ORIGINAL ARTICLE

Seasonal Variation of Relationship between Climate and Suicide Attempts

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Objective: The relationship between suicide attempt, climate and air-pollution has been suggested in the literature. This study aimed to evaluate the seasonal variation of these associations. **Methods:** The association between the number of weekly emergency room (ER) visit for a suicide attempt, climatic factors and air-pollution factors were examined statistically. **Results:** During 617 weeks, a total of 2,181 patients have visited an ER of a university-affiliated hospital in South Korea. There was no difference in the number of visit among seasons. In the multivariate regression analysis, diurnal temperature range was positively associated with ER visits for a suicide attempt in the spring. On the other hand, the maximum temperature was related to the weekly number of ER visit for a suicide attempt in autumn and winter. Among the air-pollution factors, ozone level was positively associated with the ER visit for a suicide attempts in the correlational analysis, however, such association was not found in the multivariate regression analysis. **Conclusion:** The association between climatic factors and suicide attempt varied according to the season. In addition, the influence of air-pollution on suicide attempt might be moderated by climatic factors.

Key Words: Suicide attempt; Seasonality; Climate; Air-pollution

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INTRODUCTION

Suicide is a worldwide problem. According to WHO statistics, 800,000 suicides occurred in 2015 [1]. Suicide rate of South Korea is 28.7 per 100,000 people, 2.4 times the OECD average suicide rate, the highest among OECD countries since 2003 [2]. According to Bertolote et al. [3], depression is the overt cause of suicide worldwide and accounts for 30%. However, in addition to psychiatric disorders such as depressive disorder, various causes are involved in suicide. Socioeconomic, genetic, environmental and bioclimatic factors can lead to suicide [4-8]. Among bio-climatic component, particularly in terms of meteorology, previous studies have reported that suicide shows seasonality. And many studies have shown that suicide rates peak in spring and early summer [7,9-11]. These meteorological factors include temperature, sunlight, solar radiation, air pressure, precipitation, humidity, and air-pollutants [12-14].

Recent studies have focused on the link between the climate factor and the neuroendocrine system [15,16]. Serotonin is a neu-

rotransmitter that affects mood particularly. Low levels of serotonin cause depression and impulsivity, which in turn, can lead to suicidal behavior [9,17,18]. In addition, changes in serotonin 1-A receptor which attached to limbic system are controlled by light and have an effect on mood [19]. As mentioned previously, serotonin is affected by climate factors like sunlight and environmental heat [9]. Previous research reported that sunshine also affects suicidal behavior [20-22] by affecting the action of hormones such as serotonin and melatonin [23-25]. Preti and Miotto [9] mentioned that temperature, solar radiation and duration of sunlight had considerable correlation with monthly suicide attempts. In addition, there have been increasing reports that air-pollutants, seasonal changes and suicide are related to each other [26,27].

The previous reports on the seasonality of suicide is consistent and is still controversial. Therefore, this study was conducted to find out the factors affecting the number of suicide attempts according to the season.

Table 1. Seasonal differences in weekly suicide attempts and climate variables

	Spring	Summer	Autumn	Winter	Total	ANOVA	
						F	p-value
Weekly suicide attempts (n)	3.53±1.96	3.67±2.13	3.58±2.18	3.35±1.81	3.53±2.03	0.642	0.588
PM ₁₀ (µg/m ³)	62.48±21.77	38.13±13.16	40.04±16.31	56.89±19.39	49.28±20.78	71.215	<0.001
O ₃ (ppm)	0.028±0.006	0.027±0.008	0.017±0.005	0.012±0.004	0.021±0.009	225.637	<0.001
NO ₂ (ppm)	0.036±0.007	0.027±0.005	0.033±0.008	0.039±0.007	0.033±0.008	90.967	<0.001
Mean temperature (°C)	11.77±5.82	24.82±2.29	15.70±6.49	-0.72±3.53	13.11±10.31	720.414	<0.001
Maximum temperature (°C)	17.01±6.21	28.96±2.29	20.42±6.63	3.42±3.64	17.68±10.41	669.882	<0.001
Minimum temperature (°C)	7.32±5.53	21.51±2.67	11.66±6.54	-4.33±3.52	9.25±10.39	745.693	<0.001
Diurnal temperature range (°C)	9.69±1.52	7.46±1.77	8.74±1.53	7.75±1.21	8.42±1.76	68.586	<0.001
Mean vapor pressure (hPa)	7.83±3.13	27.71±4.42	11.90±5.07	3.49±1.21	11.36±7.72	650.055	<0.001
Sunshine hours (hrs)	7.11±2.07	5.33±2.73	6.26±1.88	5.93±1.52	6.16±2.20	19.423	<0.001
Amount of rainfall (mm)	15.21±18.98	67.55±92.28	18.81±39.33	5.36±9.11	27.09±56.92	44.855	<0.001

All variables are presented as mean±standard deviation. PM₁₀: particulate matter 10 µm or less in diameter, O₃: ozone, NO₂: nitrogen dioxide, ANOVA: one-way analysis of variance

METHODS

Study design and participants

This study is a longitudinal study and data were collected retrospectively. Information on the number of patients who visited the emergency room (ER) in a university affiliated hospital from March 2006 to December 2017 due to suicide attempt were obtained via medical chart review. A total of 2,181 suicide attempters have visited ER during the period. Data on the climatic factors and air-pollution factors were downloaded from the webpage of Korea Meteorological Administration. This study was approved by the Institutional Review Board (IRB) of Konkuk University Hospital, and written informed consent was waived (approval number: KUMC 201910026).

Measurements

Information on climate factors were obtained from the Korea Meteorological Administration. We decided to identify two types of variables: air-pollutants and weather-related factors. Air pollutants includes particulate matter which was less than 10 µm in size (PM₁₀), ozone (O₃), nitrogen dioxide (NO₂), carbon monoxide (CO), and sulfur dioxide (SO₂). Weather-related elements contains daily mean temperature, maximum and minimum temperature, and diurnal temperature range. Here, diurnal temperature range is the difference between daily maximum and daily minimum temperature [28]. In addition, mean atmospheric pressure, mean vapor pressure, relative humidity, sunshine hours, amount of sunshine, amount of rainfall, and amount of snowfall were evaluated as weather-related factors that might be affect suicide attempts.

Statistical analysis

Number of suicide attempts were measured weekly within the study period and classified according to the four seasons. They were divided into four groups: spring (March–May), summer (June–August), autumn (September–November), and winter

(December–February).

The following analysis was conducted to investigate the relationship between the number of suicide attempts per week and the climate according to the season. One-way analysis of variance (ANOVA) was used to compare weekly suicide attempts and climate factors measured with continuous variables by four seasons. Pearson's correlation analysis was conducted to determine whether the number of suicide attempts per week was related to various climate factors. And then stepwise multiple regression analysis was carried out to find the most influential variable among the various climate factors for each season. In correlation analysis, factors that showed a significant correlation with the number of suicide attempts per week were entered as independent variables in regression analysis. All data analyses were performed using the Statistical Package for the Social Sciences, version 17 (SPSS Inc., Chicago, IL, USA). Statistical significance level was defined at $p < 0.05$.

RESULTS

The number of suicide attempts for each season was spring (n=554), summer (n=576), autumn (n=558), and winter (n=493), and it did not show significant difference between four seasons.

On the other hand, climatic and air-pollution factors appeared differently depending on the season. Among the air-pollutants, the level of PM₁₀ and O₃ generated in spring were highest ($p < 0.001$). The daily mean, maximum and minimum temperature, mean vapor pressure, and amount of rainfall were statistically significantly highest in summer. However, diurnal temperature range and sunshine hours were the highest in spring, which was statistically significant. The above mentioned contents are exhibited in Table 1.

As a result of correlation analysis, there were differences in factors related to weekly suicide attempts by season. In spring, diurnal temperature range ($r=0.179$, $p=0.025$) and sunshine hours ($r=0.166$, $p=0.038$) were positively correlated with weekly suicide attempts. O₃ ($r=0.162$, $p=0.044$), daily mean temperature ($r=0.163$, $p=0.042$), and maximum temperature ($r=0.174$,

$p=0.030$) showed significantly correlation with weekly suicide attempts during autumn. Meanwhile, mean temperature ($r=0.223$, $p=0.007$), maximum temperature ($r=0.239$, $p=0.004$), and minimum temperature ($r=0.198$, $p=0.016$) were significantly correlated with weekly suicide attempts in winter (Table 2). However, no climatic factor was associated with weekly suicide attempts in summer.

The results of multiple regression analysis were as follows. In spring, the number of weekly suicide attempts was positively associated with the diurnal temperature range ($\beta=0.231$, $p=0.025$). However, the maximum temperature was related to the number of suicide attempts per week in autumn and winter (Table 3).

DISCUSSION

The purpose of this study was to investigate the factors affecting weekly suicide attempts by season. There was no significant difference in suicide attempts between seasons in this study. However, different climate-related factors were associated with the number of suicide attempts according to the season. The diurnal temperature range in spring, and the maximum temperature in autumn and winter were related to the number of weekly suicide attempts. On the other hand, among air-pollutants, O_3 was associated with suicide attempts in autumn in correlation analysis, but not in regression analysis.

Results of previous studies suggested that temperature is highly associated with various psychiatric illnesses. Milstein et al. [29] reported that the prevalence of mood disorder increased as the difference between daily maximum and minimum temperatures was getting larger in spring and autumn. According to previous studies, sudden changes in climate, especially temperature and humidity, have been associated with increased the number of suicides [30,31]. Like seasonality of suicide attempts, the seasonal variation of mood disorders have been reported in several literatures. Exacerbation of mood disorders results in more frequent electro-con-

vulsion therapy use, hospitalization, and poorer depression scores, especially in spring [9,32-34]. Magnusson [35] also said that the number of suicides and consultation due to depression, and the prescription of antidepressants depend on the seasons. Therefore, it may be assumed that sudden changes of temperature, such as in the spring, can lead to exacerbation of mood disorders and increase the number of suicides.

Many studies report that suicide attempts tend to increase as the temperature warms up. In a study conducted in England and Wales, the suicide rate increased by 3.8% for every 1°C rise in average temperature above 18°C [36]. Previous studies mentioned that as the temperature rose, suicidal behaviors were increased because the excitability of the central nervous system extended [37,38]. Moreover, suicide attempts increased because higher temperature caused impulsivity and disinhibition [26,39], and this was related to serotonin neurotransmitter [40-43]. These studies are consistent with our findings that maximum temperatures in autumn and winter influenced suicide attempts.

This study did not show a link between suicide attempts and climate in the summer. Several assumption can be drawn to explain this. First, vacation periods are usually in summer in Korea and lots of outdoor activity favors how weather. Therefore, high temperature in summer might cause different influence to individuals according to what they do in summer. Second, the effect of high temperature on mood and suicide behavior may show ceiling effect in summer because of its high average temperature. Further studies are needed to give clear link between climate and suicide in summer.

Previous studies have generally stated that in spring, O_3 concentrations rise high [44,45], and O_3 levels can increase to 45% [46]. Biermann et al. [26] reported that O_3 might cause neurotransmitters imbalances such as serotonin and dopamine, leading to depression and suicidality. Two previous studies reported that serum cortisol level was elevated when exposed to O_3 , which can make depression worse [47,48]. In addition, O_3 have an effect on the immune system and can cause impulsive behavior, which increases the suicides [26,49-52]. Biermann et al. [26] reported that the association between O_3 level and suicide rates did not show seasonality. However, most of those results were not reported in the consideration of climatic factors other than air-pollutants. In this study, we analyzed both air-pollution factors and climate-related factors and showed that air-pollutions might not affect suicide behavior as much as climatic factors do. Besides, there was a significant positive correlation between diurnal temperature range and O_3 concentration in spring in our study, which suggest that air-pollution are highly related to the change in climate.

Table 2. Correlation between weekly suicide attempts and climate variables

Season	Climate variable	R	p-value
Spring	Diurnal temperature range	0.179	0.025
	Sunshine hours	0.166	0.038
Autumn	O_3	0.162	0.044
	Mean temperature	0.163	0.042
	Maximum temperature	0.174	0.030
Winter	Mean temperature	0.223	0.007
	Maximum temperature	0.239	0.004
	Minimum temperature	0.198	0.016

Table 3. Climate factors affecting weekly suicide attempts

Season	Climatic factor	Beta	Standardized beta	p-value	R ²
Spring	Diurnal temperature range	0.231	0.179	0.025	0.032
Autumn	Maximum temperature	0.057	0.174	0.030	0.030
Winter	Maximum temperature	0.119	0.239	0.004	0.057

Over the past 20 years, several studies have reported the tendency to increase suicide in spring [53,54], and the relationship between suicide and seasonality [14,53,55]. Factors such as solar radiation [14] and delayed circadian rhythms were suggested to be associated with increased suicide rates in spring [11]. However, suicide attempts did not increase in spring of this study. Small numbers of subjects and the regional characteristics may have caused this result since the present study was conducted in a single institution.

The limitations of this study come as follows. First of all, because the patients visited in a single institution ER, the sample was relatively small. Therefore, it is possible that sample bias could have occurred. Second, we did not include other factors such as gender, age and the presence of psychiatric disorders that could affect suicide attempts. Third, we divided a year in to four season in this study. It may not reflect seasonal differences adequately since there has been climate changes in Korea.

However, we collected data on suicide attempt, climate and air-pollution for a relatively long period, and showed that the effect of climate and air-pollution on suicide shows seasonal variation. Multi-center studies that cover wider regional area are need to clarify these associations.

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None

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Hong Jun Jeon. Data curation: Seung Beom Yang. Formal analysis: Hong Jun Jeon, Jin Shin. Investigation: Hong Jun Jeon. Methodology: Jin Shin. Supervision: Hong Jun Jeon, Doo Heum Park. Writing—original draft: Hong Jun Jeon, Seung Beom Yang, Jin Shin. Writing—review & editing: Hong Jun Jeon, Doo Heum Park.

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