



# Changing Seasonal Pattern of Suicides in Korea Between 2000 and 2019

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**Objective** This study aimed to investigate the changing seasonal pattern of suicides in Korea between 2000 and 2019.

**Methods** We calculated a seasonal pattern of suicides between 2000 and 2019 using a non-stationary cosinor model. In addition, we estimated the effect of each month on the suicide incidence compared to a reference month, using a generalized linear model with a categorical variable of the month. Then, we visualized the rate ratio curves of suicides by gender, age group, and subperiod.

**Results** We observed a seasonal pattern of suicides in Korea with a spring peak and a winter trough. The seasonal ups and downs were most pronounced in suicides among the elderly  $\geq 65$  years. However, the seasonal pattern has not been consistent over the past two decades, with lowering seasonal peaks since 2012. The amplitude of seasonality was also lower in 2010–2019 than in 2000–2009.

**Conclusion** The seasonal pattern of suicides seems to have diminished in Korea in recent years. Thus, we need further studies to investigate climatic and non-climatic factors influencing the seasonality of suicides and the consequence of the change.

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**Keywords** Cosinor; Seasonality; Suicide; Time-series analysis; Trend.

## INTRODUCTION

Suicide has been one of Korea's most serious public health and social issues.<sup>1</sup> The suicide rate in Korea increased by more than 5% per year until 2010.<sup>2</sup> After peaking at 31.7 per 100,000 in 2011, suicides decreased steadily to 26.9 per 100,000 in 2019.<sup>3</sup> However, the suicide rate remains the highest among the Organization for Economic Cooperation and Development (OECD) countries.<sup>4</sup> In addition, in Korea, suicide is two times more common in men than in women, and the suicide rate is particularly high among the elderly.<sup>5</sup> Suicide in Korea has drawn attention because of the remarkably high rate of suicide in an ethnically and geographically homogeneous population.<sup>1</sup> Thus, researchers have suggested various cultural, economic, and biological factors contributing to this phenomenon.<sup>6,7</sup>

The seasonality of suicides has been prominent in the temperate zone with distinct seasonal change. Several studies have demonstrated seasonal ups and downs in the incidence of suicide, with an increase in spring and early summer followed by a decrease in winter.<sup>8,9</sup> Researchers have speculated that circadian misalignment due to lengthening days between winter and spring might trigger the spring surge of suicide.<sup>10,11</sup> In addition, seasonal fluctuations in temperature, humidity, and agricultural activities might be underlying mechanisms for the seasonality of suicides.<sup>12-14</sup> However, despite evidence for suicide seasonality, some studies have reported a diminished seasonal pattern in Western countries over the past decades.<sup>15-17</sup>

Located in the temperate zone between 33°N and 38°N, Korea has four distinct seasons, with average temperatures ranging from about 0°C in winter to 24°C in summer.<sup>18</sup> As such, some studies have shown an association between climatic factors and suicides in Korea.<sup>19,20</sup> More recently, two studies elaborately revealed that the incidence of suicides in Korea exhibited a typical seasonal pattern, with a primary peak in spring followed by a secondary peak in late summer or autumn and a trough in winter.<sup>21,22</sup> However, these studies primarily based their results on suicide data in the 1990s, when suicide rates were not as high as today. Furthermore, there is

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no elucidation on the seasonal pattern of suicides in the late 2010s.

As mentioned above, the suicide rates in Korea peaked around 2011 and then began to decline.<sup>2,3</sup> This finding suggests some environmental changes concerning suicide around that time. In particular, considering evidence for diminishing seasonality of suicides in recent years, we need further investigation into whether there was a change in the seasonal pattern of suicides in Korea before and after the early 2010s. Against this background, this study investigated the seasonal pattern of suicides by gender, age group, and subperiod (2000–2009 and 2010–2019) in Korea between 2000 and 2019.

## METHODS

### Data sources and study population

Using the cause of death statistics provided by Statistics Korea's microdata integrated service, we obtained data on the gender, age, and date of death of 248,480 suicide victims between 2000 and 2019.<sup>23</sup> The codes assigned to the cause of death due to suicide were X60–X84 according to the International Statistical Classification of Diseases and Related Health Problems, 10th Revision. From this data, we calculated the number of suicides per month, collecting the number of suicides by gender, age group ( $\leq 34$ , 35–49, 50–64, and  $\geq 65$  years), and period (2000–2009 and 2010–2019) in the same way. The Institutional Review Board of Chonnam National University Hospital (IRB number: CNUH-EXP-2021-047) approved this study.

### Statistical analyses

To investigate whether the seasonal pattern changed from year to year, with larger peaks in some years, we applied a non-stationary cosinor model to data on the number of suicides in 2000–2019 using Markov chain Monte Carlo sampling with 2000 iterations after 500 burn-in. This model decomposes a

time series into trends, seasons, and residuals and generates potentially flexible seasonal estimates.

In addition, we estimated the rate ratio (RR) of suicides for all 11 months vs. the month in which the estimated number of suicides was lowest, using a generalized linear model with a Poisson distribution. Finally, we generated the RR curves of suicides, indicating the effect of each month on the incidence of suicides compared to the reference month, in 2000–2009, 2010–2019, and 2000–2019. We treated the peak RR as a value representing the amplitude of seasonality.

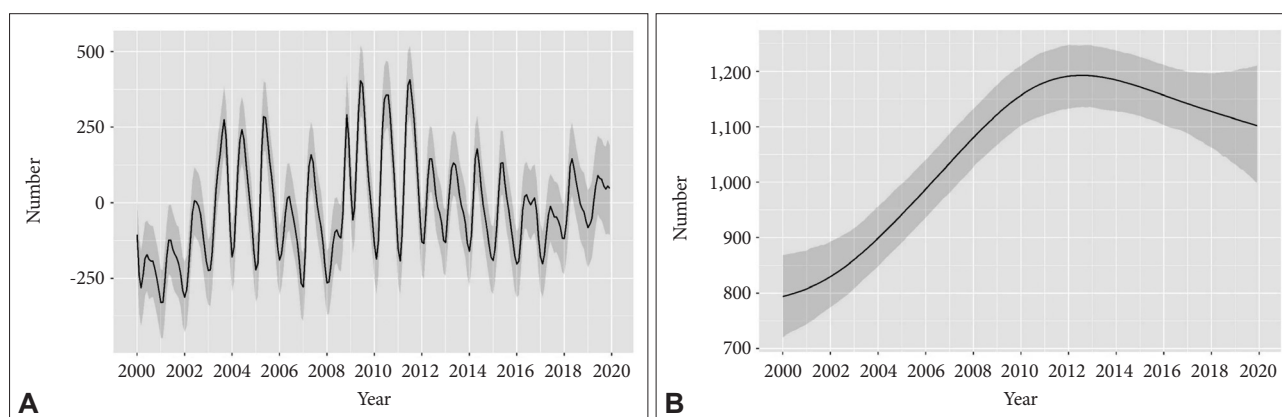
For all statistical analyses and graphics, we used R software, ver. 4.0.3 (R Development Core Team, Vienna, Austria) with the `nscosinor()` and `monthglm()` function in the `season` package, ver. 0.3.13.<sup>24–26</sup>

## RESULTS

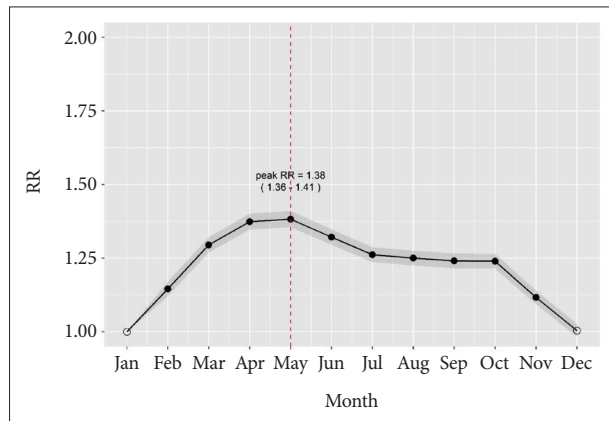
Of the 248,480 suicides in 2000–2019, there were 140,432 in 2010–2019, an increase from 108,048 in 2000–2009. In 2000–2009, 72,219 were men (66.84%) and 35,829 were women (33.16%). The number of suicides by age group was 24,048 (22.26%) in  $\leq 34$ , 31,021 (28.71%) in 35–49, 24,512 (22.69%) in 50–64, and 28,467 (26.35%) in  $\geq 65$ . In 2010–2019, 97,929 (69.73%) were men and 42,503 (30.27%) were women. The number of suicides by age group was 25,712 (18.31%) in  $\leq 34$ , 38,466 (27.39%) in 35–49, 38,039 (27.09%) in 50–64, and 38,215 (27.21%) in  $\geq 65$ .

Figure 1 depicts the non-stationary seasonal pattern and nonlinear trend of suicides in 2000–2019. The seasonal peaks have been relatively lower since 2012 than before (Figure 1A), and the trend also peaked around 2012 (Figure 1B). The estimated mean amplitude is 133.54 with the 95% confidence interval (CI) between 119.91 and 147.20, indicating that, on average, there were an extra 134 deaths per month in the spring peak compared to the year-round average.

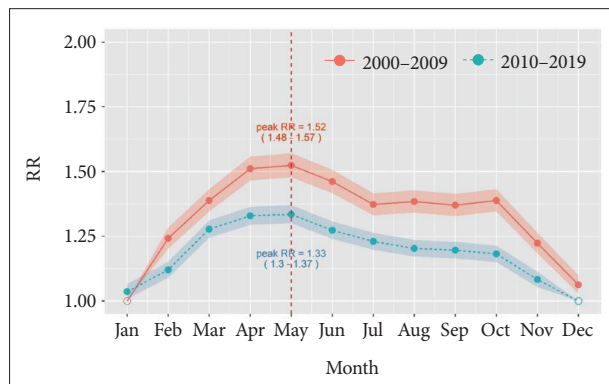
Figure 2 shows the RR curve of suicides in 2000–2019. A



**Figure 1.** Seasonality and suicide trends in Korea in 2000–2019 from a non-stationary cosinor model. The shaded area indicates the 95% confidence intervals. A: Seasonality. B: Trend.



**Figure 2.** Rate ratio (RR) curve of monthly suicides in Korea in 2000–2019 from a generalized linear model with a categorical variable of the month. The dark circles represent the significantly higher RR of suicides compared to January. The shaded area indicates the 95% confidence intervals. The vertical dashed line indicates the month of peak RR.



**Figure 3.** Rate ratio (RR) curves of monthly suicides in Korea in 2000–2009 and 2010–2019 from generalized linear models. The solid and dashed lines represent the RR of suicides in 2000–2009 and 2010–2019, respectively. The dark circles represent the significantly higher RR of suicides compared to that of a reference month (January in 2000–2009 and December in 2010–2019). The shaded area indicates the 95% confidence intervals. The vertical dashed line indicates the month of peak RR.

seasonal pattern of suicides showed a trough in January and a peak in May (peak RR [95% CI]=1.38 [1.36–1.41]) over the past 20 years. Figure 3 shows the RR curves of suicides in 2000–2009 and 2010–2019 together. The trough of suicides was in January 2000–2009 and December 2010–2019. The peak of suicide was in May in 2000–2009 and 2010–2019, but the peak RR was lower in 2010–2019 (peak RR [95% CI]=1.33 [1.30–1.37]) than in 2000–2009 (peak RR [95% CI]=1.52 [1.48–1.57]). Figure 4 shows the RR curves of suicides by gender and age group. In women and those aged ≥65, there was a secondary peak in October in addition to the spring peak (Figure 4B and F). Among the age groups, the peak RR was highest in those aged ≥65 (peak RR=1.97 [2000–2009] and 1.57 [2010–2019]) (Figure 4F), while the lowest was in those

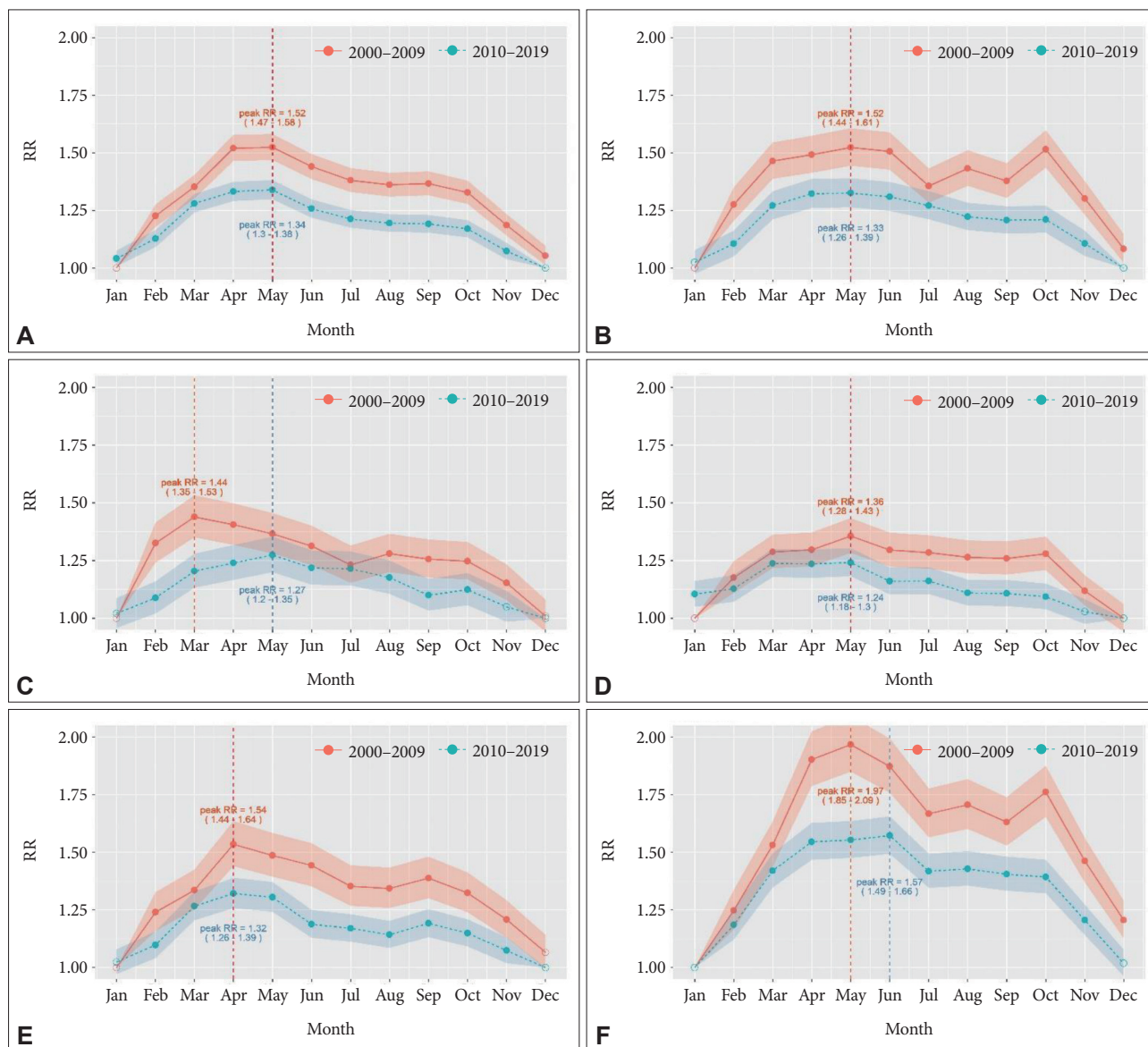
aged 35–49 (peak RR=1.36 [2000–2009] and 1.24 [2010–2019]) (Figure 4D). In all gender and age groups, the peak RR was lower in 2010–2019 than in 2000–2009.

## DISCUSSION

This study investigated seasonal patterns of suicides in Korea over the past 20 years. Regardless of gender, age, and sub-period, the incidence of suicides showed seasonal ups and downs, with a rapid increase in spring and a decrease in winter. In particular, the seasonal pattern was most pronounced in suicides among the elderly ≥65. However, we observed an inconsistent seasonal pattern over the past two decades with lowering seasonal peaks since 2012. As a result, this study shows a typical seasonal pattern in suicides in Korea, which has been diminishing over the past decade.

We observed a typical seasonal pattern of suicides in Korea with a spring peak and a winter trough. Several bioclimatic factors, including sunlight, temperature, humidity, and altitude, have been associated with the seasonality of suicides.<sup>27–29</sup> In particular, researchers have suggested that the abrupt circadian phase-shifting caused by the increased light exposure in spring is a plausible underlying mechanism of the spring surge of suicide.<sup>10,11</sup> According to the circadian rhythm model, the misalignment between the endogenous and environmental circadian rhythms could lead to mood dysregulation in susceptible individuals, consequently contributing to the spring surge of suicide and mania.<sup>10,11</sup> Considering that in Korea, the average sunshine hours increase rapidly from about 550 hours in winter to about 700 hours in spring, and then decrease to about 550 hours in summer due to the rainy season,<sup>30</sup> the circadian rhythm model can explain the seasonal pattern of suicides in Korea. In this respect, managing circadian rhythms in high-risk groups during winter may be an effective strategy to suppress the spring surge of suicides.

The seasonal patterns of suicides are heterogeneous across regions in shape, amplitude, and temporal changes, suggesting a significant influence of demographic and socio-economic conditions on suicide seasonality.<sup>8,22</sup> In the present study, the seasonal amplitude of suicides was seemingly different among the age groups. The most pronounced seasonal ups and downs in suicides were among the elderly ≥65 years; particularly in 2000–2009, the peak RR value for the age group was very high, nearly 2 in May (Figure 4F). This result is largely consistent with the findings of Yang et al.<sup>21</sup> and Yu et al.<sup>22</sup> Considering that older people are less socially active and physically debilitated, physical maladaptation to seasonal changes and circadian rhythm dysregulation might play a more significant role in suicides among the elderly. In this respect, the government should implement suicide prevention measures for the elder-



**Figure 4.** Rate ratio (RR) curves of monthly suicides among men, women, and age groups in Korea from generalized linear models. The solid and dashed lines represent the RR of suicides in 2000–2009 and 2010–2019, respectively. The dark circles represent the significantly higher RR of suicides compared to a reference month (January or December). The shaded area indicates the 95% confidence intervals. The vertical dashed line indicates the month of peak RR. A: Men. B: Women. C: Age  $\leq 34$  years. D: Age 35–49 years. E: Age 50–64 years. F: Age  $\geq 65$  years.

ly more intensively during the spring. In addition, from the perspective of the circadian rhythm model, further studies on the seasonality of mood disorders by age groups can help understand the differential seasonal effect on suicides among young and older adults.<sup>31,32</sup>

The present study aimed to investigate the changing seasonal pattern of suicides in Korea between 2000 and 2019 using a non-stationary cosinor model and Poisson regression models. Before this study, two recent studies delineated the seasonal pattern of suicides in Korea. With harmonic analysis, Yang et al.,<sup>21</sup> Hong Kong researchers, analyzed all suicide

deaths in Korea in 1991–2015. Another is a multinational study by Yu et al.,<sup>22</sup> including data on suicide deaths in six metropolitan cities in Korea in 1992–2013. Both studies demonstrated a primary peak of suicides in spring followed by a secondary peak in autumn, which is broadly consistent with the present study's findings.<sup>21,22</sup> However, the former study observed a diminishing seasonal pattern of suicides since 2006–2010,<sup>21</sup> while the latter found little change before and after 2000.<sup>22</sup> These findings imply that some change in the seasonal pattern of suicides would have occurred in Korea since the late 2000s or early 2010s.

In this study, we found a decreasing seasonal amplitude of suicides in the 2010s (Figure 1A and 3). This finding agrees with views of diminishing suicide seasonality in the modern era.<sup>15-17</sup> Thus, we speculated some explanations for this phenomenon in Korea. First, considering that Korea's suicide rate increased rapidly in the 2000s but gradually decreased since peaking around 2011,<sup>2,3</sup> there may be a temporal correlation between the decrease in suicide rates and the diminishing seasonal pattern of suicides. In that regard, efforts to prevent suicides may have suppressed the spring surge of suicide in the 2010s.<sup>33</sup> Second, the greater effect of non-climatic factors such as socio-economic conditions on suicides might dilute the seasonal effect in recent years.<sup>34,35</sup> Third, there may have been some changes in climatic conditions that could affect the seasonality of suicides since the 2000s.<sup>36</sup> We need further research to explore climatic and non-climatic factors contributing to changing seasonal patterns of suicides in Korea.

This study had some methodological limitations. First, we generated the seasonal pattern of suicides using monthly rather than weekly data. Therefore, we could not detect other minor peaks of suicide in more detail. Second, this study did not statistically compare seasonal patterns of suicides in the 2000s and 2010s. Third, this study did not address the effect of socio-economic conditions, including education, income levels, or celebrity suicides, closely related to suicide, on the seasonal pattern of suicides.

In conclusion, suicides in Korea over the past two decades have exhibited a typical seasonal pattern with a spring peak and a winter trough, most pronounced in suicides among the elderly. However, the amplitude of seasonality has been diminishing overall in recent years. Therefore, further studies could investigate factors contributing to the seasonal pattern of suicides in Korea and the consequences. Understanding the seasonal patterns of suicides could help establish clinical interventions and mental health policies to effectively prevent suicide.

### Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

### Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

### Author Contributions

Conceptualization: Hee Jung Nam, Seunghyong Ryu. Data curation: Hee Jung Nam, Hyun-Bo Sim. Formal analysis: Seunghyong Ryu. Funding acquisition: Seunghyong Ryu. Project administration: Seunghyong Ryu. Supervision: Ju-Yeon Lee, Jae-Min Kim. Writing—original draft: Hee Jung Nam, Hyun-Bo Sim, Seunghyong Ryu. Writing—review & editing: Sung-Wan Kim.

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