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Economic Burden of Cancer in Korea during 2000-2010

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Purpose
This study estimated the economic burden of cancer in Korea during 2000-2010 by cancer site, gender, age group, and cost component.

Materials and Methods
Data came from national health insurance claims data and information from Statistics Korea. Based on the cost of illness method, this study calculated direct, morbidity and mortality cost of cancer in the nation during 2000-2010 by cancer site, gender, and age group.

Results
With an average annual growth rate of 8.9%, the economic burden of cancer in Korea increased from 11,424 to 20,858 million US$ (current US dollars) during 2000-2010. Colorectal, thyroid, and breast cancers became more significant during the period, i.e., the 5th/837, the 11th/257, and the 7th/529 in 2000 to the 3rd/2,210, the 5th/1,724, and the 6th/1,659 in 2010, respectively (rank/amount in million US$ for the total population). In addition, liver and stomach cancers were prominent during the period in terms of the same measures, i.e., the 1st/2,065 and the 2nd/2,036 in 2000 to the 1st/3,114 and the 2nd/3,046 in 2010, respectively. Finally, the share of mortality cost in the total burden dropped from 71% to 51% in Korea during 2000-2010, led by colorectal, thyroid, breast, and prostate cancers during the period. These results show that the economic burden of cancer in Korea is characterized by an increasing importance of chronic components.

Conclusion
Incorporation of distinctive epidemiological, sociocultural contexts into Korea's cancer control program, with greater emphasis on primary prevention such as sodium-controlled diet and hepatitis B vaccination, may be needed.

Key words
Cancer, Burden of illness, Aging, Incidence

Introduction

Cancer burden is expected to show a rapid growth with the aging population and increasing cancer incidence [1-6]. The share of elders (or those aged 65 years or older) in the United States increased from 10.0% in 1972 to 12.7% in 2008, whereas the share for South Korea (Korea hereafter) registered a similar but steeper trend, i.e., 7.3% in 2000 to 11.1% in 2010 [1]. America's age-standardized incidence rate per 100,000 for all cancers rose from 400 in 1975 to 472 in 2004 [2], while the statistic for Korea went up from 205 in 2000 to 286 in 2010 [3]. As a result, the share of direct cost for cancer care in the United States economy doubled from 0.32% in 1972 to 0.66% in 2008 [1,4,5]. Likewise, the population-health burden of cancer in Korea (disability-adjusted life years per 100,000) showed a rapid growth from 1,109 person-years in 2000 to 1,681 person-years in 2010 [6]. As cancer burden

increases rapidly, a burden-of-cancer study designed to improve the quality of patient life and to set up national priorities for resource allocation in health services becomes more essential.

Based on previous studies, a large part of cancer burden in an advanced nation comes from breast, colon, lung, and prostate cancers [7-9]. In terms of direct cost (national dollars, million), these cancers ranked in the top four in the United States for 1996 (5,980, 5,710, 4,680, and 4,610) [7], Canada for 1998 (120, 216, 228, and 103) [8] and New South Wales in Australia for 2004 (77, 132, 77, and 121) [9]. Other research has shown that as medical technology advanced and cancer survival increased, the share of income loss from premature death in cancer burden gradually fell in the developed world [4-5,7,10-13]. The share in the United States, which was 73% in 1972 [4], decreased to 61% in 1990 [7], dipping further to 51% in 2008 [5]. Likewise, the number in Sweden went down from 45% in 2000 to 39% in 2004 [10]. However, based on recent reviews, most existing literature on national economic burden has been limited to direct medical cost and comprehensive examination on national economic burden by cancer site, gender, age group, and cost component over a long time span has been limited [10,11].

Some researchers have estimated economic burden for major cancers in Korea for 2002 and 2005 [12,13]. According to their findings, liver, stomach, and lung cancers led the nation's cancer burden, with the costs of 1,749, 1,784, and 1,289 million US$ in 2002 and 2,387, 2,321, and 1,614 million US$ in 2005, respectively (or the shares of 18.6%, 18.9%, and 13.7% in all cancers for 2002 and 17.4%, 16.9%, and 11.7% for 2005, respectively) [12,13]. However, cancers that are prevalent in other developed nations, including breast, colon, and prostate cancers, are becoming more common in Korea, a nation characterized by rapid westernization in health behavior in the past two decades [3]. In addition, Korea is becoming an aging society populated by one of the greatest proportions of elderly by 2020 [14]. With such significant transitions, updating the estimation of economic burden for major cancers in Korea during the period 2000-2010 will not only provide invaluable opportunities for designing the nation's healthcare policies for the future, but will also be helpful in establishing the direction of future study for other nations with similar transformations. In this vein, this research involves a comprehensive examination of cancer burden in Korea during 2000-2010, i.e., by cancer site, gender, age group, and cost component.

Materials and Methods

This study uses the cost of illness (COI) method [7-9,12,13] to estimate the economic burden of cancer in Korea during 2000-2010 by cancer site, gender, and age group. Based on the COI classification, the economic burden of disease consists of three components, i.e., direct, morbidity, and mortality cost. Direct cost is "expenditure for medical services associated with the treatment and care of the disease entity" whereas (indirect) morbidity/mortality cost is "productivity loss due to disability/premature death associated with the disease entity" [7].

Table 1 shows components, formulas, and data sources for the economic burden of cancer in Korea during 2000-2010. Direct cost includes medical cost covered by health insurance, medical cost uncovered, transportation cost, caregiver cost and cost for alternative medicine. Data on medical cost (covered for hospitalization, outpatient visit, and drug prescription) came from national health insurance claims data [15] (the most representative health data in Korea given that the Korean government launched a compulsory national health insurance program for the entire population in Y1989 [12]). Medical cost uncovered was derived from national surveys on out-of-pocket expenditure of patients enrolled in health insurance [16]. For calculation of transportation cost, the number of outpatient visit days [15] was multiplied by transportation cost per outpatient visit day (4.9 US$ [or $4.9 hereafter] in 2002 [12] before being adjusted for inflation [17]). This value was multiplied by 2 (with an assumption that a family member would be present for each outpatient visit [12]). For the estimation of caregiver cost, its "inpatient" and "outpatient" parts were calculated and then combined. Regarding the former part, the number of inpatient days [15] was multiplied by caregiver cost per inpatient day ($50 in 2002 [12] before being adjusted for inflation [17]). Regarding the latter part, the number of outpatient visit days [15] was multiplied by 4 (the number of hours per outpatient visit) [12] and caregiver cost per outpatient visit hour ($9.3 in 2002 [12] before being adjusted for inflation [17]). For calculation of cost for alternative medicine, the number of patients [15] was multiplied by cost for alternative medicine per patient ($1,150 in 2002 [12] before being adjusted for inflation [17]) (Table 1).

Morbidity and mortality costs were derived based on a human capital approach, which assumes that the monetary value of productivity loss equals the current wage [7-9,12,13,18]. It was assumed that those younger than 15 or older than 69 did not work [12,13]. For calculation of morbidity cost, productivity loss due to cancer-specific disability "inside" and "outside" the labor market were estimated and then combined. Regarding the former loss, the

Table 1. Cancer burden: components, formulas, and data sources

Component / Formula		Data source
Direct cost		
Medical, covered (MC)		
i/j	Gender (M, F)/age group index	
$MC1_{ij}$	MC hospitalization	[15]
$MC2_{ij}$	MC outpatient visit	[15]
Formula	$\sum_{ij} (MC_{1ij}+MC_{2ij})$	[12]
Medical, uncovered (MU)		
R_1	$MU_1/(MC_1+MU_1)$ hospitalization	[16]
R_2	$MU_2/(MC_2+MU_2)$ outpatient visit	[16]
MU_{1ij}	$MC_{1ij}*[R_1/(1–R_1)]$	[15,16]
MU_{2ij}	$MC_{2ij}*[R_2/(1–R_2)]$	[15,16]
Formula	$\sum_{ij}(MU_{1ij}+MU_{2ij})$	[13]
Transportation		
T_{ij}	Transportation cost per visit day	$4.9 in 2002 [12]
D_{2ij}	Outpatient visit days	[15]
2	Factor from family member's visit	[12]
Formula	$\sum_{ij} T_{ij}*D_{2ij}*2$	Inflation [12,17]
Caregiver		
C_{1ij}	Caregiver cost per inpatient day	$50 in 2002 [12]
D_{1ij}	Inpatient days	[15]
C_{2ij}	Caregiver cost per visit hour	$9.3 in 2002 [12]
4	Hours per outpatient visit	[12]
D_{2ij}	Outpatient visit days	[15]
Formula	$\sum_{ij}(C_{1ij}*D_{1ij})+\sum ij(C_{2ij}*4*D_{2ij})$	Inflation [12,17]
Alternative medicine (AM)		
AM_{ij}	AM cost per patient	$1,150 in 2002 [12]
P_{ij}	Patients	[15]
Formula	$\sum_{ij} AM_{ij}*P_{ij}$	Inflation [12,17]
Indirect cost		
Morbidity		
W_{ij}	Yearly wage (W_{Fj}: for women)	[17]
P_{ij}	Patients	[15]
A_{ij}	Participation rate for economic activity	[17]
E_{ij}	Employment rate	[17]
L_1	Patient's job loss rate	0.51 [13]
H	Participation rate for housework	0.67 [13]
L_2	Patient's housework loss rate	86.5/365.0 days [13]
Formula	$\sum_{ij}W_{ij}*P_{ij}*A_{ij}*E_{ij}*L_1+$ $\sum_j W_{Fj}*P_{Fj}*(1–A_{Fj})*H*L_2$	[13]
Mortality		
k	Year Index (t+1, t+2,… , t+70 - j)	-
M_{ij}	Mortalities at year t	[17]
w	Average annual wage growth rate	0.08 for 2000-2010 [17]
W_{ijk}	W_{ij} at year t+k [or $W_{ij}*(1+w)^k$]	[17]
A_{ijk}	A_{ij} at year t+k [or $A_{i,j}+k$]	[17]
E_{ijk}	E_{ij} at year t+k [or $E_{i,j}+k$]	[17]
H	H at year t+k [or H]	0.67 [13]
r	Discount rate	0.03 [13]
Formula	$\sum_{ij}M_{ij}\{\sum_k [(W_{ijk}*A_{ijk}*E_{ijk})/(1+r)^k]\}+$ $\sum_j MF_j\{\sum_k [W_{Fjk}*(1–A_{Fjk})*H/(1+r)^k]\}$	[13]

Table 2. Number of cancer patients in Korea by cancer site and gender in 2000 and 2010

Cancer type	ICD-10 code	Men		Women		Total		Rank for total	
		2000	2010	2000	2010	2000	2010	2000	2010
Thyroid	C73	14,382	59,191	31,237	137,299	45,619	196,490	5	1
Stomach	C16	59,491	87,846	32,430	47,156	91,921	135,002	1	2
Colorectum	C18-C21	32,420	65,443	27,001	51,922	59,421	117,365	2	3
Breast	C50	600	996	42,005	96,511	42,605	97,507	6	4
Lung	C33-34	37,243	38,226	15,659	16,071	52,902	54,297	4	5
Liver	C22	41,348	38,657	15,813	15,151	57,161	53,808	3	6
Prostate	C61	9,881	36,105	0	0	9,881	36,105	14	7
Kidney	C64	6,465	18,412	3,390	10,170	9,855	28,582	15	8
Uterine cervix	C53	0	0	27,990	28,021	27,990	28,021	7	9
Bladder	C67	9,089	16,075	2,585	5,011	11,674	21,086	12	10
NHL	C82-C85	5,570	4,944	11,691	11,627	17,261	16,571	8	11
Ovary	C56	0	0	16,403	14,542	16,403	14,542	9	12
Mouth	C00-C14	9,224	7,647	6,515	5,559	15,739	13,206	10	13
Brain	C69-C72	5,690	6,333	5,611	6,088	11,301	12,421	13	14
Leukemia	C91-C95	4,516	6,500	4,127	5,904	8,643	12,404	17	15
Pancreas	C25	5,700	6,001	4,139	4,687	9,839	10,688	16	16
Uterus	C54-C55	0	0	4,209	9,989	4,209	9,989	21	17
Skin	C43-C44	2,262	4,800	2,523	5,053	4,785	9,853	20	18
Esophagus	C15	5,979	5,990	1,092	1,067	7,071	7,057	18	19
Larynx	C32	5,334	6,192	851	740	6,185	6,932	19	20
MM	C90	1,522	2,390	1,258	1,965	2,780	4,355	22	21
Gallbladder	C23-C24	7,832	1,605	6,602	1,402	14,434	3,007	11	22
Testis	C60,62,63	1,722	1,747	0	0	1,722	1,747	23	23
HL	C81	552	475	925	956	1,477	1,431	24	24
Others		7,372	7,958	6,152	6,923	13,524	14,881		
Total		274,194	423,534	270,208	483,813	544,402	907,347		

Source: Korea Health Insurance Corporation [15]. ICD-10, International Classification of Diseases 10th revision; NHL, non-Hodgkin lymphoma; MM, multiple myeloma; HL, Hodgkin lymphoma.

yearly wage (or productivity loss) [17] was multiplied by the number of patients [15], the participation rate for economic activity [17], the employment rate [17], and the rate of job loss for the cancer patient (0.51) [13] (the participation rate for economic activity and the employment rate vary by gender, age group, and year). Regarding the latter loss, women's yearly wage (or productivity loss) [17] was multiplied by the number of female patients [15], women's non-participation rate for economic activity [17], women's participation rate for housework (0.67) [13], and the rate of housework loss for the female cancer patient (86.5 days/365.0 days) [13] (The women's non-participation rate for economic activity varies by age group and year). Likewise, for calculation of mortality cost, productivity loss due to cancer-specific premature death "inside" and "outside" the labor market were estimated and then combined. Regarding the former loss, the number of mortalities [17] was multiplied by the expected value of the future income during potential years of life lost [17] with a discount rate (0.03) [13]. Regarding the latter loss, the number of women's mortalities [17] was multiplied by the expected value of women's opportunity cost (for housework) during potential years of life lost [13,17] with a discount rate (0.03) [13]. For calculation of the expected value of the future income or women's opportunity cost for housework during potential years of life lost from a base year (e.g., 2010), it was assumed that (1) the participation rate for economic activity and the employment rate (varying by gender and age group in a given year) stay the same in the future as in the base year and (2) the women's non-participation rate for economic activity (varying by age group in a given year) remains the same in the future as in the base year.

Table 3. Number of cancer mortalities in Korea by cancer site and gender in 2000 and 2010

Cancer type	ICD-10 code	Men		Women		Total		Rank for total	
		2000	2010	2000	2010	2000	2010	2000	2010
Lung	C33-C34	8,575	11,411	2,965	4,204	11,540	15,615	1	1
Liver	C22	7,697	8,350	2,343	2,855	10,040	11,205	3	2
Stomach	C16	7,434	6,512	4,069	3,520	11,503	10,032	2	3
Colorectum	C18-C21	2,239	4,350	1,962	3,351	4,201	7,701	4	4
Pancreas	C25	1,546	2,323	1,162	1,983	2,708	4,306	5	5
Gallbladder	C23-C24	1,355	1,758	1,289	1,744	2,644	3,502	6	6
Breast	C50	21	10	1,148	1,858	1,169	1,868	9	7
Leukemia	C91-C95	789	922	574	696	1,363	1,618	8	8
NHL	C82-C85	553	807	316	623	869	1,430	12	9
Esophagus	C15	1,351	1,254	149	98	1,500	1,352	7	10
Prostate	C61	545	1,328	0	0	545	1,328	18	11
Brain	C69-C72	534	652	464	543	998	1,195	11	12
Bladder	C67	588	822	182	278	770	1,100	13	13
Mouth	C00-C14	661	742	393	221	1,054	963	10	14
Uterine cervix	C53	0	0	726	956	726	956	15	15
Ovary	C56	0	0	561	895	561	895	17	16
Kidney	C64	337	562	175	235	512	797	19	17
MM	C90	169	399	118	364	287	763	21	18
Larynx	C32	651	383	109	33	760	416	14	19
Skin	C43-C44	168	177	132	206	300	383	20	20
Thyroid	C73	73	94	193	262	266	356	22	21
Uterus	C54-C55	0	0	584	316	584	316	16	22
HL	C81	156	46	91	35	247	81	23	23
Testis	C60,62,63	38	20	0	0	38	20	24	24
Total		35,480	42,922	19,705	25,276	55,185	68,198		

Source: Korea Health Insurance Corporation [17]. ICD-10, International Classification of Diseases 10th revision; NHL, non-Hodgkin lymphoma; MM, multiple myeloma; HL, Hodgkin lymphoma.

Results

Tables 2 and 3 shows the number of patients (or mortalities) in Korea by cancer site and gender in 2000 and 2010, listed based on the rank in 2010. The total number of cancer patients increased by 66.67%, from 544,402 to 907,347 during 2000-2010. The increase in cancer prevalence during the period was more pronounced for women than for men, with the growth rate of 79.1% versus 54.5% (from 270,208 to 483,813 vs. from 274,194 to 423,534). Thyroid, breast, and prostate cancers led this rapid growth of prevalence during the period. For example, the rank/number of prevalence increased from the 5th/45,619 to the 1st/196,490 for thyroid cancer, from the 6th/42,605 to the 4th/97,507 for breast cancer, and from the 14th/9,881 to the 7th/36,105 for prostate cancer. It is also noteworthy that kidney and bladder cancers entered the top ten during the period, i.e., the 15th/9,855 and the 12th/11,674 in 2000 to the 8th/28,582 and the 10th/21,086 in 2010, respectively. On the contrary, the ranks/numbers of prevalence for liver cancer, non-Hodgkin lymphoma, and ovary cancer declined during the period, i.e., the 3rd/57,161, the 8th/17,261, and the 9th/16,403 in 2000 to the 6th/53,808, the 11th/16,571, and the 12th/14,542 in 2010, respectively. Table 4 and Fig. 1 describe economic burden in Korea by cancer site and gender during 2000-2010 (with the shares of mortality cost in parentheses for the table). In terms of the total burden for the total population (million $), liver, stomach, and lung cancers ranked 1st (3,114), 2nd (3,046), and 4th (1,988) in 2010 after holding the same positions in 2000 (2,065, 2,036, and 1,202). Colorectal cancer, a top five (837) in 2000, replaced leukemia as a top three in 2010 (2,210). Thyroid cancer, out of the top ten in 2000 (11th, 257), made the top five in 2010 (1,724). Likewise, breast cancer, a top seven (529) in 2000, became a top six (1,659) in 2010. A similar trend was observed for men. In terms of the total burden, liver, stomach, and lung cancers constituted the top three both in 2000 (1,744, 1,332, and 881) and in 2010 (2,638, 2,090, and 1,476). Colorectal cancer and leukemia, which ranked 5th (525) and 4th (790) in 2000, switched their positions in

Table 4. Economic burden in Korea by cancer site, gender in 2000 and 2010 (million US$)

Cancer type	ICD-10 code	Men (M)		Women (W)		Total (T)		Rank for total [M/W]	
		2000	2010	2000	2010	2000	2010	2000	2010
Liver	C22	1,744 (0.80)	2,638 (0.74)	322 (0.75)	477 (0.62)	2,065 (0.79)	3,114 (0.72)	1 [1/5]	1 [1/7]
Stomach	C16	1,332 (0.67)	2,090 (0.51)	704 (0.78)	956 (0.61)	2,036 (0.71)	3,046 (0.54)	2 [2/1]	2 [2/3]
Colorectum	C18-C21	525 (0.55)	1,420 (0.42)	312 (0.57)	790 (0.41)	837 (0.55)	2,210 (0.41)	5 [5/6]	3 [4/4]
Lung	C33-C34	881 (0.69)	1,476 (0.57)	322 (0.76)	512 (0.63)	1,202 (0.71)	1,988 (0.58)	4 [3/4]	4 [3/5]
Thyroid	C73	110 (0.08)	707 (0.02)	147 (0.07)	1,017 (0.01)	257 (0.07)	1,724 (0.01)	11 [13/10]	5 [6/2]
Breast	C50	11 (0.68)	11 (0.05)	518 (0.57)	1,648 (0.38)	529 (0.57)	1,659 (0.37)	7 [21/2]	6 [21/1]
Leukemia	C91-C95	790 (0.93)	965 (0.80)	433 (0.91)	521 (0.71)	1,223 (0.92)	1,475 (0.77)	3 [4/3]	7 [5/6]
Brain	C69-C72	395 (0.88)	678 (0.84)	303 (0.89)	324 (0.78)	698 (0.89)	1,002 (0.82)	6 [6/7]	8 [7/10]
NHL	C82-C85	260 (0.81)	416 (0.57)	133 (0.64)	236 (0.59)	394 (0.75)	649 (0.58)	8 [7/11]	9 [9/11]
Pancreas	C25	210 (0.79)	420 (0.76)	95 (0.75)	198 (0.69)	304 (0.78)	618 (0.73)	9 [8/13]	10 [8/12]
Uterine cervix	C53	0 (0.00)	0 (0.00)	257 (0.49)	448 (0.47)	257 (0.49)	448 (0.47)	12 [22/8]	11 [22/8]
Kidney	C64	116 (0.62)	303 (0.32)	57 (0.75)	98 (0.30)	173 (0.67)	402 (0.31)	15 [12/15]	12 [10/15]
Ovary	C56	0 (0.00)	0 (0.00)	179 (0.51)	364 (0.53)	179 (0.51)	364 (0.53)	14 [22/9]	13 [22/9]
Mouth	C00-C14	134 (0.55)	253 (0.52)	48 (0.50)	85 (0.52)	182 (0.53)	338 (0.52)	13 [11/16]	14 [12/16]
Prostate	C61	55 (0.21)	295 (0.11)	0 (0.00)	0 (0.00)	55 (0.21)	295 (0.11)	22 [16/23]	15 [11/23]
Gallbladder	C23-C24	173 (0.67)	164 (0.84)	121 (0.71)	106 (0.84)	293 (0.69)	270 (0.84)	10 [9/12]	16 [15/14]
Bladder	C67	81 (0.33)	182 (0.21)	16 (0.39)	39 (0.22)	98 (0.34)	220 (0.21)	17 [14/20]	17 [14/19]
Esophagus	C15	142 (0.68)	183 (0.49)	17 (0.75)	15 (0.40)	159 (0.69)	198 (0.48)	16 [10/19]	18 [13/21]
MM	C90	33 (0.61)	102 (0.48)	16 (0.49)	59 (0.35)	49 (0.57)	161 (0.43)	23 [19/21]	19 [16/18]
Skin	C43-C44	46 (0.72)	81 (0.47)	22 (0.59)	66 (0.52)	68 (0.68)	147 (0.49)	21 [18/18]	20 [18/17]
Uterus	C54-C55	0 (0.00)	0 (0.00)	91 (0.79)	140 (0.39)	91 (0.79)	140 (0.39)	18 [22/14]	21 [22/13]
Larynx	C32	76 (0.57)	86 (0.31)	6 (0.48)	5 (0.14)	82 (0.57)	91 (0.30)	19 [15/22]	22 [17/22]
HL	C81	49 (0.91)	31 (0.59)	28 (0.88)	20 (0.68)	77 (0.90)	52 (0.62)	20 [17/17]	23 [20/20]
Testis	C60,62,63	31 (0.68)	42 (0.54)	0 (0.00)	0 (0.00)	31 (0.68)	42 (0.54)	24 [20/23]	24 [19/23]
Others		52 (0.00)	117 (0.00)	30 (0.00)	75 (0.00)	82 (0.00)	191 (0.00)		
Total		7,247 (0.72)	12,659 (0.56)	4,178 (0.68)	8,198 (0.46)	11,424 (0.71)	20,844 (0.52)		

Values in rounded parentheses are presented as share of mortality cost. ICD-10, International Classification of Diseases 10th revision; NHL, non-Hodgkin lymphoma; MM, multiple myeloma; HL, Hodgkin lymphoma.

2010 (4th, 1,420 vs. 5th, 965). Thyroid cancer, out of the top ten in 2000 (13th, 110), joined the top six in 2010 (707) (Tables 2-4, Fig. 1).

Some gender differences can be seen in Table 4, as breast and thyroid cancers made the top two instead of liver and stomach cancers for women's total burden in 2010 (1,648, 1,017 vs. 477, 956). Economic burden in Korea by cancer site and age group in 2000 and 2010 is described in Table 5. For the age group 0-14 years old, leukemia, brain cancer, and non-Hodgkin lymphoma led the total burden during 2000-2010. For those aged 15 years or older, liver, stomach, colorectal, and lung cancers constituted the top four in both 2000 and in 2010. However, the former two were more dominant for the age group 15-69 years old, while the latter two were more significant for those aged 70 years or older. Indeed, the rise of colorectal cancer was more evident for the older age group and the opposite was true for thyroid cancer. Finally, Table 6 and Fig. 2 show the economic burden of cancer in Korea by cost component during 2000-2010. With an average annual growth rate of 8.9%, the total burden (million $) increased from 11,424 to 20,858 during the period. The share of mortality cost in the total burden dropped from 70.7% to 51.7% during 2000-2010, as the figures for most cancers fell by more than 10.0% during the period (Table 4, Fig. 1). On the contrary, the shares of direct and morbidity cost in the total burden rose during 2000-2010, from 5.6% to 14.7% for medical cost (covered), from 2.9% to 3.8% for medical cost (uncovered), from 0.2% to 0.4% for transportation cost, from 2.5% to 4.4% for caregiver cost, from 5.4% to 6.7% for the cost of alternative medicine, and from 12.8% to 18.3% for morbidity cost. Colorectal, thyroid, breast, and prostate cancers led this rapid growth of direct and morbidity cost during the period (Table 4, Fig. 1). For example, the rank/amount of direct cost (million $) increased from the 4th/211 to the 1st/855 for colorectal cancer, from the 6th/120 to the 3rd/703 for thyroid cancer, from the 5th/131 to the

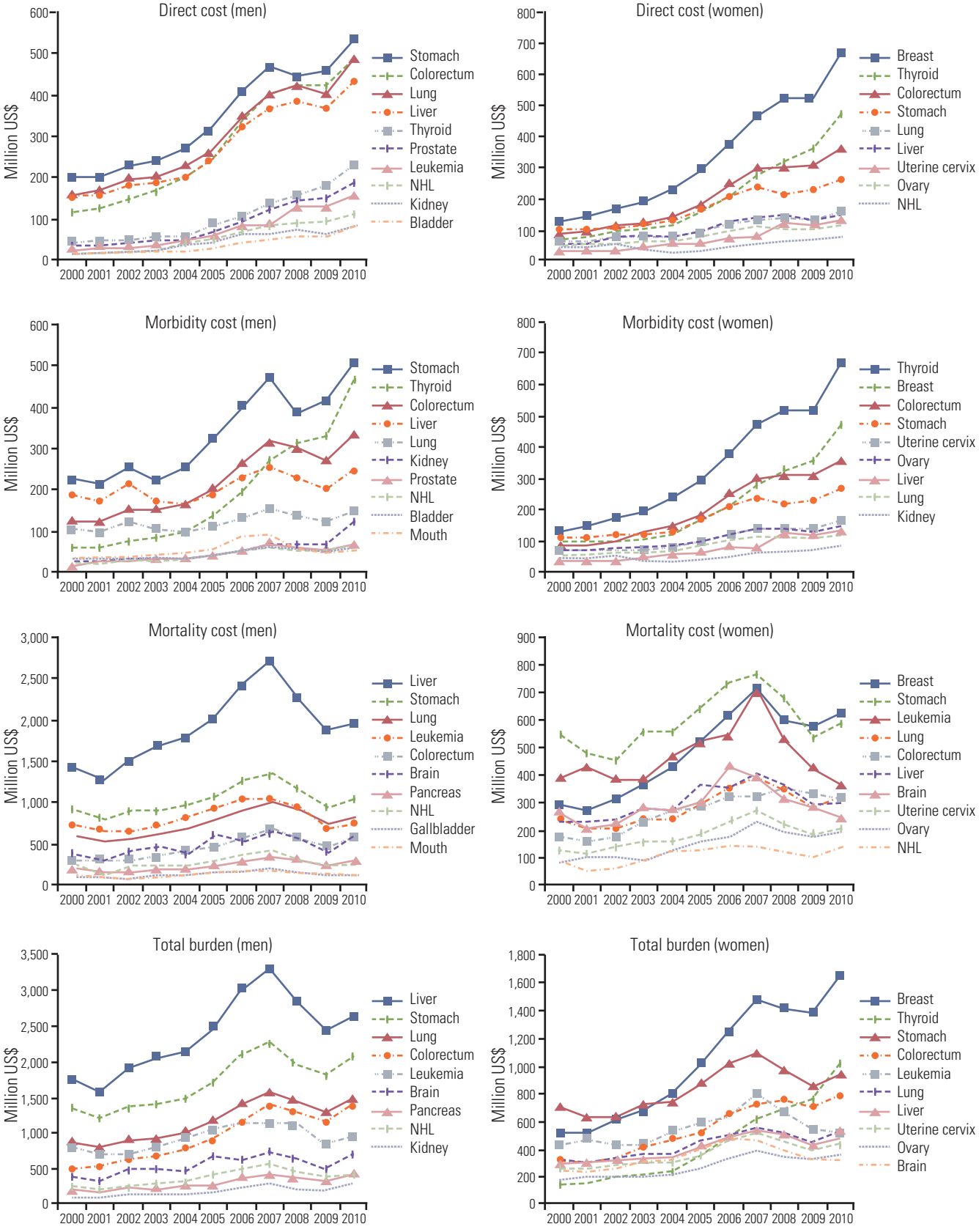

Fig. 1. Economic burden of cancer in Korea by cancer site during 2000-2010. NHL, non-Hodgkin lymphoma.

Table 5. Economic burden in Korea by cancer site, age group in 2000 and 2010 (thousand US$)

Cancer type	ICD-10 code	0-14 yr (A)		15-69 yr (B)		≥ 70 yr (C)		Rank for A/B/C	
		2000	2010	2000	2010	2000	2010	2000	2010
Liver	C22	43,776	23,809	1,993,174	2,960,679	28,418	129,555	5/1/4	4/1/4
Stomach	C16	3,603	46	1,976,338	2,797,811	56,015	247,969	14/2/1	18/2/3
Colorectum	C18-C21	10,295	37	784,502	1,923,877	42,367	286,032	8/4/3	19/3/1
Lung	C33-C34	20,177	64	1,128,019	1,734,244	54,284	253,344	7/3/2	15/4/2
Thyroid	C73	3,524	7,071	240,046	1,639,136	13,497	77,580	15/12/6	8/5/6
Breast	C50	43	4,319	524,637	1,614,472	4,231	40,564	21/6/15	11/6/10
Leukemia	C91-C95	577,293	466,899	641,730	981,122	4,081	27,152	1/5/16	01/7/13
Brain	C69-C72	343,198	366,666	350,613	617,273	3,920	18,510	2/7/17	2/8/17
Pancreas	C25	2,780	64	291,896	570,309	9,709	47,922	16/9/8	16/9/8
NHL	C82-C85	92,814	61,488	295,933	547,329	4,911	40,612	3/8/14	3/10/9
Uterine cervix	C53	6	74	251,202	425,395	5,829	22,199	23/11/13	14/11/15
Kidney	C64	49,065	14,517	117,672	353,401	6,231	33,783	4/16/12	5/12/11
Ovary	C56	492	5,002	175,717	344,064	3,083	14,856	19/13/19	10/13/20
Mouth	C00-C14	584	786	174,734	312,946	6,969	23,956	17/14/10	12/14/14
Gallbladder	C23-C24	4,423	11	271,831	261,641	17,123	8,117	10/10/5	21/15/21
Prostate	C61	26	55	42,270	173,096	12,926	122,017	22/22/7	17/16/05
Esophagus	C15	4,374	0	148,564	167,247	6,510	30,273	11/15/11	23/17/12
Bladder	C67	86	32	90,383	166,394	7,061	54,070	20/17/9	20/18/07
MM	C90	497	592	46,920	140,699	2,079	19,883	18/21/21	13/19/16
Uterus	C54-C55	4	0	90,252	134,039	733	5,612	24/18/22	24/20/22
Skin	C43-C44	3,981	5,820	61,862	123,175	2,581	18,464	12/20/20	9/21/18
Larynx	C32	3,731	5	75,002	75,495	3,728	15,983	13/19/18	22/22/19
HL	C81	35,108	7,830	42,083	42,570	287	1,307	6/23/24	7/23/23
Testis	C60,62,63	5,264	8,877	25,180	32,105	433	846	9/24/23	6/24/24
Others		5,481	12,979	71,531	157,980	4,656	20,191		
Total		1,210,624	987,043	9,912,090	18,296,498	301,665	1,560,796		

ICD-10, International Classification of Diseases 10th revision; NHL, non-Hodgkin lymphoma; MM, multiple myeloma; HL, Hodgkin lymphoma.

4th/673 for breast cancer, and from the 18th/26 to the 8th/194 for prostate cancer (data not reported in the tables) (Tables 5 and 6, Fig. 2).

Discussion

1. Main findings of this study

Colorectal, thyroid, and breast cancers became more significant in terms of economic burden for Korea during 2000-2010. The rise of colorectal cancer was more evident for the older age group and the opposite was true for thyroid cancer. In addition, liver and stomach cancers were prominent in the nation during the period. Finally, the share of mortality cost in the total burden dropped from 71% to 51% in Korea during 2000-2010, and the relative growths of direct and morbidity cost were led by colorectal, thyroid, breast, and prostate cancers during the period. These results show that the economic burden of cancer in Korea is characterized by an increasing importance of chronic components.

2. What is already known on this topic

The economic burden of cancer in an advanced nation centers on breast, colon, lung, and prostate cancers. Indeed, as medical technology advances and cancer survival increases, the share of mortality cost in cancer burden registers a graduate fall in the developed world.

3. What this study adds

This research presents a very rare analysis of economic burden by cancer site, gender, age group, and cost compo-

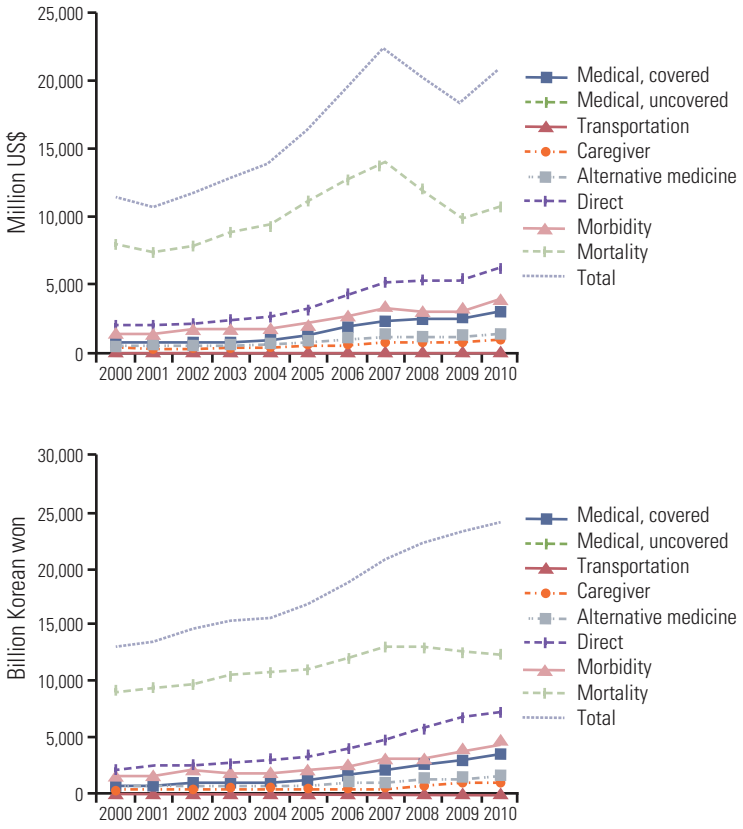

Fig. 2. Economic burden of cancer in Korea by cost component during 2000-2010.

nent in Korea during 2000-2010. Most existing literature on national economic burden has been limited to direct medical cost, and comprehensive examination of the national economic burden by cancer site, gender, age group, and cost component over a long time span has been limited.

This research shows that Korea is converging with other advanced nations in the economic burden of cancer. In terms of direct cost, breast, colon, lung and prostate cancers, which ranked in the top four in the United States for 1996, Canada for 1998 and New South Wales in Australia for 2004, constituted the top eight in Korea for 2010, i.e., colorectal cancer (first position, 855 million US$), breast cancer (fourth, 673 million US$), lung cancer (fifth, 651 million US$) and prostate cancer (eighth, 194 million US$). In addition, the share of mortality cost in the total burden, which dropped from 73% to 51% in the United States during 1972-2008, registered a similar trend in Korea, i.e., a fall from 71% to 51%, albeit during a much shorter period, 2000-2010. Korea's convergence with other advanced nations in cancer burden might reflect their convergence in living standards, the age structure, health behavior and medical technology during the past four decades. The rise of Korea's Gross Domestic Product per capita relative to the Organisation for Economic Cooperation and Development average (e.g., from 0.26 to 0.77 during 1980-2012 in terms of Purchasing Power Parity current international dollars [1]) has been accompanied by the growing proportion of the elderly population and the rise of meat consumption. Korea's share of the population aged 60 years or older, which was 15% in 2009, is likely to reach 21% in 2018, the figure for the developed regions in 2009 [14,17]. The average share of energy intake from meat consumption increased from 5.1% to 14.2% in the nation during 1970-1993 [19]. This "modified (or westernized)" dietary pattern became more robust among younger and metropolitan residents with more education and higher income in the nation during 1998-2005 [20]. Korea's convergence with other developed nations has been apparent in medical technology as well, particularly in selective, customized cancer treatment [21]. With the establishment of the National Cancer Center in 2000 and the legislation of the Cancer Control Act in 2003, the Second 10-Year Plan for Cancer Control in Korea during 2006-2015 has contributed to the rise of 5-year relative cancer survival from 53.7% during 2001-2005 to 64.1% during 2006-2010 [22]. These economic, demographic, behavioral, technological, and sociopolitical changes might have aided in the shift of cancer

Table 6. Cost components and their shares in total cost of cancer in Korea during 2000-2010 (million US$, %)

	Year										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Direct cost (million US$)	1,892	1,948	2,187	2,375	2,689	3,258	4,238	5,047	5,316	5,314	6,252
Share in total cost (%)	16.6	18.3	18.5	18.4	19.3	19.8	21.5	22.5	26.2	29.1	30.0
Medical, covered (million US$)	635	663	740	879	1,021	1,355	1,918	2,380	2,572	2,512	3,059
Share in total cost (%)	5.6	6.2	6.2	6.8	7.3	8.2	9.7	10.6	12.7	13.8	14.7
Medical, uncovered (million US$)	331	349	386	452	521	480	578	609	780	863	787
Share in total cost (%)	2.9	3.3	3.3	3.5	3.7	2.9	2.9	2.7	3.8	4.7	3.8
Transportation (million US$)	21	24	27	33	38	50	64	77	73	76	93
Share in total cost (%)	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Caregiver (million US$)	284	295	332	377	429	535	680	814	787	759	926
Share in total cost (%)	2.5	2.8	2.8	2.9	3.1	3.3	3.4	3.6	3.9	4.2	4.4
Alternative medicine (million US$)	621	617	701	635	681	837	997	1,168	1,103	1,104	1,388
Share in total cost (%)	5.4	5.8	5.9	4.9	4.9	5.1	5.1	5.2	5.4	6.1	6.7
Indirect cost (million US$)	9,533	8,720	9,661	10,531	11,241	13,188	15,471	17,375	14,987	12,920	14,606
Share in total cost (%)	83.4	81.7	81.5	81.6	80.7	80.2	78.5	77.5	73.8	70.9	70.0
Morbidity (million US$)	1,457	1,445	1,709	1,649	1,725	2,160	2,726	3,289	3,108	3,004	3,815
Share in total cost (%)	12.8	13.5	14.4	12.8	12.4	13.1	13.8	14.7	15.3	16.5	18.3
Mortality (million US$)	8,075	7,275	7,952	8,882	9,517	11,028	12,744	14,086	11,879	9,917	10,791
Share in total cost (%)	70.7	68.2	67.1	68.8	68.3	67.1	64.7	62.8	58.5	54.4	51.7
Total cost (million US$)	11,424	10,668	11,848	12,906	13,931	16,445	19,708	22,422	20,302	18,234	20,858
GDP (million US$)	533,309	504,586	576,132	643,633	722,973	844,855	951,484	1,049,349	930,296	834,439	1,014,944
Direct cost/GDP (%)	0.35	0.39	0.38	0.37	0.37	0.39	0.45	0.48	0.57	0.64	0.62
Total burden/GDP (%)	2.14	2.11	2.06	2.01	1.93	1.95	2.07	2.14	2.18	2.19	2.06

Source: Korea Health Insurance Corporation [17]. GDP, gross domestic product.

from acute to chronic in Korea.

Unlike Australia, Canada, and the United States, however, Korea has been characterized by the continued importance of stomach and liver cancers during 2000-2010 according to the results of this work. In terms of the total burden, these two cancers ranked first and second in 2000 (2,065, 2,036 million US$), holding the same positions in 2010 (3,114, 3,046 million US$). Indeed, a change in the pattern of economic burden for major cancers in Korea has been much more dramatic than in other advanced nations. For example, it took 36 years in the United States for the share of mortality cost to hit 51% (in 2008) from 73% (in 1972). However, the length of that period was just 10 years for Korea, given that the statistic for the nation started at 71% in 2000 and arrived at 51% in 2010. These results suggest that the economic burden of cancer in Korea follows the pattern of other advanced nations in general but also registers some unique characteristics affected by its distinctive epidemiological and sociocultural contexts, e.g., higher sodium intake (regarding stomach cancer), higher infection of hepatitis B virus (regarding liver cancer), over-diagnosis of thyroid cancer, and sudden advent of an aging society (regarding direct/morbidity cost) [14,17]. With such a rapidly aging population, Korea's average annual rate of economic growth, which was 9.5% during 2000-2010 [17], might drop to 4.1% during 2011-2020 and decrease further to 2.8% during 2021-2030 [23]. Given these dramatic transitions, two recommendations can be made for cancer control in Korea. First, greater focus on primary prevention, including sodium-controlled diet and hepatitis B vaccination, is needed in Korea. When economic resources are limited, primary prevention is the most cost-effective strategy for reducing cancer burden, and this is particularly true for a nation like Korea, where gastrointestinal cancer is dominant with widespread bacterial infection [24]. Second, a more consistent and integrative system of cost-effective analysis (CEA) on cancer screening and treatment is needed in Korea. At this time, only a quarter of new screening/treatment technologies are covered by health insurance in Korea, largely because its CEA system is neither consistent nor integrative enough for timely and appropriate evaluation. More evidence might be helpful in reducing cancer burden in Korea. The findings of this study might provide good lessons and important policy implications for all nations striving for rapid economic growth and experiencing sudden sociocultural transformations.

4. Limitations of this study

For the calculation of the expected value of the future income or women's opportunity cost for housework during potential years of life lost from a base year, it was presumed that (1) the participation rate for economic activity and the employment rate (varying by gender and age group in a given year) stay the same in the future as in the base year and (2) the women's non-participation rate for economic activity (varying by age group in a given year) remains the same in the future as in the base year. Modifying these assumptions might improve the accuracy of estimating mortality cost. Also, projecting Korea's cancer burden over 2010-2030 might provide additional insight into existing literature on cancer burden. Indeed, comparative analysis of Korea and other nations might contribute to more systematic examination of cancer burden. In addition, the extension of this study into all main diseases in Korea is expected to further the boundary of knowledge on disease burden. Despite these limitations, this research constructs rich data and presents a rare comprehensive examination of cancer burden in Korea, a nation with the most rapid demographic, socioeconomic, behavioral, and technological transformations in the past four decades.

Conclusion

Incorporation of distinctive epidemiological, sociocultural contexts into Korea's cancer control program, with greater emphasis on primary prevention such as sodium-controlled diet and hepatitis B vaccination, may be needed.

Conflicts of Interest

Conflict of interest relevant to this article was not reported.

Acknowledgments

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