Does the environment matter?; Effect of environmental factors on COVID-19 transmission in the Republic of Korea

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Short Report

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Abstract

Background: Corona virus disease 2019 (COVID-19) has been declared a global pandemic and is a major concern of public health worldwide. In this study, we aimed to determine the role of environmental factors such as climate and air pollutants in the transmission of COVID-19 in the Republic of Korea.

Methods: We collected epidemiological and environmental data from two regions of the Republic of Korea, namely Seoul metropolitan region (SMR) and Daegu-Gyeongbuk region (DGR) from February, 2020 to July, 2020. Further, we analyzed the data to identify the correlation of each environmental factor with the confirmed cases of COVID-19 on a daily basis.

Results: Among the various environmental parameters, duration of sunshine and ozone level were found to be positively correlated with COVID-19 in both regions. However, the association of temperature variables with COVID-19 transmission showed contradictory results upon comparing the data from SMR and DGR.

Conclusions: In conclusion, our results suggest that the environmental factors could play a crucial role in the transmission of COVID-19. However, it should be noted that statistical bias could arise due to the disease outbreak being confined to a specific area and extensive epidemiological investigation.

Introduction

Since the identification of novel coronavirus (SARS-CoV-2) infection in Wuhan, China in December 2019, it has become the greatest concern among public health issues [1]. A total of 17 million confirmed cases has been reported worldwide as of 31st July, 2020. Over 200,000 novel cases of COVID-19 are being reported every day [2]. SARS-CoV-2 has similar or slightly higher reproduction number compared to the Middle East Respiratory Syndrome Coronavirus (MERS) and severe acute respiratory syndrome coronavirus 1 (SARS-CoV-1) [3]. SARS-CoV-2 infection has spread worldwide due to its highly contagious nature. SARS-CoV-2 infection, also known as coronavirus disease 2019 (COVID-19), is characterized by difficulty in breathing and pneumonia. COVID-19 has also been reported to cause kidney failure and even death in severe cases [4].

Similar to that of other viral respiratory infections, the transmission of COVID-19 could also be affected by environmental factors including climate. Numerous studies have been performed to investigate the effect of meteorological factors on the transmission of COVID-19 in various countries including Brazil [5], China [6,7], Iran [8], Singapore [3], and USA [9]. However, the effect of climate factors on the transmission of COVID-19 remains unclear [10].

Since the first confirmed case of COVID-19 in the Republic of Korea, on 20 January, 2020, a total of 14,305 confirmed cases has been reported as of July 31, 2020. The majority of confirmed cases were classified as domestic cases caused due to communal spread. The wide range of climate parameters such as temperature variables, amount of rainfall and relative humidity in the Republic of Korea makes it a suitable place to study the effect of the environment on the spread of COVID-19. Therefore, in this study, we aimed to investigate the role of environmental factors, such as climate and air pollutants in the transmission of COVID-19 by analyzing the relationship between these variables with the confirmed COVID-19 cases in the Republic of Korea on a daily basis.

Results

During our study period, a total of 12,031 confirmed cases of COVID-19 were reported to be caused due to communal spread. Among these cases, 3,010 (25.0%) and 7,998 (66.5%) cases were from SMR and DGR, respectively. Figure 1 shows daily confirmed cases in SMR and DGR. An explosive epidemic outbreak occurred due to religious gatherings between February and March in DGR. Apart from DGR, there were several major cases of local cluster infections in SMR, and the number of confirmed cases has remained relatively constant in SMR since April.

Table 1 summarizes monthly variations in various environmental parameters in SMR and DGR. As mentioned previously, there was a large difference in temperature between months. There was no significant difference in meteorological parameters between SMR and DGR with the exception of the month of July. The levels of carbon monoxide, nitrogen dioxide, and sulfur trioxide in the air were higher in SMR, and ozone was higher in DGR. However, there was almost no difference in the levels of PM_{10} and $PM_{2.5}$ between two regions.

Table 2 summarizes the relationship between the environmental factors and daily confirmed cases of COVID-19. Among the 16 environmental parameters, 11 and 10 parameters were found to be significantly correlated with confirmed COVID-19 cases in SMR and DGR, respectively. Further, duration of sunshine and ozone, were the only two parameters to commonly affect COVID-19 in both regions. When we compared the data from SMR and DGR, we obtained contradictory results in case of temperature variables and atmospheric pressure.

Discussion

In our study, various variables were included to clarify the relationship between the environment and confirmed COVID-19 cases. We found that duration of sunshine and ozone level were found to be positively correlated with the spread of COVID-19 in two selected regions. Ratnesar-Shumate et al. reported that sunlight rapidly inactivates SARS-CoV-2 on surfaces [11]. However, our findings contradicted the results of the previous study. Although we were unsure about how sunlight affected the spread of COVID-19, we hypothesized that the increase in the risk of exposure to SARS-CoV-2 could be attributed to the increase in outdoor activity [12], resulting in an increase in spread rather than inactivation of the virus by sunlight. Further, we analyzed the effect of air pollutants on the spread of COVID-19, and found that there was no or inverse correlation between COVID-19 transmission and air pollutants with the exception of ozone. This suggests that air pollutants could not be the environmental drivers of COVID-19 transmission.

Numerous studies have reported the strong association between COVID-19 transmission and temperature [3,5,13]. We selected two regions that showed almost similar temperature during the study period; however, contradictory results were observed in temperature variables between the two regions. COVID-19 transmission increased as the temperature increased in SMR; however, we observed an increase in the number of cases with a decrease in temperature in DGR. As mentioned earlier, there was huge outbreak occurred due to religious events in DGR between February and March, 2020. An extensive epidemiological investigation was performed for members who participated in this event and for individuals who were in close contact with this group. Following the outbreak in DGR, Koreans have been strictly following strategies to maintain personal hygiene, including wearing a mask, use of hand sanitizers, and social distancing, and only a few cases of local cluster and sporadic infections in SMR and DGR were reported. Extensive epidemiological investigation revealed a large number of confirmed cases in DGR. This sudden increase in the number of confirmed cases during a short period of time would result in a bias in the statistical results with respect to temperature variables. Due the rapid transmission of COVID-19 and extensive epidemiological surveillance [14,15], numerous outbreaks could occur due to religious events or social gatherings. Therefore, one should consider that a large number of confirmed cases identified due to the above situations would have a great influence

on the analysis of correlation between the environmental factors and the transmission of the disease, resulting in false negative results.

Despite the significant results demonstrating the effect of environmental factors on COVID-19, there were several limitations in our study. First, the classification of locally infected cases and imported cases could have been affected by the process used for epidemiological investigation. Therefore, the number of confirmed cases due to communal infection may not be accurate, although we collected the epidemiological data from KCDC. Second, in the early days of the COVID-19 spread, there were not enough molecular tests to diagnose COVID-19, therefore, the impact of the environmental factors might not be effectively reflected. Third, we could not consider individual health factors in statistical analyses, such as personal hygiene or exposure risk to COVID-19.

The environment plays a significant role in the regional spread of COVID-19, and our results demonstrated that the duration of sunshine and ozone level were positively correlated to the transmission of COVID-19. However, due to of the infection rate of COVID-19 and massive global efforts in terms of epidemiological investigations, outbreaks or large cluster infection can be identified in multiple population groups in a specific area, which can create a bias in statistical results. Although COVID-19 epidemiological data have been collected globally, we have been exposed to this pandemic for only eight months. For the aforementioned reasons, further studies should be conducted to confirm the relationship between the environmental factors and transmission of COVID-19 with sufficient epidemiological data over a longer duration of time.

Methods

Study area and confirmed COVID-19 cases

The Republic of Korea lies between latitudes 33° and 39°N, and longitudes 124° and 130°E. It tends to have a humid continental and subtropical climate, and typically exhibits large seasonal temperature differences. We selected two regions in the Republic of Korea, namely Seoul metropolitan region (SMR) and Daegu-Gyeongbuk region (DGR), which had relatively higher cases of COVID-19. The data for daily confirmed cases of COVID-19 from February 1, 2020 to July 31, 2020 were obtained from the website of Korea Centers for Disease Control and Prevention (KCDC; http://www.cdc.go.kr). Our study aimed to exclusively investigate the effect of environmental factors on COVID-19 transmission, therefore, we have only included the confirmed cases caused due to communal spread.

Meteorological and air pollution data

The meteorological data were collected from the database of Korea Meteorological Administration (KMA; https://data.kma.go.kr/). The KMA provides high-resolution meteorological information for specific areas on a flexible web-based platform [16,17]. Additionally, we collected the daily records on 10 basic meteorological factors, including average temperature, maximum temperature, minimum temperature, ground temperature, diurnal temperature variation, amount of rainfall, wind speed, relative humidity, atmospheric pressure, and duration of sunshine. Further, information on air pollution across the country was collected from AIRKOREA (http://airkorea.or.kr), which was launched by the Korean Ministry of Environment. This database provides an account of daily air pollutant levels including carbon monoxide, nitrogen dioxide, ozone, sulfur trioxide, PM_{10} and $PM_{2.5}$.

Ethical statement

Data on environmental conditions and COVID-19 confirmed cases were from official reports provided by public database, therefore ethical review was not required.

Statistics

Datasets were analyzed using R version 3.6.3 (http://www.R-project.org/). Descriptive analyses of monthly meteorological factors and air pollutants during the study period were performed for both the regions (SMR, DGR). Student's *t*-test was used to determine the statistical difference in monthly environmental variables between the regions. *P*-value less than 0.05 was considered significant. To examine the relationship between environmental factors and daily COVID-19 confirmed cases, we conducted Spearman rank correlation test and Kendall rank correlation test. Factors were considered to affect COVID-19, if significant difference was observed in both the statistical tests.

Data availability

The data analyzed in this study are available on GitHub at https://github.com/yoorer/COVID_ENV.

Code availability

Codes are available on GitHub at https://github.com/yoorer/COVID_ENV.

Declarations

Acknowledgments

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Author contributions

Lee MK conceived the presented idea and supervised the findings of this work. Kim HR and Kim TH performed the calculations and designed the figures. Lim YK and Kweon OJ wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version.

Conflict of interests

The authors declare no competing interests.

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Tables

Table 1. Monthly COVID-19 infection and environmental parameters (mean ± SD) in Seoul and Daegu

	February			March			April		
Parameters	SMR	DGR	*p*-value	SMR	DGR	*p*-value	SMR	DGR	*p*-value
Total cases (*n*)	199	2,428		824	5,282		299	220	
Average temperature (°C)	1.9 ± 4.4	3.5 ± 3.5	0.117	7.0 ± 3.3	8.1 ± 2.8	0.171	10.4 ± 2.3	11.2 ± 2.5	0.225
Maximum temperature (°C)	-2.7 ± 4.7	-1.7 ± 3.9	0.381	0.9 ± 2.9	1.5 ± 2.6	0.387	4.3 ± 2.3	4.3 ± 2.5	0.961
Minimum temperature (°C)	7.1 ± 4.8	9.4 ± 4.1	0.062	13.2 ± 4.1	14.7 ± 3.8	0.132	16.6 ± 3.2	18.1 ± 3.4	0.101
Ground temperature (°C)	2.8 ± 2.8	4.3 ± 2.8	0.047	7.9 ± 3.3	10.2 ± 3.3	0.009	13.9 ± 2.5	15.3 ± 2.7	0.038
Diurnal temperature variation (°C)	9.8 ± 3.1	11.1 ± 3.6	0.157	12.3 ± 3.3	13.2 ± 3.6	0.295	12.4 ± 3.2	13.7 ± 3.9	0.136
Rainfall (mm)	1.8 ± 4.3	2.0 ± 7.1	0.920	0.5 ± 1.7	0.6 ± 2	0.764	0.6 ± 2.1	1.2 ± 4.1	0.444
Wind speed (m/s)	1.8 ± 0.8	2.1 ± 1.0	0.129	2.2 ± 0.9	2.3 ± 0.9	0.95	2.6 ± 0.7	2.6 ± 0.7	0.998
Relative humidity (%)	69.8 ± 12.1	63.5 ± 16.1	0.095	57.5 ± 11.4	59.6 ± 14.0	0.534	56.9 ± 12.4	53.0 ± 14.5	0.268
Atmospheric pressure (hPa)	1017.2 ± 5.1	1010.2 ± 5.1	<0.001	1010.2 ± 4.7	1001.3 ± 13.0	<0.001	1009.6 ± 3.5	1003.1 ± 3.5	<0.001
Duration of sunshine (hr)	6.2 ± 3.3	6.6 ± 3.2	0.636	8.2 ± 3.2	7.5 ± 3.7	0.460	9.6 ± 3.2	8.8 ± 3.5	0.371
Carbon monoxide (ppm)	0.58 ± 0.14	0.53 ± 0.14	0.206	0.49 ± 0.09	0.42 ± 0.06	<0.001	0.42 ± 0.05	0.39 ± 0.05	0.016
Nitrogen dioxide (ppm)	0.0286 ± 0.0116	0.0185 ± 0.0069	<0.001	0.0244 ± 0.0104	0.0148 ± 0.005	<0.001	0.0182 ± 0.006	0.0115 ± 0.0036	<0.001
Ozone (ppm)	0.0207 ± 0.0073	0.0264 ± 0.0069	0.003	0.0295 ± 0.0062	0.0334 ± 0.0071	0.026	0.0389 ± 0.0058	0.043 ± 0.0082	0.028
Sulfur trioxide (ppm)	0.0036 ± 0.0006	0.0034 ± 0.0006	0.383	0.0035 ± 0.0005	0.0032 ± 0.0005	0.011	0.0032 ± 0.0005	0.0029 ± 0.0005	0.023
PM_{10} (□/□)	40.4 ± 18.5	36.7 ± 16.6	0.415	45.2 ± 9.7	37.1 ± 9.4	0.002	43.2 ± 14.6	38.3 ± 14.1	0.190

$PM_{2.5}$ (□/□)	26.5 ± 14.3	23.9 ± 12.9	0.473	23.9 ± 10.4	19.4 ± 6.2	0.038	19.1 ± 6.8	17.6 ± 6.2	0.388

Table 1. Continued

	May			June			July		
Parameters	SMR	DGR	*p*-value	SMR	DGR	*p*-value	SMR	DGR	*p*-value
Total case (*n*)	448	34		875	18		445	16	
Average temperature (°C)	17.2 ± 2.3	17.8 ± 2.3	0.299	22.7 ± 2	22.9 ± 1.7	0.757	23.2 ± 1.6	22 ± 1.9	0.006
Maximum temperature (°C)	12.5 ± 2.3	12.2 ± 2.6	0.566	18.4 ± 1.6	17.6 ± 1.8	0.108	20 ± 1.5	19 ± 1.9	0.025
Minimum temperature (°C)	22.8 ± 3.3	23.9 ± 3.4	0.202	28 ± 3.0	28.7 ± 2.8	0.333	27.3 ± 2.4	25.8 ± 3.0	0.039
Ground temperature (°C)	20.3 ± 2.9	22.7 ± 3.1	0.003	27.7 ± 3.7	28.4 ± 3.1	0.408	25.7 ± 2.5	25 ± 2.7	0.288
Diurnal temperature variation (°C)	10.3 ± 3.2	11.7 ± 3.8	0.116	9.6 ± 2.6	11 ± 3.2	0.064	7.3 ± 2.4	6.8 ± 3.0	0.522
Rainfall (mm)	3.7 ± 8.8	2.4 ± 6.4	0.491	3.9 ± 10.4	5.1 ± 10.1	0.669	9.1 ± 19.5	13.3 ± 21.1	0.419
Wind speed (m/s)	1.8 ± 0.4	1.9 ± 0.5	0.192	1.8 ± 0.5	1.7 ± 0.4	0.513	1.7 ± 0.6	1.4 ± 0.3	0.015
Relative humidity (%)	74.4 ± 14.5	69.6 ± 12.7	0.168	75.3 ± 8.3	71.6 ± 11.1	0.148	82.5 ± 7.8	86.8 ± 6.7	0.023
Atmospheric pressure (hPa)	1002.9 ± 4.5	997.4 ± 4.8	<0.001	999 ± 4	993.6 ± 4.2	<0.001	999.7 ± 3.6	992.4 ± 12.2	0.003
Duration of sunshine (hr)	6.1 ± 3.9	7.5 ± 3.8	0.139	7.2 ± 4.3	7.6 ± 4.2	0.724	4.6 ± 3.7	3.3 ± 3.7	0.184
Carbon monoxide (ppm)	0.42 ± 0.06	0.36 ± 0.05	<0.001	0.43 ± 0.06	0.37 ± 0.05	<0.001	0.4 ± 0.07	0.37 ± 0.08	0.09
Nitrogen dioxide (ppm)	0.0175 ± 0.0052	0.0097 ± 0.0022	<0.001	0.0168 ± 0.0053	0.0108 ± 0.0026	<0.001	0.0141 ± 0.0039	0.0097 ± 0.0023	<0.001
Ozone (ppm)	0.0374 ± 0.0076	0.0420 ± 0.0078	0.020	0.0450 ± 0.0107	0.0461 ± 0.0089	0.657	0.0319 ± 0.0108	0.0284 ± 0.0085	0.157
Sulfur trioxide (ppm)	0.0031 ± 0.0004	0.0028 ± 0.0004	0.023	0.0031 ± 0.0004	0.0029 ± 0.0005	0.097	0.0028 ± 0.0003	0.0025 ± 0.0003	<0.001
PM_{10} (□/□)	34.4 ± 17.1	35.6 ± 16.9	0.775	36.1 ± 12.2	33.5 ± 15.8	0.469	22.2 ± 11.6	19.3 ± 7.5	0.238

$PM_{2.5}$ (㎍/㎥)	17.6 ± 7.1	17.6 ± 6	0.990	19.6 ± 6.9	17.9 ± 7.2	0.360	13.2 ± 8.2	11.4 ± 5.8	0.311

SMR, Seoul metropolitan region; DGR, Daegu-Gyeongbuk region

Table 2. Summary of correlation results between COVID-19 and environmental parameters (n=182) in Seoul and Daegu

Parameters	SMR				DGR			
	Spearman rank correlation		Kendall rank correlation		Spearman rank correlation		Kendall rank correlation	
	r_S	*p*-value	τ	*p*-value	r_S	*p*-value	τ	*p*-value
Average temperature (°C)	0.507	<0.001	0.350	<0.001	-0.152	0.026	-0.179	<0.001
Maximum temperature (°C)	0.459	<0.001	0.312	<0.001	-0.212	0.002	-0.209	<0.001
Minimum temperature (°C)	0.524	<0.001	0.371	<0.001	-0.112	0.104	-0.135	0.007
Ground temperature (°C)	0.540	<0.001	0.387	<0.001	-0.101	0.144	-0.140	0.005
Diurnal temperature variation (°C)	**0.115**	**0.094**	**0.081**	**0.089**	**0.306**	**<0.001**	**0.228**	**<0.001**
Rainfall (mm)	0.074	0.279	0.056	0.290	-0.174	0.011	-0.138	0.012
Wind speed (m/s)	0.125	0.068	0.089	0.068	0.181	0.008	0.138	0.007
Relative humidity (%)	0.006	0.935	0.006	0.895	-0.302	<0.001	-0.219	<0.001
Atmospheric pressure (hPa)	-0.460	<0.001	-0.320	<0.001	0.136	0.048	0.123	0.015
Duration of sunshine (hr)	0.179	0.009	0.121	0.012	0.192	0.005	0.133	0.008
Carbon monoxide (ppm)	-0.330	<0.001	-0.245	<0.001	-0.152	0.026	-0.105	0.06
Nitrogen dioxide (ppm)	-0.251	<0.001	-0.172	<0.001	0.008	0.91	0.014	0.787
Ozone (ppm)	**0.471**	**<0.001**	**0.332**	**<0.001**	**0.204**	**0.003**	**0.129**	**0.011**
Sulfur trioxide (ppm)	-0.223	0.001	-0.179	0.001	-0.051	0.458	-0.042	0.476
PM_{10} (㎍/㎥)	-0.046	0.506	-0.031	0.519	0.172	0.012	0.128	0.011
$PM_{2.5}$ (㎍/㎥)	-0.160	0.019	-0.105	0.027	0.028	0.685	0.025	0.616

Note: significantly positive correlated factors on both regions in **bold**

SMR, Seoul metropolitan region; DGR, Daegu-Gyeongbuk region

Figures

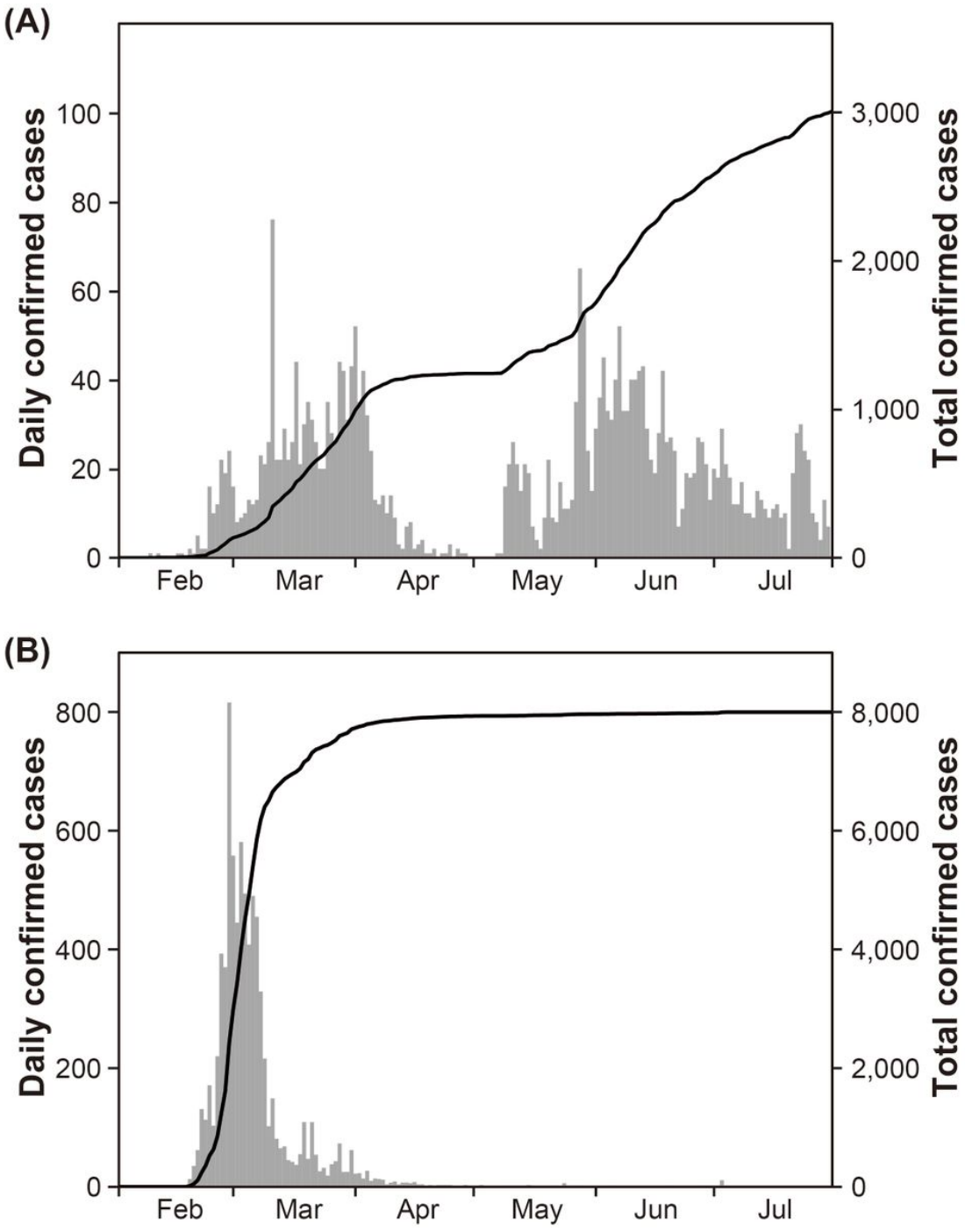

Figure 1

Daily confirmed cases (grey box) and total confirmed cumulative cases (solid line) of COVID-19 in Seoul metropolitan region (A) and Daegu-Gyeongbuk region (B).