

## Spatiotemporal Patterns of Suicide in Korea From 2009 to 2019 Using Geographic Information Systems

### ABSTRACT

**Objective:** When analyzing factors related to suicide, it is necessary to consider the regional characteristics of the areas where individuals live in addition to individual factors. This study aimed to investigate the spatiotemporal association between suicide rates and geographic features and the patterns of this association for all administrative areas in South Korea from 2009 to 2019.

**Methods:** The data used in this study were obtained from the National Statistical Office of the Korean Statistical Information Service. For suicide rates, age-standardized mortality index data per 100 000 people were used. All administrative districts from 2009 to 2019 were divided into 229 regions. Emerging hotspot analysis was used for a 3-dimensional analysis to simultaneously evaluate temporal and spatial clusters.

**Results:** In the 229 regions, there were 27 (11.8%) hotspots and 60 (26.2%) cold spots. Hotspot pattern analysis found 2 (0.9%) new spots, 1 (0.4%) persistent spot, 23 (10.0%) sporadic spots, and 1 (0.4%) oscillating spot.

**Conclusion:** This study found geographic differences in the spatiotemporal patterns of suicide rates in South Korea. The utilization of national resources for suicide prevention should be selectively and intensively prioritized in 3 areas that exhibit unique spatiotemporal patterns.

**Keywords:** Suicide, geography, Korea

### Introduction

In 2019 alone, approximately 800 000 individuals died by suicide worldwide.<sup>1</sup> Among countries belonging to the Organisation for Economic Co-operation and Development, South Korea has one of the highest suicide rates. The suicide rate has been increasing since 2017, and the suicide rate in 2019 was 24.6 per 100 000 people.<sup>2</sup> This upward trend in the suicide rate has also been reported in recent psychiatric studies.<sup>3,4</sup> Suicide causes personal problems such as deterioration of mental and physical health and occupational functioning impairment. In addition, it causes social community problems such as an increase in the social cost burden. Researchers have been trying to investigate factors related to individuals' mental health among risk factors for suicide. Previous studies on specific factors related to suicide, such as unemployment, immigrant minority status, and social isolation, assume that these factors do not differ by region.<sup>5-8</sup> However, in terms of the biopsychosocial model of psychiatry, it is also worth paying attention to studies that take a macroscopic perspective and use big data to investigate suicide-related factors in the community to which individuals belong.<sup>9-14</sup> If only individual exploratory factors for suicide are investigated in suicide-related studies, the spatial effect on suicide prevalence might be overlooked.<sup>8</sup>

The level of risk for suicide varies between individuals,<sup>15</sup> and the risk of suicide could vary due to differences in the social determinants of mental health between regions where individuals live. In a review study on the regional differences in suicide rates in various European countries, compared to neighboring areas, a higher level of deprivation, which included social fragmentation, population density, and health service accessibility, in an area was associated

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with a higher risk of suicide.<sup>16</sup> A previous meta-analysis found that not only interventions for individuals at risk for suicide but also appropriate interventions for major regions where suicide-related problems frequently occur were helpful in preventing suicide.<sup>17</sup> In this context, when analyzing factors related to suicide, it is necessary to consider the regional characteristics of the space in which individuals live in addition to individual factors.

Geographic information systems (GISs) are tools used to create, manage, analyze, and map spatial and geographic information. Geographic information systems visualize data, integrating location information and all types of descriptive information by connecting them to a map. Therefore, GISs are useful for understanding the relationships and patterns between various types of information and geographic features.<sup>18</sup> Geographic information systems can be used for research on the accessibility of mental health care facilities in psychiatry.<sup>19</sup> Geographic information systems are useful in studying the relationship between mental health and its related environmental characteristics.<sup>20</sup> However, studies that have investigated geographic regional differences and suicide rates using GISs are rare in South Korea. Previous studies on suicide using GISs had limitations in that it was difficult to generalize the results due to the limited subjects, or that spatiotemporal dynamics were not simultaneously considered.<sup>12,14</sup> To efficiently use the nation's limited resources for suicide prevention projects, research on suicide in the community needs to be selectively conducted. The studies mentioned above found regional differences in environmental factors that can be corrected using GISs in the field of mental health. This study hypothesized that suicide could also be related to environmental factors, and that suicide rates in South Korea could differ temporally and spatially depending on regional factors. The purpose of this study is to prepare evidence for selective and effective suicide prevention policies. Therefore, we use emerging hotspot analysis to investigate the spatiotemporal association between suicide rates and geographic features and the pattern of this association for all ages in all 229 administrative areas (Si, Gun, and Gu) in South Korea from 2009 to 2019.

## Methods

### Data

The data used in this study were from the National Statistical Office of the Korean Statistical Information Service (KOSIS, available from <http://kosis.kr/>). Among the statistics on the cause of death reported by the KOSIS, the population who died by suicide (X60-X84) from 2009 to 2019 was included. The subjects were approximately 1.3-1.5 million people each year. The gender, marital status, educational level, and residential area of the subjects were investigated. For suicide rates, age-standardized mortality index data per 100 000 population were used. The surveyed administrative areas were defined as

### MAIN POINTS

- There were geographic differences in the spatiotemporal patterns of suicide rates in South Korea from 2009 to 2019.
- There were 2 new hotspot areas, and 1 permanent hotspot area for the suicide rate in South Korea from 2009 to 2019.
- Spatiotemporal differences in suicide patterns can be helpful in establishing national policies that consider regional characteristics for strategies against suicides.

follows: metropolitan areas (Gu and Gun) and cities (Si, Gun, and Gu). All administrative districts from 2009 to 2019 were divided into 229 regions (including Sejong City).

### Statistical Analysis

To evaluate the spatial autocorrelation (cluster degree) of the suicide rate in South Korea, Moran's index (I) (spatial autocorrelation index) was calculated.<sup>21</sup> An emerging hotspot analysis using ArcGIS Pro 1.4 (Redlands, California, USA) was used to analyze the community-level spatiotemporal distribution.<sup>22,23</sup> Detailed information on the GIS analyses is provided in the Supplementary Materials. The definitions of hotspot and cold spot patterns are presented in Supplementary Table 1. A *P*-value of .05 was considered statistically significant.

### Ethics Statement

The data used in this study were not directly investigated in human subjects, but open source provided by the country for anyone to use, therefore, there is no separate informed consent form. This study was reviewed and approved by the Ethics Committee of Gyeongsang National University Changwon Hospital (IRB No. 2021-08-017).

## Results

### Descriptive Results

The age-adjusted suicide rate per 100 000 population for each year from 2009 to 2019 is, in order, as follows: 29.1, 28.7, 28.8, 25.1, 25.1, 23.9, 22.7, 21.9, 20.7, 22.6, and 22 (Figure 1).

### Spatiotemporal Analysis

From emerging hotspot analysis of the age-standardized suicide rate in South Korea from 2009 to 2019, 4 patterns (new spot, persistent spot, sporadic spot, and oscillating spot) were identified. Among the 229 regions, there were 27 (11.8%) hotspots and 60 (26.2%) cold spots. Hotspot pattern analysis found 2 (0.9%) new spots, 1 (0.4%) persistent spot, 23 (10.0%) sporadic spots, and 1 (0.4%) oscillating spot. The 23 hotspot areas are shown in Table 1. Figure 2 presents a geovisualization of emerging hotspots for suicide rates based on the space-time cube technique. The Getis-Ord *G*<sub>i</sub><sup>\*</sup> statistic *Z* score value was 3.557 (*P* = .000), and at the 99% confidence level, regional clustering trends in suicide rates appeared to increase.

## Discussion

This study analyzed the spatiotemporal distribution of suicide rates and the pattern between suicide rates and geographic information in South Korea using national representative data covering 11 years. The results indicate that there was a statistically significant difference in the spatial and temporal patterns of the 11-year suicide rate in South Korea depending on the region. Compared with suicide research using existing descriptive statistics, this study using spatiotemporal analysis could present a visualization of the results by mathematically calculating the suicide rate and temporal and spatial relationships. Additionally, unlike a simple visualization and comparison of regional differences in suicide rates, this analysis minimizes the subjectivity inherent in human visual interpretation and can identify and quantify data patterns and trends. The results of the emerging hotspot analysis of this study indicate that there is a spatiotemporal dependence of the suicide rate at the administrative district level, such as Si, Gun, and Gu. In addition, these results indicate that the suicide rate in South Korea displays statistically

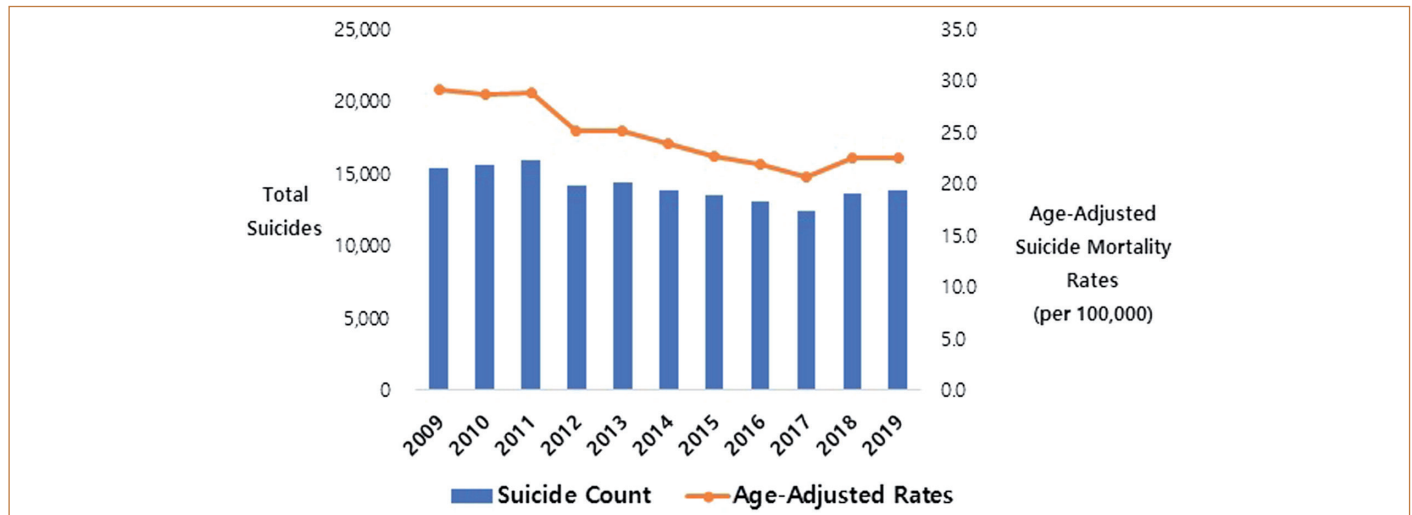


Figure 1. Suicide mortality rates (age adjusted, per 100 000) in South Korea from 2009 to 2019. In South Korea, the suicide mortality rate decreased from 2009 to 2016 but increased from 2017 to 2019.

significant spatial and temporal clustering. In particular, it is possible to identify regions (hotspot areas) with higher suicide rates for the past 11 years compared to neighboring regions in such a correlated cluster. Each of the hotspot areas had a different suicide rate pattern over the 11-year period. For example, 2 new hotspot areas, Daegu Dong-gu and Buk-gu, did not appear before the most recent time interval in the surveyed period and were areas where new hotspots appeared in 2019, the last surveyed period. Additionally, 1 persistent spot area, Chungcheongnam-do Hongseong-gun, consistently showed a higher suicide rate than surrounding areas during the 11-year period investigated. Based on these results, specific risk factors for suicide in these regions and differential prevention strategies are needed.

Previous studies found regional differences in the prevalence of suicide that showed that suicide occurs more frequently in areas with easy access to lethal means of suicide or high levels of social deprivation and social system disintegration.<sup>9,11,14</sup> Therefore, in these studies, suicide rates that differ by region are related to geographic information, suggesting the need for regionally customized suicide

prevention programs and social policies.<sup>9,11</sup> In this context, as a result of this study, various patterns of hotspot areas for suicide risk over the 11-year study period suggest that the temporal and spatial differences between the social and cultural aspects of each local administrative district affect the pattern of suicide risk.

Suicide is a risk phenomenon that typically requires a preventive approach. The risk of suicide can be reduced by improving the socio-environmental factors related to suicide, even if there is no causality.<sup>9,11,14,24,25</sup> Therefore, it is important to elucidate the quantitative and qualitative causes of suicide, and it is necessary to focus on achieving the goal of decreasing the suicide rate by finding modifiable factors that can influence suicide.<sup>14</sup> In this context, the geographical characteristics among environmental factors related to suicide can be modified; thus, the results of this study confirming the geographic dependence of the suicide rate can be evidence for preparing effective policies to reduce the suicide rate.

In conclusion, this study was able to see geographic differences in the spatiotemporal patterns of suicide rates in South Korea.

Table 1. Hotspot Areas for Age-Adjusted Suicide Mortality Rate From 2009 to 2019

Pattern Name	N	%	Hotspots		Cold Spots	
			Administrative Areas (Si, Gun, and Gu)*	N	%	
New spot	2	0.9	Daegu Dong-gu and Buk-gu	0	0.0	
Consecutive spot	0	0.0	-	0	0.0	
Intensifying spot	0	0.0	-	0	0.0	
Persistent spot	1	0.4	Chungcheongnam-do Hongseong-gun	2	0.9	
Diminishing spot	0	0.0	-	53	23.1	
Sporadic spot	23	10.0	Gyeonggi-do Yeoncheon-gun, Gangwon-do Chuncheon-si, Gangneung-si, Hongcheon-gun, Hoengseong-gun, Yeongwol-gun, Cheorwon-gun, Hwacheon-gun, Inje-gun, Yangyang-gun, Chungcheongbuk-do Chungju-si, Jecheon-si, Chungcheongnam-do Gongju-si, Boryeong-si, Asan-si, Seosan-si, Dangjin-si, Buyeo-gun, Seocheon-gun, Cheongyang-gun, Yesan-gun, Taean-gun, and Gyeongsangbuk-do Mungyeong-si	4	1.7	
Oscillating spot	1	0.4	Jeollabuk-do Gunsan-si	1	0.4	
Historical spot	0	0.0	-	0	0.0	
Sum	27	11.8	-	60	26.2	

N indicates the number of administrative areas: regional (Si, Gun, and Gu) count.

\*The area-based data consisted of 229 Si, Gun, and Gu administrative areas.

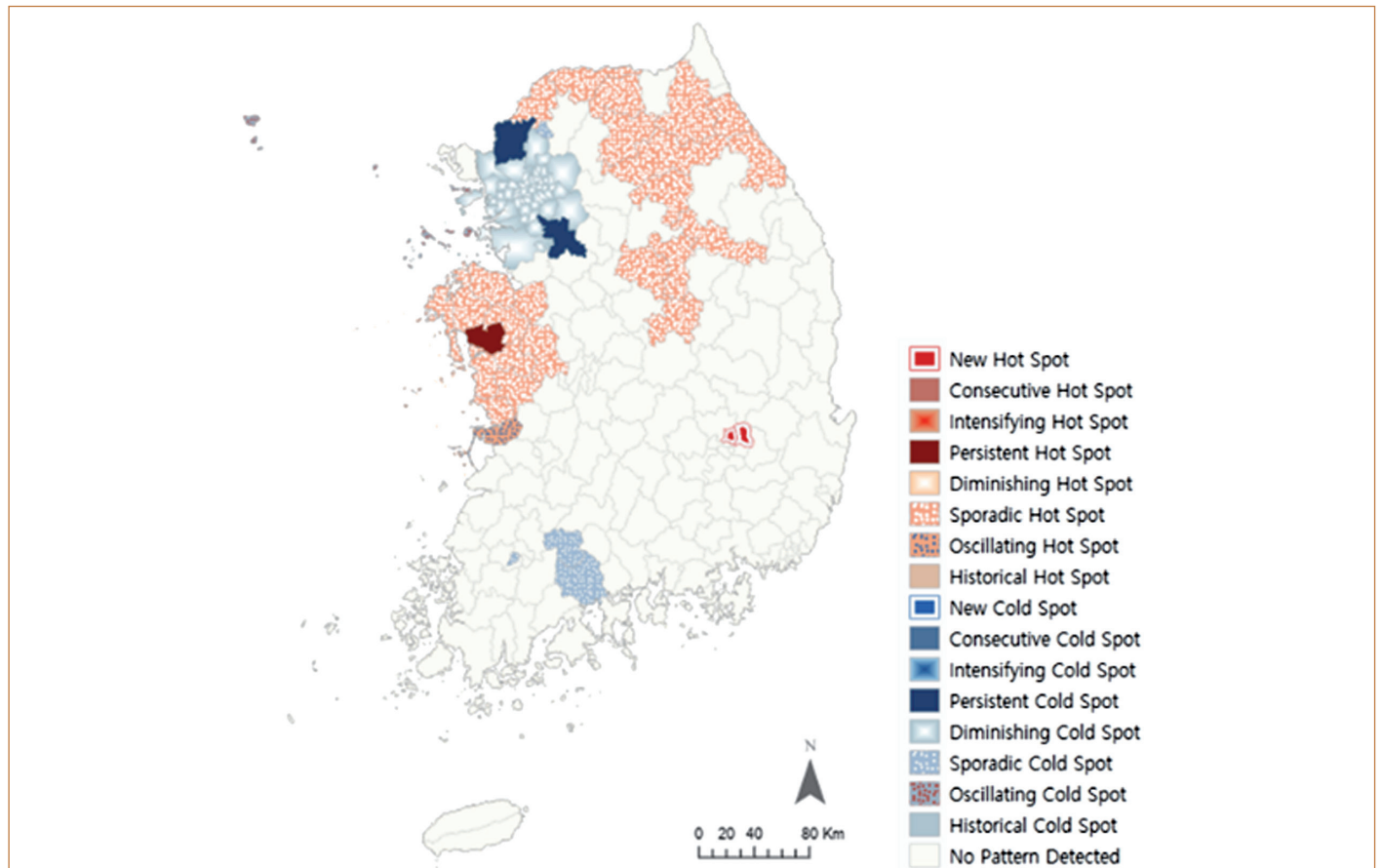


Figure 2. Spatial distribution of clusters of suicide mortality based on emerging hotspot analysis. Among 228 (229) regions, 27 hotspot regions were identified: 2 (0.9%) new spots, 1 (0.4%) persistent spot, 23 (10.0%) sporadic spots, and 1 (0.4%) oscillating spot.

This study, which found spatiotemporal differences in suicide patterns, can be helpful in establishing national policies that consider regional characteristics for strategies against suicides that require preventive and early intervention. In particular, the input of national resources for suicide prevention should be selectively and intensively prioritized in 3 areas that have unique spatiotemporal patterns: 2 new hotspot areas, Daegu Dong-gu and Buk-gu', and 1 permanent hotspot area, Chungcheongnam-do and Hongseong-gun'. As a limitation of this study, there may be regional differences in the spatiotemporal patterns of suicide rates in South Korea, but an investigation into the modifiable factors related to the differences was not conducted. Therefore, in future studies, we will investigate the sociocultural factors in the spatiotemporal differences in suicide rates through an analysis covering a longer period of time and specific spatiotemporal factors that can predict the risk of suicide.

**Data Sharing:** Data sharing does not apply to this article as no datasets were generated or analyzed during the study.

**Ethics Committee Approval:** Ethical committee approval was received from the Ethics Committee of Gyeongsang National University Changwon Hospital (Approval No: 2021-08-017).

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## References

1. World Health Organization. *Suicide in the World: Global Health Estimates*. Geneva: World Health Organization; 2019.
2. Organization for Economic Co-operation and Development. *Suicide Rates (Indicator)*. Paris, France: OECD; 2021.
3. Korkmaz S, Danacı Keleş DD, Kazgan A, et al. Emotional intelligence and problem solving skills in individuals who attempted suicide. *J Clin Neurosci*. 2020;74:120-123. [CrossRef]
4. Özsoy F, Taşçı G, Kulu M, et al. Stigmas and childhood traumas associated with psychological help-seeking in suicide attempted individuals. *Perspect Psychiatr Care*. 2022;58(4):2970-2977. [CrossRef]
5. Borges G, Breslau J, Su M, Miller M, Medina-Mora ME, Aguilar-Gaxiola S. Immigration and suicidal behavior among Mexicans and Mexican Americans. *Am J Public Health*. 2009;99(4):728-733. [CrossRef]
6. Classen TJ, Dunn RA. The effect of job loss and unemployment duration on suicide risk in the United States: a new look using mass-layoffs and unemployment duration. *Health Econ*. 2012;21(3):338-350. [CrossRef]
7. Rasic D, Kisely S, Langille DB. Protective associations of importance of religion and frequency of service attendance with depression risk,

- suicidal behaviours and substance use in adolescents in Nova Scotia, Canada. *J Affect Disord.* 2011;132(3):389-395. [\[CrossRef\]](#)
8. Trgovac AB, Kedron PJ, Bagchi-Sen S. Geographic variation in male suicide rates in the United States. *Appl Geogr.* 2015;62:201-209. [\[CrossRef\]](#)
  9. Chang SS, Sterne JA, Wheeler BW, Lu TH, Lin JJ, Gunnell D. Geography of suicide in Taiwan: spatial patterning and socioeconomic correlates. *Health Place.* 2011;17(2):641-650. [\[CrossRef\]](#)
  10. Hong J, Knapp M. Geographical inequalities in suicide rates and area deprivation in South Korea. *J Ment Health Policy Econ.* 2013;16(3):109-119.
  11. Hsu CY, Chang SS, Lee EST, Yip PSF. Geography of suicide in Hong Kong: spatial patterning, and socioeconomic correlates and inequalities. *Soc Sci Med.* 2015;130:190-203. [\[CrossRef\]](#)
  12. Joo Y. Spatiotemporal study of elderly suicide in Korea by age cohort. *Public Health.* 2017;142:144-151. [\[CrossRef\]](#)
  13. Knipe DW, Padmanathan P, Muthuwatta L, Metcalfe C, Gunnell D. Regional variation in suicide rates in Sri Lanka between 1955 and 2011: a spatial and temporal analysis. *BMC Public Health.* 2017;17(1):193. [\[CrossRef\]](#)
  14. Yeom Y. Analysing spatial and temporal dynamics of suicide in South Korea: an application of the dynamic spatial panel data model. *Geospat Health.* 2021;16(1). [\[CrossRef\]](#)
  15. Masango SM, Rataemane ST, Motojesi AA. Suicide and suicide risk factors: a literature review. *S Afr Fam Pract.* 2008;50(6):25-29. [\[CrossRef\]](#)
  16. Cairns JM, Graham E, Bamba C. Area-level socioeconomic disadvantage and suicidal behaviour in Europe: a systematic review. *Soc Sci Med.* 2017;192:102-111. [\[CrossRef\]](#)
  17. Pirkis J, Too LS, Spittal MJ, Krysiniska K, Robinson J, Cheung YT. Interventions to reduce suicides at suicide hotspots: a systematic review and meta-analysis. *Lancet Psychiatry.* 2015;2(11):994-1001. [\[CrossRef\]](#)
  18. DeMers MN. *Fundamentals of Geographic Information Systems.* Hoboken, NJ: John Wiley & Sons; 2008.
  19. Walsan R, Pai N, Dawes K. The relationship between environment and mental health: how does geographic information systems (GIS) help? *Australas Psychiatry.* 2016;24(3):315. [\[CrossRef\]](#)
  20. Walsan R, Pai N, Dawes K. Usefulness of geographic information systems (GIS) in mental health research. *Manipal J Sci.* 2016;1(2):42-45.
  21. Chen Y. New approaches for calculating Moran's index of spatial autocorrelation. *PLoS One.* 2013;8(7):e68336. [\[CrossRef\]](#)
  22. Betty EL, Bollard B, Murphy S, et al. Using emerging hot spot analysis of stranding records to inform conservation management of a data-poor cetacean species. *Biodivers Conserv.* 2020;29(2):643-665. [\[CrossRef\]](#)
  23. Getis A, Ord JK. The analysis of spatial association by use of distance statistics. *Geogr Anal.* 1992;24(3):189-206. [\[CrossRef\]](#)
  24. Biglan A. Contextualism and the development of effective prevention practices. *Prev Sci.* 2004;5(1):15-21. [\[CrossRef\]](#)
  25. Hayes S, Hayes IS, Hayes L, Reese H, Sarbin T. Analytic goals and the varieties of scientific contextualism. In: *Varieties of Scientific Contextualism.* Reno, NV: Context Press; 2015:11-27.