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Trends in major cancer mortality in Korea, 1983–2012, with a joinpoint analysis

Daroh Lim[a], Mina Ha[b], Inmyung Song[c,*]

[a] Department of Health Administration, Kongju National University College of Nursing and Health, 56 Gongjudaehak-Ro, Gongju-si, Chungnam 314-701, South Korea
[b] Department of Preventive Medicine, Dankook University College of Medicine, 119 Dandae-ro, Dongnam-gu, Cheonan, Chungnam 330-714, South Korea
[c] Department of R&D Planning, Korea Health Industry Development Institute, 187 Osongsaengmyeong 2-ro, Heungdeock-gu, Cheongju-si, Chungbuk 363-700, South Korea

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ABSTRACT

Background: Cancer is the leading cause of death in Korea. This study aims to examine changes in temporal trends in major cancer mortality.
Materials and methods: Mortality data for 1993–2012 were obtained from the *Korean Statistics Information Service*(*KOSIS*) database and age-standardized to the 2000 Korean population. Joinpoint analysis was used to identify significant changes in trends over time. The annual percentage rate change (APC) was computed for each segment of the trends.
Results: The age-standardized mortality rates (ASR) for all cancer sites combined decreased by 9.1% and 1.1% in men and women, respectively, from 1983 to 2012. ASRs from cancers of esophagus, stomach, and liver decreased substantially, whereas ASRs from cancer for all other sites increased markedly. ASRs for all cancer sites combined increased until 1994 and thereafter decreased significantly in both genders except for the period of 1998–2002 (APC: −5.5% for men [$p < 0.05$] and 0.07% for women). ASRs for esophagus and liver cancers increased until the early 1990s and thereafter declined, leading to significant decreases [$p < 0.05$] for esophagus cancer (APC: −1.85% for men and −3.82% for women) and liver cancer (APC: −1.55% for men and −0.56% for women) in 1983–2012. ASRs for stomach cancer declined (APC: −4.06% for men and −4.07% for women) except for 1990–1994. ASRs for uterine cancer peaked in 2003 and then declined (APC: 2.85%). ASRs increased significantly until 2002 for colorectal cancer in men (APC: 7.52%) and lung cancer in both genders. The most consistently upward trend was observed for non-Hodgkin's lymphoma (APC: 3.55% for men and 5.29% for women; number of joinpoints = 0). The greatest ASR increase was seen for prostate cancer for which mortality increased until 2002 at an APC of 12.56%.
Conclusion: While mortality decreased significantly for esophagus, stomach and liver cancers in recent decades in Korea, challenges still remain for many other cancers, especially pancreatic, breast, and prostate cancers and non-Hodgkin's lymphoma. Surveillance of cancer mortality trends can lend valuable insights as to the prevention and control of cancer. Public health promotion efforts to control cancer such as lowering smoking rate and obesity could reduce the burden of cancer in many sites.

1. Introduction

Cancer is a major public health problem in Korea as in many other parts of the world [1]. The top three leading causes of death in Korea in 2012 were heart diseases, cerebrovascular diseases, and cancer, with cancer causing more deaths than heart and cerebrovascular diseases combined [2]. Cancer has been the leading cause of death in Korea since 1983, and claimed 73,757 deaths in 2012, which accounted for one in three deaths for men and one in four deaths for women [3]. A previous study examined trends in cancer mortality in Korean men and women who were of target age for the national cancer screening programs using data for 1983–2007 (over 30 years for cervix, over 40 years for stomach, liver, and breast, and over 50 years for colon and rectum) [4]. Therefore, longer-term trends in cancer mortality in the entire Korean population using data for three decades merit investigation. This study aims to analyze temporal trends in major cancer mortality rates in Korea from 1983 to 2012.

* Corresponding author. Fax: +82 43 710 0001.
E-mail addresses: moon5@kongju.ac.kr (D. Lim), minaha@dku.edu (M. Ha), inmyungs@gmail.com (I. Song).

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2. Material and methods

2.1. Data

Mortality data for 1983–2012 were obtained from the *Korean Statistics Information Service* (*KOSIS*) database [5]. The causes of death in the *KOSIS*database were coded and classified according to the *International Classification of Diseases, tenth revision*(ICD-10) codes. 13 major causes of cancer death were identified based on 2012 mortality statistics. The ICD-10 codes used for the causes of cancer death were C15 for esophageal cancer, C16 for stomach cancer, C18–C21 for colon and rectum cancer, C22 for liver cancer, C25 for pancreatic cancer, C33–C34 for lung and bronchus (lung) cancer, C50 for breast cancer, C53–C55 for uterine cancer, C61 for prostate cancer, C67 for urinary bladder cancer, C71 for brain cancer, C82–C85 for non-Hodgkin's lymphoma, and C91–C95 for leukemia. Overall cancer was defined as cancer at any site (C00–C97). Crude cancer mortality rates were computed and age-standardized to account for the aging of the population using the 2010 Korean population as the standard population [6].

In Korea, the death certificate is mostly issued by a licensed physician [7]. The immediate cause of death is a direct injury or complication, and the underlying cause of death is the disease having a medically causal relationship with the immediate cause of death. For example, if a person dies with esophageal varix bleeding complicated by liver cancer, the immediate cause of death is esophageal varix bleeding and the underlying cause of death is liver cancer.

2.2. Statistical analysis

We used joinpoint regression analysis to identify the years when there were significant changes in the age-standardized mortality rates. Joinpoint regression analysis fits a series of joined straight lines to the age-standardized mortality rates on a logarithmic scale [8]. Straight light segments are joined at "joinpoints" where mortality trend changes its slope statistically significantly. The number of joinpoints started from 0 and was increased to test if the addition of joinpoints improved the fitness of model significantly. Analysis started with 0 and tested for model fit with a maximum of 5 joinpoints. The slope of each line segment of the best-fitting model was expressed as the annual percentage rate change (APC) in the age-standardized mortality rate (ASR). Significance tests were performed using the Monte Carlo permutation technique (two-sided$P < 0.05$). The best-fitting model was estimated separately for men and women. The Joinpoint Regression Program version 4.1.0 (US National Cancer Institute, Bethesda, MD, USA) was used for the statistical analysis. Approval from the institutional review board was not required for this study.

3. Results

Table 1 describes the number of deaths, crude death rates, and ASRs for major cancer sites in men and women in 1983–2012. The overall cancer mortality rates for all sites combined decreased by 9.1% and 1.1% in men and women, respectively, from 1983 to 2012. ASR % change, however, differed by site. ASRs from cancers of esophagus, stomach, and liver decreased substantially, whereas ASRs from cancer for all other sites increased markedly from 1983 to 2012. The highest increase in ASRs was observed for prostate cancer at 1053.3%. Colorectal cancer, pancreatic cancer, and non-Hodgkin's lymphoma all had over 200% increases in ASRs in both men and women. The lowest increase in ASRs was observed for leukemia at 30% and 38.1% for women and men, respectively.

Tables 2 and 3 summarize the results of joinpoint analyses for men and women, respectively. ASRs for all cancers sites combined increased until 1994 and thereafter decreased significantly in both genders except for the period of 1998–2002 (APC: −5.5% for men and 0.07% for women). In particular, ASRs from esophagus cancer increased from 1983 to 1993 among men and thereafter decreased significantly. Similarly, ASRs from liver cancer also showed an upward trend from 1983 to 1994 followed by significant declines except for the period of 1998–2002 (APC: −1.55% for men and −0.56% for women). ASRs from stomach cancer showed downward trends from 1983 to 2012 except for 1991–1994 in men and for 1990–1993 in women. ASRs from colorectal cancer, on the other hand, increased until 2002 in men and until 2004 in women and leveled off (APC: 4.25% for men and 4.01% for women). ASRs from pancreatic cancer also increased at a marked rate from 1983 to 1994 (APC until 1994: 9.82% for men and 12.57% for women), but the rate of increase slowed thereafter. ASRs from lung cancer increased at a rapid rate until 1993 in men and until 1994 in women (APC: 9.83% for men and 8.98% for women) and then at a slower rate until 2002 when they started to decrease.

ASRs from prostate cancer increased at an APC of 12.56% from 1983 to 2002 and thereafter leveled off. ASRs from breast cancer

Table 1
Crude and age-standardized death rates for major cancers in Korean men and women, 1983–2012.

	Men							Women						
	1983			2012				1983			2012			
Site	Deaths[a]	CDR[b]	ASR[c]	Deaths[a]	CDR[b]	ASR[c]	ASR % Change[d]	Deaths[a]	CDR[b]	ASR[c]	Deaths[a]	CDR[b]	ASR[c]	ASR % Change[d]
All sites	17,789	88.4	187.7	46,462	185.6	170.7	−9.1	10,998	55.6	102.78	27,297	109.3	101.7	−1.1
Esophagus	559	2.8	6.4	1,278	5.1	4.7	−26.8	121	0.6	1.19	120	0.5	0.4	−63.0
Stomach	7,566	37.6	83.5	6,090	24.3	22.4	−73.2	4,579	23.1	45.32	3,252	13.0	12.1	−73.3
Colon & Rectum	340	17.0	3.6	4,692	18.7	17.6	371.4	326	1.6	3.21	3,506	14.0	12.9	302.2
Liver	4,801	23.9	48.6	8,494	33.9	34.0	−30.0	1,583	8.0	15.13	2,841	11.4	12.6	−16.8
Pancreas	236	1.2	2.5	2,616	10.4	9.6	287.1	160	0.8	1.61	2,162	8.7	8.0	398.1
Lung	1,659	8.2	18.4	12,171	48.6	44.4	142.1	684	3.5	6.52	4,476	17.9	16.5	153.4
Breast	–	–	–	–	–	–	–	408	2.1	3.51	1,993	8.0	7.6	117.4
Uterine	–	–	–	–	–	–	–	1421	7.2	12.4	1219	4.9	5.4	−56.8
Prostate	29	0.1	0.5	1,460	5.8	5.2	1053.3	–	–	–	–	–	–	–
Bladder	120	0.6	1.5	918	3.7	3.3	125.3	36	0.2	0.36	303	1.2	1.1	202.8
Brain	130	0.6	1.0	588	2.3	2.3	134.0	84	0.4	0.6	545	2.2	2.3	314.3
Non-Hodgkin's lymphoma	139	0.7	1.2	927	3.7	3.8	221.8	75	0.4	0.6	598	2.4	2.7	339.3
Leukemia	489	2.4	2.5	919	3.7	3.5	38.1	428	2.2	2.20	747	3.0	2.9	30.0

[a] Number of deaths.
[b] Crude death rates (per 100,000).
[c] Age-standardized death rates adjusted to the 2010 Korean standard population (per 100,000).
[d] Percentage of the 1983 rate.

Table 2
Trends in age-standardized death rates for major cancers in Korean men according to joinpoint analysis, 1983–2012[a].

		Trend 1		Trend 2		Trend 3		Trend 4		Trend 5	
	APC 1983–2012	Period	APC	Period	APC	Period	APC	Period	APC	Period	APC
All sites	−0.55[b]	1983–1991	2.00[b]	1991–1994	4.54[b]	1994–1998	−2.78[b]	1998–2002	−1.00	2002–2012	−3.06[b]
Esophagus	−1.85[b]	1983–1993	4.14[b]	1993–2002	−2.34[b]	2002–2012	−5.12[b]				
Stomach	−4.06[b]	1983–1991	−3.43[b]	1991–1994	1.52	1994–1998	−6.90[b]	1998–2002	−1.97[b]	2002–2012	−6.56[b]
Colon & Rectum	4.25[b]	1983–2002	7.52[b]	2002–2012	0.16						
Liver	−1.55[b]	1983–1994	1.54[b]	1994–1998	−5.46[b]	1998–2002	1.11	2002–2012	−3.52[b]		
Pancreas	2.04[b]	1983–1994	9.82[b]	1994–2012	0.21						
Lung	1.37[b]	1983–1993	9.83[b]	1993–2002	1.82[b]	2002–2012	−2.40[b]				
Prostate	6.28[b]	1983–2002	12.56[b]	2002–2012	0.56						
Bladder	1.32[b]	1983–1995	6.44[b]	1995–1998	−4.68	1998–2002	10.43[b]	2002–2005	−8.34	2005–2012	−1.49
Brain	0.26	1983–1988	38.67[b]	1988–2012	−0.98[b]						
Non-Hodgkin's lymphoma	3.55[b]	1983–2012	3.55[b]								
Leukemia	0.51[b]	1983–1993	4.86[b]	1993–2012	−0.78[b]						

[a] APC annual percent rate change of age-standardized death rates.
[b] The annual percent rate change is significantly different from 0 (two-sided $p < 0.05$).

Table 3
Trends in age-standardized death rates for major cancers in Korean women according to joinpoint analysis, 1983–2012[a].

		Trend 1		Trend 2		Trend 3		Trend 4		Trend 5	
	APC 1983–2012	Period	APC	Period	APC	Period	APC	Period	APC	Period	APC
All sites	0.07	1983–1991	1.06[b]	1991–1994	6.18[b]	1994–1998	−2.66[b]	1998–2002	+2.16	2002–2012	−2.12[b]
Esophagus	−3.82[b]	1983–1995	0.71	1995–2012	−6.30[b]						
Stomach	−4.07[b]	1983–1990	−5.11[b]	1990–1993	4.37[b]	1993–1998	−6.34[b]	1998–2002	−2.83[b]	2002–2012	−6.13[b]
Colon & Rectum	4.01[b]	1983–1994	10.24[b]	1994–2004	5.04[b]	2004–2012	−1.09[b]				
Liver	−0.56[b]	1983–1994	1.50[b]	1994–1999	−4.13[b]	1999–2002	7.17[b]	2002–2012	−2.98[b]		
Pancreas	3.51[b]	1983–1994	12.57[b]	1994–2012	1.71[b]						
Lung	2.22[b]	1983–1994	8.98[b]	1994–2002	2.54[b]	2002–2012	−1.27[b]				
Breast	2.74[b]	1983–1990	2.85[b]	1990–1993	8.24	1993–2005	2.53[b]	2005–2012	±0.98		
Uterine	−2.43[b]	1983–2003	−1.80[b]	2003–2012	−4.47[b]						
Bladder	2.42[b]	1983–1993	10.74[b]	1993–1998	−1.13	1998–2001	13.06	2001–2012	−2.08[b]		
Brain	1.49[b]	1983–1989	33.26[b]	1989–2012	0.08						
Non-Hodgkin's lymphoma	5.29[b]	1983–2012	5.29[b]								
Leukemia	0.34	1983–1993	3.95[b]	1993–2012	−0.75[b]						

[a] APC annual percent rate change of age-standardized death rates.
[b] The annual percent rate change is significantly different from 0 (two-sided $p < 0.05$).

increased significantly from 1983 to 1990 and from 1993 to 2005. After a peak in 2003, uterine cancer mortality started its downward trend (APC: −5.66% in 2003–2012). ASRs from urinary bladder cancer fluctuated periodically, showing an M-shaped temporal pattern (Fig. 1). ASRs from brain cancer increased at a high rate in 1983–1988 in men and in 1983–1989 in women (APC: 38.35% and 32.76%, respectively) and thereafter declined. No joinpoint was identified for ASRs from non-Hodgkin's lymphoma (APC: 3.55% for men and 5.29% for women). ASRs from leukemia increased from 1983 to 1993 in both genders (APC: 4.86% for men and 3.95% for women) and thereafter declined.

4. Discussion

Overall, cancer mortality rates in Korea peaked in 1994 and thereafter decreased by 2–3% per year in both genders except for the period of 1998–2002. The decreases in mortality rates from cancers of esophagus, stomach, and liver drove the overall decrease in cancer mortality rates. The downward trend in overall cancer mortality may be partly attributable to the overarching efforts of the Korean government to improve cancer screening and control [9]. Regular screening of cervical cancer in Korea was shown to reduce the incidence of invasive cervical cancer [10]. The government initiated a comprehensive '10-year Plan for Cancer Control' in 1996, launched the National Cancer Screening Program (NCSP) in 1999, and legislated the Cancer Control Act in 2003. NCSP was initially intended to provide Medical Aid beneficiaries with free screening for stomach, breast, and cervical cancers. The coverage of the program has been gradually expanded; now in addition to Medical Aid recipients, the National Health Insurance enrollees within the lower 50% premium group receive free cancer screening for five cancer sites (the stomach, liver, colorectum, breast, and uterine cervix) exempted from a 20% out-of-pocket payment (Table S1).

While the Korean government's effort to improve cancer screening can have a more immediate impact on cancer mortality, changes in major life style factors such as diet, physical activity, and smoking can influence the occurrence of many cancers and thereby mortality although the direction of the impact can vary by type of cancer. Taken together, men experienced a steeper downward trend in cancer mortality rates compared with women. This is partly due to the decreases in mortality rates from esophagus, liver, and lung cancers, which traditionally affected men at a higher rate than women [11]. The downward trend in esophagus cancer mortality rate in Korea since 1994, particularly in men, may be related to a reduced prevalence of major risk factors for esophagus cancer such as smoking [12,13]. The rate of Korean men who smoke has significantly decreased in recent decades, partly due to the government's implementation of anti-smoking programs in 1995 as part of the National Health Promotion Act [11].

While stomach cancer has been the most commonly diagnosed cancer in Korea [14], the mortality rate has been declining since 1983 except for a brief period in the early 1990s. This is consistent with the worldwide trend of declining stomach cancer mortality

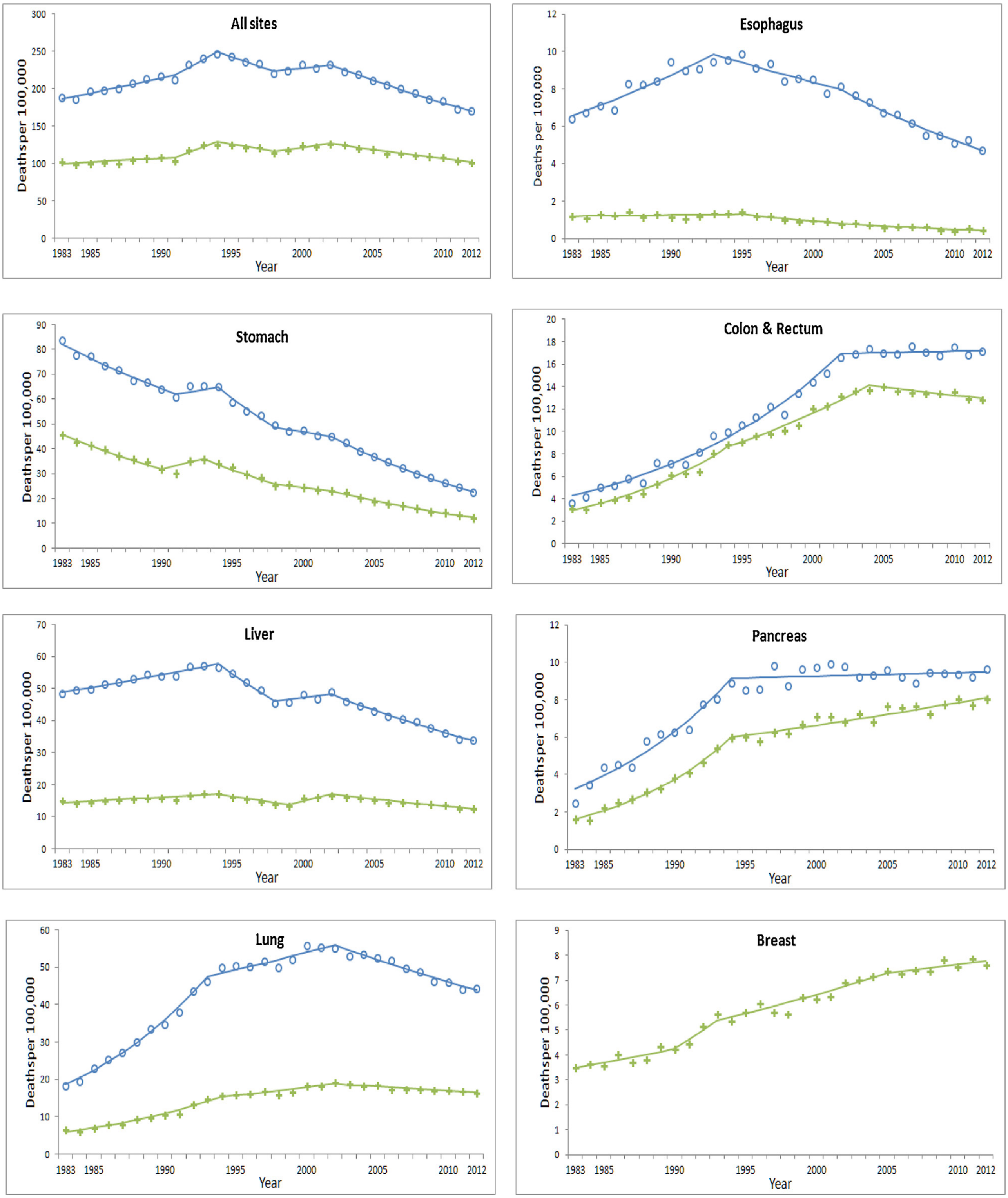

Fig. 1. Trends in age-standardized death rates for major cancers in Korea, 1983–2012. Rates are age-adjusted to the 2010 Korean standard population.

[15,16]. The downward trends were associated with socioeconomic improvements [17], a decrease in the intake of salty foods and nitrate, and the reduction of *Helicobacter pylori*infections in Korea [18–20]. In addition, the stable trend in the incidence rate of stomach cancer in Korea suggests that early diagnosis and treatment due to a higher rate of stomach cancer screenings might have contributed to the decrease in stomach cancer mortality [9,21]. The favorable mortality trends notwithstanding, stomach cancer remained the second leading cause of cancer death worldwide in 2008 [1], and the third and fourth most common cause of cancer death for Korean men and women, respectively, in 2012.

The downward trend in stomach cancer mortality was accompanied by an upward trend in colorectal cancer mortality.

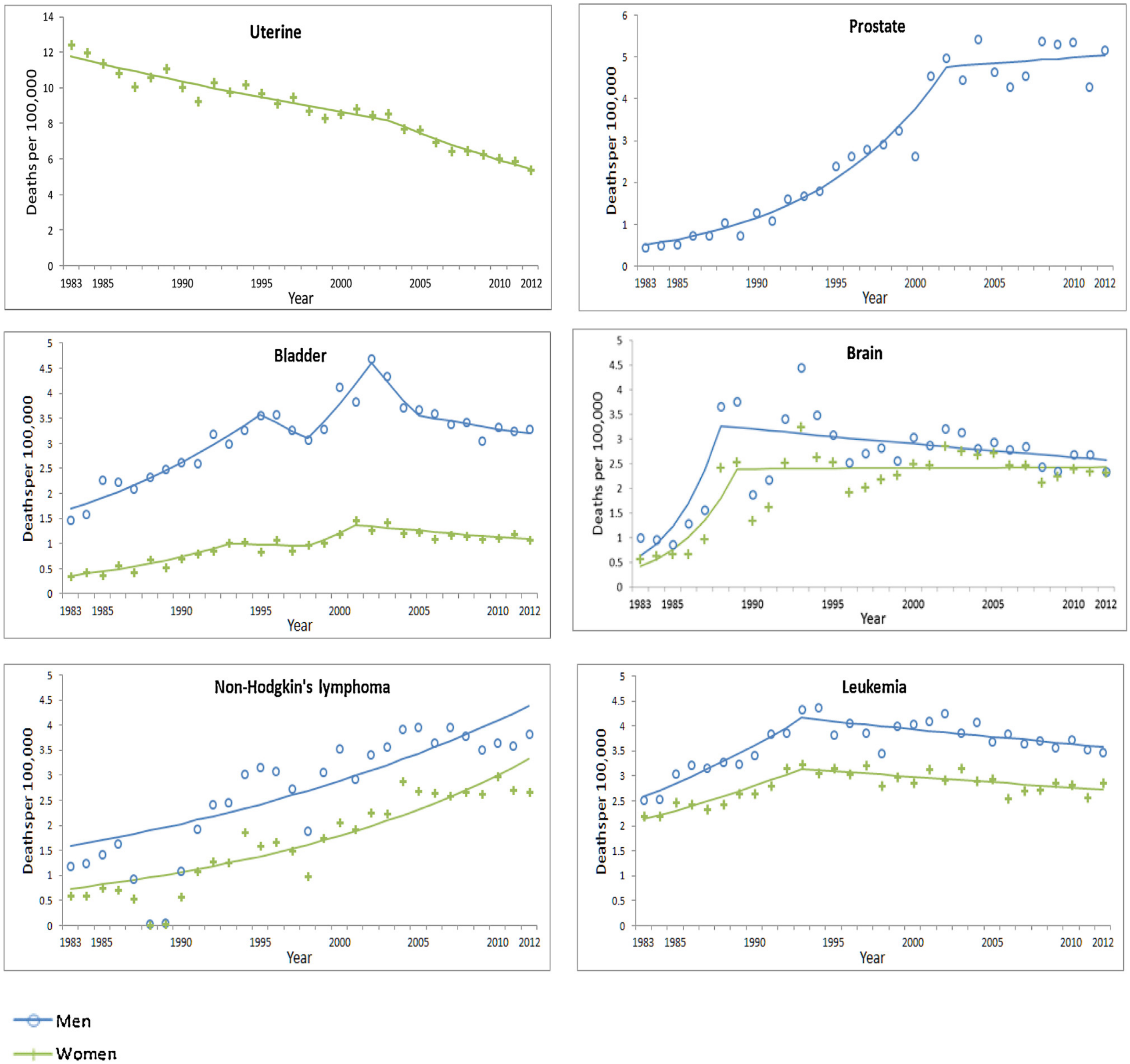

Fig. 1. (Continued)

Among all cancers considered in this analysis, colorectal cancer had the second biggest increase in ASRs from 1983 to 2012, mostly due to the increases until the early 2000s. The upward trends in colorectal cancer incidence and mortality may be linked to factors such as the adoption of Western diets, excess body weights, and physical inactivity [22,23]. However, colorectal cancer mortality leveled off over the last decade in our analysis. Similar trends in colorectal cancer mortality of steady increases followed by leveling-off were observed in Europe [24]. The recent downward trends in colorectal cancer mortality in the European Union were attributed to improvements in early diagnosis and treatment [25]. Performing colonoscopy in usual practice was associated with fewer deaths from colorectal cancer [26]. The steady increase in the incidence rate for colorectal cancer in Korea in the 2000s [27] also suggests that the recent downward mortality trend might be attributable to the wider use of colorectal cancer screening.

Liver cancer mortality increased significantly until 1994 and thereafter decreased except between 1998 and 2002. With treatments largely ineffective, liver cancer mortality is approximately the same as its incidence, highlighting the importance of prevention of liver cancer. While there were substantial variations in primary liver cancer mortality rates and temporal trends across countries [28], the incidence rates of liver cancer decreased in Asian countries in recent decades, which traditionally had higher rates than the other parts of the world [29]. Globally, 78% of hepatocellular carcinoma was attributable to hepatitis B and hepatitis C virus infections (53% and 25%, respectively) [30]. The decreases in the incidence rates of primary liver cancer in developing countries were ascribed to the decreased seroprevalence of hepatitis B virus [31]. The downward trend in liver cancer mortality in Korea may also reflect the increasing number of people who get hepatitis B vaccinations [32]. Despite the remarkable reduction in liver cancer mortality rates over the last three decades, however, liver cancer remained the second most common cause of cancer death among Korean men in 2012.

Similar to liver cancer, ASRs from pancreatic cancer in Korea increased markedly until 1994, contributing to the highest and the third highest ASR % change between 1983 and 2012 for women and men, respectively. Since 1994, however, pancreatic cancer mortality leveled off. Pancreatic cancer mortality rates also decreased in the United States [33], and leveled off in most European countries and Japan [34,35]. With the incidence rate being approximately equal to the mortality rate for pancreatic cancer, the leveling-off of pancreatic cancer mortality in recent decades reflects a stabilizing trend in the incidence rate of pancreatic cancer: the age-standardized incidence rate of pancreatic cancer in Korea have reached a plateau in 2005 [21]. The leveling-off of pancreatic cancer mortality rates, especially among Korean men, may be related to the downward trend in smoking rates, a known risk factor for pancreatic cancer, in recent decades [11,13,36].

Lung cancer was the most commonly diagnosed cancer and the most common cause of cancer death worldwide in 2008 [1]. Likewise, ASRs for lung cancer in Korea more than doubled from 1983 to 2012 in both genders, making lung cancer the leading cause of cancer death in 2012. Joinpoint analysis revealed that lung cancer mortality in Korea increased to a peak in 2002 and thereafter leveled off in both genders. A slightly different pattern between genders emerged in many European countries: lung cancer mortality showed signs of leveling off in recent decades among men, but the upward trend persisted among women [37–39], suggesting that smoking rates between the two genders are converging. No major improvements occurred in lung cancer treatment, so it is likely that various anti-smoking programs and policies may have contributed to the recent favorable trend in lung cancer mortality in Korea [11].

Breast cancer was the most common cause of cancer death among women in the world in 2008 [1]. Our analysis showed that ASRs from breast cancer in Korea increased until 2005. Breast cancer mortality has steadily declined in the last three decades in many European countries [40,41]. In developing countries, however, breast cancer mortality rates rose in the 1970s and 1980s [42]. Korea had the highest rate of increase in breast cancer mortality rate among Asian countries [43]. Korea in the past was one of the countries with the lowest breast cancer incidence and mortality rates in the world [42]. It appears, however, that the country experienced the increasing breast cancer mortality due to its economic development, lifestyle changes including delayed age of marriage and child birth, and early menarche [44]. The leveling-off of breast cancer mortality since 2005 may be ascribed to improvements in early detection and treatment of breast cancer [43].

Unlike for breast cancer, economic development appears to lead to a reduction in cervical cancer rates [45]. In Korea, whose economy witnessed remarkable progress in recent decades, uterine cervix cancer mortality rates showed the significant and persistent downward trend since 2003. The association between economy and cervical cancer mortality can also be inferred from the diverging trends in cervical cancer mortality between the developed member countries and the less developed counterparts of the European Union [46]. In addition to economic development, increasing screening for cervical cancer in Korea might have contributed to the downward trend in cervical cancer mortality which is largely preventable with early screening and treatment [9,10]. Nationwide screening programs for cervical cancer in other developed countries also were shown to have contributed to the favorable trends in cervical cancer mortality [47,48].

The most alarming trend was observed for prostate cancer mortality. Prostate cancer, which was an insignificant cause of death at the beginning of the study period, became the 6th leading cause of cancer death in 2012, as a result of the dramatic increase in the mortality in 1983–2002. The steep increase during this period might be attributable to an increase in obesity, consumption of dietary fat and physical inactivity that resulted from economic development [49]. Further economic development, however, appears to have a positive effect on reducing prostate cancer mortality: it has been increasing in developing countries but decreasing in more affluent countries [49–51]. The leveling-off of prostate cancer mortality rate in Korea since 2002 might also reflect improvements in early detection and management of the cancer [52,53].

Although they fluctuated periodically, ASRs from urinary bladder cancer declined since the early 2000s. Mortality from bladder cancer has declined in most western European countries over the last two decades [53,54]. The recent favorable trend in bladder cancer mortality in Korean men might reflect the declines in their smoking rate as cigarette smoking is a major risk factor for urinary bladder cancer [55]. However, it is not likely that smoking played a role in decreasing mortality trend in women as their smoking rate increased in recent decades [11]. The declining mortality in women might be partly due to improved control of urinary tract infections, although their role in bladder cancer remains unclear [53].

Brain cancer mortality increased by over 30% per year until 1988–1989 and thereafter stabilized although it tends to vary from year to year. Also, in the United States [56] and the Nordic countries [57], brain cancer mortality started declining or stabilized in the early 1980s. Brain and central nervous system cancers consist of a heterogeneous group of histological types [57], and little is known about the factors responsible for the majority of primary brain cancers [58]. Therefore, what might have caused the extraordinary change in trends in Korea around 1988–1989 is hard to speculate, but we cannot rule out the increase of early diagnosis and treatment due to rapid adoption of brain imaging technology, particularly computed tomography, in the country [59]. In addition, improved survival rates for brain cancer, particularly among younger patients, might have played a role, as observed in Western countries from the early 1970s [57,58].

Non-Hodgkin's lymphoma displayed the most consistent increase in mortality rates through the study period. Similar upward trends in non-Hodgkin's lymphoma mortality were observed in the United States, the European Union and Japan until the 1990s [60]. However, the mortality rates in the United States declined at a rate of 3% in the 2000s [52]. The etiologies and risk factors of most non-Hodgkin's lymphomas as well as the reasons for the upward trend remain poorly understood [61]. Neither changes in classification systems nor improved diagnostic capabilities could fully explain the upward trend in the incidence rate of non-Hodgkin's lymphoma [62]. This trend warrants further investigation.

Leukemia is a heterogeneous group of hematopoietic malignancies and the etiology for some subtypes such as acute myeloid leukemia remains unclear [63]. After a decade of increases, leukemia mortality in Korea started decreasing since 1993 reflecting improvements in the treatment of some subtypes. Downward trends in leukemia mortality in some European countries were ascribed to the fact that some subtypes, such as acute lymphoblastic leukemia of childhood, were amenable to treatment [64]. Similarly in the United States, the survival rates from leukemia improved markedly in the past three decades, and mortality from chronic myeloid leukemia declined at an annual rate of 8.4% in the 2000s [52].

We presented a comprehensive overview of trends in mortality from major cancers since 1983 in Korea. Until recently, Korea resembled the cancer mortality trends in developing countries that were predominated by the cancer types that were related to viral and bacterial infections, such as stomach, liver and uterine cervix cancers. While mortality from those cancers decreased in recent decades, Korea also experienced upwards trends in smoking-related cancers such as lung and urinary bladder cancers, as well as many other cancers for which their etiology was not fully understood.

While mortality trends can provide important insights into potential changes in the risk factors as well as improvements in early detection and treatment, they can also reflect underlying changes in diagnostic classification. Therefore, the following limitations should be considered when interpreting the results of this study because changes in mortality trends might reflect changes in documentation and diagnostic coding rather than real changes in survival. First, the observed trends in mortality may have been influenced by potential misclassification of causes of death in official death certificates. The agreement rate between death certificates and medical charts for malignant neoplasms was 80.4% in a regional district in Korea in 1998 [65]. Second, as one possible cause of misclassification is diagnostic errors, the changing temporal trends, particularly the upward trends, may reflect, to some extent, improved diagnostic techniques over time. It is likely that the accuracy of causes of death on death certificates may have evolved over time due to advances in diagnostic techniques, thereby making mortality data incomparable between different time periods. Third, the observed trends in mortality in Korea may have been affected by change of codling scheme application: the ICD-9 coding scheme in KOSIS data was replaced with the ICD-10 in 1995.

In conclusion, trends in major cancer mortality in Korea showed significant changes in recent decades and the changes varied by cancer site. While mortality decreased significantly for cancers of esophagus, stomach and liver, challenges still remain for many cancers, especially, pancreatic, breast and prostate cancers, and non-Hodgkin's lymphoma. This study highlights the importance of using cancer surveillance data to assist the development of cancer control plans. Public health promotion efforts to control cancer such as lowering smoking rate and obesity could reduce the burden of cancer in many sites.

Authorship contribution statement

Dr. Lim contributed conception and design, and acquisition of data, analysis and interpretation of data, and revision of the manuscript. Dr. Ha contributed conception and interpretation, and revision of the manuscript. Dr. Song contributed conception and interpretation, and drafting and revision of the manuscript. All authors gave final approval of the version to be submitted.

Conflict of interest

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.canep.2015.10.023.

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