

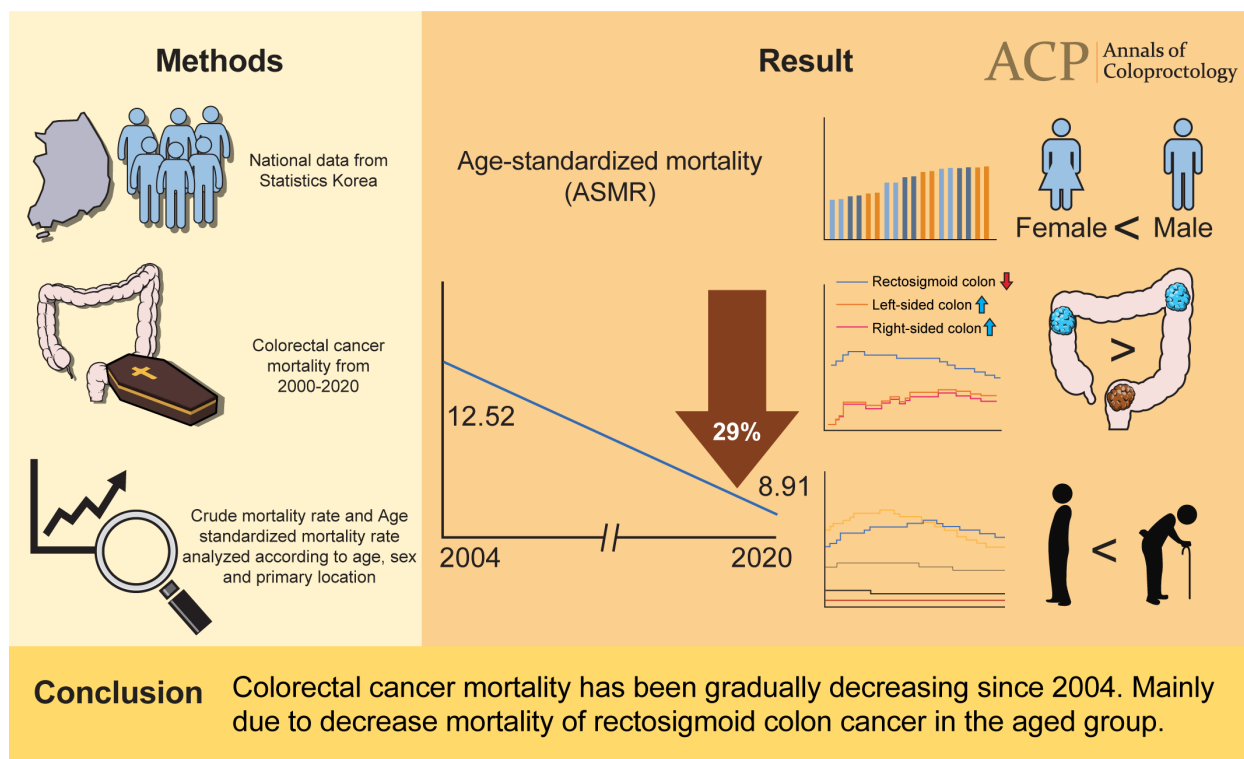


# Colorectal cancer mortality trends in the era of cancer survivorship in Korea: 2000–2020

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## Graphic Abstract



Received: Jul 27, 2022 • Revised: Aug 21, 2022 • Accepted: Aug 28, 2022

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**Purpose:** Korea has implemented an early screening for colorectal cancer since 2004. However, it is not known whether this has translated into improved survival over the years.

**Methods:** We acquired colorectal cancer mortality data from the Cause of Death Statistics in Korea from 2000 to 2020. We characterized the data into year of death, cancer-specific loci, and age group. We analyzed age-standardized mortality rates (ASMR) according to year of death, age group, and primary location to find trends in colorectal cancer mortality over a 20-year period.

**Results:** The crude mortality rate of colorectal cancer increased from 8.78 per 100,000 in 2000 to 17.27 per 100,000 in 2020. The second decade was slower in increments compared to the first decade. ASMR showed a decrease over the second decade after an initial increase in the first decade. The decrease was primarily from the lowering of ASMR for rectosigmoid cancers. Age group analysis showed a lowering of ASMR mainly in the 45–59-year, 60–74-year, and ≥75-year age groups; however, 0–29-year and 30–44-year age groups showed generally unchanged ASMR over the total period.

**Conclusion:** After a brief incline of age-specific mortality of colorectal cancers during the early 2000s, colorectal cancer mortality has gradually been decreasing in the past decade. This was mainly due to decreased mortalities in rectosigmoid colon cancers especially in the age groups that were the target of early screening.

**Keywords:** *Colorectal neoplasms; Mortality; Cancer survivors*

## INTRODUCTION

Cancer is the leading cause of death in many countries including South Korea [1]. Currently, there are 81,203 annual mortalities due to cancer which is 27.5% of the total deaths in Korea [2].

To reduce the burden of cancer on society, Korea has implemented a nationwide colorectal screening program as part of the National Cancer Screening Program since 1999 and has included colorectal cancer as part of this program since 2004 [3]. The program primarily focuses on low-income groups and provides an annual fecal occult blood test for adults aged 50 years or older for Medical Aid recipients and National Health Insurance beneficiaries within the lower 30% (broadened to lower 50% in 2005) income bracket. It also covers a subsequent colonoscopy or double-contrast barium enema study for those with a positive occult blood test. The program indirectly affected the higher income bracket by promoting the need for screening through advertisements to the general public. All procedure-related costs are paid by the individuals in these instances; however, the fees were kept affordable by the government for ease of accessibility. This has markedly increased survival outcomes through early detection and better treatment strategies. Currently, colorectal cancer is the fourth leading cause of cancer in Korea with 29,030 new cases each year [2]. And it is also one of the leading groups in the world in terms of 5-year relative survival [4].

Despite these efforts, colorectal cancer is still the 3rd leading cause of mortalities among cancer patients [2]. And recent data of the past 15 years showed that 82.1% of all colorectal cancer patients have still died due to the primary cancer [5]. This discrepancy in treatment outcomes and mortalities shows there are still obstacles to overcome. To approach this matter, we sought to find

trends in the mortality rate among colorectal cancer patients in Korea with respect to the year of mortality, primary tumor loci, and age group.

## METHODS

### Data source

We obtained Cause of Death Statistics data from Statistics Korea which is an annual survey conducted by the Korean government based on death certificates. Statistics Korea, a national agency under the Ministry of Economy and Finance collects death certificates from each local government office and analyzes 22 types of administrative data from related organizations to analyze the cause of death. Among the 22 types of administrative data, health insurance records, cancer registration data, and emergency records were surveyed in relation to cancer deaths. The data of Cause of Death Statistics is available on the Statistics Korea Microdata Integrated Service website [6].

This study was approved by the Institutional Review Board of Asan Medical Center (No. 2022-1073). The requirement for informed consent was waived because of the retrospective nature of the study.

### Data classification

We acquired data from each patient, age of death, sex, year of mortality, and the location of the primary tumor as classified by the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10). Codes used for identification of colorectal cancers were C18 Malignant neoplasm of colon — C18.0 Malignant neoplasm: cecum; C18.1 Malignant neoplasm: appendix; C18.2 Malignant neoplasm: ascending colon;

C18.3 Malignant neoplasm: hepatic flexure; C18.4 Malignant neoplasm: transverse colon; C18.5 Malignant neoplasm: splenic flexure; C18.6 Malignant neoplasm: descending colon; C18.7 Malignant neoplasm: sigmoid colon; C18.8 Malignant neoplasm: overlapping lesion of colon; C18.9 Malignant neoplasm, colon, unspecified; C19 Malignant neoplasm of rectosigmoid junction; C20 Malignant neoplasm of rectum. We did not include cancers of the anal canal (C21 Malignant neoplasm of anus and anal canal) mainly due to its pathologic and treatment differences from colorectal cancers. For analysis purposes, we further grouped the patients according to tumor loci: i.e., right-sided colon (C18.0-4), left-sided colon (C18.5-7), rectosigmoid colon (C19, C20), and unspecified colon (C18.8-9). Age groups were further classified into 5 main groups at mainly 15-year intervals with the exception of both age extremes (0–29, 30–44, 45–59, 60–74, and ≥ 75 years).

### Statistical analysis

Descriptive statistics were used for mortalities. Trends in crude mortality rate and age-standardized mortality rate (ASMR) were

shown over the observed period. The crude mortality rate is the ratio of the number of deaths in a specified population and time period to the total population at risk during the same time period and is expressed as cases per 100,000. Age-standardized rates are used when comparing rates of different populations either temporal or geographical by eliminating the age distribution as a confounding factor. It allows the direct comparison of the rates by adjusting the desired population to have the same age structure as a predefined standard population. ASMR is defined as the weighted average of the age-specific rates in which the weights represent the proportions of people in the corresponding age group in a standard population [7]. We used the mid-year population of Korea from 2005 as the standard population in our study (Supplementary Table 1) [8]. ASMR is expressed as cases per 100,000. The trends in crude mortality rate and ASMR were further analyzed according to sex, primary loci, and age group. The trends were also analyzed by age group per primary location. Data analysis was performed using spreadsheet software (Excel, Microsoft, Redmond, WA, USA)

**Table 1.** Total mortalities, CMR, and ASMR for all colorectal cancers and colorectal cancers according to the primary site

Year	All colorectal cancers			Right-sided colon cancer			Left-sided colon cancer			Rectosigmoid colon cancer			Unspecified colon cancer		
	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR
2000	4,174	8.78	10.50	54	0.11	0.14	74	0.16	0.19	1,704	3.58	4.27	2,342	4.93	5.90
2001	4,545	9.49	11.04	110	0.23	0.27	128	0.27	0.31	1,792	3.74	4.33	2,515	5.25	6.13
2002	5,067	10.53	11.82	570	1.18	1.32	577	1.20	1.34	2,241	4.66	5.21	1,679	3.49	3.95
2003	5,471	11.33	12.22	626	1.30	1.39	721	1.49	1.61	2,467	5.11	5.50	1,657	3.43	3.72
2004	5,842	12.05	12.52	635	1.31	1.36	789	1.63	1.69	2,552	5.26	5.46	1,866	3.85	4.01
2005	6,036	12.40	12.40	532	1.09	1.09	705	1.45	1.45	2,441	5.01	5.01	2,358	4.84	4.84
2006	6,238	12.76	12.27	609	1.25	1.20	867	1.77	1.71	2,642	5.40	5.20	2,120	4.34	4.16
2007	6,643	13.52	12.48	822	1.67	1.55	1,055	2.15	1.99	2,771	5.64	5.21	1,995	4.06	3.72
2008	6,802	13.77	12.16	976	1.98	1.75	1,280	2.59	2.30	2,813	5.69	5.04	1,733	3.51	3.08
2009	7,051	14.20	12.03	930	1.87	1.59	1,204	2.42	2.07	2,864	5.77	4.90	2,053	4.13	3.46
2010	7,645	15.33	12.41	1,174	2.35	1.90	1,455	2.92	2.39	3,169	6.35	5.18	1,847	3.70	2.94
2011	7,660	15.29	11.88	1,215	2.42	1.89	1,562	3.12	2.46	3,113	6.21	4.84	1,770	3.53	2.68
2012	8,135	16.16	11.97	1,498	2.98	2.20	1,708	3.39	2.54	3,310	6.57	4.92	1,619	3.22	2.32
2013	8,199	16.22	11.54	1,513	2.99	2.13	1,725	3.41	2.49	3,355	6.64	4.75	1,606	3.18	2.17
2014	8,338	16.43	11.11	1,546	3.05	2.03	1,829	3.60	2.49	3,374	6.65	4.57	1,589	3.13	2.02
2015	8,301	16.29	10.57	1,655	3.25	2.08	1,826	3.58	2.39	3,322	6.52	4.28	1,498	2.94	1.82
2016	8,358	16.35	10.11	1,672	3.27	1.99	1,826	3.57	2.27	3,315	6.49	4.08	1,545	3.02	1.77
2017	8,691	16.96	10.03	1,812	3.54	2.06	1,996	3.90	2.35	3,498	6.83	4.12	1,385	2.70	1.50
2018	8,715	16.99	9.55	1,853	3.61	1.96	2,052	4.00	2.31	3,404	6.64	3.84	1,406	2.74	1.44
2019	8,880	17.30	9.35	2,067	4.03	2.11	2,181	4.25	2.37	3,466	6.75	3.75	1,166	2.27	1.12
2020	8,869	17.27	8.91	2,113	4.11	2.05	2,208	4.30	2.29	3,447	6.71	3.57	1,101	2.14	0.99

CMR, crude mortality rate; ASMR, age-standardized mortality rate.  
CMR and ASMR are number per 100,000.

## RESULTS

### Mortality trends

The crude mortality rate of colorectal cancer increased from 8.78 per 100,000 in 2000 to 17.27 per 100,000 in 2020 (Table 1). The incline of crude mortality rate was higher during the first decade (6.6 increase; 8.78 to 15.33 per 100,000) than it was during the second decade (1.9 increase; 15.33 to 17.27 per 100,000). ASMR increased during the first few years and plateaued from 2003 to 2010 (Fig. 1); the highest being in 2004 with 12.52 per 100,000. During the second decade, ASMR showed decreasing trends from 12.41 per 100,000 in 2010 to 8.91 per 100,000 in 2020.

### Mortality trends according to primary tumor location

The crude mortality rate of right- and left-sided colon cancers has steadily risen during the observed period (Table 1, Fig. 2A). ASMR shows an increase during the first decade and leveling out during the second decade. This plateau was reached in 2012 for right-sided colon cancers and 2008 for left-sided colon cancers (Fig. 2B). There was a steeper increase of mortalities during the first decade for both right- and left-sided colon cancers. Crude mortality rate for rectosigmoid colon cancer increased during the observed period where a similar trend of higher increase during the first decade than the second was observed. On the other hand, the ASMR showed a gradual decrease after peaking in 2003 from

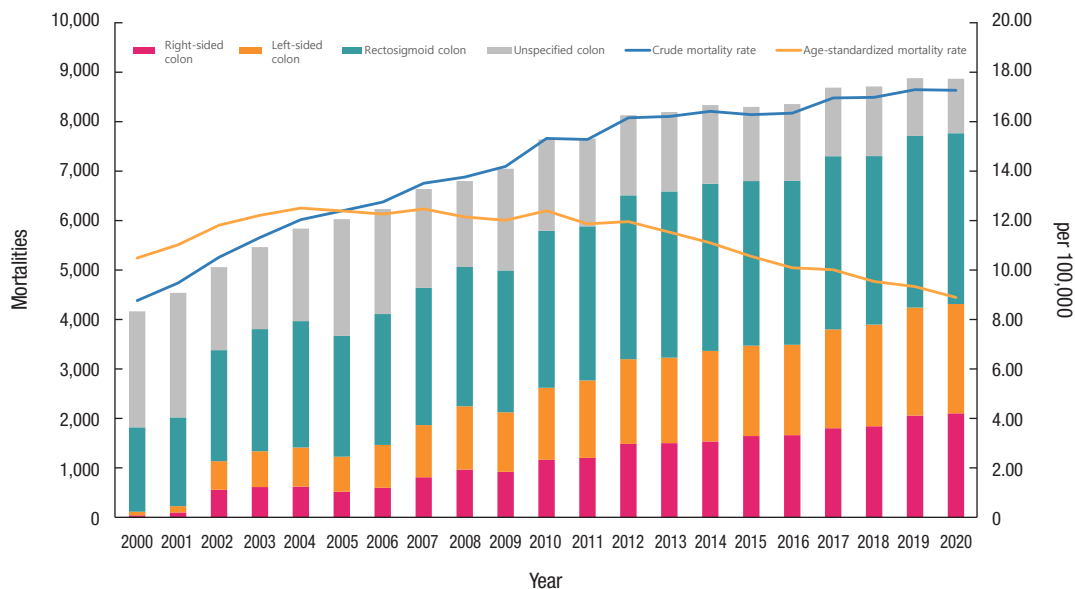


Fig. 1. Cumulative chart of total mortalities per primary loci and crude mortality rate and age-specific mortality rate for overall colorectal cancers.

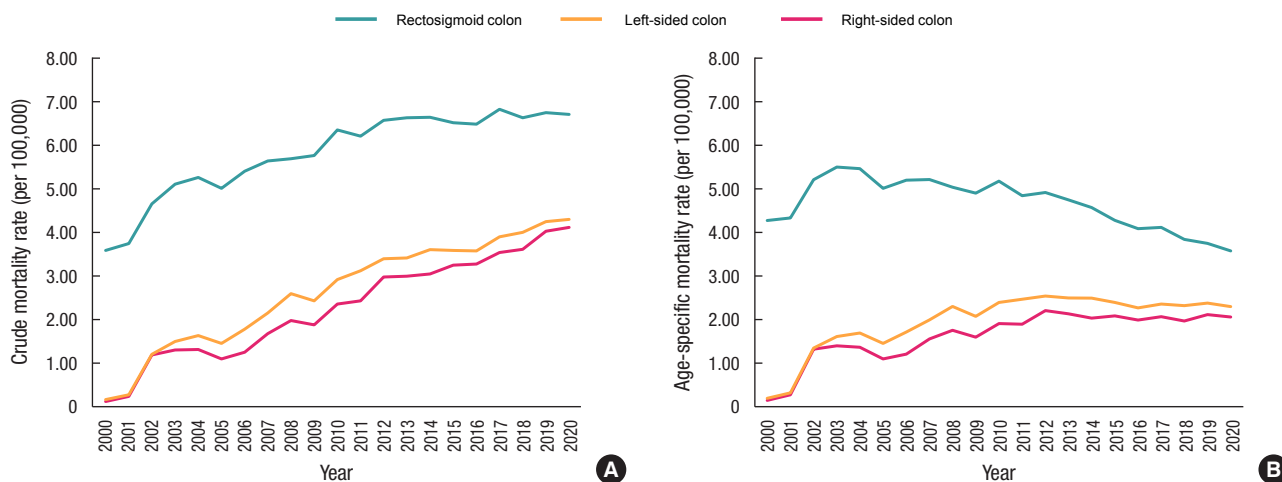


Fig. 2. (A) Crude mortality rate per primary loci. (B) Age-standardized mortality rate per primary loci.

5.5 per 100,000 to 3.57 per 100,000 in 2020. This decline was steeper during the second decade when ASMR for rectosigmoid colon cancer was 5.18 in 2010. However, the crude mortality rate and ASMR of rectosigmoid colon cancers were higher than that of right- or left-sided colon cancers even in most recent years (mortality rates in 2020: rectosigmoid crude mortality rate, 6.71/100,000 vs. right-sided colon crude mortality rate, 4.11/100,000 vs. left-sided colon crude mortality rate, 4.3/100,000; rectosigmoid ASMR, 3.57/100,000 vs. right-sided colon ASMR, 2.05/100,000 vs. left-sided colon ASMR, 2.29/100,000).

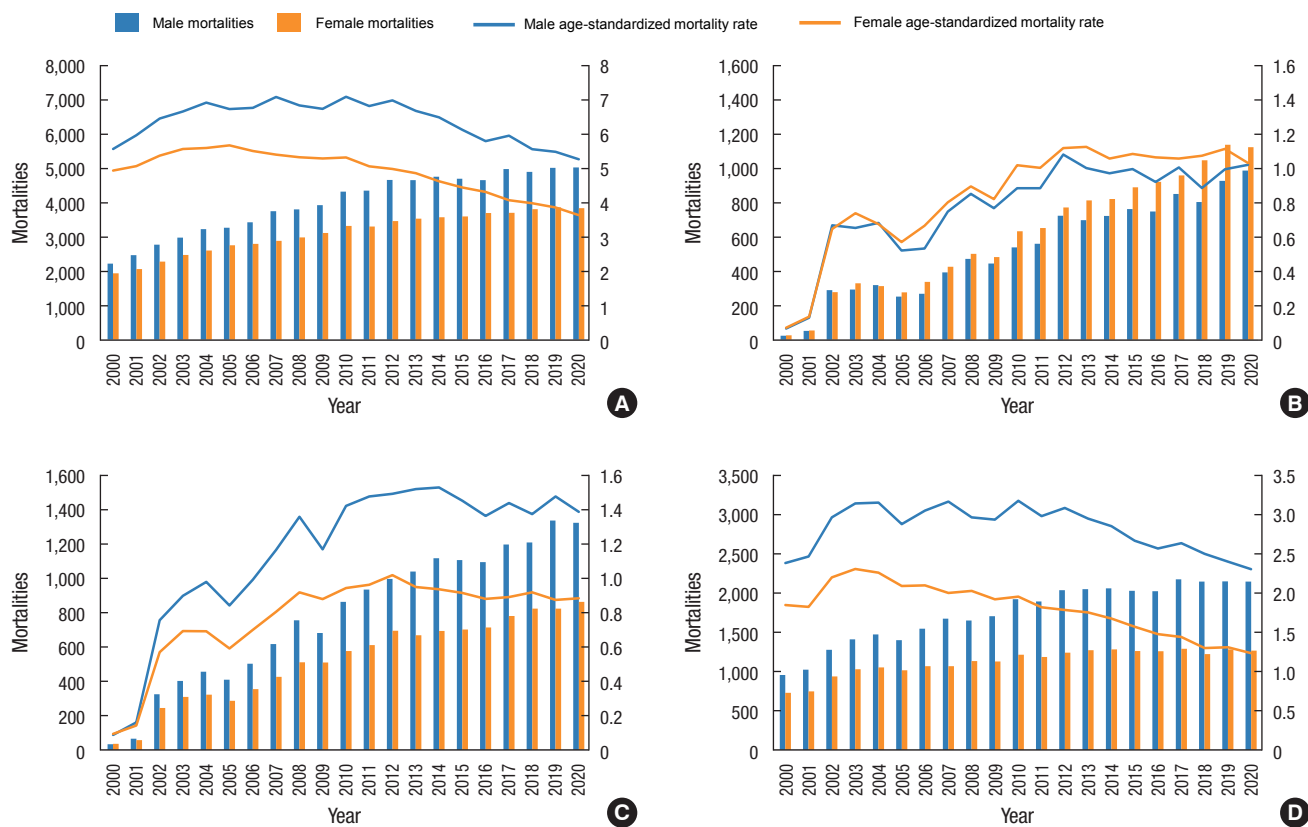
### Mortality trends according to sex: per primary tumor location

Crude mortality rate showed a steady increase for both males and females over the observed period leveling out since 2017 for males and 2018 for females (Fig. 3A, Supplementary Tables 2–3). Male ASMR for overall colorectal cancers plateaued from 2002 to 2014 and steadily declined after this period. Female ASMR for overall colorectal cancers peaked in 2005 and steadily declined since. Crude mortality rate and ASMR were higher for males than for females in overall colorectal cancers. This gap was more prominent in the left-sided colon and rectosigmoid colon cancers.

However, for right-sided colon cancers female crude mortality and ASMR both were higher than males since 2005 (Fig. 3B vs. Fig. 3C–D). Right-sided colon cancer ASMR for both sexes topped in 2012 and was relatively steady since. Left-sided colon cancer ASMR for females topped in 2012 and steadily declined. Left-sided colon cancer ASMR for males on the other hand, has remained relatively steady since 2010. For rectosigmoid colon cancers, crude mortality rate showed an increase during the first decade for both sexes. However, while there was a slight increase in crude mortality rate for males in the second decade, this remained relatively stable for females. ASMR for rectosigmoid colon cancers showed a decreasing trend for both sexes after a peak was reached. This was after 2010 for males; and for females, the decreasing trend was achieved since 2003.

### Mortality trends according to age group

Comparing crude mortality rates in each age group, the lowest was the youngest age group (0–29-year age group) and increased with each progressive age group. In the year 2000, this gap was 9.3-fold from the 0–29-year to 30–44-year age group, 5.6-fold from the 30–44-year to 45–59-year age group, 3.7-fold from the 45–59-year to 60–74-year age group, and 2.6-fold from the 60–74-



**Fig. 3.** Total mortalities and age-standardized mortality rates for males and females for (A) overall colorectal cancer, (B) right-sided colon cancer, (C) left-sided colon cancer, and (D) rectosigmoid colon cancer.

year to 75 years and older age group (Table 2). This increase was 10.5-fold, 6.7-fold, 3.2-fold, and 4.2-fold respectively for the year 2020.

The crude mortality rate did not change much in the observed period for the 0–29-year and 30–44-year age groups. Prominent decreases in crude mortality rates were found in more recent years in the latter 3 age groups (Fig. 4A). For the 45–59-year age group, crude mortality rate was 12.6 per 100,000 that peaked in 2003 and was reduced to 9.91 per 100,000 in 2020. For the 60–74-year age group, the peak was 55.36 per 100,000 in 2007 and was reduced to 31.90 per 100,000 in 2020. For the 75 years and older age group, the peak was 168.05 per 100,000 in 2012 and was reduced to 134.75 in 2020 (Table 2).

The ASMR remained relatively stable for the 0–29-year and 30–44-year age groups. Decreases were shown in the older groups (Fig. 4B). For the 45–59-year age group, the ASMR peaked at 2.35 per 100,000 in 2004 and decreased to 1.85 per 100,000 in 2020. The most substantial decrease was shown for the 60–74-year age group peaking at 5.5 per 100,000 in 2007 and decreasing to 3.17

per 100,000 in 2020. For the 75 years and older age group, the peak was in 2012 at 4.78 per 100,000 reduced to 3.83 per 100,000 in 2020. ASMR was highest in the 60–74-year age group up until 2014 when ASMR of the 75 years and older age group surpassed that of the 60–74-year age group.

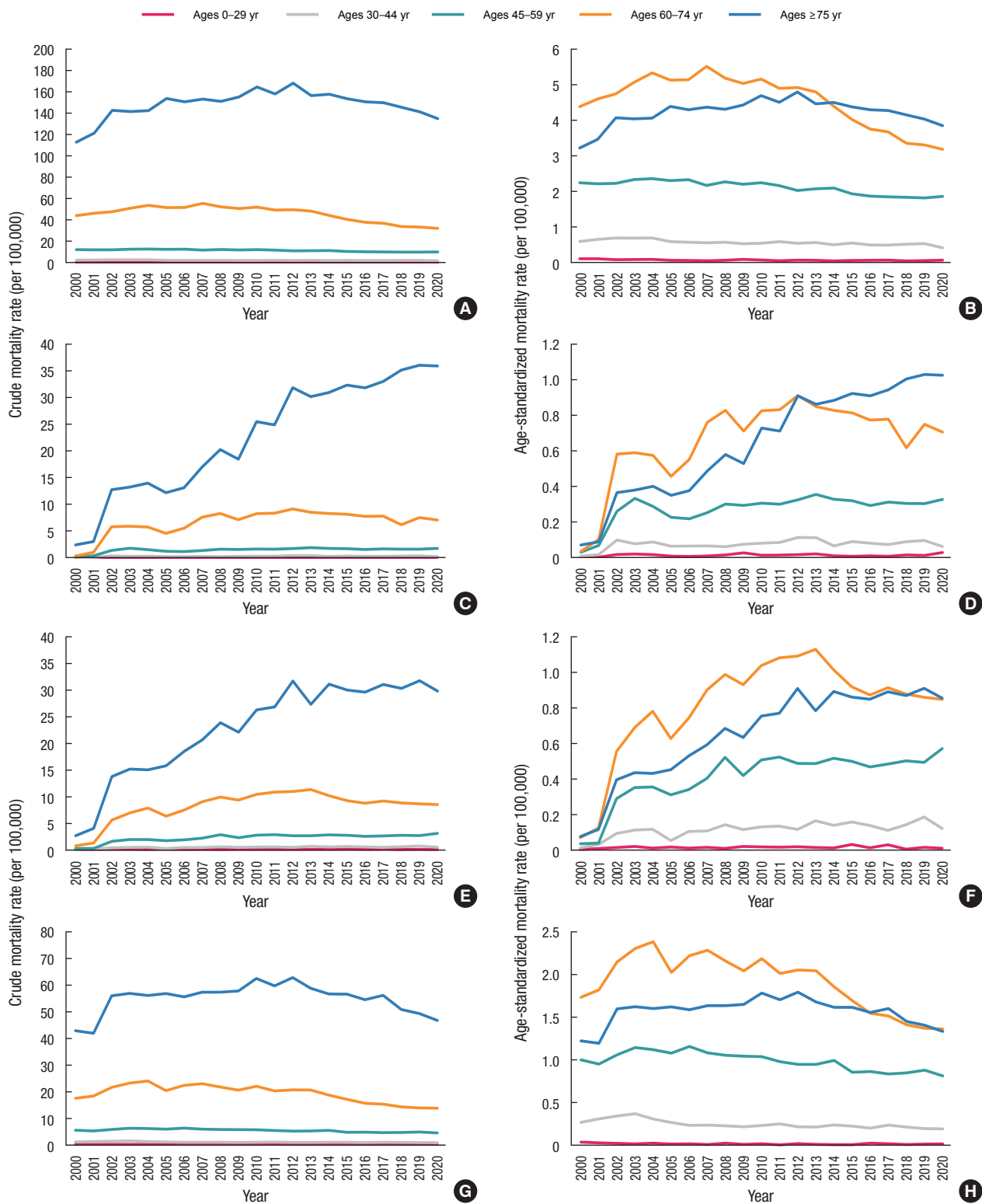
Comparison of crude mortality rate and ASMR per sex for each age group showed similar patterns. For both sexes, crude mortality rate decrease was more prominent from the first decade for the 60–74-year age group and a decrease was shown since 2012 for the 75 years and older age group (Supplementary Fig. 1A, B). Slight differences were shown between sexes in these age groups for ASMR. The general trend of decreasing ASMR starting from the first decade for the 60–74-year age group and from 2012 for the 75 years and older age group withheld for both sexes. However, male ASMR for the 60–74-year age group remained higher than that of the 75 years and older age group throughout the observed period where female ASMR for the 75 years and older age group was higher than that of the 60–74-year age group since 2001 (Supplementary Fig. 1C, D).

**Table 2.** Total mortalities, CMR, and ASMR for all colorectal cancers according to age group

Year	Age group (yr)														
	0–29			30–44			45–59			60–74			75 and older		
	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR	Mortalities	CMR	ASMR
2000	51	0.23	0.10	277	2.14	0.58	875	11.98	2.23	1,749	43.93	4.37	1,221	112.69	3.21
2001	49	0.22	0.09	311	2.37	0.64	898	11.81	2.20	1,921	46.14	4.58	1,365	121.24	3.45
2002	35	0.16	0.07	331	2.50	0.68	935	11.89	2.21	2,090	47.58	4.73	1,676	142.52	4.06
2003	36	0.17	0.07	331	2.49	0.67	1,018	12.46	2.32	2,335	50.85	5.05	1,751	141.45	4.02
2004	39	0.19	0.08	333	2.50	0.68	1,080	12.60	2.35	2,528	53.49	5.32	1,862	142.27	4.05
2005	25	0.12	0.05	280	2.12	0.58	1,114	12.29	2.29	2,488	51.43	5.11	2,129	153.69	4.37
2006	23	0.12	0.05	268	2.06	0.56	1,193	12.44	2.32	2,554	51.58	5.13	2,200	150.46	4.28
2007	18	0.09	0.04	257	1.99	0.54	1,161	11.57	2.16	2,833	55.36	5.50	2,373	153.07	4.36
2008	25	0.13	0.05	263	2.06	0.56	1,257	12.12	2.26	2,764	52.04	5.17	2,493	150.86	4.29
2009	36	0.19	0.08	244	1.91	0.52	1,256	11.75	2.19	2,770	50.50	5.02	2,745	155.08	4.41
2010	27	0.15	0.06	248	1.95	0.53	1,321	11.97	2.23	2,914	51.76	5.14	3,135	164.41	4.68
2011	18	0.10	0.04	271	2.13	0.58	1,315	11.54	2.15	2,821	49.13	4.88	3,234	157.82	4.49
2012	25	0.14	0.06	248	1.95	0.53	1,264	10.82	2.01	2,916	49.34	4.90	3,681	168.05	4.78
2013	22	0.13	0.05	255	2.03	0.55	1,324	11.05	2.06	2,944	48.14	4.78	3,654	156.29	4.45
2014	14	0.08	0.03	221	1.79	0.48	1,376	11.19	2.08	2,782	44.05	4.38	3,945	157.61	4.48
2015	20	0.12	0.05	239	1.98	0.54	1,290	10.30	1.92	2,664	40.35	4.01	4,088	153.36	4.36
2016	21	0.12	0.05	210	1.78	0.48	1,266	9.96	1.85	2,604	37.65	3.74	4,257	150.43	4.28
2017	22	0.13	0.05	203	1.77	0.48	1,266	9.84	1.83	2,652	36.81	3.66	4,548	149.69	4.26
2018	13	0.08	0.03	208	1.85	0.50	1,266	9.77	1.82	2,532	33.60	3.34	4,696	145.41	4.14
2019	16	0.10	0.04	210	1.91	0.52	1,258	9.68	1.80	2,634	33.14	3.29	4,761	141.17	4.02
2020	22	0.14	0.06	159	1.47	0.40	1,280	9.91	1.85	2,693	31.90	3.17	4,714	134.75	3.83

CMR, crude mortality rate; ASMR, age-standardized mortality rate.  
CMR and ASMR are number per 100,000.





**Fig. 4.** Crude mortality rate and age-standardized mortality rate for each age group. (A, C, E, G) Crude mortality rate for each age group for (A) overall colorectal cancer, (C) right-sided colon cancer, (E) left-sided colon cancer, and (G) rectosigmoid colon cancer. (B, D, F, H) Age-standardized mortality rate for each age group for (B) overall colorectal cancer, (D) right-sided colon cancer, (F) left-sided colon cancer, and (H) rectosigmoid colon cancer.

### Mortality trends according to age group: per primary tumor location

For right-sided colon cancer, both crude mortalities and ASMR remained relatively unchanged over the observed period for the youngest 3 groups (0–29, 30–44, and 45–59 years old). For the 60–74-year age group, there was an increase in crude mortality rate up until 2012 when it peaked at 9.14 per 100,000 and decreased to 7.07 per 100,000 in 2020 (Fig. 4C, Supplementary Table 4). ASMR also peaked in 2012 and gradually decreased since. This is also the year where the ASMR of the 75 years and older age group surpassed the 60–74-year age group. The 75 and older age group showed increases in both crude mortality rates and ASMR over the observed period (Fig. 4C, D).

For left-sided colon cancer, similar trends of unchanged mortality were observed for the youngest 2 age groups (0–29 and 30–44 years). The 45–59-year age group showed an increase in crude mortality rate and ASMR mainly during the first decade and leveling out during the second decade (Fig. 4E–F, Supplementary Table 5). The crude mortality of the 60–74-year age group increased until 2013 when it peaked at 11.33 per 100,000 and decreased to 8.49 per 100,000 in 2020. The ASMR also decreased with similar trends and converged toward the ASMR for the 75 years and older age group since 2016. For the 75 years and older age group, the crude mortality rate increased during the first decade and plateaued since 2012. The ASMR showed similar trends with a small increase during the second decade.

For rectosigmoid colon cancer, the youngest group showed higher total mortalities during the earlier years (2000–2004) but leveled out to a median of 6.5 per year afterward (Supplementary Table 6). The 30–44-year age group showed an initial spike in 2003 but crude mortality has decreased to about half since (1.37 per 100,000 in 2003 vs. 0.71 per 100,000 in 2020) (Fig. 4G, Supplementary Fig. 2A). This decrease is also evident in ASMRs (Fig. 4H, Supplementary Fig. 2B). For the 45–59-year age group, after an initial increase until 2006 both crude mortality rate and ASMR decreased by approximately 30% over the observed period (crude mortality rate, 6.15 per 100,000 in 2006 vs. 4.37 per 100,000 in 2020; ASMR, 1.15 per 100,000 in 2006 vs. 0.81 per 100,000 in 2020). The 60–74-year age group crude mortality rate peaked at 24.00 per 100,000 in 2004 and has decreased approximately 43% to 13.72 per 100,000 in 2020. ASMR has shown a similar 43% decrease from the same period (2.31 per 100,000 in 2004 vs. 1.36 per 100,000 in 2020). For the 75 years and older age group, the crude mortality rate peaked at 63.09 per 100,000 in 2012 and steadily decreased to 46.88 per 100,000 in 2020. ASMR for this group decreased 26.1% during this period. The ASMR for the 60–74-year and 75 years and older age groups have converged since 2016.

## DISCUSSION

Our study reported trends in colorectal cancer mortalities over a 20-year period with respect to sex, primary loci, and age group.

Our findings showed a biphasic increase in crude mortality rates where the second decade was slower in increments compared to the first decade. ASMR showed a decrease over the second decade after an initial increase in the first decade. The decrease was primarily from lowering of ASMR for rectosigmoid cancers contrary to right- and left-sided colon cancers remaining generally leveled out during the second decade. Age group analysis showed lowering of ASMR mainly in the 45–59-year, 60–74-year, and 75 years and older age groups; however, the 0–29-year and 30–44-year age groups showed generally unchanged ASMR over the total period.

Despite advancements in treatment and implementation of a nationwide screening program, the crude mortality rate has steadily increased during the observed period. Korea is one of the fastest aging countries in the world earning the title of aged society by World Health Organization definitions in 2017 (14% of the total population over 65 years of age) and is projected to reach super-aged society (21% of total population over 65 years of age) within 10 years [9]. The total mortalities of ages 60 years and older comprised 83.5% (7,407 of 8,869) of the total colorectal cancer mortalities in 2020. This was up from 71.2% (2,970 of 4,174) in 2000 and 79.1% (6,049 of 7,645) in 2010. The shift toward an aging population was the primary driver of higher crude mortality rates in the observed period and may continue in the years to come.

The ASMR showed an increase up to 2003, leveled out from 2003 to 2010, and decreased mainly during the second decade. This latent decrease has caused some concerns about the effect of the nationwide screening program in Korea in terms of cancer mortality prevention during the first decade of implementation [10]. However, numerous studies have shown the effect of active screening programs on lowering mortality from colorectal cancer in the long term [11–13]. Additionally, the change was not instantaneous and required leading time until the decrease in mortality was achieved [13, 14]. This trend was also evident in the Korean population and eventually ASMR decreased during the second decade. While the initiation of a nationwide screening program may have a primary role in lowering colorectal cancer ASMR through early detection and treatment of cancerous lesions in their earlier state, there are additional policy-induced contributing factors to the decrease in ASMR over the years including increasing awareness for higher adherence rates of screening [3, 15], better treatment options available through insurance coverage [16], and nationwide quality assessment of the treatment given to colorectal cancer patients [17]. This has in turn led to a higher standard of care where Korea is now one of the leading countries in terms of colorectal cancer treatment and survival rates [18, 19].

Despite these strengths, our findings show areas where improvement can be made. While the decrease in ASMR of rectosigmoid colon cancers started early and persisted throughout the second decade, the ASMR of right- and left-sided colon cancers has remained generally unchanged during the second decade. Additionally, mortalities and ASMR were higher for females than it was for males for right-sided colon cancer. Right-sided colon can-



cers are known to be predominantly female and have a higher proportion of genetic predisposition [20]. A better understanding of the pathogenesis and pathophysiologic properties of right- and left-sided colon cancers vs. rectosigmoid cancers will provide insight into the stagnation of ASMR in recent years.

Equally important regarding sexual differences, is that there is still a male predominance in left-sided and rectosigmoid colon cancer mortalities. It has been presumed that differences in risk factor exposure among sexes may have contributed to incidence and mortality differences. Bridging this gap among the sexes is also of importance. Further studies regarding the incidence and mortality per primary loci and age group among sexes may provide insight toward this matter.

Another feature is the relatively unchanged mortality trend of early-onset colorectal cancer. The incidence of young colorectal cancer is increasing in recent decades [21] and recent changes in recommendations have been made for the starting age of screening for colorectal cancer in various societies [22, 23] including Korea [24]. However, there are concerns that ever lowering the screening age may not be an economical choice and individual approaches should be made for screening those at high risk.

Limitations of this study were first, the lack of lead time or cancer stage information when the patient was first diagnosed. As discussed, the lead time was the primary cause of the delay in screening program initialization and its effects on lowering ASMR. Without this data, it is hard to distinguish mortalities that were from initially late-stage colorectal cancer from patients who received all treatment but eventually recurred or metastasized. Second is the high proportion of primary site unspecified colorectal cancer in the first decade. It is unclear whether this was the result of high proportion of initially late-stage colorectal cancers or masked results from the practice habits of physicians. Nonetheless, the proportion was lowered and was a downward trend during the second decade. Third is the usage of 2005 mid-year population of Korea as the standard population prohibiting direct comparison of ASMR rates to other countries. Although the standard population may be an arbitrary population, many international age-specific rates are derived from the Segi standard population [7] to provide direct comparison among populations in a temporal and geographical sense. However, it is criticized that this reference population does not accurately reflect the population in the present especially in the elderly. We thus used our national census data to better reflect a rapidly aging society.

After a brief incline of age-specific mortality of colorectal cancers during the early 2000s, colorectal cancer mortality has gradually been decreasing in the past decade. This was mainly due to decreased mortalities in rectosigmoid colon cancers, especially in the age groups that were the target of early screening.

## CONFLICT OF INTEREST

In Ja Park is the current editor-in-chief of *Annals of Coloproctology*.

ogy; however, she did not interfere with the reviewing or decision process of this manuscript. No other potential conflict of interest relevant to this article was reported.

## FUNDING

None.

## AUTHOR CONTRIBUTIONS

Conceptualization, Project administration: IJP, SP. Data curation, Formal analysis: NY, SP, BK. Investigation, Methodology, Validation: all authors. Resources: MHK, NY, SP. Software: MHK, NY, BK. Supervision: IJP. Visualization: MHK, NY, SP, BK. Writing—Original Draft: MHK, SP. Writing—Review & Editing: all authors.

All authors have read and approved the final manuscript.

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## SUPPLEMENTARY MATERIALS

Supplementary materials for this study are presented online (available at <https://doi.org/10.3393/ac.2022.00535.0076>).

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