

Correlation between Suicide Rates and Meteorological Factors Among Older Adults: A Case Study from Jeju Island, Korea

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Abstract

This study analyzed the impact of weather factors on the suicide rate among older adults in Jeju Island from 2017 to 2021. Results showed that suicide rates were positively correlated with maximum wind speed and precipitation days and negatively correlated with the sunshine rate. Among the weather factors, maximum wind speed found to be an important factor causing suicide rate, as Jeju Island has strong winds owing to its geography. Additionally, we analyzed the suicide rates by gender and season. The results indicated that sunshine hours were significant in spring, while atmospheric pressure and the number of heatwave days were significant in summer. Furthermore, maximum temperature and the discomfort index had an influence in autumn. Finally, the amount of snow and cloud cover influenced the suicide rate in winter. These findings confirmed that weather factors influence the suicide rate among older adults and that their effects vary by season.

요약

본 연구는 노인 자살률이 높은 한국의 제주도를 중심으로 날씨 요소가 노인 자살률에 미치는 영향을 분석하였다. 2017년부터 2021년까지 제주도와 서귀포시의 월별 노인 자살률과 기상 요인을 바탕으로 스피어만 상관분석을 적용하였다. 분석 결과, 고령 인구의 자살률은 최대 풍속과 강수일수와 양의 상관 관계가 있었으며, 일조율과는 음의 상관 관계가 있었다. 또한, 성별 및 계절별 차이를 확인하기 위해 성별 노인 자살률과 각 계절의 관련 변수를 추가하여 분석하였다. 그 결과, 봄에는 일조 시간이 양의 영향을 미쳤고, 여름에는 기압과 폭염일수가 영향을 미쳤으며, 가을에는 최고기온과 불쾌지수가, 겨울에는 최심적설과 운량이 노인 자살률에 유의미한 영향을 미쳤다. 본 연구는 기존 연구에서 주요 변수로 고려하지 않았던 날씨 변수가 노인 자살률과 관계가 있음을 밝힌 점에서 의의가 있다.

Keywords

elderly suicide rate, meteorological factors, Jeju island, spearman correlation

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Received: Aug. 13, 2024, Revised: Sep. 01, 2024, Accepted: Sep. 04, 2024
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1. Introduction

1.1 Background

South Korea has transitioned into an aging society. This demographic shift has increased research focused on the challenges and risks faced by the elderly population[1][2]. Among these challenges, the high elderly suicide rate is a significant concern, as South Korea has a higher suicide rate than other member nations of the Organization for Economic Cooperation and Development(OECD). Specifically, the average age-standardized suicide rate across OECD countries is 11.1 per 100,000 people, whereas that in Korea is 23.6[3]. Furthermore, suicide is a significant cause of death among Korean older adults, who have a higher suicide risk when compared to other age groups. The suicide rate among older adults is 39.9, which is more than twice the average of 17.2 among OECD nations[4]. Fig. 1 represents suicide rates (number of deaths per 100,000 people) by age group from 2017 to 2021[5]. According to the Korea National Statistical Office, the age group over 70 has a higher suicide rate than younger age groups.

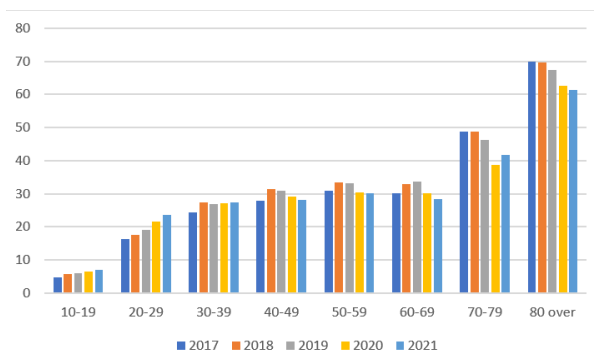


Fig. 1. Suicide rates by age groups (2017-2021)

Owing to the significance of the subject, several domestic studies have examined the effects of environmental and sociological factors on the suicide rate[6][7]. Studies that consider climate have been conducted in Western countries, and the results

indicate that climate factors affect suicide rates. The study by Burke showed that a 1°C rise in temperature corresponds to a 0.68% increase in suicide rates in the United States and 2.1% in Mexico[8]. Moreover, an increase of 1°C in the average monthly temperature was shown to be correlated with a 0.79% increase in the mention of negative sentiments such as depression, loneliness, and suicide[8]. The study by Gao showed that each 1 °C increase in temperature was significantly associated with a 1% increase in the incidence of suicide[9].

Although several studies have been conducted to explore the potential effects of climate factors on suicide rates among older adults, weather has not been considered as a major variable in studying the older adult suicide rate in Korea. Several domestic studies have focused on temperature. However, they have been conducted on the national level or in major cities. Thus, the present study examined the effects of the various weather variables on the suicide rate among older adults in Korea. Specifically, the study focuses on Jeju Island for its distinct climate from that of other regions in Korea. In addition, Jeju Island is one of the regions with high suicide rates. Fig. 2 shows that Jeju had the third-highest older adult suicide rate nationwide in 2020[10]. This study aims to comprehensively analyze meteorological factors that affect suicide rates among older adults in Jeju Island, Korea.

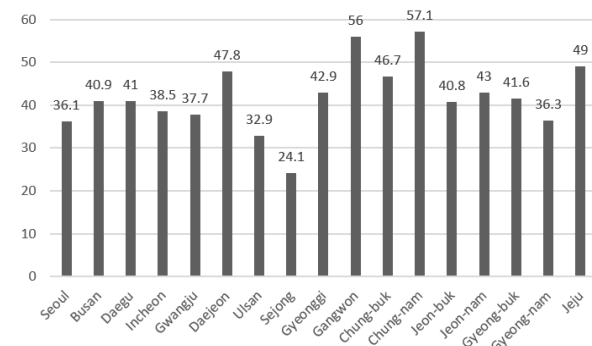


Fig. 2. Older adult suicide rate by province

1.2 Literature review

The weather conditions have been considered a risk factor for suicidality. Fountoulakis investigated the effects of climate across 29 European countries, covering the years from 2000 to 2012[11]. It suggested that suicides are correlated with low temperatures. In contrast, most studies reported that the suicide rates are higher during the period of high temperatures[12]-[14]. The study conducted in Austria reported that the suicide risk was significantly higher on days with high temperatures and low relative humidity[15]. Beside temperature, low rainfall is associated with higher suicide rates in Austria and Taiwan[15][16]. In contrast, another study suggested a positive correlation between rainfall and suicide rate in Italy[17]. Moreover, sunlight and humidity were positively correlated in Türkiye[18]. Along with that, cloudiness and atmospheric pressure were negatively correlated.

Likewise, the association between temperature and suicide has been investigated in Western countries. However, little attention has been given to whether temperature is associated with suicide in Asian countries. Lee identified seasonal patterns of suicide rates and explored their association with climate in Taiwan[19]. It considered ambient temperature, relative humidity, atmospheric pressure, rainfall, and hours of sunshine. A study conducted in South Korea observed a 1.4% increase in suicide with a 1°C increase in daily mean temperature[20]. Moreover, Lee investigated an association between dust storm occurrence and risk of suicide in Seoul, Korea[21]. The studies focused on the weather variables that characterize each region.

The weather factors have been considered an important factor influencing the suicide rate. Jeju Island is known for strong winds and fluctuating weather conditions. Therefore, this study aims to investigate various weather factors that influence the suicide rate among older adults in Jeju Island.

II. Materials and Methods

2.1 Data collection

Data on suicide counts were obtained from the Cause of Death Statistics in the Microdata Integrated Service for the period from January 1, 2017, to December 31, 2021. Intentional self-harm (code 55) was selected from the classification codes of the 57 listed causes of death. The number of suicides per month among those over 65 years of age was used to calculate monthly suicide rates in Jeju and Seogwipo. The number of older adult suicides per month in each city was divided by the corresponding population per month and multiplied by 100,000 to calculate the monthly rate of older adult suicides per 100,000 people. Population data were obtained from the Ministry of Public Administration and Security. For further analysis, the older adult suicide rate was calculated based on gender.

Meteorological data were collected from the Jeju and Seogwipo observation stations under the Korea Meteorological Administration. Each observation station provided monthly values for meteorological elements from 2017 to 2021. Weather variables were selected based on the climate characteristics of Jeju Island.

Jeju is in the subtropical wet climate zone[22]. The summer is longer, and the winter is shorter. Due to its geographical location in the southeastern sea of the Korean Peninsula, weather changes are clear. Strong winds occur throughout the year and exceed 13.9 m/s for 14.5 days in Jeju City (North) and 2.8 days in Seogwipo City (South) annually. Jeju Island experiences high precipitation, with the rainfall being highest in August and lowest in December.

The variables used in this study were selected based on the variables commonly found to be significant in previous studies. They are minimum sea level pressure (hPa), average monthly temperature (°C), and relative humidity (%).

In addition, the variables were selected considering the strong winds in the Jeju region: maximum wind speed (m/s), maximum instantaneous wind speed (m/s), and maximum wind speed level. The maximum wind speed was classified based on strong wind (wind speeds above 14 m/s) or gale warnings (wind speeds above 12 m/s). Also, precipitation days and sunshine rates were selected as Jeju Island experiences high precipitation. Table 1 shows the measurement and data sources of the final variables used in the analysis.

2.2 Methodology

Spearman correlation analysis was conducted to examine the relationship between meteorological factors

and the older adult suicide rate. The Spearman correlation is appropriate as it measures a monotonic relationship between two variables. The recent studies suggest that climate change could lead to an increase in mental disorders and suicide rates. This study aims to find the correlation between the meteorological variables and suicide rate instead of the causal relationship. The meteorological factors were selected in consideration of Jeju Island's climate and variables used in previous studies. According to previous studies, the effect of weather variables on suicide rates differs by gender and season. Thus, the correlation results were compared by gender and season. Fig. 3 is the analytical flowchart of the research.

Table 1. Measurement and data sources of the variables

Variable (identifier)	Explanation	Measurement	Data source
Dependent variable			
Elderly suicide rate	Monthly elderly suicide rate per 100,000 people = (death from suicide \div the monthly population of the elderly) \times 100,000	%	Cause of death statistics, (Micro data integrated service), resident registration data
Independent variables			
Sunshine Rate (SR)	SR = sunlight hours \div sunshine duration hours	%	Korea meteorological administration (Automated synoptic observing system)
Maximum Wind Speed Level (MWSL)	Level 1: wind speed below 12 m/s Level 2: wind speed above 12 m/s Level 3: wind speed above 14 m/s	Value: 1, 2, 3	
Maximum Wind Speed (MWS)	The wind speed that blew the strongest on average for any 10 minutes during the day.	m/s	
Maximum Instantaneous Wind Speed (MIWS)	The wind speed that blew the strongest during the day.	m/s	
Precipitation Days (PD)	The number of days when the daily precipitation is more than 0.1 mm.	Days	
Lowest sea level Pressure (LPS)	The lowest sea level pressure among 1,440 values measured during the day.	hPa	
Average Maximum Temperature (AMT)	The average value of the daily maximum temperature	$^{\circ}$ C	
Relative Humidity (RH)	RH = water vapor pressure saturated water vapor pressure \div 100	%	

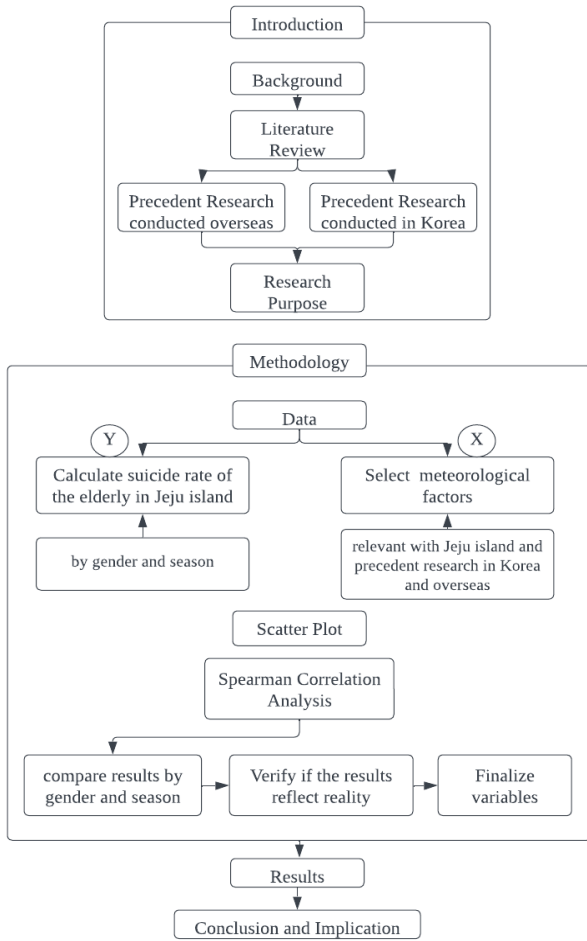


Fig. 3. Analytical flochart

III. Results

3.1 Basic statistics

Fig. 4 and Fig. 5 show the differences in older adult suicide rates between men and women. The monthly suicide rate for men was higher and had greater variance than that for women. Fig. 6 is the monthly suicide rate among older adults in 2020, indicating high suicide rates in April, June, August, and October. Since previous studies have found seasonal variations in suicide, this study investigated which weather factors influence the suicide rate in each season[23]-[25]. The four seasons are spring (March, April, and May), summer (June, July, and August), autumn (September, October, and November), and winter (December, January, and February).

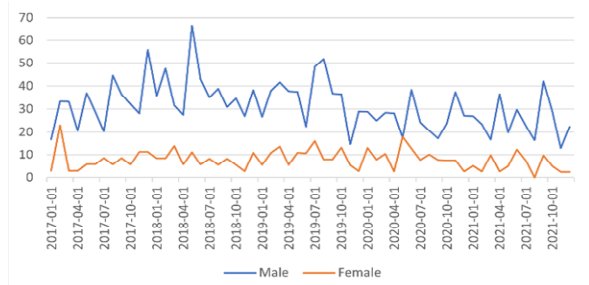


Fig. 4. Elderly suicide rate in Jeju city by gender

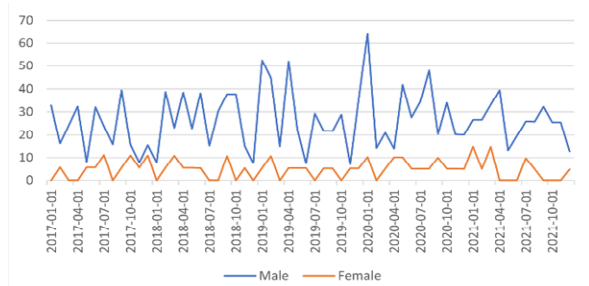


Fig. 5. Elderly suicide rate in Seogwipo city by gender

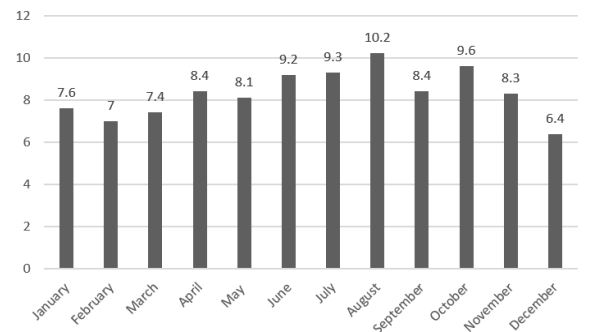


Fig. 6. Monthly older adult suicide rates in 2020

Table 2 is the descriptive statistics for the weather variables, with 120 observations for each variable. Monthly data for Jeju City and Seogwipo City from 2017 to 2021 are included. The mean and median of the variables are similar, and no outliers were observed. The values for maximum wind speed level are 1, 2, and 3, representing wind strength.

Table 2. Descriptive statistics for weather variables

Weather stat.	SR (%)	MWVSL	MWS (m/s)	MIWS (m/s)	PD (days)	LPS (hPa)	AMT (°C)	RH (%)
Count	120	120	120	120	120	120	120	120
Mean	46.510	1.975	9.565	17.755	9.633	1001.881	20.198	73.192
St. dev	11.417	0.716	3.036	5.020	3.478	8.976	6.937	9.799
Min	15	1	4.9	9.7	4	970.9	7.3	56
Median	47.51	2	9.65	17.2	9	1002.5	20.45	72
Max	67.89	3	25	37.1	20	1017.1	32.8	97

3.2 Spearman correlation result of suicide rate and weather variables

Fig. 7 is the Spearman correlation heatmap. The values closer to 1 are presented in red and negative values in blue. Maximum wind speed level, maximum wind speed, and maximum instantaneous wind speed are correlated with each other.

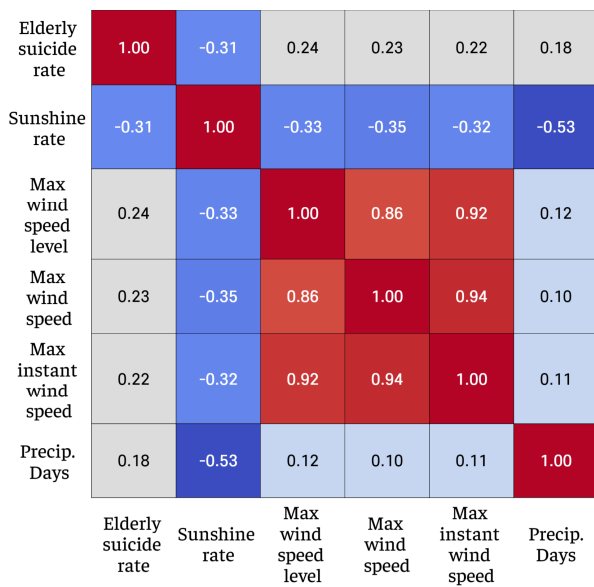


Fig. 7. Spearman correlation heatmap

Table 3 is the results of the Spearman correlation analyses for suicide rates and weather variables. The sunshine rate, wind speed, and days of rain were significant ($p < 0.05$). The correlation value for the sunshine rate was -0.310, indicating a negative correlation with the suicide rate. The sunshine rate represents the amount of sunlight to which the ground is exposed[26]. Sun exposure is believed to increase serotonin production in the brain. Low brain serotonin levels are associated with poor memory and a depressed mood[27]. The low sunshine rate is associated with higher suicide rates. The sunshine rate was negatively correlated with suicide rates for women but positively correlated with suicide rates for men, indicating that the suicide rate decreases as the sunshine rate increases for women.

Table 3. Spearman correlation between suicide rate and weather factors

weather gender	SR	MWSL	MWS	MIWS	PD	LPS	AMT	RH
suicide rate	-0.310** *	0.237**	0.233**	0.223*	0.184*	-	-	-
male	0.271***	0.194**	0.199***	0.184***	0.131***	-	-	-
female	-0.2241**	0.161***	0.185***	0.167***	-	-	-	-

* $p < .05$, ** $p < .01$, *** $p < .001$

After the sunshine rate, the variables related to wind speed had higher coefficient values. Maximum wind speed level, maximum wind speed, and maximum instantaneous wind speed were positively correlated with suicide rate. The results were similar between men and women: the correlation between maximum wind speed and suicide rate was 0.199 for men and 0.185 for women. Thus, wind speed had a slightly greater influence on men.

The number of days of precipitation has a correlation value of 0.184, indicating a slight positive correlation with the suicide rate. Precipitation days are defined as the number of days with precipitation of more than 0.1 mm. The precipitation was measured as the amount of rain that fell on the ground. Precipitation of 0.1 mm indicates a small amount of rain. The results showed that suicide rates increased with the number of precipitation days; however, this correlation was only significant in men. Lowest sea level pressure, average maximum temperature, and relative humidity did not show significant effects in our correlation analysis. The variables selected considering Jeju Island's weather characteristics were found to be correlated with suicide rates.

The study also examined the weather variables affecting the older adult suicide rate in each season. In addition to the variables in Table 3, variables that characterized each season were considered. Table 4 shows the correlation results for spring. Sunshine Hours(SH) appeared to be significant, along with the sunshine rate. In addition, the number of precipitation days was positively correlated (0.407) with the male suicide rate.

Table 4. Spearman correlation for spring

weather gender	SH	SR	PD
suicide rate	-0.386*	-0.372*	-
male	-	-	0.407*
female	-	-	-

*p<.05, **p<.01, ***p<.001

The result of weather factors on the suicide rate during summer is shown in Table 5. Sunshine hours and Average Wind Speed(AWS) influenced the suicide rate, along with the weather factors in Table 3. In addition, precipitation days, lowest sea level pressure, and Heatwave Days(HD) were correlated with the female suicide rate. This correlation was slightly negative for the lowest sea level pressure. The mean value of the lowest sea level pressure was 1001.881 hPa, and one unit of pressure was 1013.25 hPa, indicating that low pressure has a negative effect on humans. Kim suggested that atmospheric pressure provides a large amount of oxygen and promotes health[20]. The lowest sea level pressure had a negative impact on women, and the number of heatwave days had a slight positive correlation with the female suicide rate. Heatwave days are the number of days with a daily maximum temperature of 33 °C or higher. An increase in the number of hot summer days increases suicide rates among women.

Table 5. Spearman correlation for summer

weather gender	SR	AWS	MWS	MIWS	SH	PD	LPS	HD
suicide rate	-0.310**	0.270**	0.234*	0.223*	-0.212*	-	-	-
male	-0.271*	0.223*	0.199*	-	-	-	-	-
female	-	-	-	-	-	0.243*	-0.235*	0.197*

*p<.05, **p<.01, ***p<.001

Table 6 shows the correlation results for autumn. Maximum Temperature(MT), Average Maximum Temperature(AMT), Perceived Temperature(PT), and Average Water Vapor Pressure(AWVP) were positively related to suicide rates, indicating that an increase in

temperature can increase the suicide rate. These results are consistent with those of foreign and domestic studies[11][20][23]. In addition to temperature, the Discomfort Index(DI) had a positive correlation of 0.431. The discomfort index is calculated using atmospheric temperature and humidity and measures the degree of discomfort felt on a hot day. As the discomfort index increased, the suicide rate also increased. The results differed by gender. Precipitation day sand Average Wind Speed(AWS) has a positive correlation with the female suicide rate.

Table 6. Spearman correlation for autumn

weather gender	MT	AMT	DI	AWVP	PT	PD	AWS
suicide rate	0.581** *	0.441*	0.431*	0.420*	0.420*	-	-
male	0.537**	0.463*	-	-	-	-	-
female	0.376*	-	-	-	-	0.461*	0.381*

*p<.05, **p<.01, ***p<.001

Table 7. Spearman correlations for winter

weather gender	SD	AWS	MWS	ACC	MIWS	PD	SH	SR	LPS
suicide rate	0.547*	0.270**	0.234*	0.226*	0.184*	-0.212*	-0.310***		
male		0.223*	0.199*		0.184*		-0.184*	-0.271**	-0.186*
female				0.217*		0.243*			-0.235*

*p<.05, **p<.01, ***p<.001

Finally, Table 7 shows the correlations between weather factors and suicide rates in winter. Additional variables that influence the suicide rate during winter are Snow Depth(SD) and Average Cloud Cover (ACC). Snow depth was measured in centimeters, and the average cloud cover was measured on a scale of 0 to 10. The suicide rate increased with the amount of snow and average cloud cover. Although the results differed by gender, sunshine rate, wind speed, and precipitation days were found to have significant effects on the suicide rate. Weather variables that characterized each season were also significant, including sunshine hours, heat wave days, maximum

temperature, discomfort index, snow depth, and average cloud cover. Table 8 summarizes correlation results for all seasons.

Table 8. Spearman correlation compared by season

season weather	Spring	Summer	Autumn	Winter
SH	-0.386*	-0.212*	-	-0.310***
SR	-0.372*	-0.310***	-	-
AWS	-	0.270**	-	0.270**
MWS	-	0.234*	-	0.234*
MIWS	-	0.223*	-	0.184*
MT	-	-	0.581***	-
AMT	-	-	0.441*	-
PT	-	-	0.420*	-
DI	-	-	0.431*	-
AWVP	-	-	0.420*	-
ACC	-	-	-	0.226*
PD	-	-	-	0.184*
SD	-	-	-	0.547*

*p<.05, **p<.01, ***p<.001

IV. Conclusion

This study investigated various weather factors that influenced the suicide rate among older adults in the Jeju Island region of Korea from 2017 to 2021. This study examined the correlation between weather and suicide rates using data from the National Statistical Office of South Korea and the Korea Meteorological Administration. It focuses on Jeju Island, as this area has the third highest suicide rate among older adults nationwide and its weather conditions are distinct from those of other regions. In addition to the temperature, various weather factors were considered in the analysis.

Previous studies have focused on the climate factors that influence suicide rates; however, these studies were mainly conducted in Western countries. Some similar studies have been conducted in South Korea that clearly showed differences between men and women as well as a seasonal effect on suicide rates. Therefore, this study considered weather factors that are relevant to Jeju Island and compared the results by gender and season.

Older adult suicide rates were positively correlated with maximum wind speed and precipitation days and negatively correlated with the sunshine rate. Jeju Island has strong winds owing to its geographical factors. Increases in wind and precipitation were found to negatively affect suicide rates. However, an increase in sunshine decreased the suicide rate among older adults. Light is essential for the maintenance of circadian rhythms, which are closely linked to increased mood disorders[28].

Furthermore, a correlation analysis between weather variables and older adult suicide rates was conducted for each season. Sunshine hours were significant in spring, while atmospheric pressure and heatwave days were significant in summer. In autumn, the maximum temperature and discomfort index influenced the suicide rate. Finally, in winter, the amount of snow and cloud cover influenced the suicide rate.

The research undertook an examination of the correlation between weather and suicide rates. The findings indicate a correlation between weather conditions and suicide rates, suggesting that weather indirectly influences suicide occurrences. According to mental health statistics, the causes of suicide deaths include mental, economic, and physical health issues[29]. It has been observed that weather causes mental health problems and seasonal affective disorder[30]. Moreover, recent studies have highlighted the adverse effects of air pollution on mental health, encompassing cognitive disorders, depression, and an increased risk of suicide[31]. The finding suggests that weather conditions could indirectly contribute to higher suicide rates by exacerbating respiratory illnesses. The population with respiratory diseases may be more susceptible to weather conditions.

Despite these findings, our study is limited by its reliance on simple correlation analysis and the lack of consideration for structural variables that could mediate the relationship between weather and suicide rates. The limitation highlights the need to investigate the structural variables that may underlie this relationship.

The study is significant in determining the effects of wind speed, sunshine rate, and precipitation on suicide rates in Jeju Island, a region that was not covered in previous studies. The regional studies are important in understanding the relationship between weather and suicide.

Acknowledgement

This paper is a revised and supplemented version of the research awarded at the 2024 ADINTECH of the KIIT. "The association between meteorological factors and the suicide rate among older adults in Jeju Island, Korea[32]".

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