ ), rainfall from 2 months ago ( $\hat{b}_2=0.002, p<0.001$ ), industrial production index from 5

**Table 1. Poisson regression of suicide rates in both sexes and climatic factors**

	Estimate	
	Male	Female
Intercept	-44.88***	-30.92***
Pressure	0.023***	0.025**
Temp	0.0113*	0.0053
Rainfall	0.0002**	0.0002**
Rh	0.0004	0.0001
Sunshine	0	0.0007

\*  $p < 0.05$  \*\*  $p < 0.001$  \*\*\*  $p < 0.0001$

months ago, and unemployment rate from 5 months ago were significantly associated with female suicide rates.

## Discussion

The key finding of this study is that after controlling for economic factors and important

events, decline in pressure or increase in rainfall is associated with increase in suicide rate. According to previous studies, increased suicide risk is associated with high pressure conditions<sup>[9-11]</sup>. However, in those studies, the focus was on current pressure conditions and suicide rates. In our study, time series analysis showed that the current suicide rate negatively correlates with the pressure 5 months ago, which implies that a rise in the suicide rate in winter may be associated with low pressure conditions in summer.

It is interesting to note that high rainfall has a positive correlation with suicide rate. From monthly suicide and rainfall data, the frequencies of heavy rainfall and suicides increased after 2004 and the results of Poisson regression analysis showed good correlation between these two variables. An increase in rainfall may influence the risk of suicide. After controlling for economic factors and important events, time series analysis supported these results. In the present study, suicide rates among both sexes were positively correlated with rainfall with 2 month lag, which means that

**Table 2a. Estimates of climatic factors with male suicide rate**

	Coefficient	Coefficient	Coefficient
Intercept	195.7	-7.59**	
<b>Climate indicator</b>			
Pressure <sub>t-5</sub>	-2.203**		
Rainfall <sub>t-2</sub>		0.003*	
Rh <sub>t-2</sub>			0.004
<b>Economic indicator</b>			
IPI <sub>t-4</sub>	0.208***	0.215***	0.217***
Unemployment rate <sub>t-5</sub>	0.785*	1.248**	1.121*
Important event 1	-2.113**	-1.142	-1.348
Important event 2	2.564	1.739	1.789
Important event 3	-4.929**	-4.94**	-4.414**
R <sup>2</sup>	65.5%	61.8%	60.1%
R <sup>2</sup> <sub>a</sub>	63.6%	59.7%	57.8%
AIC	4.63	4.73	4.77
SC	4.79	4.89	4.94

Table 2b. *Estimates of climatic factors with female suicide rate*

	Coefficient	Coefficient	Coefficient
Intercept	103.8***	-4.647**	-2.45
<b>Climate indicator</b>			
Pressure <sub>t-5</sub>	-0.108***		
Rainfall <sub>t-2</sub>		0.002**	
Rh <sub>t-3</sub>			-0.012
<b>Economic indicator</b>			
IPI <sub>t-5</sub>	0.097***	0.101***	0.099***
Unemployment rate <sub>t-5</sub>	0.546**	0.827**	0.662**
Important event 1	-0.239	0.327	0.116
Important event 2	-0.693	-1.127	-1.111
Important event 3	-1.709*	-1.830*	-1.308
R <sup>2</sup>	61.3%	58.0%	53.9%
R <sup>2</sup> <sub>a</sub>	59.2%	55.7%	51.3%
AIC	3.17	3.25	3.35
SC	3.34	3.42	3.51

increased precipitation might raise the suicide rate 2 months later. This indicates that compared to the influences of pressure, there is a greater effect of rainfall, and this effect is more immediate. This finding is in accordance with a previous study which pointed out that the risk of suicide is significantly higher on the day of and the days following a thunderstorm<sup>[10]</sup>, which means that high rainfall increases mental pressure in the short term and raises the risk of suicide.

Most previous studies have shown no relationship between suicide and rainfall. However, some studies have revealed an association between decrease in precipitation and increase in suicide rate<sup>[11-13]</sup>, which differs from our results. There are large differences in climate and geographical features between Taiwan and the countries discussed above. A decline in precipitation in those countries might lead to drought, depressing rural economic activity and bringing economic pressure. Taiwan is an island highly affected by the ocean with plentiful rainfall. That is, the residents of Taiwan might have dissimilar feelings about

or requirements for rainfall. Heavy and sudden downpours can result in mudflows and landslides, which cause loss of or damage to property. This might explain the increased risk of suicide among survivors.

In interpreting the results of the present study, there are some limitations. First, as this is an ecological study, the findings cannot be treated as individual-level results and might contain ecological fallacy. Second, suicide is a sensitive topic in eastern societies. There may be reported or misclassified suicides, leading to information bias.

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