Impact of the COVID-19 Epidemic on Healthcare Utilization and Death Among Critically ill Patient

Hye Jin Jang
Department of Medicine

The Graduate School, Yonsei University

Impact of the COVID-19 epidemic on Healthcare Utilization and Death Among Critically ill Patient

Directed by Professor Young Sam Kim

The Doctoral Dissertation
submitted to the Department of Medicine,
the Graduate School of Yonsei University
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

Hye Jin Jang

December 2022

This certifies that the Doctoral Dissertation of
Hye Jin Jang is approved.

Thesis Supervisor : Young Sam Kim

Thesis Committee Member#1: Hyeon Chang Kim

Thesis Committee Member#2: Chung Mo Nam

Thesis Committee Member#3: Gee Young Suh

Thesis Committee Member#4: Sungho Won

The Graduate School
Yonsei University

December 2022

ACKNOWLEDGEMENTS

I would like to thank my dissertation supervisor Professor Young Sam Kim, who is my mentor and academic adviser, made this work possible. I would like to express my deep respect and gratitude to him for helping me not only with my degree but also with my life.

My sincere thanks and respect also goes to my mentor, Professor Moo Suk Park, who provided insightful comments and encouragement as well as an opportunity to join me as a pulmonologist and researcher.

I also appreciate Professor Hyeon Chang Kim, Chung Mo Nam, Gee Young Suh and Sungho Won for valuable advice and guidance but also hard questions. Their perspectives and feedback have helped me to strengthen and widen this work. Also, I thank Professor Bora Lee for her help in statistical analysis.

I am deeply grateful to my family who always showed me infinite and unconditional love, trust, and support. Thanks to the support shown by my parents, I was able to study anywhere and anytime, enjoying the whole process.

Lastly, I sincerely thank to Jae Young Kim, my most precious friend, beloved husband, soul mate, and companion, who share this journey. I am grateful for his dedication to academic debates during this whole difficult course. He gave me a lot of strength, being with me through the brightest moments and the hardest moments.

I will try to be a person who can help others based on the teachings I received during my degree course. Thanks again to everyone.

<TABLE OF CONTENTS>

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Impact of the COVID-19 Epidemic on Healthcare Utilization and Death Among Critically Ill Patients

Hye Jin Jang

Department of Medicine
The Graduate School, Yonsei University

(Directed by Professor Young Sam Kim)

The coronavirus disease 2019 (COVID-19) pandemic is a major public health problem worldwide. If patients across the spectrum of illness and injury avoid seeking hospital care out of concerns about acquiring COVID-19, mortality rates from ailments other than COVID-19 may increase. This study estimated the impact of SARS-CoV-2 in terms of the excess mortality from any cause during the COVID-19 pandemic in the Republic of Korea. The numbers of total deaths and COVID-19–related deaths were counted from January 2020 through May 2022, using public data from the Korean Statistical Information Service (KOSIS) of Statistics Korea. These numbers were compared with nationwide mortality data from January 1, 2015, through December 2019. There were more than 24,000 reported deaths officially across Korea from January 2020 through May 2022. Excess mortality was observed nationwide in March, August, October, November, and December 2020; January, March, July, and August 2021; and October 2021 through May 2022, which was consistent with the epidemic waves in the country.

In this study, the excess mortality during the COVID-19 pandemic was analyzed using the number of deaths over the past 5 years in Korea. Little excess mortality occurred during the analysis at the national level in 2020; however, excess mortality was observed in certain months. After 2021, significant excess mortality occurred at the national level despite decreasing COVID-19 case fatality rates and decreased admissions to intensive care units, which means there was an indirect impact of the COVID-19 pandemic on all-cause

mortality aside from the direct effect of deaths from COVID-19.

Key words : COVID-19; excess mortality; medical resources;

Impact of the COVID-19 epidemic on Healthcare Utilization and Death Among Critically ill Patient

Hye Jin Jang

Department of Medicine
The Graduate School, Yonsei University

(Directed by Professor Young Sam Kim)

I. INTRODUCTION

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first identified at the Huanan Seafood Market, Wuhan, China, in December 2019 [1]. SARS-CoV-2 has spread widely, with a total of 579.5 million confirmed cases and 6.4 million deaths reported worldwide as of July 2022. In the Republic of Korea, the pandemic continues with more than 19.5 million cases and more than 25,000 deaths. In response to this new infectious disease, most countries are focusing on medical care. As a result, high proportions of available medical resources and facilities are designated for use in the management of patients with coronavirus disease 2019 (COVID-19). Therefore, an imbalanced distribution of medical resources allocated for the care of patients with COVID-19 vs. other diseases and injuries is expected. For some patients, scheduled procedures and tests have been postponed or canceled, and it may not be possible to allocate resources, which should have been assigned in a timely manner to other patients. Additionally, emergency procedures may be delayed as negative COVID-19 results are required for hospital admission, which is known as ‘collateral damage.’ A study conducted in Italy found that the COVID-19 outbreak was associated with a remarkable decrease in the rates of percutaneous coronary intervention across the entire spectrum of acute coronary syndrome, which might have other important clinical consequences,

including increased risk of heart failure or sudden cardiac death [2]. Other research also demonstrated a significant decrease in acute coronary syndrome–related hospitalization rates across several cardiovascular centers in northern Italy during the early days of the COVID-19 outbreak [3]. Similarly, a drastic decrease in the number of elective neurosurgical procedures was reported, resulting in these patients being put at risk of deterioration over time and delayed presentation to hospital with progressed disease [4].

These clinical conditions resulting from delays or failure to seek or receive care for acute emergencies for non–COVID-19 medical conditions have collectively been termed the 'corona collateral damage syndrome (CCDS)' [5]. Strict lockdowns and restrictions were proposed by the Public Health Agency in Korea. In particular, the older adults were advised to stay at home, as well as avoid social gatherings and public transportation [6]. Therefore, with an overburdened healthcare system and reduced access by the general public to medical, social, and informal care, new conditions may not be diagnosed in a timely manner, and existing health conditions may worsen [6].

This study analyzed changes in mortality rates and intensive care unit (ICU) admission in Korea before and after the COVID-19 pandemic.

II. MATERIALS AND METHODS

1. Study Design

I conducted a retrospective study to evaluate excess mortality during the COVID-19 pandemic in Korea. The reference period before the COVID-19 pandemic was from January 1, 2015, through December 31, 2019, and the monthly and regional mortality rates for 5 years were analyzed.

The COVID-19 outbreak period for comparison was from January 1, 2020, through December 31, 2021, reflecting the fact that the first case occurred in the Republic of Korea was confirmed on January 20, 2020, and the first confirmed COVID-19–related death

occurred on February 20, 2020. The mortality rate during the outbreak period (2020-2021) was analyzed and compared with the data during the reference period.
P-score was defined as the percentage difference between the reported and estimated mortality relative to that determined by a previous study [7].

2. Definition of Excess Mortality and Data Sources

Excess mortality was defined as the difference between the observed numbers and the expected numbers of deaths associated with COVID-19 from 2020 through 2021. The database from which the mortality data were captured collates three categories of data: (1) deaths from all causes at the national and local levels, (2) COVID-19–related deaths at the same levels, and (3) residential registration data. These data were officially provided by the Korean Statistical Information Service (KOSIS) of Statistics Korea [8]. Nationwide data from January 1, 2015, through May 2022 were captured for study purposes. Deaths were considered as related to COVID-19 when occurring in persons whose positive tests for SARS-CoV-2 via real-time polymerase chain reaction were reported to the national COVID-19 surveillance program, which maintains an open-source database and is run by the Korea Centers for Disease Control and Prevention (KCDC) [9]. The data of hospitalized patients—organized by disease group—were collected from the Health Insurance Review and Assessment (HIRA) service [10]. ICU admissions data were obtained from National Health Insurance (NHI) database systems in Korea.

This research protocol was approved by the institutional review board of Severance Hospital, South Korea (IRB No.4-2020-1146). The requirement to obtain informed patient consent was waived owing to the retrospective study design.

3. Statistical Analysis

To estimate the excess deaths, I used a random-coefficient Poisson regression model fitted

to monthly death data from January 2015 through December 2019. It was adjusted for the time point (month) with the region as a random level and the logarithm of the population each month as an offset variable to model the between-region variances. Considering the calendar year (2015-2020) and seasonal category (January-February, March-April, May-June, July-August, September-October, November-December) as covariates, I constructed several with and without the overall fixed-effects term and random-effects terms for intercept and slopes. The overdispersion was assessed by an approximation of an overdispersion parameter, but there was no statistically significant overdispersion detected [11]. Based on a Bayesian information criterion (BIC), the full model, with a random intercept, random slope for the calendar year, and consideration of the seasonal factor, was chosen as the best model that yielded the lowest BIC.

I estimated monthly expected deaths using this model, and the 95% bootstrapped confidence interval (CI) was calculated via 10,000 replicates using a normal approximation [12]. I compared the overall number of estimated excess deaths with the reported numbers of COVID-19–related and all-cause deaths in each region. Statistical analyses were conducted with R, version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria), and p-values <0.05 were considered statistically significant.

The average annual percentage change (AAPC) was calculated using Joinpoint Regression, version 4.9.1.0 (April, 2022; National Cancer Institute, Bethesda, MD, USA).

III. RESULTS

1. Excess Mortality and COVID-19–Related Mortality

(1) Excess Deaths by Year

Table 1 shows the yearly estimated mortality and excess mortality, along with the number of confirmed cases of COVID-19 in 2020, 2021, and January through May 2022. In 2020,

there were 304,948 reported deaths and 1,231 excess deaths, which was within the 95% CI (−22 to 2,484). As the number of confirmed cases increased, the number of excess deaths increased to 9,460 (95% CI, 7,882 to 11,044; P-score, 1.03) in 2021 and 36,825 (95% CI, 36,002 to 37,646; P-score, 1.28) in 2022.

Table 1. Yearly estimated and excess mortality during the COVID-19 outbreak in the Republic of Korea (2020.01-2022.05).

Region	Confirmed cases (N)	Total deaths		
		Estimated deaths (N, 95% CI)	Reported deaths (P-score)	Total excess deaths (N, 95% CI)
Nationwide	18,103,334	744124 (740466, 747778)	791640 (1.06)	47516 (43862, 51174)
Year				
2020	60,726	303717 (302464, 304970)	304948 (1)	1231 (-22, 2484)
2021	570,069	308314 (306730, 309892)	317774 (1.03)	9460 (7882, 11044)
2022 (~May)	17,472,539	132093 (131272, 132916)	168918 (1.28)	36825 (36002, 37646)

Source of reported death data: Korean Statistical Information Service (KOSIS) of Statistics Korea
Source of confirmed case data: Korean Centers for Disease Control and Prevention (KCDC)

(2) Excess Mortality by Month

Table 2 summarizes that the monthly mortality data from January 2020 through May 2022, with comparisons of the predicted mortality analyzed based on data during the reference period (2015 through 2019). The confirmed cases per month are shown to indicate the epidemic peaks in Korea. The first peak was in March 2020, followed by the second, third, fourth, and fifth peaks in August 2020, December 2020, July 2021, and March 2022, respectively.

Excess mortality was observed nationwide in the months of March, August, October, November, and December 2020; January, March, July, and August 2021; and October 2021 through May 2022. During these periods, there were more actual deaths than estimated deaths. After July 2021, the P-score was maintained at 1.00 or higher, with surging of confirmed cases, especially from October 2021 through April 2022.

March 2022 had the highest P-score (1.68) and the most confirmed cases (9,960,539). Figure 1 depicts the estimated and reported mortality by month with 95% CIs. Figure 2 shows the monthly P-scores.

Table 2. Monthly estimated and excess mortality during the COVID-19 outbreak in the Republic of Korea (2020.01-2022.05).

Region	Confirmed cases (N)	Total deaths		
		Estimated deaths (N, 95% CI)	Reported deaths (P-score)	Total excess deaths (N, 95% CI)
Nationwide	18,103,334	744124 (740466, 747778)	791640 (1.06)	47516 (43862, 51174)
Month				
2020.01	11	25790 (25672, 25909)	28430 (1.1)	2640 (2521, 2758)
2020.02	2,920	25701 (25589, 25813)	25423 (0.99)	-278 (-390, -166)
2020.03* (The 1st epidemic)	6,855	25613 (25507, 25719)	25850 (1.01)	237 (131, 343)
2020.04	979	25526 (25424, 25627)	24674 (0.97)	-852 (-953, -750)
2020.05	703	25438 (25340, 25536)	24346 (0.96)	-1092 (-1190, -994)
2020.06	1,331	25351 (25254, 25447)	23638 (0.93)	-1713 (-1809, -1616)
2020.07	1,506	25265 (25169, 25361)	23989 (0.95)	-1276 (-1372, -1180)
2020.08* (The 2nd epidemic)	5,641	25179 (25082, 25276)	25289 (1)	110 (13, 207)
2020.09	3,865	25094 (24994, 25194)	24352 (0.97)	-742 (-842, -642)
2020.10*	2,700	25007 (24903, 25111)	26488 (1.06)	1481 (1377, 1585)
2020.11*	7,688	24920 (24812, 25029)	25603 (1.03)	683 (574, 791)
2020.12* (The 3rd epidemic)	26,527	24833 (24718, 24948)	26866 (1.08)	2033 (1918, 2148)
2021.01*	17,471	26241 (26096, 26386)	27230 (1.04)	989 (844, 1134)
2021.02	11,467	26151 (26012, 26290)	23795 (0.91)	-2356 (-2495, -2217)
2021.03*	13,415	26003 (25869, 26136)	26550 (1.02)	547 (414, 681)
2021.04	18,927	25912 (25783, 26042)	25077 (0.97)	-835 (-965, -706)
2021.05	18,331	25815 (25688, 25941)	25577 (0.99)	-238 (-364, -111)
2021.06	16,623	25722 (25596, 25847)	24398 (0.95)	-1324 (-1449, -1198)
2021.07* (The 4th epidemic)	41,374	25634 (25509, 25759)	25748 (1)	114 (-11, 239)
2021.08*	53,077	25546 (25420, 25671)	25953 (1.02)	407 (282, 533)
2021.09	59,857	25458 (25330, 25585)	25674 (1.01)	216 (89, 344)

2021.10*	53,415	25369 (25238, 25499)	27775 (1.09)	2406 (2276, 2537)
2021.11*	82,517	25278 (25143, 25412)	28363 (1.12)	3085 (2951, 3220)
2021.12*	183,595	25185 (25046, 25324)	31634 (1.26)	6449 (6310, 6588)
2022.01*	214,818	26611 (26438, 26784)	29686 (1.12)	3075 (2902, 3248)
2022.02*	2,288,497	26517 (26349, 26685)	29189 (1.1)	2672 (2504, 2840)
2022.03* (The 5th epidemic)	9,960,539	26419 (26256, 26583)	44487 (1.68)	18068 (17904, 18231)
2022.04*	4,142,604	26320 (26160, 26480)	36697 (1.39)	10377 (10217, 10537)
2022.05*	866,081	26226 (26069, 26384)	28859 (1.1)	2633 (2475, 2790)

Source of reported death data: Korean Statistical Information Service (KOSIS) of Statistics Korea;
Source of confirmed case data: Korean Centers for Disease Control and Prevention (KCDC)
*The months when there were more actual deaths than estimated deaths. Bold text indicates the epidemic peaks.

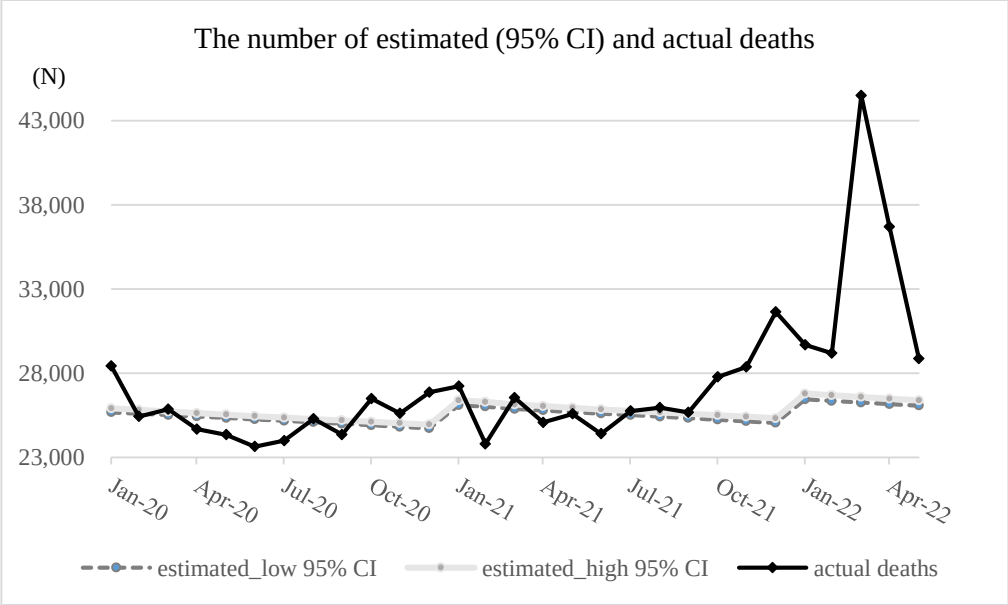

Figure 1. Monthly estimated mortality with 95% confidence interval and actual number of deaths (2020.01-2022.05).

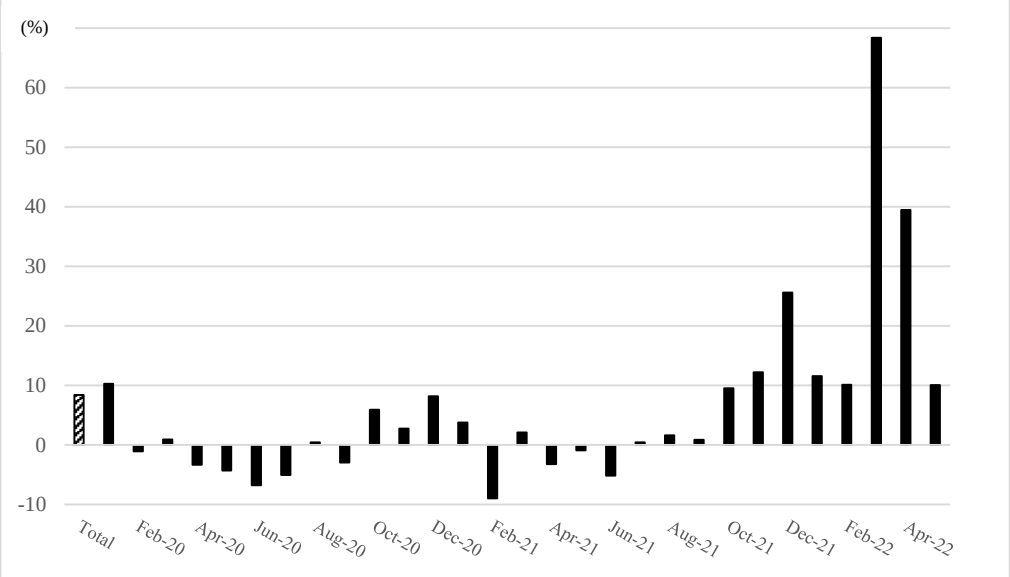

Figure 2. P-score by month (2020.01-2022.05).

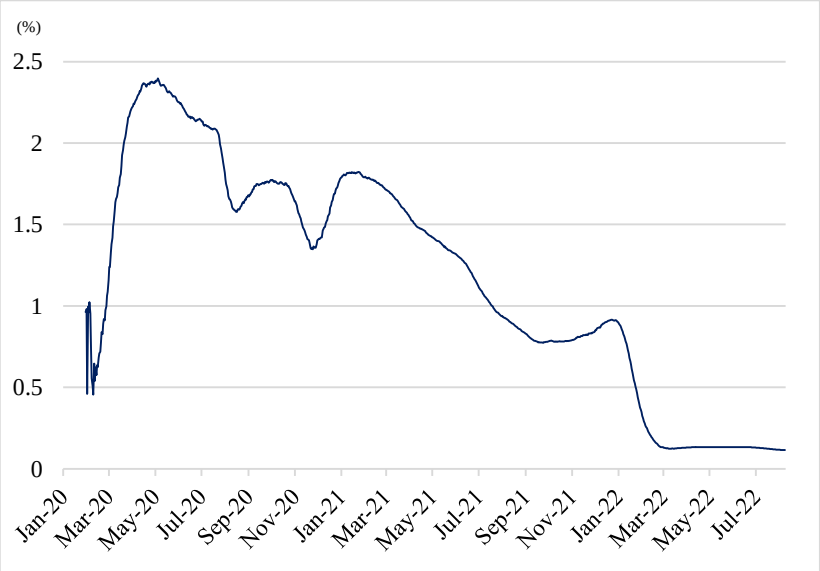

Figure 3. COVID-19 case fatality rate in Republic of Korea (the number of confirmed deaths divided by the number of confirmed cases).

(3) COVID-19 Deaths vs. Non-COVID Deaths Among Overall Excess Deaths

Table 3 shows the proportion of COVID-19–related deaths among total excess deaths. The ratio of excess deaths to reported COVID-19–related deaths was 1.97 overall, with 24,160 COVID-19–related deaths and 47,516 total excess deaths. The ratio was 1.61 during the first epidemic wave (March 2020). A negative number of excess deaths indicates that the actual number of reported deaths was lower than the predicted number of deaths. In February 2020, the excess death calculation yielded a negative number (−278) despite 16 COVID-19 deaths. After the second epidemic peak, the ratios of excess deaths in August and October of 2020 were 4.23 and 28.48, respectively, with the ratio decreasing until February 2021. After July 2021, there were consistently positive ratios, from 1.00 in September 2021 to 6.63 in October 2021.

After December 2021, the COVID-19 mortality consistently surpassed 1,000 deaths, with 8,172 in March 2022 and 6,564 in April 2022.

Table 3. Deaths caused by COVID-19 among total excess deaths by month in the Republic of Korea (2020.01-2022.05).

	Total excess deaths (N, 95% CI)	COVID-19 deaths (N)	Ratio between excess deaths to reported COVID-19 deaths
Nationwide	47,516 (43862, 51174)	24,160	1.97 (1.82, 2.12)
2020	1231 (-22, 2484)	950	1.30 (-0.02, 2.61)
2021	9460 (7882, 11044)	5030	1.88 (1.57, 2.20)
2022 (~May)	36825 (36002, 37646)	18,613	1.98 (1.93, 2.02)
Month			
2020.01	2640 (2521, 2758)	0	-
2020.02	-278 (-390, -166)	16	-17.38 (-24.38, -10.38)
2020.03*	237 (131, 343)	147	1.61 (0.89, 2.33)
2020.04	-852 (-953, -750)	93	-9.16 (-10.25, -8.06)
2020.05	-1092 (-1190, -994)	30	-36.40 (-39.67, -33.13)
2020.06	-1713 (-1809, -1616)	12	-142.75 (-150.75, -134.67)
2020.07	-1276 (-1372, -1180)	22	-58.00 (-62.36, -53.64)

2020.08*	110 (13, 207)	26	4.23 (0.50, 7.96)
2020.09	-742 (-842, -642)	93	-7.98 (-9.05, -6.90)
2020.10*	1481 (1377, 1585)	52	28.48 (26.48, 30.48)
2020.11*	683 (574, 791)	63	10.84 (9.11, 12.56)
2020.12*	2033 (1918, 2148)	396	5.13 (4.84, 5.42)
2021.01*	989 (844, 1134)	511	1.94 (1.65, 2.22)
2021.02	-2356 (-2495, -2217)	197	-11.96 (-12.66, -11.25)
2021.03*	547 (414, 681)	138	3.96 (3.00, 4.93)
2021.04	-835 (-965, -706)	111	-7.52 (-8.69, -6.36)
2021.05	-238 (-364, -111)	141	-1.69 (-2.58, -0.79)
2021.06	-1324 (-1449, -1198)	70	-18.91 (-20.70, -17.11)
2021.07*	114 (-11, 239)	98	1.16 (-0.11, 2.44)
2021.08*	407 (282, 533)	201	2.02 (1.40, 2.65)
2021.09	216 (89, 344)	215	1.00 (0.41, 1.60)
2021.10*	2406 (2276, 2537)	363	6.63 (6.27, 6.99)
2021.11*	3085 (2951, 3220)	839	3.68 (3.52, 3.84)
2021.12*	6449 (6310, 6588)	2146	3.01 (2.94, 3.07)
2022.01*	3075 (2902, 3248)	1192	2.58 (2.43, 2.72)
2022.02*	2672 (2504, 2840)	1303	2.05 (1.92, 2.18)
2022.03*	18068 (17904, 18231)	8172	2.21 (2.19, 2.23)
2022.04*	10377 (10217, 10537)	6564	1.58 (1.56, 1.61)
2022.05*	2633 (2475, 2790)	1382	1.91 (1.79, 2.02)

Source of COVID-19 death data: Korean Centers for Disease Control and Prevention (KCDC)
*The months when the number of actual deaths was greater than the predicted number of deaths. Bold text indicates the epidemic peaks.

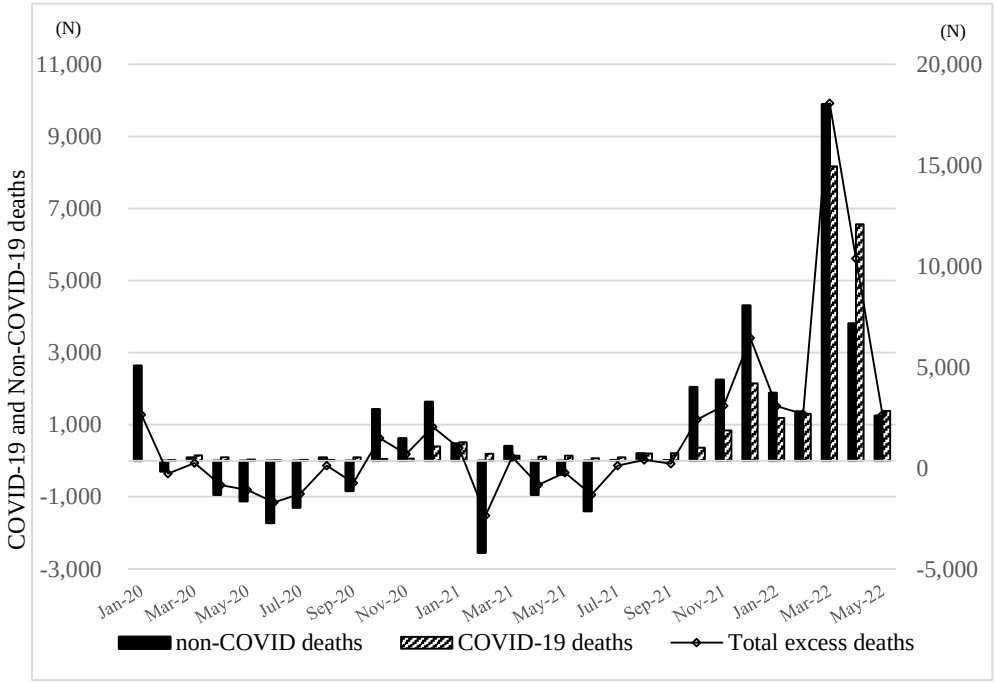

Figure 4. COVID-19 and non-COVID-19 deaths among the excess deaths in the Republic of Korea (2020.01-2022.05).

(4) COVID-19 Mortality by Gender

Table 4 shows the monthly numbers of confirmed cases and deaths, as well as the calculation of the number of COVID-19 deaths divided by the number of confirmed COVID-19 cases shown percentage (%). There was no significant difference in mortality between males and females.

Table 4. The number of confirmed COVID-19 cases and deaths by gender

Sex / Month	Total			MALE			FEMALE		
	Confirm	Death	(%)	Confirm	Death	(%)	Confirm	Death	(%)
Jan-20	11	0	-	8	-	-	3	-	-
Feb-20	2920	17	0.58	1087	-	-	1833	-	-

Mar-20	6855	145	2.12	2811	-	-	4044	-	-
Apr-20	979	85	8.68	447	-	-	532	-	-
May-20	703	23	3.27	443	13	2.93	260	10	3.85
Jun-20	1359	12	0.88	715	8	1.12	644	4	0.62
Jul-20	1505	19	1.26	968	9	0.93	537	10	1.86
Aug-20	5642	23	0.41	2562	12	0.47	3080	11	0.36
Sep-20	3865	89	2.30	1939	45	2.32	1926	44	2.28
Oct-20	2699	51	1.89	1388	31	2.23	1311	20	1.53
Nov-20	7690	62	0.81	3971	27	0.68	3719	35	0.94
Dec-20	26539	374	1.41	13289	173	1.30	13250	201	1.52
Jan-21	17465	520	2.98	8763	255	2.91	8702	265	3.05
Feb-21	11471	183	1.60	5847	97	1.66	5624	86	1.53
Mar-21	13412	128	0.95	6961	62	0.89	6451	66	1.02
Apr-21	18919	97	0.51	9562	46	0.48	9357	51	0.55
May-21	18333	131	0.71	9459	62	0.66	8874	69	0.78
Jun-21	16621	59	0.35	8887	30	0.34	7734	29	0.37
Jul-21	41384	77	0.19	22090	43	0.19	19294	34	0.18
Aug-21	53076	190	0.36	28438	101	0.36	24638	89	0.36
Sep-21	59868	196	0.33	33657	108	0.32	26211	88	0.34
Oct-21	53411	368	0.69	30600	202	0.66	22811	166	0.73
Nov-21	82530	775	0.94	42195	397	0.94	40335	378	0.94
Dec-21	183608	1939	1.06	92130	1017	1.10	91478	922	1.01
Jan-22	214871	1192	0.55	108332	598	0.55	106539	594	0.56
Feb-22	2288747	1303	0.06	1100177	609	0.06	1188570	694	0.06
Mar-22	9961175	8172	0.08	4667065	3846	0.08	5294110	4326	0.08
Apr-22	4142247	6564	0.16	1905485	3145	0.17	2236762	3419	0.15
May-22	865760	1382	0.16	399489	707	0.18	466271	675	0.14

Source of COVID-19 death data: Korean Centers for Disease Control and Prevention (KCDC).

(5) COVID-19 Mortality by Age

Table 5 describes the number and proportion of COVID-19 deaths in patients by age. Most

of the people who died of COVID-19 were over the age of 80 years in all periods except June 2021. The proportion was the highest among older patients, including the value of 33.44% among patients over 80 years old in January 2021. However, there was a decreasing trend over time, despite peaks during certain periods, such as the peak of 15.42% in December 2021. Figure 3 depicts the monthly overall case fatality rate (CFR) data in the whole period.

Figure 5 shows the proportion of COVID-19 deaths by age. In the oldest age group, 58.9% of deaths were COVID-19 deaths. Figure 6 shows CFRs by age, with oldest age group having the highest CFR.

Table 5. The number of confirmed COVID-19 cases and deaths by age.

Age / Month	60-69			70-79			80 or above		
	Confirm	Death	(%)	Confirm	Death	(%)	Confirm	Death	(%)
21-Jan	2641	61	2.31	1241	135	10.88	903	302	33.44
21-Feb	1756	17	0.97	802	47	5.86	451	107	23.73
21-Mar	1963	15	0.76	824	45	5.46	376	60	15.96
21-Apr	2791	15	0.54	1186	38	3.2	572	40	6.99
21-May	2515	15	0.6	985	30	3.05	406	77	18.97
21-Jun	1771	14	0.79	515	23	4.47	165	18	10.91
21-Jul	2591	19	0.73	714	17	2.38	281	27	9.61
21-Aug	4362	43	0.99	1363	37	2.71	630	56	8.89
21-Sep	4985	47	0.94	1924	41	2.13	902	59	6.54
21-Oct	6119	62	1.01	2748	96	3.49	1747	163	9.33
21-Nov	15519	108	0.7	7764	201	2.59	4764	435	9.13
21-Dec	33214	326	0.98	13587	535	3.94	6292	970	15.42
22-Jan	13277	219	1.65	4744	357	7.53	3552	540	15.2
22-Feb	176030	125	0.07	68473	281	0.41	45847	820	1.79
22-Mar	998086	798	0.08	461955	1761	0.38	279780	5161	1.84
22-Apr	468766	713	0.15	248954	1372	0.55	151168	4095	2.71
22-May	91523	154	0.17	49260	298	0.6	29471	806	2.73

Age / Month	30-39			40-49			50-59		
	Confirm	Death	(%)	Confirm	Death	(%)	Confirm	Death	(%)
21-Jan	2192	3	0.14	2589	3	0.12	3278	16	0.49
21-Feb	1737	0	0.00	1642	4	0.24	2021	7	0.35
21-Mar	2128	1	0.05	2152	0	0.00	2319	5	0.22
21-Apr	2593	0	0.00	3061	0	0.00	3552	4	0.11
21-May	2836	1	0.04	3071	1	0.03	3254	7	0.22
21-Jun	2780	0	0.00	3086	0	0.00	2938	4	0.14
21-Jul	6970	2	0.03	7309	2	0.03	6812	8	0.12
21-Aug	8923	2	0.02	8355	5	0.06	8240	44	0.53
21-Sep	11266	7	0.06	10159	11	0.11	7223	29	0.40
21-Oct	9015	6	0.07	7937	12	0.15	5822	27	0.46
21-Nov	10214	1	0.01	9734	6	0.06	10344	23	0.22
21-Dec	23263	9	0.04	24427	26	0.11	24357	71	0.29
22-Jan	32903	9	0.03	33555	20	0.06	22356	45	0.20
22-Feb	349016	6	0.00	369832	13	0.00	257619	52	0.02
22-Mar	1463421	33	0.00	1533300	93	0.01	1201458	295	0.02
22-Apr	601972	16	0.00	639882	83	0.01	546828	260	0.05
22-May	122844	9	0.01	126962	36	0.03	114804	68	0.06

Age / Month	0-9			10-19			20-29		
	Confirm	Death	(%)	Confirm	Death	(%)	Confirm	Death	(%)
21-Jan	893	0	0.00	1433	0	0.00	2241	0	0.00
21-Feb	638	0	0.00	828	0	0.00	1597	1	0.06
21-Mar	749	0	0.00	979	0	0.00	1921	2	0.10
21-Apr	912	0	0.00	1520	0	0.00	2732	0	0.00
21-May	912	0	0.00	1469	0	0.00	2885	0	0.00
21-Jun	959	0	0.00	1345	0	0.00	3062	0	0.00
21-Jul	2479	0	0.00	4334	0	0.00	9894	2	0.02
21-Aug	3422	0	0.00	5543	0	0.00	12238	3	0.02
21-Sep	3879	0	0.00	5967	0	0.00	13563	2	0.01
21-Oct	4209	0	0.00	6853	0	0.00	8961	2	0.02

21-Nov	7210	1	0.01	9529	0	0.00	7452	0	0.00
21-Dec	20793	2	0.01	19483	0	0.00	18192	0	0.00
22-Jan	25564	0	0.00	35793	0	0.00	43127	2	0.00
22-Feb	297734	2	0.00	329831	1	0.00	394365	3	0.00
22-Mar	1279469	6	0.00	1352843	2	0.00	1390863	23	0.00
22-Apr	448518	8	0.00	481776	5	0.00	554383	12	0.00
22-May	74926	3	0.00	108232	1	0.00	147738	7	0.00

Source of COVID-19 death data: Korean Centers for Disease Control and Prevention (KCDC); CFR, case fatality rate, is the number of COVID-19 deaths divided by the number of confirmed COVID-19 cases during the same period.

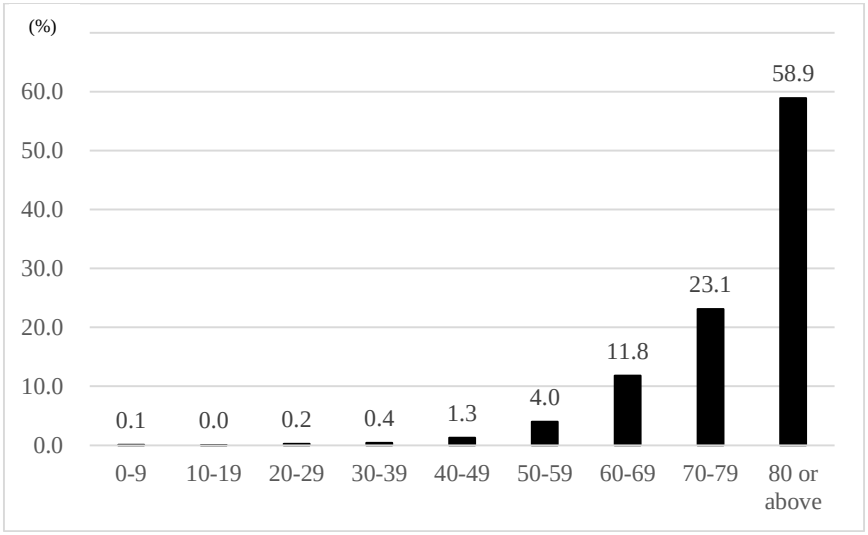

Figure 5. The proportion of COVID-19 deaths by age group (2021.1.1~2022.5.31).

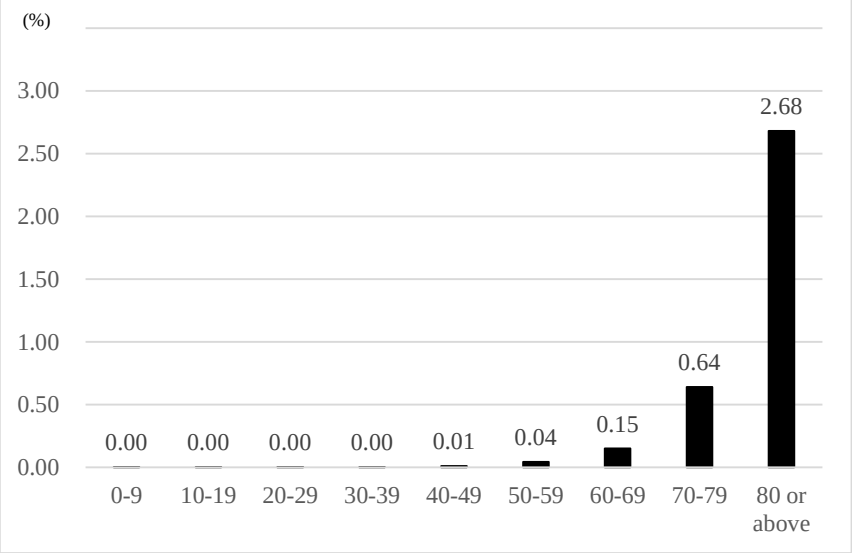

Figure 6. The case fatality rate by age group (2021.1.1~2022.5.31).

(6) Nationwide Mortality Data by Month and Year

Table 6 shows the nationwide monthly mortality data. There was seasonal variation and monthly trends, with mortality increasing during the coldest months (December and January). During the COVID-19 outbreak, a similar trend was observed in 2020; however, the number of deaths significantly increased from the end of 2021. The overall death count reached nearly 30,000, and more than 40,000 of deaths were recorded in March 2022. In 2022, the death count was higher during all months compared with the corresponding data from the pre-pandemic period (2015-2019), except January 2018 had a higher death count than January 2022.

Table 6. Nationwide monthly mortality data.

	2015	2016	2017	2018	2019	2020	2021	2022
January	24,760	24,708	25,902	31,550	27,366	28,430	27,230	29,686
February	23,209	24,601	22,884	25,001	22,918	25,423	23,795	29,189
March	26,493	25,208	24,230	25,252	24,985	25,850	26,550	44,487

April	23,610	22,830	23,142	23,963	23,833	24,674	25,077	36,697
May	22,935	23,125	23,766	23,996	24,756	24,346	25,577	28,859
June	21,345	21,350	21,986	22,596	23,056	23,638	24,398	
July	21,534	22,053	22,245	23,886	23,216	23,989	25,748	
August	21,496	22,604	22,846	23,937	23,707	25,289	25,953	
September	21,375	22,081	22,622	22,906	23,570	24,352	25,674	
October	23,050	23,610	24,624	25,010	25,569	26,488	27,775	
November	22,678	23,333	24,404	24,200	25,412	25,603	28,363	
December	23,410	25,324	26,883	26,523	26,722	26,866	31,634	

Source: Korean Statistical Information Service (KOSIS) of Statistics Korea

2. Changes in Healthcare Utilization During the COVID-19 Outbreak

(1) ICU Admissions by Year and Month

The ICU admissions data from 2015 to 2021 are shown in Table 7. During the pre-pandemic period (2015-2019), the average annual percentage changes (AAPC) of ICU admissions were −0.8 (95% CI, −3.1 to 1.7) and 3.1 (95% CI, 0.8 to 5.5) in March and July. Statistical significance was observed in April, May, July, August, and October. The annual percentage change of ICU admissions was calculated for 2020 and 2021 and compared with the number of ICU admissions in 2019. In 2020, starting during the COVID-19 pandemic, there was a decline in ICU admissions from March except in June. The largest decline occurred in April 2020 (−11.48%)—soon after the declaration of the COVID-19 pandemic. From July 2020 through December 2021 (with a rise in June 2021), there was a steady decline in ICU admissions.

Table 7. ICU admissions by year and month

	2015	2016	2017	2018	2019	2020	2021	AAPC (95% CI)	APC 2020	APC 2021
Jan	40,215	40,648	41,641	44,054	41,998	42,730	37,904	1.7 (-1.1, 4.5)	1.74	-9.75*
Feb	30,336	31,956	32,406	30,713	30,728	31,579	29,385	-0.1 (-3.4, 3.2)	2.77	-4.37*

Mar	36,166	36,153	37,286	35,028	35,370	33,397	34,973	-0.8 (-3.1, 1.7)	-5.58*	-1.12
Apr	33,695	33,607	34,851	34,714	35,647	31,556	33,992	1.5 (0.4, 2.6) ‡	-11.48*	-4.64*
May	33,325	34,916	35,475	35,269	36,265	33,793	33,969	1.8 (0.3, 3.4) ‡	-6.82*	-6.33*
June	29,445	33,538	34,297	33,241	33,904	34,576	34,381	2.8 (-2.4, 8.2)	1.98	1.41
July	32,433	34,926	36,030	36,366	37,014	35,445	34,833	3.1 (0.8, 5.5) ‡	-4.24*	-5.89*
Aug	32,731	34,701	35,488	35,556	35,623	32,468	34,227	2.0 (-0.2, 4.2) †	-8.86*	-3.92*
Sep	31,238	32,414	34,174	32,403	34,085	32,082	31,780	1.8 (-1.3, 4.9)	-5.88*	-6.76*
Oct	33,128	34,507	34,103	34,964	35,467	33,989	33,666	1.5 (0.2, 2.8) ‡	-4.17*	-5.08*
Nov	32,828	34,532	35,102	34,652	35,665	33,281	33,776	1.7 (-0.2, 3.6) †	-6.68*	-5.30*
Dec	32,817	34,332	34,407	33,993	35,269	31,796	31,514	1.4 (-0.4, 3.2) †	-9.85*	-10.65*
Total	398,357	416,230	425,260	420,953	427,035	406,692	404,400	1.5 (-0.2, 3.3) †	-4.76*	-5.30*

Source: National Health Insurance (NHI) systems; AAPC, average annual percentage change; APC (2020, 2021), annual percentage change, was calculated with data from 2019; CI, confidence interval. ‡P-value < 0.05. † P-value < 0.1. *APC deviates from 95% CI of AAPC.

(2) Older Adults Hospitalized With Major Diseases and Associated Mortality by Year

Table 8 shows the numbers of hospitalized patients with major diseases among older age groups by year. The number of hospitalizations for pneumonia significantly decreased in all ages (244,423 in 2020 vs. 164,863 in 2021). However, the number of deaths did not significantly decrease (22,257 in 2020 vs. 22,812 in 2021).

The numbers of patients hospitalized for stroke, other cerebrovascular disease, acute myocardial infarction, heart failure, intracranial hemorrhage, and sepsis were similar during all periods; however, the number of deaths increased in 2020 and 2021.

Table 8. The number of patients hospitalized with major diseases among older age groups and the number of deaths (2015-2021).

Age \ Year	2015	2016	2017	2018	2019	2020	2021
	Pneumonia (J12-J18)						
60-69 (J18)	18,522	21,109	20,649	22,550	22,777	14,344	9,889
70-79 (J18)	34,166	34,227	35,190	38,884	37,523	26,256	19,359
80- (J18)	39,506	42,405	48,472	56,479	57,030	44,912	37,638
All ages	379,221	428,563	361,676	374,864	419,827	244,423	164,863

The number of deaths (all ages)	14,718	16,476	19,378	23,280	23,168	22,257	22,812
Stroke (I63)							
60-69	18,962	20,560	20,295	21,297	21,671	22,058	22,224
70-79	32,929	34,409	33,308	34,251	33,377	31,606	30,405
80-	26,867	30,259	32,037	34,745	36,075	36,583	36,703
All ages	95,521	103,676	103,284	107,970	108,640	107,319	105,635
The number of deaths (all ages)	7,941	7,453	7,148	7,322	7,103	7,414	9,031
Other cerebrovascular disease (I67)							
60-69	6,726	8,993	9,211	12,263	13,490	13,458	15,192
70-79	4,808	5,786	5,880	7,458	8,265	7,761	8,241
80-	2,334	2,200	2,643	3,170	3,604	3,283	3,200
All ages	29,019	35,419	34,872	43,299	45,691	43,026	45,447
The number of deaths (all ages)	577	380	355	468	486	404	503
Acute myocardial infarction (I21)							
60-69	6,108	6,638	6,794	7,719	7,795	8,209	8,165
70-79	6,501	6,883	6,686	7,431	7,348	7,153	6,553
80-	4,059	4,555	4,985	5,453	5,757	5,756	5,593
All ages	26,257	28,108	28,272	31,439	31,583	31,553	30,162
The number of deaths (all ages)	10,439	10,171	9,594	9,819	9,677	9,927	9,693
Intracranial hemorrhage (I61)+other non-traumatic intracranial hemorrhage (I62)							
60-69	5,326	6,031	5,887	6,351	6,248	6,297	6,351
70-79	6,770	7,337	7,338	7,711	7,386	7,178	6,784
80-	4,297	5,144	5,436	6,025	6,337	6,616	6,630
All ages	25,397	28,466	27,623	29,563	28,972	28,494	27,450
The number of deaths (all ages)	5,328	5,064	5,017	5,003	5,024	5,109	5,629
Sepsis (A40-A41)							
60-69	2,559	2,737	2,722	3,030	3,135	3,928	4,316
70-79	7,124	7,371	7,681	8,223	8,824	10,205	10,489
80-	10,083	11,422	13,770	16,160	18,145	23,086	25,471
All ages	26,960	28,617	29,970	33,061	35,112	41,164	43,983
The number of deaths (all ages)	3,045	3,596	3,994	4,665	4,903	6,086	6,429
Heart failure (I50)							
60-69	2,498	2,793	2,730	3,240	3,355	3,145	3,307
70-79	6,786	7,394	7,529	8,413	8,435	7,677	7,237
80-	9,758	11,326	12,369	14,522	15,496	15,293	15,295
All ages	21,181	23,917	25,052	29,110	30,102	28,851	28,814
The number of deaths (all ages)	4,587	5,094	5,887	6,755	6,758	7,256	8,177

Source: Health Insurance Review and Assessment (HIRA) service, Korean Statistical Information Service (KOSIS) of Statistics

Table 9. World Health Organization analysis of excess mortality by country.

WHO data					
Country	year	population (per 100k)	Excess (mean)	Excess (low)	Excess (high)
Korea	2020	512.69183	0	-6	7
Korea	2021	513.05184	12	4	19
Korea	2020-2021	512.871835	6	1	11
Japan	2020	1264.76458	-24	-32	-16
Japan	2021	1260.50796	8	-1	18
Japan	2020-2021	1262.63627	-8	-14	-2
USA	2020	3310.02647	141	132	149
USA	2021	3329.15074	140	129	151
USA	2020-2021	3319.588605	140	134	147
UK	2020	678.86004	126	112	140
UK	2021	682.07114	93	78	109
UK	2020-2021	680.46559	109	98	121
New Zealand	2020	48.22233	-43	-50	-36
New Zealand	2021	48.60642	-13	-20	-5
New Zealand	2020-2021	48.414375	-28	-33	-23

Table 10. *Lancet* analysis of excess mortality by country.

	Reported COVID-19 deaths	Estimated excess deaths	Estimated excess mortality rate (per 100k)	Ratio between excess mortality rate and reported COVID-19 mortality rate
Korea	5620	4630 (-658, 9580)	4.4 (-0.6, 9.1)	0.82 (-0.12, 1.70)
Japan	18400	111000 (103000, 116000)	44.1 (41.0, 46.4)	6.02 (5.58, 6.33)
USA	824000	1130000 (1080000, 1180000)	179.3 (170.7, 187.5)	1.37 (1.31, 1.44)
UK	173000	169000 (163000, 174000)	126.8 (122.3, 130.9)	0.97 (0.94, 1.01)
New Zealand	51	–872 (–1330, –451)	–9·3 (–14·1, –4·8)	–17·10 (–26·06, –8·84)

IV. DISCUSSION

In this study, the excess deaths during the COVID-19 pandemic were analyzed using

mortality data from the past 5 years in the Republic of Korea. Relatively few excess deaths occurred during the analysis at the national level until December 2020. However, excess mortality was observed in 2021 and 2022, especially from July 2021. In 2022, the ratio of actual deaths to predicted deaths (P-score) was 1.28, which was higher than the P-scores of 1.00 in 2020 and 1.03 of 2021. However, the ratio of excess deaths to reported COVID-19 deaths was 1.30 in 2020, 1.88 in 2021, and 1.98 in 2022. In 2020, as stringent government restrictions regarding social activity and thorough self-monitoring were in place, the overall number of COVID-19 cases was relatively small, but there was high mortality due to high SARS-CoV-2 virulence. It is believed that the proportion of deaths caused by COVID-19 was relatively higher than in other years because effective strategies were not yet in place to cope with the new virus. This study only includes 2022 data from January through May, so it is hard to compare 2022 with previous years.

Although the COVID-19 CFR was not high, it was confirmed that the excess mortality increased over time relative to that of previous epidemic waves, as the number of confirmed cases increased. Until May 2022, the number of excess deaths was 47,516; however, the number of COVID-19 deaths was 24,160. The number of deaths from causes other than COVID-19 may have increased for various reasons, such as patients not visiting the hospital because of lockdown or concerns about infection, or patients having difficulties presenting to hospitals because of hospitals' COVID-19 policies. This suggests that there was a strong indirect impact of COVID-19 on overall mortality.

Many studies have investigated excess mortality at the national [13,14] or regional [14,15] levels. A study published in 2021 [16] analyzed excess deaths in Korea using national and regional data and found that the mortality trends in 2020 were similar to historical trends.

Other researchers have investigated excess mortality during the pandemic period, hypothesizing temporal variations and variations depending on COVID-19 mutations [17-19]. Other research has investigated deaths from various causes, including COVID-19, during the pandemic [20-22], and roughly 13% of the excess mortality observed in 2020 was due to non–COVID-19 causes in certain groups of people, such as males and young people [20].

The gap between excess deaths and reported deaths could be affected by numerous factors, such as medical accessibility, lockdown policies, and the number of COVID-19 tests. The mortality rates of patients with chronic diseases have declined over the pandemic period in Europe [23], likely in large part due to the most vulnerable individuals dying the earlies after the onset of the COVID-19 pandemic. In contrast, the number of suicides increased during the same period in Japan [24]. The net effects associated with excess deaths are difficult to characterize.

One study compared CFRs between the United Kingdom, Taiwan, Italy, Spain, New Zealand, United States, Korea, and Japan and determined that the highest COVID-19 mortality rates were among people over 60 years old, particularly in the United States, United Kingdom, Spain, Italy, Japan, Korea, and New Zealand (in descending order) [25].

In Korea, the COVID-19 CFR and mortality rate is relatively low compared with other high-income countries; however, the COVID-19 mortality was higher in 2021 than in 2020 [26], which could have contributed to excess mortality.

There was also a study investigating excess deaths conducted in other countries that analyzed the results for each of the first and second epidemic waves. The mortality rate in second waves were low because of improvements in the preparedness of the healthcare services [27].

The results of a World Health Organization (WHO) analysis are shown in Table 9, and in Korea, there was no excess mortality in 2020. However, excess mortality occurred in 2021, was well as the entire period of 2020-2021, and these findings aligned with those of our study.

The WHO also investigated annual and seasonal variations using the Poisson regression model with the reference period of 2015-2019. Excess mortality occurred during 2020-2021 in the USA, UK, and Korea (140, 109, and 6 cases per 100,000 persons, respectively), whereas mortality decreased in Japan and New Zealand (which had excess mortality calculations of −8 and −28, respectively).

A study published in *The Lancet* [28] determined that excess mortality occurred in Korea in

2020-2021; however, this result was not statistically significant (Table 10). They applied the ensemble model with REGMOD, a Poisson regression model, and simple assumptions with corrections for seasonality, secular time trend, and yearly effect (similar to our study). Their analysis showed that excess mortality occurred in the USA, UK, Japan, and Korea (again, the Korean finding was not statistically significant). In New Zealand, their data demonstrated a decrease in deaths, which aligned with the WHO analysis.

When comparing the results of a study conducted in '*our mortality data*'[7] with our study results (Figure 7), the P-score trends were similar between the analyses, and I compared the P-score findings from our study with those of other countries. As described in Figure 7, unlike other countries, the P-scores determined in our study were higher in the later COVID-19 pandemic period in Korea. Daily excess mortality data are shown in Figure 8, which also shows a similar P-score pattern. The later increases in excess mortality in Korea may be related to increased demand for ICU care and medical resources of both COVID-19 and non-COVID-19 critically ill patients.

The decrease in ICU admissions for the non-COVID-19 patients suggests that they did not receive adequate medical care relative to the care provided during the pre-pandemic period (due to a scarcity of medical resources). During the pandemic, a large proportion of medical resources, including ICU care at tertiary hospitals, have been allocated to caring for critically ill patients with COVID-19. The number of facilities with available ICU space and resources (such as mechanical ventilators, extracorporeal membrane oxygenation, and continuous renal replacement therapy) for non-COVID-19 patients might have also been reduced. This disparate distribution of medical resources would have acted as a substantial burden causing excess mortality and morbidity.

Our study also showed increased mortality from with major diseases in 2020 and 2021, even if the number of admissions was decreased or maintained. This suggests that the quality of medical care was compromised during the pandemic period because of prolonged excessive working hours among healthcare workers, accumulated fatigue, and a scarcity of medical resources. Previous research revealed that in-hospital mortality was increasing as

the numbers of nursing staff and intensivists decreased [29]. I can estimate that this deterioration in the quality of medical care has contributed to excess mortality.

As far as I know, this was the first study analyzing the indirect effects of COVID-19 with such a long analysis period and that investigated the association between excess deaths and ICU admissions. However, there were some limitations. First, mortality is affected by many variables, such as population structure and aging, in addition to time and region, and I could not account or adjust for all of these factors. However, I have analyzed published mortality data from the previous five years as references and determined the annual trends and seasonal variation, which are the most influential factors. Second, I could not reflect the COVID-19 variants and vaccination status in our findings. The prevalent COVID-19 variants (alpha, beta, gamma, delta, and omicron) were different in each period and that the vaccination policies varied between periods, and these variations might have affected the excess mortality findings. Omicron, for example, is known to be associated with mild clinical manifestation [22] and low mortality rates; however, the excess mortality during the omicron period was higher than that of the previous period. Third, the causes of death (other than COVID-19) were not specifically analyzed, and it would be important to find out which diseases contributed most to excess mortality.

V. CONCLUSION

In conclusion, it is difficult to say that excess mortality occurred at the national level in 2020; however, it excess mortality was present according to the monthly analysis. After 2021, significant excess mortality occurred at the national level, affecting older adults, even if the CFR was decreasing. It is evident that there was an indirect impact of COVID-19 on all-cause mortality, particularly in terms of decreases in ICU admissions of non-COVID-19 patients and increased mortality rates associated with major diseases and a COVID-19–related scarcity of medical resources. It is important to maintain a balance between the management of non-infectious conditions and new infectious diseases in terms of proper

medical care as well as establishing public health strategies and equitably distributing medical resources.

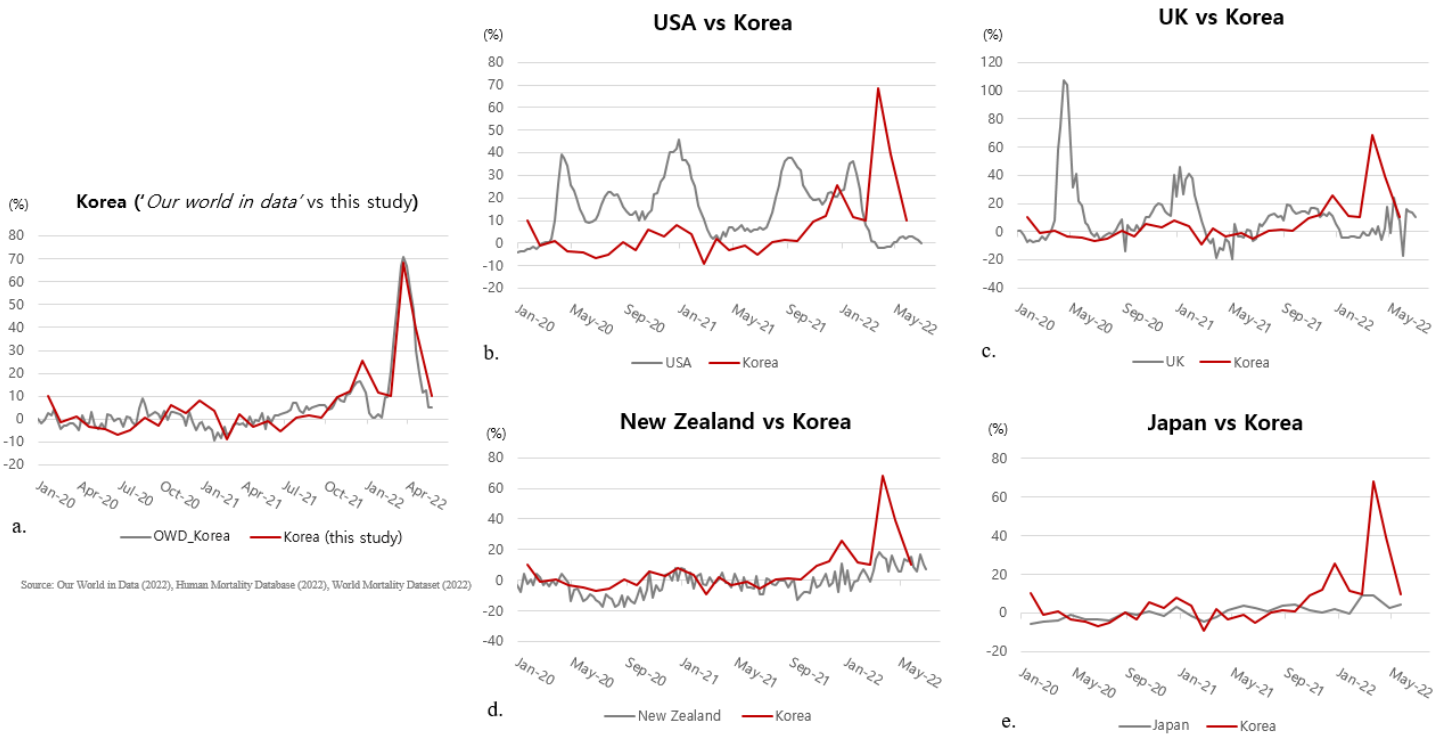

Figure 7. P-score comparison between other countries and Republic of Korea.
7a, P-score of 'Our world in data' and this study; 7b, P-score of United States of America and Korea; 7c, P-score of United Kingdom and Korea; 7d, P-score of New Zealand and Korea; 7e, P-score of Japan and Korea.
Source of data (USA, UK, New Zealand, and Japan): Our world in data.

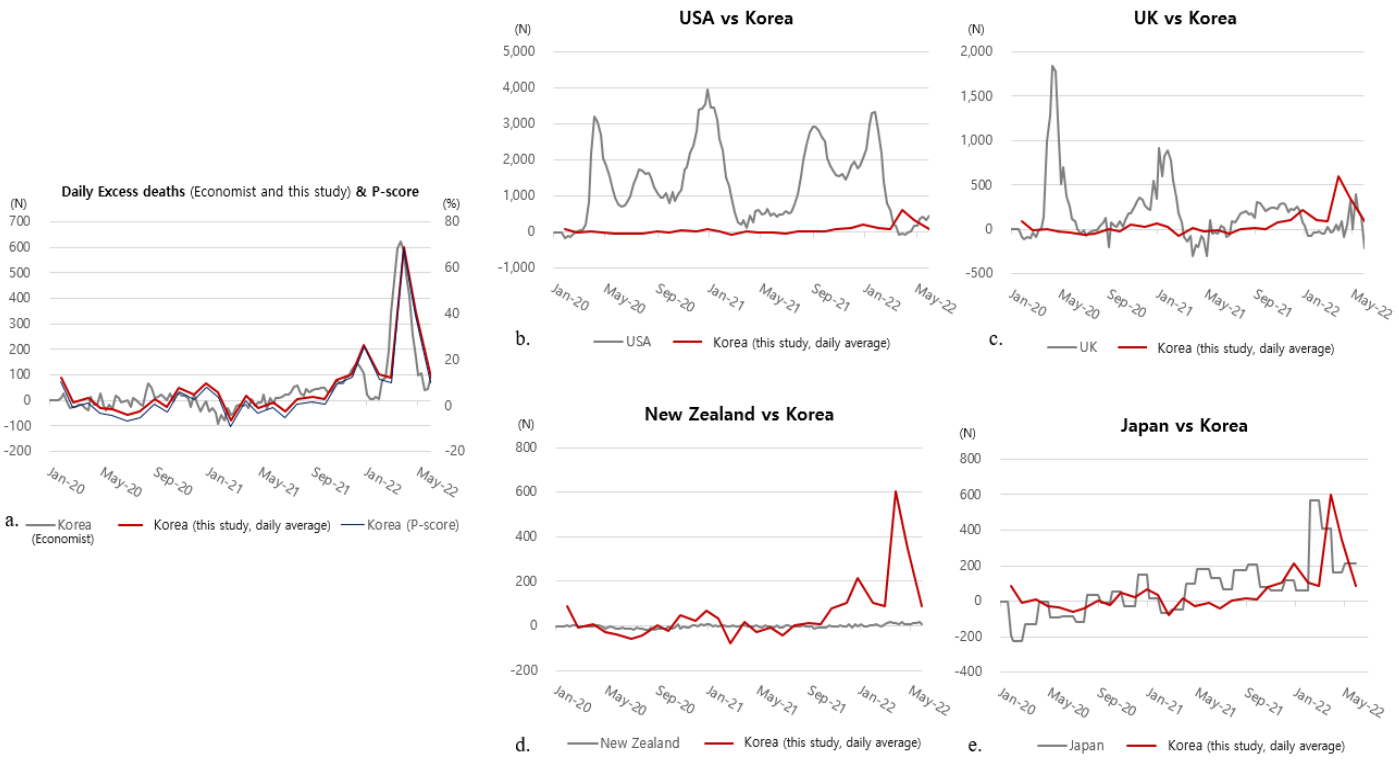

Figure 8. Daily excess deaths between other countries and Republic of Korea.
8a, Comparison of daily excess deaths in Korea between 'The Economist' data and this study with P-score; 8b, Daily excess deaths of United States of America and Korea; 8c, Daily excess deaths of United Kingdom and Korea; 8d, Daily excess deaths of New Zealand and Korea; 8e, Daily excess deaths of Japan and Korea.
Source of data (USA, UK, New Zealand, and Japan): Our world in data (2022), The Economist (2022), Johns Hopkins University (2022)

REFERENCES

1. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. 2020;395(10223):497-506.
2. Piccolo R, Bruzzese D, Mauro C, et al. Population trends in rates of percutaneous coronary revascularization for acute coronary syndromes associated with the COVID-19 outbreak. 2020;141(24):2035-2037.
3. De Filippo O, D'Ascenzo F, Angelini F, et al. Reduced rate of hospital admissions for ACS during Covid-19 outbreak in Northern Italy. 2020;383(1):88-89.
4. Goyal N, Venkataram T, Singh V, Chaturvedi JJJoCN. Collateral damage caused by COVID-19: change in volume and spectrum of neurosurgery patients. 2020;80:156-161.
5. Stock L, Brown M, Bradley GJWJoEMIECwPH. First do no harm with COVID-19: corona collateral damage syndrome. 2020;21(4).
6. Beridze G, Triolo F, Grande G, Fratiglioni L, Calderón-Larrañaga AJBo. COVID-19 collateral damage—psychological burden and behavioural changes among older adults during the first outbreak in Stockholm, Sweden: a cross-sectional study. 2022;12(1):e058422.
7. Hannah Ritchie EM, Lucas Rodés-Guirao, Cameron Appel, Charlie Giattino, Esteban Ortiz-Ospina, Joe Hasell, Bobbie Macdonald, Diana Beltekian and Max Roser. Coronavirus Pandemic (COVID-19). 2020. Accessed October 13, 2022.
8. Korea S. Monthly, quarterly, yearly population trends (birth, death, marriage, divorce). 2022; https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1B8000G&conn_path=I2.
9. (KCDC) KCfDCaP. Coronavirus (COVID-19), Republic of Korea. 2022; https://ncov.kdca.go.kr.
10. services HIRaA. Frequent disease statistics. 2022.
11. Gelman A, Hill J. *Data analysis using regression and multilevel/hierarchical models.* Cambridge university press; 2006.
12. Goldstein E, Viboud C, Charu V, Lipsitch MJE. Improving the estimation of influenza-related mortality over a seasonal baseline. 2012;23(6):829.
13. Stokes AC, Lundberg DJ, Elo IT, Hempstead K, Bor J, Preston SH. COVID-19 and excess mortality in the United States: A county-level analysis. *PLoS medicine.* 2021;18(5):e1003571.
14. Lima EE, Vilela EA, Peralta A, et al. Investigating regional excess mortality during 2020 COVID-19 pandemic in selected Latin American countries. *Genus.* 2021;77(1):1-20.
15. Vestergaard LS, Nielsen J, Richter L, et al. Excess all-cause mortality during the COVID-19 pandemic in Europe–preliminary pooled estimates from the EuroMOMO network, March to April 2020. *Eurosurveillance.* 2020;25(26):2001214.
16. Shin MS, Sim B, Jang WM, Lee JY. Estimation of Excess All-cause Mortality

during COVID-19 Pandemic in Korea. *J Korean Med Sci.* 2021;36(39):0.
17. Basellini U, Alburez-Gutierrez D, Del Fava E, et al. Linking excess mortality to mobility data during the first wave of COVID-19 in England and Wales. 2021;14:100799.
18. Rivera R, Rosenbaum JE, Quispe WJE, Infection. Excess mortality in the United States during the first three months of the COVID-19 pandemic. 2020;148.
19. Molenberghs G, Faes C, Verbeeck J, et al. COVID-19 mortality, excess mortality, deaths per million and infection fatality ratio, Belgium, 9 March 2020 to 28 June 2020. 2022;27(7):2002060.
20. Cronin CJ, Evans WN. Excess mortality from COVID and non-COVID causes in minority populations. *Proceedings of the National Academy of Sciences.* 2021;118(39):e2101386118.
21. Lee W-E, Park SW, Weinberger DM, et al. Direct and indirect mortality impacts of the COVID-19 pandemic in the US, March 2020-April 2021. *medRxiv.* 2022.
22. Henry NJ, Elagali A, Nguyen M, Chipeta MG, Moore CE. Variation in excess all-cause mortality by age, sex, and province during the first wave of the COVID-19 pandemic in Italy. *Scientific reports.* 2022;12(1):1-12.
23. Schwarz V, Mahfoud F, Lauder L, et al. Decline of emergency admissions for cardiovascular and cerebrovascular events after the outbreak of COVID-19. 2020;109(12):1500-1506.
24. Nakanishi M, Yamasaki S, Endo K, et al. Suicide rates during the COVID-19 pandemic in Japan from April 2020 to December 2021. *Psychiatry Research.* 2022;316:114774.
25. Hong D, Lee S, Choi YJ, et al. The age-standardized incidence, mortality, and case fatality rates of COVID-19 in 79 countries: a cross-sectional comparison and their correlations with associated factors. *Epidemiology and health.* 2021;43:e2021061.
26. (KOSIS) KSIS. Deaths and death rates by cause(104 item)/By sex/By age(five-year age). 2022; https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1B34E01&vw_cd=MT_ETITLE&list_id=F_27&scrId=&seqNo=&language=en&obj_var_id=&itm_id=&conn_path=A6&path=%252Feng%252Fsearch%252FsearchList.do. Accessed December 13, 2022.
27. Dorrucci M, Minelli G, Boros S, et al. Excess mortality in Italy during the COVID-19 pandemic: assessing the differences between the first and the second wave, year 2020. 2021:927.
28. Wang H, Paulson KR, Pease SA, et al. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020–21. *The Lancet.* 2022;399(10334):1513-1536.
29. Lee SH, Hong JH, Kim YS, Park EC, Lee SM, Han CH. Impact of Intensivist and Nursing Staff on Critically Ill Patient Mortality: A Retrospective Analysis of the Korean NHIS Cohort Data, 2011–2015. *Yonsei Med J.* 2021;62(1):50-58.

ABSTRACT(IN KOREAN)

우리나라 코로나-19 유행이 중환자의 의료이용 및 사망에 미치는 영향

<지도교수 김 영 삼>

연세대학교 대학원 의학과

장 혜 진

새로운 감염병인 코로나 바이러스 (COVID-19) 대유행은 전 세계적으로 주요 공중 보건 문제로 대두되었다. 코로나-19 감염에 대한 우려로 환자들이 병원을 찾지 않거나 병원 자체의 방역 정책 등에 따라 예정된 시술, 수술이 연기되거나 취소되기도 하는 등 의료 접근성에 대한 문제로 코로나 감염과 무관한 사망자가 늘어날 수 있다.

이 연구는 한국에서 코로나-19 전염병 기간 동안의 새로운 감염병으로 인한 영향과 초과 사망에 대한 분석을 시행하였다. 통계청 (KOSIS)의 공개 데이터를 사용하여 2020년 1월부터 2022년 5월까지의 총 사망자 수와 코로나-19 관련 사망자 수를 평가하였고, 감염병 유행 이전 시기인 2015년 1월 1일부터 2019년 12월까지 5개년의 사망자수를 기반으로 2021년과 2022년의 예측 사망자수를 추정하였다. 2020년 2022년 5월까지 예측 사망자수와 실제 사망자수를 비교해보았을 때, 2020년에는 초과사망이 뚜렷하지 않았으나 월별 비교 시 일부 시기에서 관찰되었다. 2021년과 2022년 5월까지는 초과사망이 뚜렷하게 확인되었다. 코로나-19의 치사율이 시간이 갈수록 감소함에도 불구하고 오히려 감염병 유행 초기 시기보다 후반부로 갈수록 초과사망이 증가하는 양상을 보여주고 있으며, 주요

선진국의 초과 사망 패턴과 확연히 다른 양상임을 알 수 있었다. 이는 코로나 감염에 의한 사망보다 이외의 원인으로 인한 간접 사망도 함께 발생했다는 것을 시사한다. 주요 질환의 입원 환자수를 확인하였을 때, 폐렴의 경우 입원 환자수가 2020년과 2021년에 확연히 감소한 추세를 보였으나 사망자수는 일정하게 유지되었으며, 월별 중환자실 입실 건수 역시 감염병 이전 시기에 비해 감소하였고 이는 초과사망이 발생한 시기와 일치하였다. 심부전, 뇌경색의 경우에는 입원 건수는 유지되었으나, 2021년에 사망자수가 크게 증가하였다.

따라서, 코로나로 인한 직접적인 사망 뿐만 아니라 한정된 의료인력 및 자원을 새로운 감염병 대비에 집중하면서 기존 비-코로나 환자들이 의료 접근성 또는 의료 질 저하 등 간접적인 영향을 받았음을 알 수 있고, 의료 이용의 접근성과 더불어 의료 자원에 대한 분배가 적절하게 필요하다는 점을 시사한다.

핵심되는 말 : 코로나-19, 초과 사망, 의료이용