IS SUICIDE MORTALITY ASSOCIATED WITH METEOROLOGICAL AND SOCIO-ECONOMIC FACTORS? AN ECOLOGICAL STUDY IN A CITY IN TAIWAN WITH A HIGH SUICIDE RATE

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SUMMARY

Background: Keelung City has the highest suicide rate in Taiwan. This study aimed to determine whether meteorological and socio-economic factors are associated with suicide mortality in Keelung City, by gender and by means of suicide.

Subjects and methods: Data on suicides between January 2006 and December 2010 were provided by the Department of Health, Keelung City Government. The suicide victims were categorized into non-violent and violent groups, based on the International Classification of Disease, Ninth Revision. Meteorological data were obtained from the Central Weather Bureau of Taiwan. Socio-economic data were gathered from the Accounting and Statistics Office, Keelung City Government. Multiple linear regression analysis with backward elimination was performed to determine the model that was most effective in predicting dependent variables.

Results: During the 5-year study period, the overall suicide mortality rate was negatively associated with ambient temperature. Male suicide mortality was positively correlated with unemployment, and negatively correlated with ambient temperature, barometric pressure, rainy days, family income and number of holidays. Female suicide mortality and violent suicide mortality were not significantly correlated with any meteorological or socio-economic factors. Non-violent suicide mortality was positively correlated with unemployment, and negatively correlated with ambient temperature, barometric pressure and family income.

Conclusions: Suicide is a complex psychopathological phenomenon. Further studies with individual data are warranted to confirm how meteorological and socio-economic conditions influence ones' suicidal behaviour.

Key words: *suicide – weather – meteorologic – economic – gender - method of suicide*

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INTRODUCTION

There are almost one million deaths from suicide per year worldwide, and it has become a major public health concern (Hawton & van Heeringen 2009). Suicide is a complex psychopathological phenomenon rather than one single cause, and is influenced by an interaction of individual and environmental factors (Neeleman 2002). The individual factors have been reported to be psychiatric illnesses, impulsive personality traits and substance misuse (Mann et al. 1999). Environmental issues such as meteorological and socio-economic factors have received increasing attention with regards to their association with suicide mortality (Deisenhammer 2003, Rehkopf & Buka 2006).

Meteorological conditions potentially impact mental health (Berry et al. 2010) and suicidal behaviour (Christodoulou et al. 2012). Increasing epidemiologic evidence has demonstrated that suicide rates fluctuate by season (Woo et al. 2012). Moreover, previous studies have reported that suicide rates are positively correlated with ambient temperature (Kim et al. 2011, Likhvar et al. 2011) and negatively correlated with barometric pressure (Lee et al. 2006). With regard to other meteorological factors, Nicholls et al. (2006) demonstrated that low rainfall may plausibly increase the suicide rate.

Ruuhela et al. (2009) indicated that winters with low global radiation may increase the risk of suicide. Deisenhammer et al. (2003) reported a significant negative correlation between suicide numbers and mean relative humidity. However, although many weather factors had been reported to be associated with suicidal acts, Deisenhammer (2003) doubted whether a specific meteorological condition contributes to a generally higher risk for suicide. Furthermore, some researchers have indicated that the relationship between weather and suicide is more prominent in men than in women (Ajdacic-Gross et al. 2007, Kim et al. 2011), although not all researchers agree (Sun et al. 2011). Many studies have investigated the association of meteorological factors and violent and non-violent suicide (Lin et al. 2008, Parker et al. 2001, Yang et al. 2011), with conflicting results.

Since the late nineteenth century, socio-economic characteristics have been proposed to be determinants of suicide. Researchers generally suggest an inverse relationship, with lower rates of suicide in higher socio-economic areas (Rehkopf & Buka 2006) and areas of greater economic activity (Nandi et al. 2012). However, this relationship may vary by country. Unemployment rate, which is the most frequently presented socio-economic factor, has been shown to have a direct

relationship to suicide mortality in numerous studies (Inoue et al. 2010, Lundin et al. 2012, Schneider et al. 2011). Other economic indices such as median household income (Chang et al. 2011), rates of money supply (Inoue et al. 2010), and stock market volatility (Inoue et al. 2012), have been reported less with regards to the association with suicide rates. Some studies have suggested that suicide among men is more significantly correlated to economic conditions than among women (Inoue et al. 2007, Nandi et al. 2012). However, not all studies support a gender difference (Rehkopf & Buka 2006, Yang et al. 2011). In addition, little is known about whether socio-economic factors affect the means of suicide (violent or non-violent).

Taiwan is an island country with 23 million people located in East Asia. Suicide is an important public health problem in Taiwan, and has been a top 10 cause of death since 1997 (Lin & Lu 2008). Chang et al. (2011) reported that geographical variations exist in suicide rates, as well as the relationships between suicide and spatial and socio-economic patterns. Keelung is a harbour city located in north-east Taiwan, and Keelung City has had the highest suicide rate in the whole country since 2003 (Lin et al. 2010). Keelung City also has a special climate and socio-economic conditions, having one of the heaviest rainfall figures and humidity in Taiwan. Moreover, the harbour-related industries and economic development in Keelung City have slowed down and even regressed in recent decades (Lin 2009). Whether the aforementioned correlations of suicide can be generalized across different circumstances remains unclear. Furthermore, few studies have comprehensively investigated the relationships between suicide, meteorological and socio-economic characteristics (Woo et al. 2012, Yang et al. 2011).

Therefore, the aim of this study was to determine the meteorological and socio-economic factors associated with suicide mortality in a city with a high suicide rate in Taiwan. Whether there were differences in the correlations of suicide mortality with means of suicide and between gender were also examined.

SUBJECTS AND METHODS

Suicide data

The Department of Health of Keelung City Government provided data on suicide mortality between January 2006 and December 2010. The data were in electronic format, and the demographic variables consisted of gender, date of birth and death, marital status and means of suicide. The suicide victims were categorized into non-violent and violent groups, based on the International Classification of Disease, Ninth Revision (ICD-9-CM). The non-violent group (ICD-9-CM codes E950-E952) included poisoning by solid or liquid substances, poisoning by gas used domestically, and poisoning by other gases and vapours. The violent group (ICD-9-CM codes E953-E958) included hanging,

drowning, firearms, air guns and explosives, cutting and piercing instruments, jumping from high places, and other and unspecified means. This classification method has been widely adopted by previous studies (Chung et al. 2008, Lin et al. 2008). The study received approval from the Institutional Review Board of Chang Gung Memorial Hospital.

Meteorological data

The weather in Taiwan is typically subtropical, with seasons ranging from warm to hot, and high humidity all year around. Keelung City is located in the north-east of Taiwan. Under the influence of the north-east monsoon, the weather in Keelung City is generally rainy and humid, particularly in the winter. Meteorological data were obtained from 19 observation stations of the Central Weather Bureau (CWB) of Taiwan, and included ambient temperature, barometric pressure, relative humidity, rainfall, number of rainy days and sunshine duration. The monthly mean values of these data in each area can be found on the website of CWB (Bureau). We used the meteorological data for Keelung City from January 2006 to December 2010 to explore the association with suicide mortality.

Socio-economic data

The total population of Keelung City was 384,134 in 2010. Socio-economic data were obtained from the Accounting and Statistics Office, Keelung City Government, and included family income, unemployment rate, persons receiving urgent/medical assistance, and families with low incomes. Based on the Social Assistance Act in Taiwan, families with low incomes were defined as those living on a budget of less than 6,553 NT per member/month (the currency exchange rate at the end of 2010: 1 NT = 0.033 USD). If a member of a low income family can not afford an unforeseen circumstance or necessary medical expenditure, they are able to apply for urgent/medical assistance from the local government. In addition, the number of official holidays in each month (including Saturday and Sunday) was obtained from the announcement of the Directorate-General of Personnel Administration, Executive Yuan, Taiwan. We used these socio-economic data across the 5-year study period to explore the association with suicide mortality.

Statistical Analyses

Data were analyzed using the statistical software package SPSS, version 16.0 (SPSS Inc., Chicago, IL, USA). The phi coefficient was used to test possible associations of the categorical variables. Autoregressive integrated moving average regression was used to examine the seasonal pattern of suicide mortality, and the Ljung-Box Q test was used to assess serial correlations within the time series. Multiple linear regression analysis with backward elimination was performed to

determine the model that was most effective in predicting dependent variables. The dependent variable was set as suicide mortality, and the independent variables were set as meteorological and socio-economic factors. Two-tailed p values of less than 0.05 were considered statistically significant.

RESULTS

During the 5-year study period, the mean annual age-adjusted suicide mortality rate was approximate 25.3 per 100,000 in Keelung City, which was relatively high compared with the national age-adjusted suicide mortality rate in Taiwan (15.0 per 100,000) during the same time period. In average, 8.5 persons died by suicide per month. The monthly mean numbers of suicide deaths by male, female, violent methods and non-violent methods were 5.9, 2.7, 4.9 and 3.6, respectively. Male/female suicides were not significantly correlated with violent/non-violent suicides (phi=0.03, p=0.470). Figure 1 illustrates the monthly mean number of suicide deaths from 2006 to 2010. There were no significant seasonal patterns in total (Q=10.71, p=0.871), male (Q=14.88, p=0.670), female (Q=17.86, p=0.398), violent (Q=9.60, p=0.944) and non-violent suicide (Q=25.71, p=0.107) deaths.

Table 1 summarizes the monthly averages of suicide deaths, meteorological and socio-economic variables. With regards to the meteorological data, the monthly average of ambient temperature was 22.8°C, barometric pressure 1010.0 mmHg, relative humidity 76.8%, rainfall 307.0 mm, 15.9 rainy days and 111.6 hours with sunshine. In terms of the socio-economic data during

the 5-year study period, the average unemployment rate was 4.7%, and the average family income was 86,885 NT per month (approximately equal to 2,867 U.S.D.). Five hundred and fifty-seven persons received urgent assistance, 1.7 persons received medical assistance, 1296.2 families had a low income, and there were 9.5 official days off per month.

Table 2 shows the meteorological and socio-economic factors which were associated with suicide mortalities. The overall suicide mortality rate was negatively associated with ambient temperature (B=−0.47, p=0.008), while barometric pressure had a marginal statistical significance (B=−0.32, p=0.052). The overall suicide mortality rate was not associated with other meteorological or socio-economic factors. The male suicide mortality rate was positively correlated with unemployment rate (B=1.67, p=0.014), and negatively correlated with ambient temperature (B=−0.68, p<0.001), barometric pressure (B=−0.40, p=0.003), rainy days (B=−0.19, p=0.003), family income (B=−0.35, p=0.018) and number of holidays (B=−0.36, p=0.029). Female and violent suicide mortality rates were not significantly correlated with any meteorological or socio-economic factor. Non-violent suicide mortality was positively correlated with unemployment rate (B=1.13, p=0.048), and negatively correlated with ambient temperature (B=−0.42, p=0.002), barometric pressure (B=−0.26, p=0.021) and family income (B=−0.28, p=0.024). Other meteorological and socio-economic factors including relative humidity, rainfall, sunshine duration, receiving urgent/ medical assistance and low family income were not associated with suicide deaths either by gender or by means of suicide.

Table 1. Monthly averages of suicide mortality, meteorological and socio-economic factors in Keelung City, Taiwan, January 2006 to December 2010

Variables	Mean (SD)	Minimum	Maximum
Suicide mortality			
Total (persons)	8.5 (2.4)	3	14
Male (persons)	5.9 (2.2)	2	13
Female (persons)	2.7 (1.5)	0	6
Violent (persons)	4.9 (2.1)	1	12
Non-violent (persons)	3.6 (1.8)	1	9
Meteorological factors			
Ambient temperature (°C)	22.8 (4.7)	14.2	30.0
Barometric pressure (mmHg)	1010.0 (5.5)	1000.8	1019.4
Relative humidity (%)	76.8 (4.0)	69.0	88.0
Rain fall (mm)	307.0 (189.4)	5.0	946.2
Rainy days (days)	15.9 (4.6)	4	25
Sunshine duration (hours)	111.6 (66.9)	2.0	263.7
Socio-economical factors			
Family income (1,000 NT)	86.9 (2.9)	82.7	90.4
Unemployment rate (%)	4.7 (0.6)	4.2	5.7
Urgent assistance (persons)	557.0 (82.7)	442	720
Medical assistance (persons)	1.7 (0.8)	0	4
Families with low income (families)	1296.2 (80.5)	1162	1446
Number of official holiday (days)	9.5 (1.5)	7	14

Table 2. Factors associated with total suicide mortality, male suicide mortality and non-violent suicide mortality

Total suicide mortality		Male suicide mortality		Non-violent suicide mortality	
Predictors	B (95%CI)	Predictors	B (95%CI)	Predictors	B (95%CI)
Ambient temperature	−0.47 (−0.85, −0.09)*	Ambient temperature	−0.68 (−0.98, −0.37)***	Ambient temperature	−0.42 (−0.67, −0.17)**
Barometric pressure	−0.32 (−0.65, 0.003)	Barometric pressure	−0.40 (−0.65, −0.14)**	Barometric pressure	−0.26 (−0.47, −0.04)*
		Rainy days	−0.19 (−0.32, −0.07)**		
		Family income	−0.35 (−0.64, −0.06)*	Family income	−0.28 (−0.53, −0.04)*
		Unemployment rate	1.67 (0.35, 2.98)*	Unemployment rate	1.13 (0.01, 2.24)*
		Number of holiday	−0.36 (−0.69, −0.04)*		

Note: *P<0.05, **p<0.01, ***p<0.001; B, unstandardized coefficients examined using multiple linear regression analysis with backward elimination; 95%CI, 95% Confidence interval; No predictors were significantly associated with female suicide mortality or violent suicide mortality
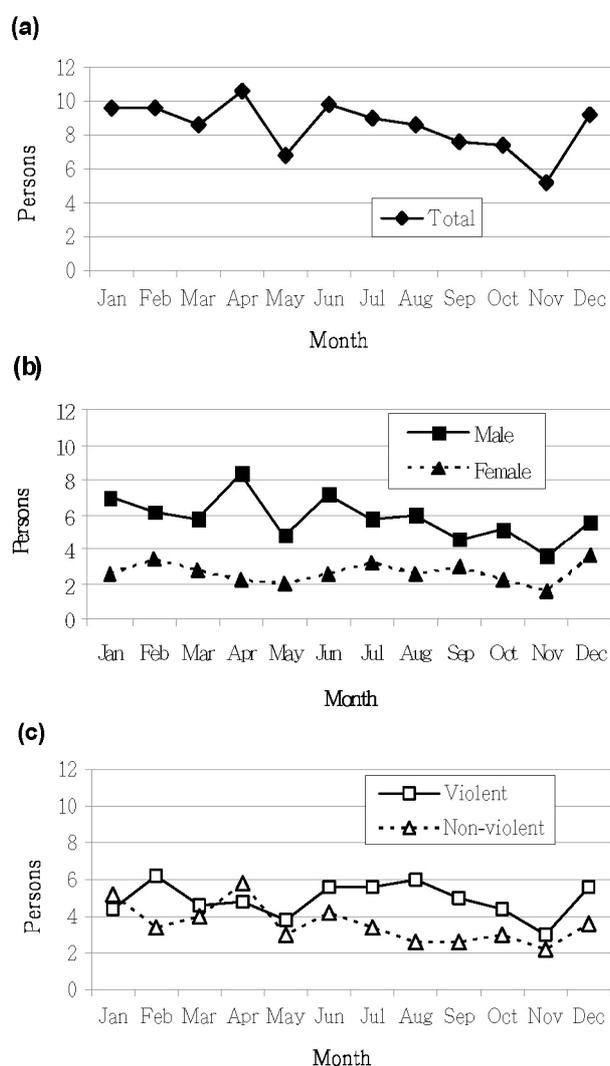
Figure 1. Mean monthly number of total suicide deaths (a) male/female suicide deaths (b) and violent/non-violent suicide deaths (c) in Keelung City, Taiwan, from January 2006 to December 2010 (Y-axis represents the average number of suicide deaths; X-axis represents the specific month)

DISCUSSION

Significant seasonal patterns of suicide, typically with peaks in the spring and early summer have been demonstrated in many studies regardless of gender (Lee et al. 2006, Lin et al. 2008, Sun et al. 2011). Nevertheless, a recent review suggested that the seasonality of suicide is decreasing, and therefore seasonal patterns may no longer be considered to be universal and homogeneous phenomena (Ajdacic-Gross et al. 2010). There was no significant seasonality of suicide deaths observed in this study. However, we found that ambient temperature and barometric pressure were correlated with total, male and non-violent suicide mortality. Many studies have investigated the association between suicide rates and ambient temperature, and a positive correlation has been reported in the majority of these studies (Deisenhammer 2003). In contrast, ambient temperature showed a negative correlation with suicide mortality in our study. Interestingly, the investigations which suggested a positive correlation of suicide rates and temperature were mostly performed in countries at a higher latitude than Taiwan (Kim et al. 2011, Likhvar et al. 2011, Page et al. 2007). Hormone production, which is associated with exposure to daylight, has been reported to play a role in suicide deaths (Petridou et al. 2002). Thus, differences in latitude between studies may be a possible explanation for the inconsistent findings. Barometric pressure has been reported to have a negative correlation with suicide rates (Lee et al. 2006), which is compatible with the findings in the current study. Weather conditions potentially influence neurobiological mechanisms, and sociological and interpersonal factors (Deisenhammer 2003), and thus may further affect suicidal behaviour. However, the climate, spatial and cultural characteristics differ in the previous studies, and the suicide-associated meteorological factors may be geographically specific, i.e. the factors which are found in one area may not be generalized into another. In addition, a growing body

of evidence indicates that the relationship between weather and suicide is more prominent in men than in women (Ajdacic-Gross et al. 2007, Bureau 2012, Kim et al. 2011). The findings in this study generally agree with this. From a traditional viewpoint, men tend to work more outdoors and so they are exposed to relatively more environmental conditions than women. Moreover, men seem to have a poorer ability to control their skin temperature than women (Violani & Lombardo 2003), and may be more sensitive to changes in weather condition. It needs to be clarified whether this phenomenon plays a role in gender difference in association between weather condition and suicidal behaviours.

Socio-economic factors were not associated with suicide mortality in total and in females in this study. However, male suicide mortality was positively correlated with unemployment rate, and negatively correlated with family income. Some studies have demonstrated that men are more vulnerable to the influence of economic conditions than women (Inoue et al. 2007, Nandi et al. 2012), which is compatible with the findings of this study. However, some studies have suggested that men and women are equally affected by socio-economic factors with regards to suicide (Lundin et al. 2012, Rehkopf & Buka 2006). People experience more stress with increased unemployment and decreased income (Uutela 2010). Traditionally in Taiwan, men have the major responsibility of providing financial resources for their family. The men in our study population may have been under more stress than the women with the worsening economic situation, thus leading to the gender differences in suicide. Another interesting finding in this study is that suicide among men, but not women, was negatively correlated with the number of holidays. Carley & Hamilton (2004) found a general trend of a reduction in the number of suicides in December, and in particular around the days preceding Christmas Day. People may have more opportunities to be with and receive support from their families during holidays compared to weekdays, and this may explain the protective effect of holidays. However, it remains unclear why this effect is only observed among men. Whether or not the heterogeneous findings for gender differences in suicide are attributable to cultural differences warrants further investigation.

With regards to the means of suicide, non-violent suicide mortality was positively correlated with unemployment rate, and negatively correlated with ambient temperature, barometric pressure and family income. These correlations were not observed among violent suicide. These results are in contrast to some previous studies (Lin et al. 2008, Parker et al. 2001), which reported that violent suicide showed more significant seasonality and a greater association with meteorological factors than non-violent suicide. However, the findings of a study by Yang et al. (2011) are in agreement with our study. This discrepancy may be the result of differences in geographical and chronological factors, and in the distribution of means of suicide. The non-violent suicides in this study included poisoning by gas, vapours, solid or liquid substances. Death by charcoal-burning, which is classified as non-violent suicide, has increased rapidly in Taiwan since the late 1990s (Chang et al. 2010). Death by charcoal-burning accounted for the majority (86.3%) of non-violent suicide deaths in this study. Therefore, the environmental correlation of non-violent suicide may mainly refer to charcoal-burning suicide. It is important to clarify whether people use a specific suicide method under special weather and economic conditions. Some studies have demonstrated that neurochemical profiles (Mann et al. 1989) and childhood growth (Mittendorfer-Rutz et al. 2008) potentially influence the risk of violent and non-violent suicide. These issues may affect people's vulnerability to environmental conditions, and further affect the means of suicide.

There are several limitations to this study. First, the study period was five years, so we were only able to analyse 60 months of data. In addition, the monthly numbers of suicide deaths were small, especially for female suicides. This reduces the statistical power for determining the potential long-term relationships between suicide and environmental factors. Second, the deaths from suicide in Keelung City were identified according to information from the census register. However, some people may have migrated or commuted from/to other cities in northern Taiwan. Those who committed suicide may have been exposed to environmental conditions in another city, and this may have confounded the results. Third, there was no individual information for those who committed suicide such as mental illness, which may also be an important determinant. Last, analyses for the relationships between meteorological factors and suicide numbers month-by-month may be less reliable than those for day-by-day. For example, an unusual hot (or cold) day in a month would influence the monthly temperature mean but might have less impact on suicidal acts during the rest of the month. However, the daily mean values of meteorological factors was unavailable in this study.Therefore, caution should be taken in applying the results to clinical practice.

CONCLUSIONS

The results of this study demonstrated a possible association between environmental factors with suicide deaths in a city with a high suicide rate in Taiwan. However, suicide is a complex multi-dimensional phenomenon, and it is difficult to identify a specific meteorological or socio-economic condition which leads to an increasing risk for suicide. How the environmental conditions relate to brain function and suicidal behaviour needs to be confirmed through further studies with individual data.

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