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Excess Deaths in Korea During the COVID-19 Pandemic: 2020-2022

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Objectives: Excess deaths, an indicator that compares total mortality rates before and during a pandemic, offer a comprehensive view of the pandemic's impact. However, discrepancies may arise from variations in estimating expected deaths. This study aims to compare excess deaths in Korea during the coronavirus disease 2019 pandemic using 3 methods and to analyze patterns using the most appropriate method.

Methods: Expected deaths from 2020 to 2022 were estimated using mortality data from 2015-2019 as reference years. This estimation employed 3 approaches: (1) simple average, (2) age-adjusted average, and (3) age-adjusted linear regression. Excess deaths by age, gender, and cause of death were also presented.

Results: The number of excess deaths varied depending on the estimation method used, reaching its highest point with the simple average and its lowest with the age-adjusted average. Age-adjusted linear regression, which accounts for both the aging population and declining mortality rates, was considered most appropriate. Using this model, excess deaths were estimated at 0.3% for 2020, 4.0% for 2021, and 20.7% for 2022. Excess deaths surged among individuals in their 20s throughout the pandemic, largely attributed to a rise in self-harm and suicide. Additionally, the results indicated sharp increases in deaths associated with "endocrine, nutritional, and metabolic diseases" and "symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified."

Conclusions: Substantial variations in excess deaths were evident based on estimation method, with a notable increase in 2022. The heightened excess deaths among young adults and specific causes underscore key considerations for future pandemic responses.

Key words: COVID-19, Excess mortality, Mortality, Pandemics, SARS-CoV-2, Suicide

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic, which originated from an unidentified cause of pneumonia in Wuhan, China, in late December 2019, was officially declared a pandemic by the World Health Organization on March 11, 2020. Over the next 3 years, it inflicted considerable damage worldwide. The impact of this pandemic on society has 2 main types: direct damage caused by the disease itself and collateral damage resulting from infection control policies. Direct damage is exemplified by the deaths attributed to COVID-19, while collateral damage includes a broad spectrum of adverse effects on physical and mental health, the economy, education, and various other societal dimensions [1].

Various studies are being conducted to evaluate the impact of the pandemic from different perspectives. One such approach involves estimating the excess deaths experienced by each

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country. Excess deaths represent a metric for comparing total mortality rates before and during the pandemic. This metric accounts for not only direct deaths from COVID-19 but also those that may have occurred due to the pandemic and its associated policies [2]. Therefore, excess deaths are considered a comprehensive indicator for assessing the overall impact of the pandemic on a country.

However, the number of excess deaths can vary depending on the estimation method. To calculate excess deaths, one must initially establish a reference year prior to the pandemic. Then, the expected number of deaths during the pandemic is determined by applying the mortality rate from the reference year to the population at the time. This expected mortality figure is then compared to the actual number of deaths observed. Notably, the selection of the reference year and the methodology employed to estimate expected deaths can produce different results [3].

For instance, Our World in Data, which consistently provides information on excess deaths by country, has employed 2 methods to calculate excess deaths [4]. In the early stages of the COVID-19 pandemic, their estimation of expected deaths was based on the average mortality rate observed from 2015 to 2019. Later, they utilized regression equations derived from mortality rates between 2015 and 2019 to estimate expected deaths. In Korea, Statistics Korea reported excess deaths by using the highest number of deaths observed weekly over the past 3 years as the expected number and comparing this to the observed deaths during the pandemic [5]. However, this reporting has been suspended.

Although numerous articles have documented excess deaths in various countries during the pandemic [6,7], including Korea [8-10], few studies have compared excess death estimates obtained with different methodologies [11,12]. For example, an analysis of excess deaths in 2020-2021 across 33 countries, using 6 distinct methods, underscored the importance of age adjustment. While there were strong correlation coefficients of around 0.9 between excess death estimates from different methodologies, considerable absolute differences in the estimated excess deaths were observed across most countries [11].

Thus, this study was conducted with 2 primary objectives. First, we compared the differences in excess deaths from 2020 to 2022 using 3 estimation methods, including those similar to the ones commonly employed by publicly available websites such as Our World in Data and Statistics Korea. Second, we presented the excess deaths from 2020 to 2022, categorized by age group, gender, and cause of death, using the method that was determined to be the most appropriate.

METHODS

Data Sources

Data on deaths from 2015 to 2022 were obtained from Statistics Korea's cause-of-death statistics. This dataset includes information such as age, gender, cause of death, and place of death [13]. Among the 2 431 753 deaths recorded from January 2015 to December 2022, 308 deaths lacking age information were excluded from this study. The monthly resident registered population by age group, segmented into 10-year intervals ranging from 0-9 years to 80 years or older, was acquired from the Korean Statistical Office [13].

Statistical Analysis

In this study, excess deaths were quantified using 2 approaches: (1) by calculating the difference between the observed and expected number of deaths, and (2) by determining the P-score, which is defined as ([(observed deaths−expected deaths)/expected deaths]×100) [14]. The term "observed deaths" refers to the actual number of deaths recorded from 2020 to 2022. In contrast, expected deaths were estimated using 3 distinct methods, based on the reference period of 2015-2019:

(1) Multiplying the average monthly mortality rates from 2015 to 2019 by the monthly population figures from 2020 to 2022; (2) Stratifying by age, in which the average monthly mortality rates from 2015 to 2019 were multiplied by the age-stratified monthly population figures from 2020 to 2022; and (3) Conducting linear regression analysis on the age-stratified monthly mortality rates from 2015 to 2019 to predict mortality rates for 2020 to 2022. These predicted rates were then multiplied by the corresponding age-stratified monthly population figures from 2020 to 2022.

Excess deaths estimated using these methods were based on (1) simple average, (2) age-adjusted average, and (3) age-adjusted linear regression methods.

Age-adjusted linear regression-based excess deaths were deemed the most suitable method among the 3 considered, as this approach accounts for both changes in age structure and mortality rate trends. Therefore, excess deaths were characterized by age, gender, and cause of death using estimates from this method. For the analysis, age was categorized into 9 groups at 10-year intervals. Causes of death were examined according to 22 major categories from the Korean Standard Classification of Diseases (KCD), which have remained consistent from 2015 to 2022 [13]. The analysis was performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA) and SPSS version 25.0 (IBM Corp., Armonk, NY, USA).

Ethics Statement

This study utilized publicly available secondary data, so ethical approval was not required.

RESULTS

Comparison of 3 Methods for Estimating Excess Deaths

Excess death estimates varied significantly based on the 3 methods used to calculate expected deaths, as illustrated in Table 1 and Figure 1. The simple average-based method, which does not consider changes in age structure, suggested the occurrence of 16 951 excess deaths in 2020, corresponding to a P-score of 5.9%. In contrast, the age-adjusted average method, which accounts for shifts in age structure, yielded an estimate of -27 491 excess deaths and a P-score of -8.3%. Additionally, when calculating age-adjusted excess deaths while also considering changes in mortality trends in each age group, the estimated number of excess deaths was 937, with a P-score of 0.3%. Despite substantial monthly variations in excess deaths, no correlation was observed between the monthly excess deaths and the monthly COVID-19 deaths for any method. Specifically, the correlation coefficient for the age-adjusted linear regression method was -0.119.

In 2021, we noted a clear increase in excess deaths compared to 2020, as evidenced by both simple average-based and age-adjusted linear regression-based estimates. The total excess deaths were 30 469 and 12 216, with P-scores of 10.6% and 4.0%, respectively. However, when using the age-adjusted average method, excess deaths did not differ notably from those in 2020. Additionally, a monthly analysis of excess deaths revealed no clear correlation with the number of monthly COVID-19 deaths. The correlation coefficient for the age-adjusted linear regression was +0.151.

When comparing excess deaths in 2022 with those in 2020 and 2021, all 3 methods indicated sharp increases. The simple average-based and age-adjusted average-based methods estimated excess deaths at 86 585 and 13 035, respectively, with corresponding P-scores of 30.2% and 3.6%. In comparison, the age-adjusted linear regression-based method estimated excess deaths at 63 907, with a P-score of 20.7%. Analysis of the monthly excess death data, as determined by the age-adjusted linear regression, revealed a strong correlation with monthly COVID-19 deaths ($r=0.929$).

Comparison of Excess Deaths by Age Group Using Age-adjusted Linear Regression

Table 2 presents excess deaths by age group. In 2020, the age group with the highest number of excess deaths was the 20s, with 231 excess deaths and a P-score of 9.3%. In 2021, this age group continued to have the highest number, with 371 excess deaths and a P-score of 15.4%, indicating a worsening situation compared to 2020. The 60s and 70s age groups also saw increased excess deaths, with P-scores of 7.8% and 6.1%, respectively. In 2022, a notable increase in excess deaths was observed among the elderly population. The 80s age group experienced the highest number, with 39 354 excess deaths and a P-score of 24.4%. This was followed by the 70s and 60s age groups. The 20s age group also saw an increase, with 433 excess deaths and a P-score of 18.6%.

Comparison of Excess Deaths by Gender Using Age-adjusted Linear Regression

Table 3 presents excess deaths by gender. Due to privacy concerns related to the age distribution of COVID-19 deaths by gender, it was not feasible to calculate excess deaths excluding those from COVID-19. In both 2020 and 2021, excess deaths were more pronounced among men than women, with P-scores for men at 0.7% and 4.5%, respectively, while the scores for women were -0.1% and 3.4%. However, a shift occurred in 2022, with women experiencing more excess deaths than men, evidenced by P-scores of 23.6% for women and 18.1% for men. When analyzing excess deaths by both gender and age, high excess deaths were noted among individuals in their 20s, regardless of gender. In 2020, the excess deaths of women in their 20s exceeded those of men in the same age group, with P-scores of 15.0% for women and 6.0% for men. This trend reversed in 2021 and 2022, with excess deaths among men in their 20s surpassing those among women; P-scores for men were 19.6% and 21.0%, respectively, compared to 8.6% and 14.9% for women.

Table 1. Excess deaths estimated by 3 different methods from 2020 to 2022

Year	COVID-19 deaths	Observed deaths	Simple average		Age-adjusted average		Age-adjusted linear regression	
			All cause	Except COVID-19	All cause	Except COVID-19	All cause	Except COVID-19
2020								
Jan	-	28 427	1475 (5.5)	1475 (5.5)	-2701 (-8.7)	-2701 (-8.7)	-2472 (-8.0)	-2472 (-8.0)
Feb	16	25 422	1615 (6.8)	1599 (6.7)	-2186 (-7.9)	-2202 (-8.0)	1884 (8.0)	1868 (7.9)
Mar	146	25 849	528 (2.1)	382 (1.5)	-3513 (-12.0)	-3659 (-12.5)	1994 (8.4)	1848 (7.7)
Apr	85	24 669	1123 (4.8)	1038 (4.4)	-2540 (-9.3)	-2625 (-9.6)	887 (3.7)	802 (3.4)
May	23	24 341	556 (2.3)	533 (2.2)	-3091 (-11.3)	-3114 (-11.4)	-692 (-2.8)	-715 (-2.9)
Jun	12	23 638	1516 (6.9)	1504 (6.8)	-1863 (-7.3)	-1875 (-7.4)	177 (0.8)	165 (0.7)
Jul	19	23 987	1347 (6.0)	1328 (5.9)	-2078 (-8.0)	-2097 (-8.0)	-212 (-0.9)	-231 (-1.0)
Aug	23	25 288	2320 (10.1)	2297 (10.0)	-1165 (-4.4)	-1188 (-4.5)	591 (2.4)	568 (2.3)
Sep	89	24 350	1792 (7.9)	1703 (7.5)	-1635 (-6.3)	-1724 (-6.6)	262 (1.1)	173 (0.7)
Oct	51	26 484	2068 (8.5)	2017 (8.3)	-1672 (-5.9)	-1723 (-6.1)	181 (0.7)	130 (0.5)
Nov	62	25 601	1554 (6.5)	1492 (6.2)	-2149 (-7.7)	-2211 (-8.0)	-318 (-1.2)	-380 (-1.5)
Dec	374	26 865	1056 (4.1)	682 (2.6)	-2896 (-9.7)	-3270 (-11.0)	-1347 (-4.8)	-1721 (-6.1)
Total	900	304 921	16 951 (5.9)	16 051 (5.6)	-27 491 (-8.3)	-28 391 (-8.5)	937 (0.3)	37 (0.0)
2021								
Jan	520	27 219	279 (1.0)	-241 (-0.9)	-5345 (-16.4)	-5865 (-18.0)	-5052 (-15.7)	-5572 (-17.3)
Feb	183	23 786	-11 (0.0)	-194 (-0.8)	-5097 (-17.6)	-5280 (-18.3)	585 (2.5)	402 (1.7)
Mar	128	26 557	1303 (5.2)	1175 (4.7)	-3877 (-12.7)	-4005 (-13.2)	3942 (17.4)	3814 (16.9)
Apr	97	25 070	1588 (6.8)	1491 (6.3)	-3114 (-11.1)	-3211 (-11.4)	1613 (6.9)	1516 (6.5)
May	131	25 564	1852 (7.8)	1721 (7.3)	-2830 (-10.0)	-2961 (-10.4)	483 (1.9)	352 (1.4)
Jun	59	24 380	2330 (10.6)	2271 (10.3)	-2021 (-7.7)	-2080 (-7.9)	781 (3.3)	722 (3.1)
Jul	77	25 728	3162 (14.0)	3085 (13.7)	-1259 (-4.7)	-1336 (-5.0)	1298 (5.3)	1221 (5.0)
Aug	190	25 917	3024 (13.2)	2834 (12.4)	-1473 (-5.4)	-1663 (-6.1)	938 (3.8)	748 (3.0)
Sep	196	25 661	3179 (14.1)	2983 (13.3)	-1244 (-4.6)	-1440 (-5.4)	1349 (5.5)	1153 (4.7)
Oct	368	27 747	3414 (14.0)	3046 (12.5)	-1399 (-4.8)	-1767 (-6.1)	1156 (4.3)	788 (3.0)
Nov	775	28 364	4402 (18.4)	3627 (15.1)	-359 (-1.3)	-1134 (-3.9)	2142 (8.2)	1367 (5.2)
Dec	1939	31 662	5947 (23.1)	4008 (15.6)	861 (2.8)	-1078 (-3.5)	2980 (10.4)	1041 (3.6)
Total	4663	317 655	30 469 (10.6)	25 806 (9.0)	-27 156 (-7.9)	-31 819 (-9.2)	12 216 (4.0)	7553 (2.5)
2022								
Jan	1192	29 841	3001 (11.2)	1809 (6.7)	-3919 (-11.6)	-5111 (-15.1)	-3586 (-10.7)	-4778 (-14.3)
Feb	1303	29 290	5585 (23.6)	4282 (18.1)	-659 (-2.2)	-1962 (-6.6)	6701 (29.7)	5398 (23.9)
Mar	8171	44 613	19 407 (77.0)	11 236 (44.6)	12 804 (40.3)	4633 (14.6)	22 819 (104.7)	14 648 (67.2)
Apr	6564	36 679	13 247 (56.5)	6683 (28.5)	7270 (24.7)	706 (2.4)	13 427 (57.7)	6863 (29.5)
May	1382	28 902	5236 (22.1)	3854 (16.3)	-759 (-2.6)	-2141 (-7.2)	3555 (14.0)	2173 (8.6)
Jun	371	24 910	2901 (13.2)	2530 (11.5)	-2684 (-9.7)	-3055 (-11.1)	944 (3.9)	573 (2.4)
Jul	500	26 072	3549 (15.8)	3049 (13.5)	-2145 (-7.6)	-2645 (-9.4)	1161 (4.7)	661 (2.7)
Aug	1717	30 038	7196 (31.5)	5479 (24.0)	1382 (4.8)	-335 (-1.2)	4502 (17.6)	2785 (10.9)
Sep	1642	29 231	6837 (30.5)	5195 (23.2)	1170 (4.2)	-472 (-1.7)	4508 (18.2)	2866 (11.6)
Oct	769	29 787	5550 (22.9)	4781 (19.7)	-686 (-2.3)	-1455 (-4.8)	2633 (9.7)	1864 (6.9)
Nov	1332	30 155	6287 (26.3)	4955 (20.8)	95 (0.3)	-1237 (-4.1)	3334 (12.4)	2002 (7.5)
Dec	1650	33 403	7789 (30.4)	6139 (24.0)	1166 (3.6)	-484 (-1.5)	3908 (13.2)	2258 (7.7)
Total	26 593	372 921	86 585 (30.2)	59 992 (21.0)	13 035 (3.6)	-13 558 (-3.8)	63 907 (20.7)	37 314 (12.1)

Values are presented as number or number (P-score, %).
COVID-19, coronavirus disease 2019.

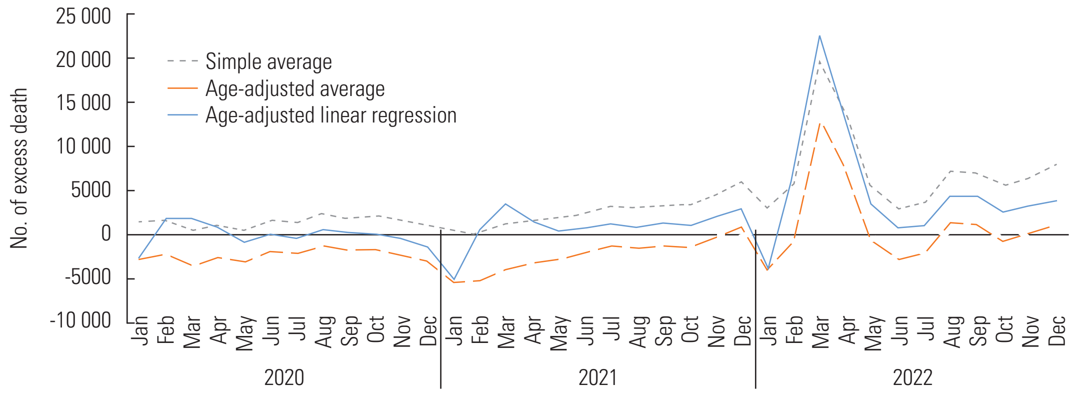

Figure 1. Comparison of excess deaths using three methods (simple average, age-adjusted average, and age-adjusted linear regression) from 2020 to 2022.

Table 2. Excess deaths by age based on age-adjusted linear regression from 2020 to 2022

Year	Age (yr)	COVID-19 deaths	Observed deaths	All cause	Except COVID-19
2020	0-9	0	1001	-91 (-8.3)	-91 (-8.3)
	10-19	0	766	-2 (-0.3)	-2 (-0.3)
	20-29	0	2706	231 (9.3)	231 (9.3)
	30-39	3	4759	43 (0.9)	40 (0.8)
	40-49	7	11 574	178 (1.6)	171 (1.5)
	50-59	30	26 390	-171 (-0.6)	-201 (-0.8)
	60-69	106	41 095	745 (1.8)	639 (1.6)
	70-79	258	68 301	747 (1.1)	489 (0.7)
	≥80	496	148 329	-743 (-0.5)	-1239 (-0.8)
	Total	900	304 921	937 (0.3)	37 (0.0)
2021	0-9	3	913	-43 (-4.5)	-46 (-4.8)
	10-19	0	773	35 (4.7)	35 (4.7)
	20-29	12	2778	371 (15.4)	359 (14.9)
	30-39	32	4541	-2 (-0.1)	-34 (-0.8)
	40-49	70	11 222	434 (4.0)	364 (3.4)
	50-59	245	25 413	-147 (-0.6)	-392 (-1.5)
	60-69	742	44 457	3208 (7.8)	2466 (6.0)
	70-79	1245	68 819	3927 (6.1)	2682 (4.1)
	≥80	2314	158 739	4433 (2.9)	2119 (1.4)
	Total	4663	317 655	12 216 (4.0)	7553 (2.5)
2022	0-9	34	949	120 (14.5)	86 (10.4)
	10-19	19	796	52 (7.0)	33 (4.5)
	20-29	65	2757	433 (18.6)	368 (15.8)
	30-39	113	4427	-55 (-1.2)	-168 (-3.7)
	40-49	358	11 539	1097 (10.5)	739 (7.1)
	50-59	1039	26 341	1241 (4.9)	202 (0.8)
	60-69	2814	48 998	7833 (19.0)	5019 (12.2)
	70-79	5803	76 621	13 830 (22.0)	8027 (12.8)
	≥80	16 348	200 493	39 354 (24.4)	23 006 (14.3)
	Total	26 593	372 921	63 907 (20.7)	37 314 (12.1)

Values are presented as number or number (P-score, %).
COVID-19, coronavirus disease 2019.

Table 3. Excess deaths by gender based on age-adjusted linear regression from 2020 to 2022

Year	Men		Women	
	Observed deaths	All cause	Observed deaths	All cause
2020				
0-9	573	-43 (-7.0)	428	-48 (-10.1)
10-19	486	34 (7.6)	280	-37 (-11.5)
20-29	1660	95 (6.0)	1046	136 (15.0)
30-39	2968	-73 (-2.4)	1791	115 (6.9)
40-49	7737	44 (0.6)	3837	134 (3.6)
50-59	19 171	-294 (-1.5)	7219	124 (1.7)
60-69	29 774	383 (1.3)	11 321	362 (3.3)
70-79	43 649	794 (1.9)	24 652	-47 (-0.2)
≥80	59 136	140 (0.2)	89 193	-883 (-1.0)
Total	165 154	1080 (0.7)	139 767	-143 (-0.1)
2021				
0-9	509	-30 (-5.6)	404	-13 (-3.1)
10-19	475	57 (13.7)	298	-23 (-7.0)
20-29	1783	292 (19.6)	995	79 (8.6)
30-39	2848	-84 (-2.9)	1693	82 (5.1)
40-49	7521	329 (4.6)	3701	105 (2.9)
50-59	18 249	-397 (-2.1)	7164	250 (3.6)
60-69	32 344	2232 (7.4)	12 113	975 (8.8)
70-79	43 958	2468 (5.9)	24 861	1459 (6.2)
≥80	64 277	2508 (4.1)	94 462	1925 (2.1)
Total	171 964	7375 (4.5)	145 691	4841 (3.4)
2022				
0-9	537	69 (14.8)	412	51 (14.0)
10-19	479	65 (15.6)	317	-12 (-3.7)
20-29	1717	298 (21.0)	1040	135 (14.9)
30-39	2875	-48 (-1.6)	1552	-7 (-0.5)
40-49	7551	621 (9.0)	3988	477 (13.6)
50-59	18 977	666 (3.6)	7364	575 (8.5)
60-69	35 339	5143 (17.0)	13 659	2691 (24.5)
70-79	48 980	8459 (20.9)	27 641	5371 (24.1)
≥80	80 008	14 892 (22.9)	120 485	24 463 (25.5)
Total	196 463	30 164 (18.1)	176 458	33 742 (23.6)

Values are presented as number or number (P-score, %).

Analyzing Cause-specific Excess Deaths Using Age-adjusted Linear Regression

Table 4 presents the estimated excess deaths for the 22 categories of causes of death according to the KCD. The U00-U99 category, which includes deaths from COVID-19, displayed a sharp rise in mortality since 2020. Consequently, these deaths were omitted from the cause-of-death analysis, as it was not suitable to estimate expected deaths using regression analysis for this category. Furthermore, we only reported excess deaths for causes where the difference was 1000 or more deaths and the P-score was at least 5.0%. When calculating excess deaths, if the absolute number of deaths is low, the P-score may appear inflated. For instance, if the expected number of deaths for a disease is 10 and the observed number is 20, the excess deaths would be 10, yielding a P-score of 100%. However, such an increase would not be considered meaningful from a public health perspective.

In 2020, we noted an increase in excess deaths associated with endocrine, nutritional, and metabolic diseases (E00-E90; P-score=13.9%), and with symptoms, signs, and abnormal clinical and laboratory findings not elsewhere classified (R00-R99; P-score=7.6%). In contrast, deaths from diseases of the respiratory system (J00-J99) decreased, as indicated by a P-score of -12.3%. Similarly, in 2021, excess deaths were greatest in E00-E90, with a P-score of 32.6%, more than doubling from 2020. Additionally, excess deaths increased significantly in R00-R99, with a P-score of 25.2%, more than tripling from 2020. Conversely, deaths from respiratory system diseases (J00-J99) decreased further (P-score=-16.6%).

In 2022, excess mortality was noted across various causes. The highest excess deaths were recorded in the E00-E90 category, with a P-score of 83.3%. Additionally, the R00-R99 category saw an estimated doubling of excess deaths from the previous year, reaching a P-score of 41.5%. Moreover, diseases of the nervous system (G00-G99), diseases of the digestive system (K00-K93), diseases of the circulatory system (I00-I99), and certain other consequences of external causes (S00-T98) exhibited P-scores of 32.6%, 15.4%, 14.8%, and 6.0%, respec-

Table 4. Excess deaths by cause of death based on age-adjusted linear regression from 2020 to 2022[1]

Year	Trend	Observed deaths (n)	Cause of death[2]	n (P-score, %)
2020	+	10 051	E00-E90 Endocrine, nutritional and metabolic diseases	1223 (13.9)
	+	31 796	R00-R99 Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	2245 (7.6)
	-	36 361	J00-J99 Disease of the respiratory system	-5107 (-12.3)
2021	+	10 524	E00-E90 Endocrine, nutritional and metabolic diseases	2585 (32.6)
	+	37 826	R00-R99 Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	7608 (25.2)
	-	36 826	J00-J99 Disease of the respiratory system	-7350 (-16.6)
2022	+	12 865	E00-E90 Endocrine, nutritional and metabolic diseases	5845 (83.3)
	+	44 033	R00-R99 Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	12 920 (41.5)
	+	19 855	G00-G99 Diseases of the nervous system	4885 (32.6)
	+	69 032	I00-I99 Diseases of the circulatory system	8882 (14.8)
	+	14 123	K00-K93 Diseases of the digestive system	1883 (15.4)
	+	26 683	S00-T98 Injury, poisoning, and certain other consequences of external causes	1511 (6.0)
	-	41 917	J00-J99 Diseases of the respiratory system	-5609 (-11.8)

[1]Among the 22 classifications of causes of death, only categories with excess deaths exceeding ±1000 and a P-score exceeding ±5.0% were presented.
[2]From the Korean Standard Classification of Diseases.

tively. Conversely, we observed a continued decline in the J00-J99 category, which had a P-score of -11.8%.

Additionally, an analysis was conducted on the causes of death among individuals in their 20s, who consistently exhibited high P-scores from 2020 to 2022. Within this age group, the highest P-score was for S00-T98, which mainly includes injuries, poisoning, and certain other consequences of external causes, with values of 12.0% in 2020, 21.2% in 2021, and 16.4% in 2022. A detailed examination revealed that the primary cause was self-harm, specifically suicide (Supplemental Material 1).

DISCUSSION

This study revealed significant variations in excess deaths depending on the method used to calculate expected deaths during the pandemic. Among 3 different methods, the approach based on the simple average showed the highest excess deaths. However, this method likely overestimated excess deaths because it failed to account for the rapidly aging population structure. In contrast, the age-adjusted average method, which considered changes in age structure when estimating expected deaths, may have underestimated excess deaths. This potential underestimation is due to the decreasing trends in age-specific mortality rates from 2015 to 2019 in most age groups. Therefore, both methods could potentially mislead the public about the actual extent of excess deaths. Consequently, the age-adjusted linear regression-based method, which considered both changes in age structure and mortality rate trends, appeared to be the most appropriate among the 3 methods.

The estimation of excess deaths has been conducted using a variety of methods. For instance, a study estimated excess deaths in Korea from March 2020 to June 2022 using a quasi-Poisson interrupted time-series model. This model used monthly mortality rates from January 2013 to February 2020 as the reference period [8]. The study reported P-scores of 2.1% for 2020, 6.0% for 2021, and 24.4% for 2022. These figures are generally higher than those from the current study, which found P-scores of 0.3% for 2020, 4.0% for 2021, and 20.7% for 2022, although slight differences were present in the study periods for 2020 and 2022 between the studies. In contrast, other studies focusing on the year 2020 reported no excess deaths [10] or even negative excess deaths [9]. Studies comparing international data have also shown a wide range of excess death estimates, depending on the methodology used [6]. This variability makes it challenging to determine the most valid method.

During the pandemic, P-scores for 2020 and 2021 were notably low but surged in 2022. This trend could be associated with Korea's COVID-19 strategy, which enforced stringent measures to control the virus until the end of 2021. The strategy then underwent a marked shift with the emergence of the milder Omicron variant [15]. However, other factors may have played a more substantial role, considering that most East Asian countries experienced lower COVID-19 impacts than Europe and America in the first year of the pandemic, despite having diverse policies [16].

The comparison between Korea and Japan is particularly intriguing because Japan adopted a relatively relaxed policy, especially regarding COVID-19 testing [17], in contrast to Korea's compulsory testing and contact tracing approach [18]. For instance, during the early stages of the pandemic, Japan primarily conducted polymerase chain reaction tests among patients who exhibited persistent symptoms or had risk factors [17]. Given the high proportion of asymptomatic cases [19], Japan likely experienced greater community transmission than Korea. In support of this view, a study of healthcare workers in Japan during mid-2020 revealed that 64% of seropositive cases had not been previously diagnosed with COVID-19 [20]. Despite Japan's more lenient approach, the age-standardized mortality rate in Japan exhibited a decreasing trend in 2020 and only a slight increase in 2021 [21], which was similar to the trends observed in Korea.

One potential explanation for the favorable outcomes observed in East Asian countries could be that individuals in this region may possess a high level of pre-existing immunity [16]. Prior exposure to other coronaviruses, such as endemic human coronaviruses and severe acute respiratory syndrome coronavirus 1, might confer immunity to COVID-19, resulting in better clinical outcomes [22,23]. Indeed, genomic evidence of past coronavirus epidemics has been found in East Asian populations [24], and a considerable number of people in Southeast Asia are infected annually with previously undetected coronaviruses that originate from bats [25,26]. Therefore, East Asia may represent a region where individuals experience more frequent and repeated exposure to coronaviruses and other related viruses compared to other regions, potentially bolstering their resistance to COVID-19.

One of the key findings from the analysis of excess deaths by age group is the marked excess deaths among individuals in their 20s throughout the pandemic. Further examination of the causes of death indicates that most of these excess deaths were due to self-harm and suicide. Particularly noteworthy is that, while the total number of COVID-19 deaths was only 900 in 2020, the estimated excess deaths in the 20s age group was estimated to be 231. This finding is of critical public health importance, considering that most COVID-19 fatalities occurred among elderly individuals with multiple comorbidities, and the COVID-19 mortality rate for those in their 20s was nearly 0% [27]. Previous studies have consistently reported increases in suicide among adolescents and young adults in Korea [28,29] and other countries [30,31]. Further research is needed to understand the reasons behind the rise in suicide rates among young adults, which may be associated with the deterioration of mental and emotional health during the COVID-19 pandemic [32,33].

In the analysis of cause-specific excess deaths, the categories of "endocrine, nutritional, and metabolic diseases" (E00-E90) and "symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified" (R00-R99) exhibited the greatest increases in excess deaths during the COVID-19 pandemic. The number of excess deaths and the P-score for these categories rose by more than fivefold from 2020 to 2022. While the cause of the surge in E00-E90 excess deaths remains uncertain, it may be associated with a general decline in healthy living during the pandemic, including increased obesity rates, reduced physical activity, unhealthy dietary habits, sleep disturbances, and mental stress [15,34]. The increase in excess deaths within the R00-R99 category calls for further investigation to ascertain whether this trend was directly tied to the COVID-19 pandemic or whether other factors contributed. This trend may also be linked to a rise in the number of elderly individuals dying at home rather than in healthcare facilities [35].

Conversely, excess deaths attributed to respiratory diseases (J00-J99) have consistently decreased, with the P-score falling by more than 10%. While this decline may be influenced by various factors, it is important to interpret this finding within the context of COVID-19 deaths. As respiratory disease deaths predominantly occur among the elderly, there may be a competing risk between COVID-19 and other respiratory diseases. If vulnerable elderly individuals primarily die from COVID-19, a corresponding decrease in excess deaths from other respiratory diseases would be an expected observation.

Our study has several limitations. First, we did not consider alternative methods for estimating excess deaths. While we deemed the age-adjusted regression equation-based method the most appropriate of the 3 methods used, more accurate approaches may exist. Notably, however, sophisticated statistical methodologies do not necessarily ensure the validity of excess death estimates. For instance, a study [6] that assessed global excess mortality in 2020 and 2021 using an ensemble of 6 models faced strong criticism for producing unrealistic figures for many countries [36]. Second, excess deaths do not account for the number of life years lost. Deaths occurring at very old ages typically result in fewer life years lost than those at younger ages. Therefore, additional analyses that focus on years of life lost could offer a more detailed perspective on the pandemic's impact. Third, our analysis of cause-specific excess deaths was limited to several categories with enough deaths. This limitation was due to the small number of deaths across many categories.

In summary, this study revealed significant differences in excess deaths depending on the methodologies employed to determine expected mortality. This underscores the critical importance of incorporating adjustments for shifts in population age structure as well as mortality rate trends. Furthermore, while the annual data on excess deaths revealed a pronounced spike in 2022, age-specific analysis showed a consistent rise in excess deaths among individuals in their 20s throughout the duration of the pandemic. In anticipation of future infectious disease outbreaks, it is imperative to thoroughly evaluate the policies implemented during the COVID-19 pandemic. This should include the formulation of plans that address both the direct health consequences of the pandemic and the collateral damage to society that may arise from protective measures.

NOTES

Supplemental Materials

Supplemental material is available at https://doi.org/10.3961/jpmph.24.254.

Conflict of Interest

The authors have no conflicts of interest associated with the material presented in this paper.

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