




Article

# Association of Geomagnetic Disturbances and Suicide Attempts in Taiwan, 1997–2013: A Cross-Sectional Study

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**Abstract:** Background: A previous study in Japan found that monthly mean K index values were related to the monthly number of male, but not female, suicides. Correlations between geomagnetic disturbances and suicide/depression have also been reported in countries such as Canada, South Africa, Finland, Australia, Russia, and Japan. We have previously shown that stronger geomagnetism is linked to a higher standardized mortality ratio for suicide. To date, however, no published studies have reported the correlation between geomagnetic disturbances and suicide attempts in Taiwan. Methods: Data on the monthly number of suicide attempts in Taiwan from January 1997 to December 2013 were obtained. We performed a multivariable analysis, with the number of suicide attempts as the response variable and monthly Kp10 index, F10.7 index, sulfur dioxide, carbon monoxide, ozone, fine particulate matter (PM2.5), temperature, humidity, unemployment rate, and cosmic rays as the explanatory variables. Results: The multivariable analysis showed that Kp10 index, temperature, humidity, unemployment rate, and cosmic rays were associated with the number of male suicide attempts and that Kp10 index, F10.7 index, carbon monoxide, temperature, humidity, and unemployment rate were associated with the number of female suicide attempts. Conclusion: This is the first article reporting statistically significant relationships between the monthly number of male and female suicide attempts and the monthly mean Kp10 value in Taiwan.

**Keywords:** electromagnetic field; geomagnetic field; geomagnetic storm; suicide

## 1. Introduction

Worldwide, there were 804,000 deaths from suicide in 2012, and the global age-standardized suicide rate is estimated to be 11.4 (15.0 male and 8.0 female) per 100,000 population [1]. Previous suicide attempts, psychiatric disorders, abuse of alcohol and other substances, employment status,

financial loss, despair, chronic pain, chronic illness, and family history of suicide have been reported as risk factors for suicide [1]. Environmental factors such as air pollution [2,3], electromagnetic fields [4,5], and season [6–8] have also been reported as suicide risk factors.

Epidemiological studies have reported the possibility of an electromagnetic field at electric utility sites or a power line affecting depression and suicide [4,5,9]. In previous research, correlation between geomagnetic disturbances and suicide/depression has been reported in countries such as Canada, South Africa, Finland, Australia, Russia, and Japan [8,10–15]. In our previous work, we have also shown that stronger geomagnetism is linked to a higher standardized mortality ratio for suicide [16]. However, we did not include air pollution data in our previous studies [10,16], and air pollution has previously been reported to be associated with suicide [2,3] and depression [17,18]. In this study, we included air pollution data in the analyses. Furthermore, no studies have yet reported a correlation between geomagnetic disturbances and suicide attempts in Taiwan. Taiwan and Japan have similar cultures. In addition, global warming has progressed, and the current climate in Taiwan may represent the future climate in Japan.

In this study, we examined the correlations of geomagnetic disturbances, as the independent variables of interest, with suicide attempts in Taiwan after adjusting for other explanatory variables that have been reported to be correlated with suicide.

## 2. Materials and Methods

### 2.1. Study Participants and Medical Records

To identify suicide attempts (International Classification of Diseases, Ninth Revision, Clinical Modification codes E950–E959), we linked two datasets from the National Health Insurance Research Database in Taiwan ([http://nhird.nhri.org.tw/date\\_01\\_en.html](http://nhird.nhri.org.tw/date_01_en.html)) [19], i.e., in-patient expenditures and the registry for beneficiaries, using unique encrypted personal identifiers. The datasets contain in-patient claims and demographic data from 1997 to 2013 on the 23 million beneficiaries in the Taiwan National Health Insurance program, which covers over 99% of the entire population. We calculated the monthly number of suicide attempts from 1997 to 2013. We counted patients with more than one record of suicide attempt in the same month as a single case for that month.

### 2.2. Air Pollution Data

In this study, we also investigated whether suicide attempts were associated with air pollution variables such as sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), ozone (O<sub>3</sub>), particulate matter ≤ 10 (PM<sub>10</sub>) or ≤ 2.5 (PM<sub>2.5</sub>) micrometers in diameter, nitrogen oxides (NO<sub>x</sub>), nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>), total hydrocarbons (THC), non-methane hydrocarbons (NMHC), and methane (CH<sub>4</sub>).

Data on daily air quality variables, including temperature (°C), relative humidity (%), and concentrations of SO<sub>2</sub> (ppb), CO (ppm), O<sub>3</sub> (ppm), PM<sub>10</sub> (µg/m<sup>3</sup>), PM<sub>2.5</sub> (µg/m<sup>3</sup>), NO<sub>x</sub> (ppb), NO (ppb), NO<sub>2</sub> (ppb), THC (ppm), NMHC (ppm), and CH<sub>4</sub> (ppm), from 1997 to 2013 were obtained from the Taiwan Environmental Protection Administration (EPA) website (<https://taqm.epa.gov.tw/taqm/en/YearlyDataDownload.aspx>) [20]. There are 76 EPA air monitoring stations in Taiwan. Daily values of temperature, relative humidity, and concentrations of each pollutant from all stations were aggregated to determine monthly patterns. In a previous study in Japan, we included air pressure and day length in the analysis, but these two variables are available in Taiwan only after 2009, so were not included.

### 2.3. Unemployment Rate

Monthly unemployment rates from 1997 to 2013 were downloaded from the website of the Directorate General of Budget, Accounting, and Statistics of the Executive Yuan (<https://www.dgbas.gov.tw/mp.asp?mp=1>) [21].

#### 2.4. Geomagnetic Field and Space-Related Data

The definition of K-index was described by Menviene et. al., 'The K indices are based upon the range in the irregular variations, measured in the two horizontal geomagnetic components after eliminating the so-called non-K variations; the vertical component Z is not considered because Z transient variations may be dominated by internal induction effects.' [22]. *Kp10* is an indicator of disturbances in the Earth's magnetic field. The F10.7 index is an indicator of solar activity. Solar wind speed is referred to as bulk speed.

Data on the geomagnetic field and space-related variables were extracted from the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) OMNI dataset through OMNIWeb (<https://omniweb.gsfc.nasa.gov/form/dx1.html>) [23], and cosmic ray data were extracted from the website of the Institute of Cosmophysical Research and Radio Wave Propagation, Far Eastern Branch of the Russian Academy of Sciences (<http://cr0.izmiran.ru/mgdn/main.htm>) [24]. The geomagnetic field and the space-related variables *Kp10* index, F10.7 index, and bulk speed were downloaded through the OMNIWeb interface. Monthly geomagnetic field and space-related variables were calculated from the daily data.

#### 2.5. Procedure and Statistical Analysis

We performed this analysis using a cross-sectional design. The number of suicide attempts, air pollution variables, unemployment rate, and geomagnetic field and space-related variables were merged by year and month. Pearson correlation coefficients were calculated for all two-variable combinations of temperature, relative humidity, air pollutants, and magnetic field-related variables. Any pair of variables with an absolute value of Pearson's correlation coefficient > 0.7 was considered highly correlated, and we selected variables that had lower correlations with each other as explanatory variables for linear regression analysis.

In the linear regression analysis, the response variable was the monthly number of suicide attempts, and the explanatory variables were *Kp10* index, F10.7 index, SO<sub>2</sub>, CO, O<sub>3</sub>, PM<sub>2.5</sub>, temperature, humidity, unemployment rate, and cosmic rays. To investigate the association between monthly number of suicide attempts and all factors used in the univariate analysis, we used the multivariable regression model [25]. All statistical analyses were performed using SAS software, Version 9.4 (SAS Institute Inc., Cary, NC, USA).

#### 2.6. Ethics Approval and Consent to Participate

In the National Health Insurance Research Database in Taiwan, patients' personal information is encrypted to protect individuals' privacy. Researchers are provided with anonymous identification numbers associated with relevant claims information, including sex, date of birth, medical services received, and prescriptions. Patient consent is not required to access the National Health Insurance Research Database. This study was judged to fulfill the conditions for exemption by the institutional review board of China Medical University (CMUH104-REC2-115-CR2), which also specifically waived the consent requirement.

In Japan, according to the "Ethical Guidelines for Medical and Health Research Involving Human Subjects," the guidelines do not apply to research utilizing only specimens and information that have already been anonymized and that cannot be linked to individuals. No ethical review was necessary.

### 3. Results

#### 3.1. Correlation of Air Pollutants with Geomagnetic Field and Space-Related Variables

Based on the Pearson correlation coefficients, we selected the following explanatory variables: *Kp10* index, F10.7 index, SO<sub>2</sub>, CO, O<sub>3</sub>, PM<sub>2.5</sub>, temperature, humidity, unemployment rate, and cosmic rays (Tables 1 and 2).

**Table 1.** Correlation coefficients for air pollutants during the study period.

| Covariate         | SO <sub>2</sub> <sup>a</sup> | CO <sup>b</sup> | O <sub>3</sub> <sup>c</sup> | PM <sub>10</sub> <sup>d</sup> | PM <sub>2.5</sub> <sup>e</sup> | NO <sub>x</sub> <sup>f</sup> | NO <sup>g</sup> | NO <sub>2</sub> <sup>h</sup> | THC <sup>i</sup> | NMHC <sup>j</sup> | CH <sub>4</sub> <sup>k</sup> | Temperature | Humidity |
|-------------------|------------------------------|-----------------|-----------------------------|-------------------------------|--------------------------------|------------------------------|-----------------|------------------------------|------------------|-------------------|------------------------------|-------------|----------|
| SO <sub>2</sub>   | 1                            |                 |                             |                               |                                |                              |                 |                              |                  |                   |                              |             |          |
| CO                | 0.68                         | 1               |                             |                               |                                |                              |                 |                              |                  |                   |                              |             |          |
| O <sub>3</sub>    | −0.17                        | −0.26           | 1                           |                               |                                |                              |                 |                              |                  |                   |                              |             |          |
| PM <sub>10</sub>  | 0.57                         | 0.50            | 0.42                        | 1                             |                                |                              |                 |                              |                  |                   |                              |             |          |
| PM <sub>2.5</sub> | 0.55                         | 0.63            | 0.25                        | <b>0.80</b>                   | 1                              |                              |                 |                              |                  |                   |                              |             |          |
| NO <sub>x</sub>   | <b>0.77</b>                  | <b>0.92</b>     | −0.26                       | 0.63                          | 0.69                           | 1                            |                 |                              |                  |                   |                              |             |          |
| NO                | <b>0.72</b>                  | <b>0.86</b>     | −0.56                       | 0.33                          | 0.43                           | <b>0.92</b>                  | 1               |                              |                  |                   |                              |             |          |
| NO <sub>2</sub>   | <b>0.72</b>                  | <b>0.87</b>     | −0.01                       | <b>0.78</b>                   | <b>0.80</b>                    | <b>0.96</b>                  | <b>0.77</b>     | 1                            |                  |                   |                              |             |          |
| THC               | 0.50                         | <b>0.85</b>     | −0.21                       | 0.39                          | 0.63                           | <b>0.80</b>                  | <b>0.73</b>     | <b>0.77</b>                  | 1                |                   |                              |             |          |
| NMHC              | 0.61                         | <b>0.82</b>     | −0.26                       | 0.45                          | 0.66                           | <b>0.83</b>                  | <b>0.77</b>     | <b>0.79</b>                  | <b>0.94</b>      | 1                 |                              |             |          |
| CH <sub>4</sub>   | 0.42                         | <b>0.83</b>     | −0.17                       | 0.33                          | 0.58                           | <b>0.74</b>                  | 0.67            | <b>0.72</b>                  | <b>0.98</b>      | <b>0.85</b>       | 1                            |             |          |
| Temperature       | −0.45                        | −0.50           | −0.10                       | <b>−0.77</b>                  | −0.66                          | −0.67                        | −0.46           | <b>−0.75</b>                 | −0.35            | −0.44             | −0.29                        | 1           |          |
| Humidity          | 0.22                         | 0.64            | −0.43                       | −0.04                         | 0.02                           | 0.54                         | 0.63            | 0.41                         | 0.58             | 0.49              | 0.59                         | −0.11       | 1        |

Bold typeface indicates a coefficient with more than 0.70 or less than −0.70. <sup>a</sup> sulfur dioxide (ppb), <sup>b</sup> carbon monoxide (ppm), <sup>c</sup> ozone (ppm), <sup>d</sup> PM: particulate matter<sub>10</sub> (μg/m<sup>3</sup>), <sup>e</sup> PM: particulate matter<sub>2.5</sub> (μg/m<sup>3</sup>), <sup>f</sup> nitrogen oxides (ppb), <sup>g</sup> nitric oxide (ppb), <sup>h</sup> nitrogen dioxide (ppb), <sup>i</sup> total hydrocarbons (ppm), <sup>j</sup> non-methane hydrocarbons (ppm), <sup>k</sup> methane (ppm).

**Table 2.** Correlation coefficients for geomagnetic field and space-related variables during the study period.

| Covariate   | <i>Kp10</i> | F10.7 | Bulk Speed |
|-------------|-------------|-------|------------|
| <i>Kp10</i> | 1           |       |            |
| F10.7       | 0.50        | 1     |            |
| Bulk speed  | <b>0.81</b> | 0.16  | 1          |

Bold typeface indicates a coefficient with more than 0.70 or less than −0.70.

### 3.2. Linear Regression Analysis for Monthly Number of Suicide Attempts

The monthly number of male suicide attempts ranged from 70 to 266, whereas the monthly number of female suicide attempts ranged from 98 to 308. Table 3 shows the results of the univariate regression analysis for male and female suicide attempts. All the variables except for O<sub>3</sub> and PM<sub>2.5</sub> were significantly associated with the number of male suicide attempts. *Kp10* index, F10.7 index, CO, temperature, and cosmic rays were associated with the number of female suicide attempts.

**Table 3.** Results of the univariate linear regression analysis.

| Covariate  | Male        |                 |                 | Female      |      |                 |
|--|-------------|-----------------|-----------------|-------------|------|-----------------|
|  | Coefficient | SE <sup>a</sup> | <i>p</i> -Value | Coefficient | SE   | <i>p</i> -Value |
| <i>Kp10</i> index                                  | 2.45        | 0.40            | <0.0001         | 4.66        | 0.47 | <0.0001         |
| F10.7 index, solar flux units                      | 0.19        | 0.06            | 0.004           | 0.50        | 0.08 | <0.0001         |
| SO <sub>2</sub> <sup>b</sup> , ppb                 | −13.4       | 2.64            | <0.0001         | −5.30       | 3.65 | 0.149           |
| CO <sup>c</sup> , ppm                              | −58.3       | 16.8            | 0.001           | 48.5        | 22.4 | 0.031           |
| O <sub>3</sub> <sup>d</sup> , ppm                  | 0.91        | 0.47            | 0.052           | −0.36       | 0.61 | 0.556           |
| PM <sub>2.5</sub> <sup>e</sup> , µg/m <sup>3</sup> | −0.39       | 0.23            | 0.084           | 0.16        | 0.30 | 0.606           |
| Temperature, °C                                    | 2.98        | 0.57            | <0.0001         | 2.89        | 0.77 | 0.0002          |
| Humidity, %  | −1.21       | 0.46            | 0.009           | 0.73        | 0.60 | 0.228           |
| Unemployment rate, %                               | 11.2        | 2.36            | <0.0001         | 2.53        | 4.28 | 0.555           |
| Cosmic rays  | −0.04       | 0.01            | <0.0001         | −0.05       | 0.01 | <0.0001         |

Response variable: Monthly number of suicide attempts from 1997 to 2013 (N = 204 for male suicide attempts; N = 204 for female suicide attempts); <sup>a</sup> standard error, <sup>b</sup> sulfur dioxide, <sup>c</sup> carbon monoxide, <sup>d</sup> ozone, <sup>e</sup> particulate matter<sub>2.5</sub>.

Table 4 presents the results of the multivariable analysis. *Kp10* index, temperature, humidity, unemployment rate, and cosmic rays were associated with the number of male suicide attempts. *Kp10* index, F10.7 index, CO, temperature, humidity, and unemployment rate were associated with the number of female suicide attempts.

**Table 4.** Results of the multivariable analysis.

| Covariate  | Male        |                 |                 | Female      |      |                 |
|--|-------------|-----------------|-----------------|-------------|------|-----------------|
|  | Coefficient | SE <sup>a</sup> | <i>p</i> -Value | Coefficient | SE   | <i>p</i> -Value |
| <i>Kp10</i> index                                  | 2.44        | 0.49            | <0.0001         | 3.23        | 0.60 | <0.0001         |
| F10.7 index, solar flux units                      | 0.004       | 0.09            | 0.960           | 0.33        | 0.11 | 0.002           |
| SO <sub>2</sub> <sup>b</sup> , ppb                 | 6.25        | 4.02            | 0.120           | 9.23        | 5.06 | 0.068           |
| CO <sup>c</sup> , ppm                              | −0.30       | 34.9            | 0.993           | 164         | 44.2 | 0.0002          |
| O <sub>3</sub> <sup>d</sup> , ppm                  | 0.58        | 0.42            | 0.171           | 0.08        | 0.53 | 0.882           |
| PM <sub>2.5</sub> <sup>e</sup> , µg/m <sup>3</sup> | −0.48       | 0.33            | 0.152           | −0.69       | 0.41 | 0.094           |

Table 4. Cont.

| Covariate            | Male        |                 |         | Female      |      |         |
|----------------------|-------------|-----------------|---------|-------------|------|---------|
|                      | Coefficient | SE <sup>a</sup> | p-Value | Coefficient | SE   | p-Value |
| Temperature, °C      | 2.12        | 0.67            | 0.002   | 4.04        | 0.83 | <0.0001 |
| Humidity, %          | -1.58       | 0.61            | 0.009   | -2.68       | 0.77 | 0.001   |
| Unemployment rate, % | 10.2        | 2.35            | <0.0001 | 22.8        | 4.78 | <0.0001 |
| Cosmic rays          | -0.02       | 0.01            | 0.010   | -0.01       | 0.01 | 0.325   |

Response variable: Monthly number of suicide attempts from 1997 to 2013 (N = 204 for male suicide attempts; N = 204 for female suicide attempts). Explanatory variables: Variables listed in Table 1. <sup>a</sup> standard error, <sup>b</sup> sulfur dioxide, <sup>c</sup> carbon monoxide, <sup>d</sup> ozone (ppm), <sup>e</sup> particulate matter<sub>2.5</sub>.

### 3.3. Changes in the Monthly Number of Male Suicide Attempts and Monthly Kp10 Values

Changes in the monthly number of male suicide attempts and monthly Kp10 values are shown in Figures 1 and 2. The peak in monthly number of male and female suicide attempts occurred in May (Figures 1 and 2).

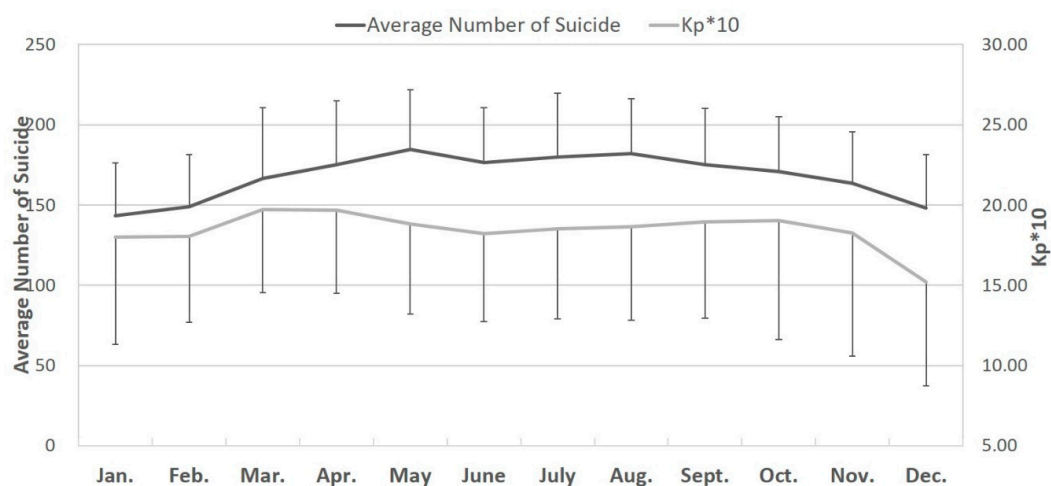


Figure 1. Changes in the monthly number of male suicide attempts and monthly Kp10 values from January 1997 to December 2013.

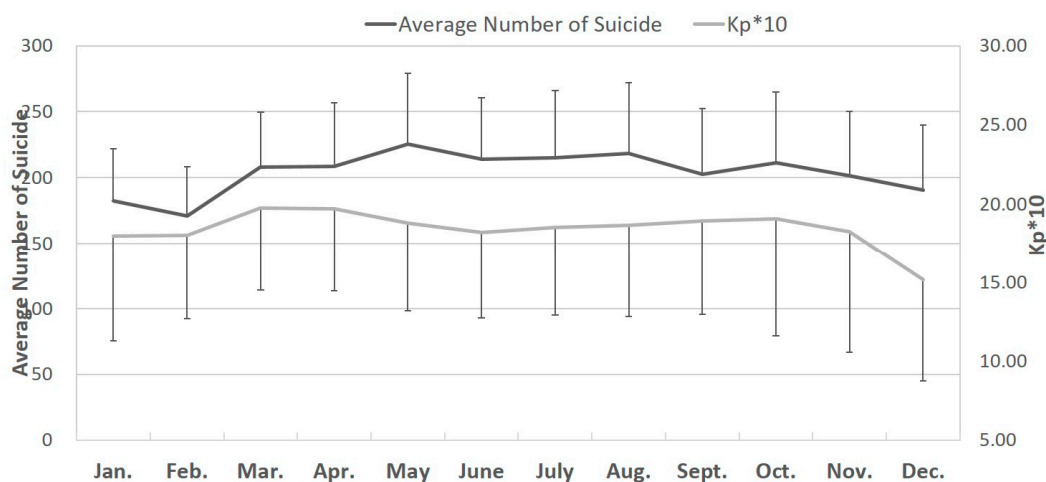


Figure 2. Changes in the monthly number of female suicide attempts and monthly Kp10 values from January 1997 to December 2013.

#### 4. Discussion

In this study, we used data from Taiwan to confirm the reproducibility of our previous study in Japan. There was a relationship between the monthly number of male suicide attempts and the monthly mean *Kp10* value in Taiwan, as we had previously found to be the case in Japan.

In our previous study of men in Japan, monthly mean *K*-index value, number of sunspots, unemployment rate, air pressure, and humidity were related to the monthly number of suicides among males [10]. In the present study of men in Taiwan, monthly mean *Kp10* index, temperature, humidity, and unemployment rate were associated with the monthly number of male suicide attempts. The present findings for monthly mean *Kp10* index, humidity, and unemployment rate correspond with the findings of our previous study in Japan.

In our previous study of women in Japan, monthly mean air pressure and day length were associated with the monthly number of female suicides [10]. In the present study of women in Taiwan, monthly mean *Kp10* index, F10.7 index, CO, temperature, humidity, and unemployment rate were associated with the monthly number of female suicides. We were unable to include air pressure and day length in the present analysis because of the lack of appropriate data for Taiwan. None of our findings on the factors relating to female suicide attempts correspond with the results of our previous study in Japan. However, the present study's finding that monthly mean CO was associated with the monthly number of female suicide attempts does correspond with other previous reports showing the relationship between air pollution and suicide [2,3].

In previous studies in Japan, the *Kp* index was used [10], but because the *Kp* index in Taiwan was not available, the *Kp10* index was used in this study. *Kp10* is an indicator of global geomagnetic disturbances. Since geomagnetic disturbances are a global phenomenon, we consider it appropriate to have used the *Kp10* index in this study.

Regarding the mechanism by which geomagnetism affects human health, there have been many reports on melatonin reduction due to geomagnetic disturbances [26]. Other potential mechanisms may influence the human mind through opioid receptors, as described in previous papers [10].

As to the synchronization of geomagnetic storms and suicide attempts, i.e., either delayed or immediate effects of geomagnetic disturbances on suicide attempts, Kay reported 'significant 36.2% increase in male hospital admissions with a diagnosis of depressed phase, manic-depressive illness in the second week following such storms compared with geomagnetically quiet control periods.' [15].

In this study, temperature and humidity were added to the covariates. Rainfall, which would reflect the effects of typhoons and heavy rains, was not used due to the short time period of available data. However, in this study, humidity was added to the covariates, which may reflect the effects of typhoons and heavy rain. We are considering analyzing earthquakes in a future study.

In contrast to the finding that monthly mean CO was positively associated with the monthly number of female suicide attempts, the CO regression coefficient for male suicide attempts was sufficiently large and negative (Table 3). Because sex differences have been reported in the impact of PM<sub>2.5</sub> on depression [17], similar sex differences may be present in the impact of CO. There also seem to be gender differences in response to other environmental factors such as F10.7 index and cosmic rays.

A previous study using data in Japan found no association between the average *K*-index value and the monthly average number of female suicides [10]. However, in the present study in Taiwan, the monthly mean *Kp10* value was related to the monthly number of both male and female suicide attempts.

In previous work, we have shown that stronger geomagnetism is linked to a higher standardized mortality ratio for suicide [16]. There is a possibility that the influence of geomagnetism is smaller in a location in which geomagnetism is weaker. Moving to a location with weaker geomagnetism could be one solution.

Limitations of the present study are the complicated environmental and ecological factors influencing suicides, which meant that we could not deny the possibility that the seasonality of geomagnetic disturbances [27] and the seasonality of suicides [6–8] tend to synchronize with each other.

## 5. Conclusions

The multivariable analysis showed that *Kp10* index, temperature, humidity, unemployment rate, and cosmic rays were associated with the number of male suicide attempts and that *Kp10* index, F10.7 index, carbon monoxide, temperature, humidity, and unemployment rate were associated with the number of female suicide attempts.

These findings are the first to report a statistically significant relationship between the monthly number of male and female suicide attempts and the monthly mean *Kp10* value in Taiwan.

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