

Suicide Rate and Social Environment Characteristics in South Korea: The Roles of Socioeconomic, Demographic, Urbanicity, General Health Behaviors, and Other Environmental Factors On Suicide Rate

Hyemin Jang

Ewha Womans University

Whanhee Lee

Yale University

Yong-ook Kim

Seoul National University

Ho Kim (✉ hokim@snu.ac.kr)

Seoul National University

Research Article

Keywords: suicide, social environment factors, longitudinal study, linear mixed-effect model

Posted Date: September 9th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-817624/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at BMC Public Health on March 1st, 2022. See the published version at <https://doi.org/10.1186/s12889-022-12843-4>.

Abstract

Background: Suicide is a serious worldwide public health concern, and South Korea has shown the highest suicide rate among Organisation for Economic Co-operation and Development (OECD) countries since 2003. Nevertheless, most previous Korean studies on suicide had limitations in investigating various social environment factors using long-term nationwide data. Thus, this study aimed to examine how various social environment characteristics are related to the suicide rate on a district-level, using nationwide longitudinal data over 11 years.

Methods: We used the district-level age-standardized suicide rate and a total of 12 annual social environment characteristics of socioeconomic, demographic, urbanicity, general health behaviors, and other environmental characteristics from 229 administrative districts in South Korea. A linear mixed-effect model (LMEM) was used to examine the association between the rate of suicide and the social environment indicators selected for the study.

Results: In the total population, the indicators “% population aged 65 and older eligible for the basic pension”, “% vacant houses in the area”, “% divorce”, “% detached houses”, and “% current smokers” showed positive associations with the suicide rate. In contrast, “% people who regularly participated in religious activities” and “number of sports facilities per 1,000 persons” showed negative associations with suicide rate. The associations between social environment characteristics and suicide rate were generally more pronounced in males and more urbanised areas, than in females and less urbanised areas; however, associations differed amongst age groups, depending on the social environment characteristic variable under study.

Conclusions: This study investigated the complex role of social environments on suicide rate in South Korea and revealed that higher suicide rates were associated with lower values of socioeconomic status, physical exercise, and religious activities, and with higher social isolation and smoking practice. Our results can be used in the development of targeted suicide prevention policies.

Background

The World Health Organization (WHO) reported that more than 700,000 people die by suicide every year, and accounted for 1.3% of all deaths in 2019 [1]. In an effort to reduce suicidal deaths globally, the WHO Mental Health Action Plan 2013–2020 has been extended to 2030. Among Organization for Economic Cooperation and Development (OECD) countries, South Korea (hereafter referred to as Korea) has had the highest suicide rate for the period 2003 to 2019 (24.6 per 100,000 persons in 2019) [2]. Suicide is the fifth leading cause of death in Korea, and this trend has been more pronounced in the younger population aged 10 ~ 59 years (suicide is the first and second leading cause of death in people aged 10 ~ 39 years and aged 40 ~ 59 years, respectively) than in the older population aged 60 years and older (Statistics Korea, 2019). The current statistics prompts us to recognize suicide as a public health priority, and it has become more important to examine various factors that may contribute towards suicide.

Previous studies have reported that cultural/social-level factors, such as social integration, socioeconomic status, and residential conditions, are closely related to suicide [3]. However, many Korean studies in the last decade have examined the temporal trend of suicide rate and individual-level risk factors [4, 5], and only a few studies have investigated the roles of social environmental characteristics on suicide rate. Cheong et al. showed that urbanicity was associated with regional suicide (that is, rural areas showed higher suicide rates compared with urban areas), and regional economic status was also related to suicide rate in the elderly population [6]. Kim also reported that the regional income-levels, prevalence of heavy drinking, and the % elderly (people aged 65 years and older) in the community were associated with suicide rates [7]. However, most of the previous studies in Korea are limited when examining various social environment factors and/or have used suicide data from relatively short study periods (less than 5 years).

Therefore, to address these knowledge gaps, this study aimed to examine the complex roles of social environment characteristics, including multiple regional socioeconomic, demographic, urbanicity, general health behaviors, and other environmental factors on suicide rate, using district-level nationwide longitudinal data from 2008 through 2018, from 229 administrative districts in Korea. In addition, we aimed to investigate the different effects of the social environment characteristics on suicide rate in areas grouped according to their urbanisation level, and for male and female sexes, and for different age groups.

Methods

Suicide data

We obtained population-based longitudinal data on annual mortality counts for each district for the period 2008–2018 from the Korea National Statistics Office. The mortality data include the location of death (that is, the administrative district), and the age and sex of the deceased. Data for our study were extracted from the national mortality data, which used the 10th revision of the International Classification of Diseases (ICD-10) codes to define deaths due to suicide (designated in the range X60–X84).

In this study, a crude rate of suicide was calculated for each district in each study year. We also calculated the age-standardized suicide rate per 100,000 persons for each study year (hereafter, suicide rate), using the 2005 resident-registered population in Korea [8]. The age-standardized suicide rate for each study year was used in the statistical analyses.

Social environment characteristics

To address the complex effects of social environment characteristics on suicide rate, this study collected a total of 12 district-level annual indicators covering socioeconomic, demographic, urbanicity, general health behaviors, and other environmental characteristics from all 229 administrative districts in Korea (that is, “si/gun/gu”, which are second-level basic local administrative districts). The indicators were “% population aged 65 and older eligible for the basic pension” (a proxy for low socioeconomic status), “%

vacant houses in the area" (i.e. vacancy rate), "% divorce", "% single elderly households", "% detached houses", "% people who regularly participated in religious activities", "number of sports facilities per 1,000 persons", "park area per person (km²)", "% current smokers", "% people exhibiting a high risk drinking", "% population with recognized stress", and "% population that is obese". These indicators were obtained from the database of community health outcomes and health determinants that is maintained by the Korean Centers for Disease Control and Prevention [8]. If variables were missing for a year, we linearly interpolated or extrapolated their values using available data [9]. Detailed information on the social environment indicators (for instance, definitions of the variables and survey years) are reported in the Supplementary Materials.

Sub-group analysis

Firstly, to examine the effects of the social environment characteristics on suicide rate according to the urbanisation level of areas, we divided 229 districts into three groups using population density (person per km², an indicator of urbanisation level). Seventy six districts with average population densities in the range 19.8–136.2 persons per km² (corresponding to the 0th – 33.3th percentiles) were categorized as low-density areas, 77 districts with average population densities in the range 136.8–2077.1 persons per km² (corresponding to the 33.3th – 66.7th percentiles) were regarded as mid-density areas, and the remaining 77 districts with population densities in the range 2811.0–28081.1 persons per km² (corresponding to the 66.7th – 100th percentiles) were classified as high-density areas.

In addition, we used the age-standardized suicide rates for each study year, which were calculated for groups of people aged 10–39 years, 40–59 years, and 60 years and older) in each district. Suicide rates were calculated for each sex (male and female) per district.

Statistical Analysis

We applied a linear mixed-effects model (LMEM) to examine the association between the rate of suicide and time-varying annual social environment characteristics. All 12 time-varying annual social environment characteristics were included as linear terms in LMEM. To avoid potential temporal and spatial confounding, we fitted the LMEM with district-specific random intercepts and adjusted indicator variables for the years 2008–2018, and the coordinate (longitude and latitude) of each district, in order to address potential temporal and spatial confounding. We estimated the association between suicide rate and each social environment characteristic as the change in suicide rate per unit change in each social environment characteristic variable. All the analytical procedures were repeated for each sub-population (low-, mid-, and high-density areas; male and female sexes; and age groups). For all statistical analyses, we used R statistical software (version 4.0.2).

Results

Table 1 displays descriptive statistics of suicide rates and confounders. During the entire study period, low-density areas, males, and people aged 60 years and older showed higher suicide rates on average,

compared to mid- or high-density areas, females, and people aged 40–59 or 10–39 years, respectively. Low-density areas showed the highest suicide rate across all sub-populations (sexes and age groups), except for people aged 60 years and older. The geographical distribution of average suicide rates for the period 2008–2018 across 229 districts can be seen in Fig. 1.

Table 1

Descriptive statistics of suicide rates and social environment characteristics in the total population and at different urbanisation levels.

	Total	Low-density areas	Mid-density areas	High-density areas
Total suicide rate	27.07 (18.30, 37.86)	29.74 (17.50, 44.10)	27.43 (19.21, 36.40)	24.04 (18.15, 30.60)
Male suicide rate	38.59 (25.00, 55.10)	42.64 (23.14, 64.30)	39.31 (27.70, 54.29)	33.83 (24.70, 43.90)
Female suicide rate	16.21 (7.59, 25.90)	16.95 (3.70, 32.71)	16.40 (9.10, 24.90)	15.29 (9.80, 21.15)
Aged 10 ~ 39y suicide rate	20.17 (9.92, 32.17)	22.17 (5.29, 41.74)	20.01 (11.50, 29.85)	18.34 (12.29, 24.59)
Aged 40 ~ 59y suicide rate	36.84 (22.08, 54.90)	41.70 (19.40, 66.34)	36.97 (23.83, 51.23)	31.86 (22.40, 42.28)
Aged 60 + y suicide rate	56.89 (30.89, 88.85)	59.32 (26.75, 99.55)	60.75 (35.21, 93.33)	50.62 (32.10, 71.99)
% population aged 65 and older eligible for the basic pension	70.50 (56.94, 84.46)	80.65 (72.31, 86.54)	68.65 (59.74, 78.45)	62.21 (48.24, 73.73)
% vacant houses in the area	8.49 (2.68, 14.55)	12.57 (8.80, 16.51)	8.77 (4.54, 13.60)	4.14 (1.90, 7.24)
% divorce	2.19 (1.70, 2.70)	2.07 (1.70, 2.50)	2.33 (1.90, 2.80)	2.17 (1.70, 2.70)
% single elderly households	21.22 (14.94, 28.48)	25.84 (20.10, 30.97)	20.24 (14.07, 25.11)	17.59 (14.10, 21.97)
% detached houses	44.33 (10.10, 87.15)	77.43 (61.54, 90.47)	36.28 (14.42, 62.84)	19.28 (6.33, 35.26)
% people who regularly participated in religious activities	25.15 (16.55, 34.10)	22.36 (14.10, 30.60)	25.33 (16.70, 34.00)	27.76 (20.15, 35.08)
Number of sports facilities per 1,000 persons	0.05 (0.00, 0.11)	0.09 (0.02, 0.19)	0.04 (0.01, 0.07)	0.01 (0.00, 0.01)
Park area per person (km ²)	22.66 (2.73, 41.42)	26.47 (9.68, 49.65)	31.09 (8.27, 60.37)	10.47 (0.62, 22.82)

	Total	Low-density areas	Mid-density areas	High-density areas
% current smokers	23.89 (19.96, 27.84)	24.05 (20.40, 27.80)	24.13 (19.94, 28.20)	23.49 (19.70, 27.45)
% people exhibiting a high risk drinking	17.91 (12.60, 22.90)	17.93 (11.40, 24.30)	18.24 (13.14, 23.00)	17.57 (13.50, 21.30)
% population with recognized stress	27.00 (20.66, 32.60)	24.36 (18.20, 30.50)	27.68 (22.54, 32.50)	28.97 (24.30, 33.40)
% population that is obese	26.52 (20.60, 34.74)	26.95 (20.35, 35.70)	27.14 (21.20, 35.26)	25.46 (20.30, 33.00)
<p>Note) Numbers: Average (10th percentile, 90th percentile). Seventy six districts with average population densities in the range 19.8–136.2 persons per km² (corresponding to the 0th–33.3th percentiles) were categorized as low-density areas, 77 districts with average population densities in the range 136.8–2077.1 persons per km² (corresponding to the 33.3th – 66.7th percentiles) were regarded as mid-density areas, and the remaining 77 districts with population densities in the range 2811.0–28081.1 persons per km² (corresponding to the 66.7th – 100th percentiles) were classified as high-density areas.</p>				

Figure 2 shows the annual trend of suicide rate in the total population and for each sub-population. In the total population, the suicide rate gradually decreased from 2009, except for an increase in 2018. This decreasing pattern was most prominent in low-density areas, and among males and people aged 60 years and older.

Table 2 shows the association between social environment characteristics and suicide rate in the total population and for low-, mid-, or high-density areas. In the total population, higher values of the indicators, “% population aged 65 and older eligible for the basic pension”, “% vacant houses in the area”, “% divorce”, “% detached houses”, and “% current smokers” were associated with higher suicide rates. In contrast, “% people who regularly participated in religious activities” and “the number of sports facilities per 1,000 persons” showed a negative association with suicide rate in the total population. In general, the associations observed with these social environment characteristics were more prominent (i.e. lower p-values) in high-density areas than in low- and mid-density areas.

Table 2

Association between social environment characteristics and suicide rate in the total population and at different urbanisation levels.

	Total	Low-density areas	Mid-density areas	High-density areas
% population aged 65 and older eligible for the basic pension	0.10 (0.04, 0.16)*	0.08 (-0.11, 0.27)	0.09 (-0.01, 0.18)	0.07 (0.01, 0.14)*
% vacant houses in the area	0.21 (0.10, 0.32)*	0.36 (0.15, 0.58)*	0.06 (-0.10, 0.21)	0.32 (0.12, 0.51)*
% divorce	2.13 (1.10, 3.15)*	-1.53 (-3.83, 0.77)	4.10 (2.65, 5.56)*	4.67 (3.31, 6.03)*
% single elderly households	0.03 (-0.05, 0.11)	-0.30 (-0.66, 0.05)	0.03 (-0.03, 0.10)	0.21 (-0.10, 0.51)
% detached houses	0.05 (0.02, 0.07)*	0.05 (-0.03, 0.13)	0.09 (0.05, 0.12)*	-0.02 (-0.07, 0.03)
% people who regularly participated in religious activities	-0.07 (-0.14, 0.00)*	-0.01 (-0.14, 0.12)	-0.23 (-0.32, -0.14)*	0.02 (-0.07, 0.11)
Number of sports facilities per 1,000 persons	-4.16 (-7.88, -0.44)*	-4.31 (-9.36, 0.73)	-0.98 (-17.58, 15.62)	-95.64 (-147.45, -43.84)*
Park area per person (km ²)	-0.01 (-0.02, 0.00)	0.02 (-0.02, 0.07)	-0.01 (-0.02, 0.00)	-0.01 (-0.04, 0.02)
% current smokers	0.16 (0.03, 0.29)*	0.17 (-0.10, 0.44)	-0.02 (-0.19, 0.16)	0.14 (0.00, 0.27)*
% people exhibiting a high risk drinking	-0.06 (-0.15, 0.03)	-0.02 (-0.19, 0.15)	-0.03 (-0.15, 0.10)	0.03 (-0.08, 0.13)
% population with recognized stress	0.01 (-0.07, 0.08)	0.00 (-0.14, 0.14)	-0.01 (-0.11, 0.10)	0.08 (0.00, 0.15)
% population that is obese	0.08 (-0.03, 0.18)	0.03 (-0.18, 0.24)	-0.04 (-0.20, 0.12)	-0.05 (-0.18, 0.07)

	Total	Low-density areas	Mid-density areas	High-density areas
<p>Note) Numbers: Changes in suicide rate per 100,000 persons (95% confidence interval). Seventy six districts with average population densities in the range 19.8–136.2 persons per km² (corresponding to the 0th–33.3th percentiles) were categorized as low-density areas, 77 districts with average population densities in the range 136.8–2077.1 persons per km² (corresponding to the 33.3th – 66.7th percentiles) were regarded as mid-density areas, and the remaining 77 districts with population densities in the range 2811.0–28081.1 persons per km² (corresponding to the 66.7th – 100th percentiles) were classified as high-density areas.</p>				
*p < 0.05				

Table 3 shows the sex-specific and age group-specific associations between social environment characteristics and suicide rate. The associations with social environment characteristics observed in the total population were generally more evident in males than in females, and a negative association between suicide rate and “% people who regularly participated in religious activities” and “% people exhibiting a high risk drinking” were observed in males. Meanwhile, age groups showed heterogeneous associations of social environment characteristics with suicide risk. First, “% current smokers” and “% population aged 65 and older eligible for the basic pension” were positively associated with suicide rate only in people aged 40–59 years and people aged 60 years and older, respectively. Further, the negative association of suicide rate with “park area per person (km²)” and “number of sports facilities per 1,000 persons” were observed only in people aged 10–39 years. Moreover, the negative relationship between suicide rate and “% people who regularly participated in religious activities” was more pronounced in people aged 40–59 years and 60 years and older, than in people aged 10–39 years. Also, the positive association between suicide rate and “% detached houses” was observed only for people aged 10–39 and 40–59 years. Finally, positive associations of suicide rate with “% divorce” and “% vacant houses in the area” were observed across all age groups.

Table 3

Sex-specific and age group-specific associations between social environment characteristics and suicide rate.

	Male	Female	Aged 10 ~ 39y	Aged 40 ~ 59y	Aged 60 +y
% population aged 65 and older eligible for the basic pension	0.19 (0.10, 0.29)*	0.03 (-0.03, 0.08)	0.02 (-0.05, 0.09)	0.08 (-0.01, 0.18)	0.38 (0.16, 0.60)*
% vacant houses in the area	0.26 (0.08, 0.43)*	0.13 (0.01, 0.24)*	0.21 (0.07, 0.35)*	0.25 (0.05, 0.44)*	0.42 (0.07, 0.78)*
% divorce	3.19 (1.56, 4.83)*	1.18 (0.13, 2.22)*	1.64 (0.31, 2.96)*	4.68 (2.87, 6.49)*	3.97 (0.74, 7.21)*
% single elderly households	0.07 (-0.06, 0.19)	-0.01 (-0.10, 0.07)	0.13 (0.02, 0.24)*	0.01 (-0.14, 0.16)	-0.14 (-0.37, 0.09)
% detached houses	0.06 (0.02, 0.10)*	0.02 (0.00, 0.04)	0.04 (0.01, 0.07)*	0.12 (0.08, 0.16)*	-0.04 (-0.13, 0.05)
% people who regularly participated in religious activities	-0.12 (-0.23, -0.01)*	0.01 (-0.05, 0.08)	-0.01 (-0.10, 0.07)	-0.18 (-0.29, -0.06)*	-0.28 (-0.51, -0.06)*
Number of sports facilities per 1,000 persons	-5.89 (-11.83, 0.04)	-3.42 (-7.38, 0.53)	-6.88 (-12.00, -1.76)*	-2.94 (-9.90, 4.03)	7.91 (-3.17, 19.00)
Park area per person (km ²)	-0.01 (-0.03, 0.02)	-0.01 (-0.03, 0.00)	-0.02 (-0.04, -0.01)*	-0.01 (-0.03, 0.02)	0.04 (0.00, 0.08)
% current smokers	0.32 (0.12, 0.53)*	-0.01 (-0.16, 0.13)	0.13 (-0.06, 0.31)	0.26 (0.01, 0.52)*	0.32 (-0.05, 0.70)
% people exhibiting a high risk drinking	-0.15 (-0.29, -0.01)*	0.04 (-0.05, 0.14)	-0.03 (-0.16, 0.10)	-0.12 (-0.29, 0.05)	0.03 (-0.22, 0.29)
% population with recognized stress	0.05 (-0.07, 0.17)	-0.02 (-0.10, 0.06)	0.00 (-0.10, 0.11)	0.03 (-0.12, 0.17)	0.12 (-0.10, 0.33)
% population that is obese	0.10 (-0.07, 0.27)	0.08 (-0.04, 0.19)	0.01 (-0.14, 0.16)	0.10 (-0.11, 0.31)	0.20 (-0.12, 0.51)

Note) Numbers: Changes in suicide rate per 100,000 persons (95% confidence interval).

	Male	Female	Aged 10 ~ 39y	Aged 40 ~ 59y	Aged 60 +y
*p < 0.05					

Discussion

In this study, we investigated the association between social environment characteristics and suicide rate in Korea, using nationwide longitudinal data covering all 229 districts over 11 years (2008–2018). We found that 1) poor socioeconomic conditions and isolation characteristics (higher “% population aged 65 and older eligible for the basic pension”, “% vacant houses in the area”, “% divorce”, and “% detached houses”) were associated with higher suicide rates; 2) higher smoking rates were associated with higher suicide rates; and 3) higher religious activity and greater access to recreational opportunities (sports facilities and parks) were associated with lower suicide rate. Associations with social environment characteristics were found to differ by age group; in general, the associations with socioeconomic status and health behavior characteristics were more evident in older age groups, whereas the associations with indicators of isolation and recreational opportunities were more prominent in younger age groups.

Lower socioeconomic status has been suggested as a major risk factor of suicide. The suicide rate increased during economic depressions [10, 11], and the higher suicide rates among people with lower income and education levels have been reported globally and consistently [12–15]. This study also showed that poor socioeconomic levels were associated with higher suicide rates at a district-level, as “% population aged 65 and older eligible for the basic pension” and “% vacant houses in the area” showed a positive association with suicide rate. Moreover, we found that the association between “% population aged 65 and older eligible for the basic pension” and suicide rate is the highest in the people aged 60 and older (Table 3). Previous studies also suggested that poverty and economic difficulties are dominant factors of suicide in the elderly, along with poor physical health [6, 16]. Thus, this result has crucial implications for suicide prevention policies in Korea, which showed a distinctively higher suicide rate in the elderly population than in other age groups.

Further, social isolation together with lower socioeconomic levels has been identified as another major risk factor of suicide [17–19]. Results from our study were consistent with this finding, as a positive association was found between suicide rate and “% divorce” and “% detached houses”. Moreover, we found that the effects of poor socioeconomic status and social isolation on suicide rate were more prominent in males than in females. We postulate that men’s higher levels of participation in economic activity in Korea might be related to this gender difference. According to the Korea National Statistics Office, the labour force in 2019 comprised 73.5% men and 53.5% women. In addition, these results can be partly explained by the gender difference in social relationship patterns. Previous studies revealed that males were more susceptible to social isolation than females [20, 21] and females usually have bigger social networks, receive more social support, and engage more actively in their social relationships than

males [22–24]. Although further studies are required, our results suggest the need for gender-differentiated suicide prevention policies that focus on different social vulnerability factors.

This study also found that regional variables related to physical exercise and park availability can affect a reduction in the suicide rate. Numerous studies reported that increased levels of physical exercise lead to a reduction in stress and depressive disorders that may be related to suicide [25, 26]. Further, although existing results are mixed, a recent systematic review study reported a statistically significant negative association between physical activity and suicidal ideation [27]. A Korean study also revealed that more physical activity is associated with less suicidal thoughts and attempts in adolescents [28]. In addition, previous studies have reported that parks and green space provide positive effects, leading to fewer suicidal outcomes (suicide mortality, suicide ideation, and suicide attempts) [29–31], while improving health by encouraging physical and social activities [32, 33]. The effects of physical exercise and park availability on suicide rate in this study were more prominent in the youngest age group (aged 10–39) than in other, older, age groups. We considered that this may be associated with outdoor activity patterns in younger people. In other words, young people may be more likely to engage in outdoor and physical activities than older adults, and thus the average time spent using parks and sports facilities may also be higher. Future research is merited to further explore how physical exercise and park use affect suicide in relation to age, and these results can be useful for establishing effective suicide prevention policies for the young generation.

This study also found a positive association between “% current smokers” and suicide rate, and this association was more evident in the older populations (aged 40–59 and aged 60 and older), than in people aged 10–39. Previous studies have addressed smoking as one of the important risk factors of suicide [34] and reported that higher smoking was significantly associated with higher risks of suicidal ideation, planning, and attempt, as well as suicide death [35]. We could not find a positive significant relationship between “% people exhibiting a high risk drinking” and suicide rate at a district level, and even the male population showed a negative association between high risk drinking behavior and suicide rate (Table 3). Because numerous existing studies consistently reported the detrimental effects of drinking on suicidal behavior [36, 37], the results of this study should be addressed carefully. Firstly, this result can be related to Korean socioeconomic culture. Korean men, especially young males, tend to build social capital mainly at the workplace and through economic activities [38], and a group dinner after work is a major part of the drinking culture of Korea. It implies that there is a possibility that more alcohol consumption at group dinners can be beneficial to develop social networks and therefore reduce the social isolation that may lead to an increase in suicide risk. Secondly, the results are estimates at a district level using aggregated data; thus, this association should be examined in greater detail in future studies.

Finally, this study found that the association between social environment characteristics and suicide rate was different by regional urbanicity, with the relationships between social environment characteristics and suicide rate being generally more evident in high-density areas (i.e. more urbanised areas) than other areas (i.e. less urbanised areas). We speculate that higher percentages of young and mid-aged populations present in more urbanised areas, which suggested the isolation experienced in areas with

higher social activity levels might have a detrimental impact on the suicide rate as we have found there are more evident associations of suicide rate with isolation characteristics. In addition, the association between suicide rate and % basic pension was more evident in high- and mid-density areas than in low-density areas, although the “% population aged 65 and older eligible for the basic pension” was highest in low-density areas. We postulate this result can be related to larger relative deprivation in mid- and high-density areas; however, this study provided limited epidemiological evidence, and further investigations should be performed to determine the regional differences in relation to poor economic status of the population aged 65 years and older.

The study had several limitations. Firstly, as we mentioned earlier, the study results have a limited interpretation with respect to the individual-level association between social environment characteristics and suicide. Because the mortality data provided by the Korea National Statistics Office does not include individuals' socioeconomic status and residential addresses, we were unable to examine the specific effects of individual-level socioeconomic status and individual-level environmental exposure data. Therefore, our study results reflected aggregated community-level results. Secondly, collection of several social environment characteristic variables (“% people who regularly participated in religious activities”, “% current smokers”, “% people exhibiting a high risk drinking”, “% population with recognized stress”, and “% population that is obese”) was limited to self-reporting, as these variables were obtained from the Korean Community Health Survey (KCHS) [8]. Although previous studies have reported the good quality of self-reported data, and quality control assessments have been performed for KCHS [39], there may be underlying problems in misclassifications and recall bias. Given these possible shortcomings, our study needs to be complemented by data from future individual-level cohort studies.

Nevertheless, our study has some key strengths that can offset its limitations. Firstly, the study analyzed a large nationwide database of suicide deaths in Korea, with more than 154,866 cases over 11 years. Moreover, we collected data for a total of 12 annual social environment indicators of regional-level socioeconomic, demographic, urbanicity, general health behaviors, and other environmental characteristics, and analyzed the associations between these annual variables and suicide rates using advanced statistical methods. Finally, by sub-population analyses, we found distinct roles these social environment characteristics perform in reducing or increasing suicide rate measured across densification of areas, sex, and age. These results can be used for establishing evidence-based and targeted suicide prevention policies for each sub-population. To our knowledge, this is the largest study investigating the complex roles of social environment characteristics on suicide rate in Korea.

Conclusion

This study examined the association between social environment characteristics and suicide rate in Korea, using nationwide longitudinal data from 2008 through 2018. Our study revealed that lower socioeconomic level and greater isolation were associated with a higher suicide rate. Higher prevalence of smoking and lower physical and religious activities were also associated with a higher suicide rate. The associations were generally more prominent in more urbanised areas. Our results may provide

epidemiological evidence to inform targeted public health interventions for reducing the suicide rate in Korea.

List Of Abbreviations

LMEM linear mixed-effect model

OECD Organisation for Economic Co-operation and Development

WHO World Health Organization (WHO)

Declarations

Ethics approval and consent to participate: Not required. The dataset used in this study was an open dataset to the general public and completely anonymous without any personal information.

Availability of data and materials: The data used in this study are available from the corresponding authors upon reasonable request.

Competing interests: None.

Funding

This study was supported by the Korea Ministry of Environment via the “Climate Change Correspondence Program” (project number: 2014001310007). The funding body played no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Authors' contributions

HJ conceived the idea, designed the research, collected and analyzed data, and wrote the paper. WL and YK reviewed and revised the whole parts of manuscripts. HK supported and counseled all processes of this study.

Consent for publication

Not applicable.

Acknowledgements

Not applicable.

References

1. Organization WH: **Suicide worldwide in 2019: global health estimates**. 2021.

2. **The Global Health Observatory, Mental Health** [<https://www.who.int/data/gho/data/themes/mental-health>]
3. Fässberg MM, Orden KAv, Duberstein P, Erlangsen A, Lapierre S, Bodner E, Canetto SS, Leo DD, Szanto K, Waern M: **A systematic review of social factors and suicidal behavior in older adulthood.** *International journal of environmental research and public health* 2012, **9**(3):722–745.
4. Lee S-U, Park J-I, Lee S, Oh I-H, Choi J-M, Oh C-M: **Changing trends in suicide rates in South Korea from 1993 to 2016: a descriptive study.** *BMJ open* 2018, **8**(9):e023144.
5. Choi K-H, Kim D-H: **Trend of suicide rates according to Urbanity among Adolescents by Gender and Suicide Method in Korea, 1997–2012.** *International journal of environmental research and public health.* 2015, **12**(5):5129–5142.
6. Cheong K-S, Choi M-H, Cho B-M, Yoon T-H, Kim C-H, Kim Y-M, Hwang I-K: **Suicide rate differences by sex, age, and urbanicity, and related regional factors in Korea.** *Journal of Preventive Medicine and Public Health.* 2012, **45**(2):70.
7. Kim AM: **Factors associated with the suicide rates in Korea.** *Psychiatry research* 2020, **284**:112745.
8. Kim D, Jeong, J., Ko, Y., Kwon, Y., Kim, Y.: **The construction of database of community health outcomes and health determinants in the Republic of Korea.** *Public Health Weekly Report, KCDC* 2018, **11**(30):979–983.
9. Shi L, Wu X, Yazdi MD, Braun D, Awad YA, Wei Y, Liu P, Di Q, Wang Y, Schwartz J: **Long-term effects of PM2· 5 on neurological disorders in the American Medicare population: a longitudinal cohort study.** *The Lancet Planetary Health* 2020, **4**(12):e557-e565.
10. Chang S-S, Stuckler D, Yip P, Gunnell D: **Impact of 2008 global economic crisis on suicide: time trend study in 54 countries.** *Bmj* 2013, **347**.
11. Jeon SY, Reither EN, Masters RK: **A population-based analysis of increasing rates of suicide mortality in Japan and South Korea, 1985–2010.** *BMC public health* 2016, **16**(1):1–9.
12. Denney JT, Rogers RG, Krueger PM, Wadsworth T: **Adult suicide mortality in the United States: marital status, family size, socioeconomic status, and differences by sex.** *Social science quarterly* 2009, **90**(5):1167–1185.
13. Lewis G, Sloggett A: **Suicide, deprivation, and unemployment: record linkage study.** *Bmj* 1998, **317**(7168):1283–1286.
14. Värnik P: **Suicide in the world.** *International journal of environmental research and public health.* 2012, **9**(3):760–771.
15. Organization WH: **Suicide in the world: global health estimates.** In.: World Health Organization; 2019.
16. Shin KM, Cho S-M, Hong CH, Park KS, Shin YM, Lim KY, Koh SH: **Suicide among the elderly and associated factors in South Korea.** *Aging & mental health.* 2013, **17**(1):109–114.
17. Trout DL: **The role of social isolation in suicide.** *Suicide and Life-Threatening Behavior.* 1980, **10**(1):10–23.

18. Hall-Lande JA, Eisenberg ME, Christenson SL, Neumark-Sztainer D: **Social isolation, psychological health, and protective factors in adolescence.** *Adolescence* 2007, **42**(166).
19. Näher A-F, Rummel-Kluge C, Hegerl U: **Associations of suicide rates with socioeconomic status and social isolation: Findings from longitudinal register and census data.** *Frontiers in psychiatry* 2020, **10**:898.
20. Vandervoort D: **Social isolation and gender.** *Current psychology* 2000, **19**(3):229–236.
21. Neri AL, Yassuda MS, Fortes-Burgos ACG, Mantovani EP, Arbex FS, de Souza Torres SV, Perracini MR, Guariento ME: **Relationships between gender, age, family conditions, physical and mental health, and social isolation of elderly caregivers.** *International Psychogeriatrics* 2012, **24**(3):472–483.
22. Antonucci TC, Akiyama H: **An examination of sex differences in social support among older men and women.** *Sex roles* 1987, **17**(11–12):737–749.
23. Leavy RL: **Social support and psychological disorder: A review.** *Journal of community psychology* 1983, **11**(1):3–21.
24. Belle D: **Gender differences in the social moderators of stress.** 1991.
25. Grasdalsmoen M, Eriksen HR, Lønning KJ, Sivertsen B: **Physical exercise, mental health problems, and suicide attempts in university students.** *BMC psychiatry* 2020, **20**(1):1–11.
26. Chekroud SR, Gueorguieva R, Zheutlin AB, Paulus M, Krumholz HM, Krystal JH, Chekroud AM: **Association between physical exercise and mental health in 1· 2 million individuals in the USA between 2011 and 2015: a cross-sectional study.** *The Lancet Psychiatry* 2018, **5**(9):739–746.
27. Vancampfort D, Hallgren M, Firth J, Rosenbaum S, Schuch FB, Mugisha J, Probst M, Van Damme T, Carvalho AF, Stubbs B: **Physical activity and suicidal ideation: A systematic review and meta-analysis.** *Journal of affective disorders* 2018, **225**:438–448.
28. Cho K-O: **Physical activity and suicide attempt of south Korean adolescents—evidence from the eight Korea youth risk behaviors web-based survey.** *Journal of sports science and medicine.* 2014, **13**(4):888.
29. Helbich M, De Beurs D, Kwan M-P, O'Connor RC, Groenewegen PP: **Natural environments and suicide mortality in the Netherlands: a cross-sectional, ecological study.** *The Lancet Planetary Health* 2018, **2**(3):e134-e139.
30. Min K-b, Kim H-J, Kim H-J, Min J-y: **Parks and green areas and the risk for depression and suicidal indicators.** *International journal of public health* 2017, **62**(6):647–656.
31. Jiang W, Stickley A, Ueda M: **Green space and suicide mortality in Japan: An ecological study.** *Social Science & Medicine.* 2021:114137.
32. Fong KC, Hart JE, James P: **A review of epidemiologic studies on greenness and health: Updated literature through 2017.** *Current environmental health reports* 2018, **5**(1):77–87.
33. James P, Banay RF, Hart JE, Laden F: **A review of the health benefits of greenness.** *Current epidemiology reports* 2015, **2**(2):131–142.

34. Li D, Yang X, Ge Z, Hao Y, Wang Q, Liu F, Gu D, Huang J: **Cigarette smoking and risk of completed suicide: a meta-analysis of prospective cohort studies.** *Journal of psychiatric research* 2012, **46**(10):1257–1266.
35. Poorolajal J, Darvishi N: **Smoking and suicide: a meta-analysis.** *PloS one* 2016, **11**(7):e0156348.
36. Bernal M, Haro JM, Bernert S, Brugha T, de Graaf R, Bruffaerts R, Lépine JP, de Girolamo G, Vilagut G, Gasquet I: **Risk factors for suicidality in Europe: results from the ESEMED study.** *Journal of affective disorders* 2007, **101**(1–3):27–34.
37. Pompili M, Serafini G, Innamorati M, Dominici G, Ferracuti S, Kotzalidis GD, Serra G, Girardi P, Janiri L, Tatarelli R: **Suicidal behavior and alcohol abuse.** *International journal of environmental research and public health.* 2010, **7**(4):1392–1431.
38. Seok J, Jang E: **The effect of social relationship resource by gender on the life satisfaction of elderly living alone.** *Korean Journal of Gerontological Social Welfare* 2016, **71**(2):321–349.
39. Lee WH, Choo J-Y, Son J-Y, Kim H: **Association between long-term exposure to air pollutants and prevalence of cardiovascular disease in 108 South Korean communities in 2008–2010: A cross-sectional study.** *Science of The Total Environment* 2016, **565**:271–278.

Figures

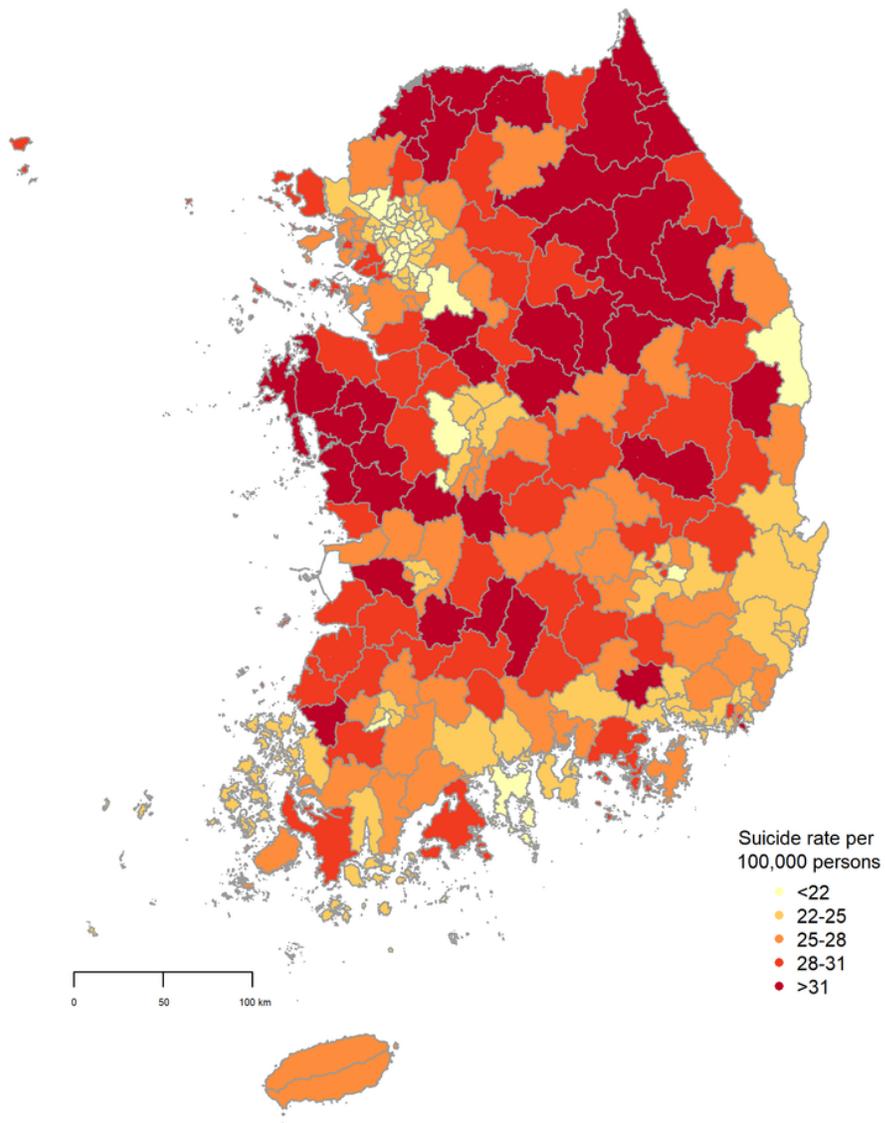


Figure 1

Geographical distribution of average suicide rates across 229 districts in Korea during the period 2008-2018.

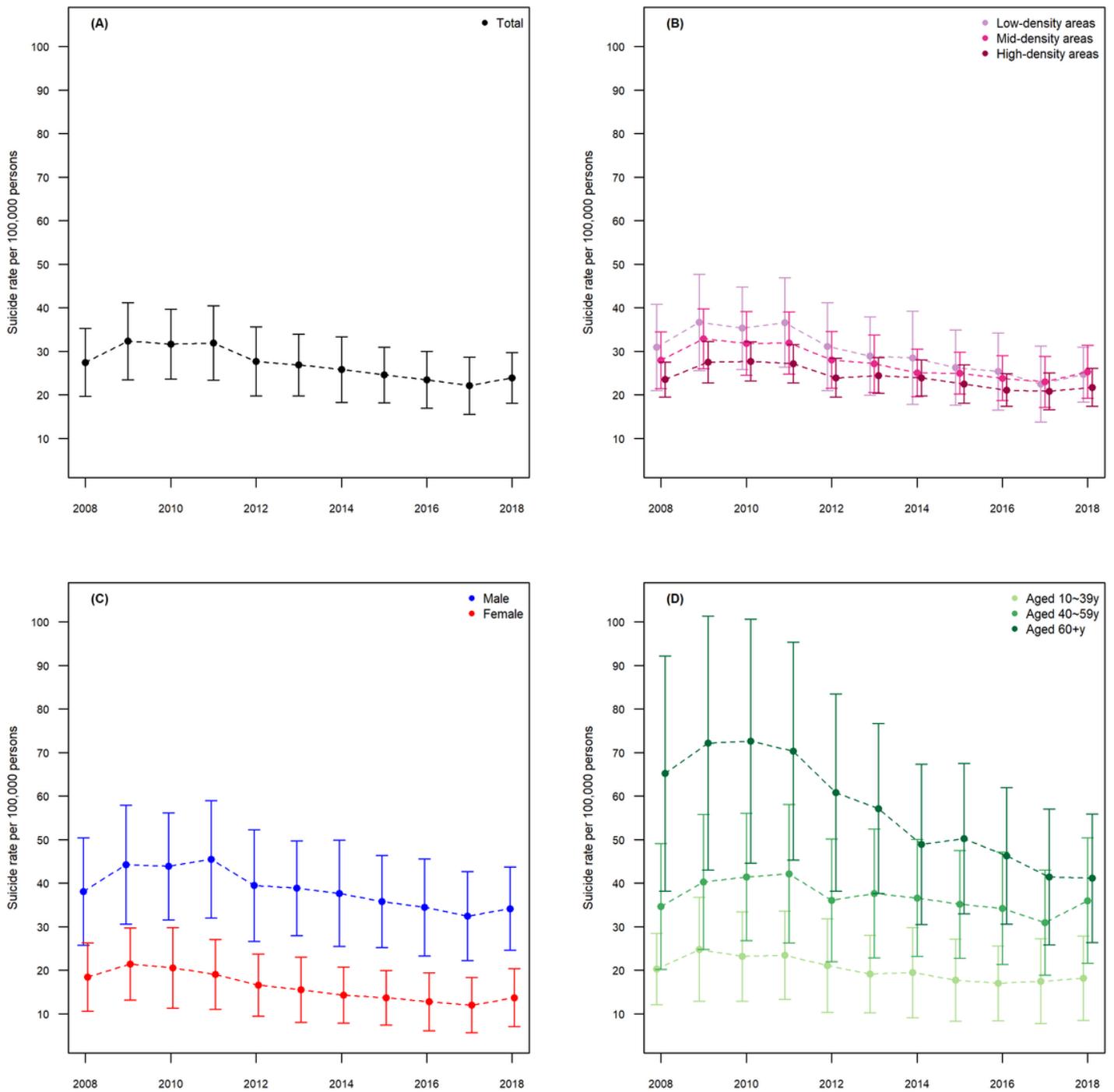


Figure 2

Annual trend of suicide rate in the total population and for each sub-population: (A) Total population, (B) Areas divided by population density, (C) Sex, and (D) Age groups.

Supplementary Files

This is a list of supplementary files associated with this preprint. [Click to download.](#)

- [SupplementaryMaterials20210813.docx](#)