RESEARCH ARTICLE

A Single Measure of Cancer Burden in Korea from 1999 to 2010

Kyoung-Hee Cho[1,2], Sohee Park[2,4], Kwang-Sig Lee[2,3], Sung-In Jang[2,3], Ki-Bong Yoo[1,2], Jae-Hyun Kim[1,2], Eun-Cheol Park[2,3]*

Abstract

Background: The purpose of this study was to develop a single measure of cancer burden (SMCB), which can prioritize cancer sites by considering incidence and mortality. Materials and Methods: Incidence data from 1999 to 2010 were obtained from the Korea Central Cancer Registry. Mortality data from 1999 to 2010 were obtained from Statistics Korea. The SMCB was developed by adding incidence and mortality scores. The respective scores were given such that incidence and mortality were classified by ten ranges of equal intervals. Results: According to the SMCB in 2010, stomach cancer ranked 1st in males with 20 points, and colorectal cancer was 2nd with 11 points. Breast cancer and thyroid cancer were joint 1st with 11 points for females. The SMCB for females was less than that for males. The burden of stomach cancer was 1st in males from 1999-2010. The incidences of lung cancer and liver cancer decreased, whereas thyroid cancer and colon cancer increased during the period. Breast cancer and thyroid cancer burden showed tendencies to increase in females. Comparison of SMCB with disability-adjusted life years (DALY) and socioeconomic costs in 2005 showed that the top five cancer sites were similar, but there were differences in the size of the cancer burden. Conclusions: The SMCB indicated that the burdens of stomach cancer in males and thyroid and breast cancers in females were large. The single measure showed an advantage, reflected as the equivalent dimensions of incidence and mortality, whereas DALY and economic costs showed tendencies to reflect premature death.

Keywords: Single indicator - summary measure - incidence - mortality - cancer burden

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Introduction

The burden of disease caused by cancer presents significant challenges to individuals, families, and society. According to the National Statistics Office, the average mortality rate from cancer was 142.8 people per 100,000 in 2011. Cancer was the leading cause (Statistics Korea and Ministry of Gender Equality and Family, 2012). Cancer is the most crucial factor threatening public health. The socioeconomic burden caused by cancer continues to increase (Jung, 2008). The burden from increased incidence of cancer and cancer-related mortality are also increasing (National Cancer Institute, 2013) due to aging of the population (Statistics Korea, 2013a), changes in eating habits (Hong et al., 2011), environmental changes (Kim et al., 2006), high smoking rate (Statistics Korea, 2013b), and reduced physical activity (Korea Centers for Disease Control and Prevention, 2013).

As the cancer burden grows, there are two reasons that measuring the burden according to specific cancer site is important. The first reason is that measuring burden of specific cancer sites can differentiate fatal and nonfatal cancers. The second reason is that policy makers can seek strategies to prioritize cancers, which may help to more efficiently reduce the cancer burden.

Cancer burden can be measured by three methods. The traditional method is to identify burden based on epidemiologic indicators, such as incidence, mortality, and prevalence. The second method is to measure cancer burden by socioeconomic burden. The final method is to measure burden by disability-adjusted life years (DALY), which takes quality of life into consideration (Prüss-Üstün et al., 2003; Yoon and Bae, 2004; Yoon et al., 2012).

This study will discuss the traditional epidemiologic method of measuring cancer burden by incidence and mortality. After the comprehensive framework of global burden of disease (GBD) was developed in 1990, GBD researchers tried to find a single measure of disease burden by considering death and disability due to disease and injury (World Bank, 1993). Similarly, a single measure that considers incidence and mortality is needed to measure the epidemiological burden of cancer.

Most previous studies that dealt with incidence (Datta et al., 2010; Eser et al., 2010) and mortality compared these two parameters according to cancer site (Lin and Chen, 2009). Some studies examined annual trends for specific cancer sites and ranked findings according to incidence and mortality(Kumar and Yeole, 2005; Bener et al., 2007). Alternatively, some studies ranked cancer sites according to incidence and mortality (Yancik, 1997;

*[1]Department of Public Health, [2]Institute of Health Services Research, [3]Department of Preventive Medicine, [4]Graduate School of Public Health, Yonsei University College of Medicine, Korea *For correspondence: ecpark@yuhs.ac*

Shibuya et al., 2002; Kamangar et al., 2006; Ferlay et al., 2010; Jemal et al., 2010). However, incidence and mortality are not usually ranked the same for individual cancer sites. For example, cancer sites are classified into 24 cancers by the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10) (Centers for disease control and prevention, 2013). The incidence of thyroid cancer was ranked 1st in females (Ministry of Health And Welfare, 2013b), but the mortality ranking for thyroid cancer was 15th (Ministry of Health And Welfare, 2013a). The burden of thyroid cancer was considered greatest if only incidence was considered. However, the burden of thyroid cancer was low if only mortality was considered. It is difficult to prioritize cancers with these approaches. Thus, previous studies had limitations, because incidence and mortality were not simultaneously considered.

Therefore, the aims of this study were to develop a single measure of cancer burden, which can determine priority for any cancer by comprehensively considering incidence and mortality. Thus, an indicator that anyone can easily use can be created with this simple and reasonable method.

Materials and Methods

Incidence data from 1999 to 2010 were obtained for approximately 24 cancers from the Ministry of Health and Welfare and for about 61 cancers from the Korea Central Cancer Registry (Ministry of Health And Welfare, 2013b). Mortality data from 1999 to 2010 were obtained for 103 causes of death and 236 causes of death from Statistics Korea (Ministry of Health And Welfare, 2013a).

Causes of death were coded and classified according to ICD-10 (Centers for disease control and prevention, 2013). Incidence data were coded and classified according to the International Classification of Diseases for Oncology, 3rd edition. Diseases related to cancer were reclassified into 22 cancers to allow us to make comparisons. Cancer cases were reclassified as follows: cancers of the lip, oral cavity, and pharynx (C00-C14), esophageal cancers (C15), stomach cancer (C16), cancers of the colon, rectum, and anus (C18-C21), liver and intrahepatic bile duct (liver) cancers (C22), cancers in the gallbladder or other parts of the biliary tract (gallbladder) (C23-C24), pancreatic cancers (C25), cancers of the larynx (C32), lung and bronchial (lung) cancers (C33-C34), breast cancers (C50), cervical uterine cancers (C53), corpus uterine and other unknown uterine cancers (C54-C55), ovarian cancers (C56), prostate cancers (C61), cancers of the male reproductive organ except prostate (C60, C62-C63), kidney cancers (C64), bladder cancers (C67), brain and central nervous system cancers (C70-C72), thyroid cancers (C73), non-Hodgkin's lymphoma (C82-C85, C96), multiple myeloma (C90), and leukemia (C91-C95). Hodgkin's lymphoma was excluded, because the mortality could not be estimated.

A single measure was developed by considering both incidence and mortality. The method was developed as follows. Age-adjusted incidence and age-adjusted mortality were estimated from 1999 to 2010 with the mid-year population in 2005. Population data were obtained from the resident registration population, which was reported by Statistics Korea.

A maximum value of age-adjusted incidence for the whole population was identified in 2010. The maximum value of incidence was 67.5 cases of thyroid cancer per 100,000 people. Based on this value, the range was set by dividing data into 10 equal intervals from 0 to 67.5. Age-adjusted incidence was scored by sex and cancer site. The range of 0 to less than 6.75 was scored with 1 point. The range of 6.75 to less than 13.5 was scored as 2 points, and the range of 13.5 to less than 20.25 was assigned 3 points. Thus, the score was given 9 points, and 10 points were assigned at values greater than 60.75 (6.75×9).

Mortality data were scored in a similar manner. The maximum value of age-adjusted mortality for the whole population was identified in 2010. The maximum value of mortality was 25.3 cases of lung cancer per 100,000 people. Based on this value, the range was set by dividing data into 10 equal intervals from 0 to 25.3. Age-adjusted mortality was scored by sex and cancer site.

The scores for incidence and mortality were added by sex and cancer site. Scores ranged from 2 points to 20 points. Rank was determined by sex and cancer site according to the sum of scores.

Respective rank was determined by sex and cancer site according to age-adjusted incidence and age-adjusted mortality. The rank of single measure and the respective rank by age-adjusted incidence and age-adjusted mortality were compared. Scores were assigned for annual age-adjusted incidence and annual age-adjusted mortality by the same method. The trend was analyzed by year, sex, and cancer site according to the single measure of cancer burden.

Finally, single measure of cancer burden was compared with previous data on DALY and economic cancer burden.

Results

Comparison of ranking by incidence and mortality with ranking by Single Measure of Cancer Burden (SMCB) is shown in Table 1. Stomach cancer was the most frequent cancer among Korean males in 2010 with 71.2 cases per 100,000 (Table 1). The order of ranking was lung cancer (50.8), liver cancer (41.3), colon cancer (26.5), and thyroid cancer (23.3). The age-adjusted mortality for lung cancer was 45.7 people per 100,000. Age-adjusted mortalities per 100,000 people according to cancer site were lung cancer (45.7), liver cancer (31.3), stomach cancer (25.8), colon cancer (17.3), and pancreatic cancer (9.0). In the case of thyroid cancer, the incidence was ranked higher than 5th, and the mortality rank was 18th. According to the rankings for incidence and mortality, cancer burden by cancer site showed a different pattern. The burden of stomach cancer was greatest according to the SMCB score of 20, which included 10 points for incidence and 10 points for mortality. The SMCB scores were in the following order. Lung cancer had 18 points with 8 points for incidence and 10 points for mortality. Liver cancer had 17 points with 7 points for incidence and 10 points for mortality. Colon cancer had 11 points with 4 points for incidence and 7

Table 1. Cancer-Specific Burden in 2010, for Male and Female

Cancer sites[§]	Incidence[*]	Mortality[**]	SMCB Score			Rank comparison		
			Total	Incidence	Mortality	Incidence[†]	Mortality[‡]	SMCB[#]
Male:								
Stomach (C16)	71.2	25.9	20	10	10	1	3	1
Lung (C33-C34)	50.8	45.7	18	8	10	2	1	2
Liver (C22)	41.3	31.3	17	7	10	3	2	3
Colon, rectum, and anus (C18-C21)	26.5	17.3	11	4	7	4	4	4
Pancreas (C25)	8.8	9.0	6	2	4	9	5	5
Gallbladder (C23-C24)	8.7	7.1	5	2	3	10	6	6
Thyroid (C73)	23.3	0.4	5	4	1	5	18	6
Esophagus (C15)	7.1	5.0	4	2	2	12	7	8
Bladder (C67)	9.4	3.4	4	2	2	7	9	8
Non-Hodgkin's lymphoma (C82-C85,C96)	7.9	3.2	4	2	2	11	10	8
Prostate (C61)	13.0	2.0	3	2	1	6	14	11
Kidney (C64)	8.9	2.1	3	2	1	8	13	11
Lip, oral cavity, and pharynx (C00-C14)	6.6	2.8	3	1	2	13	11	11
Leukemia (C91-C95)	5.8	3.6	3	1	2	14	8	11
Larynx (C32)	3.7	1.4	2	1	1	15	17	15
Breast (C50)	0.0	0.0	2	1	1	19	19	15
Male reproductive organ except prostate (C60-C63)	0.5	2.0	2	1	1	18	14	15
Brain and central nervous system (C70-C72)	3.5	2.5	2	1	1	16	12	15
Multiple myeloma (C90)	2.1	1.5	2	1	1	17	16	15
Female:								
Breast (C50)	51.1	6.4	11	8	3	2	5	1
Thyroid (C73)	111.5	0.6	11	10	1	1	15	1
Stomach (C16)	30.3	10.1	9	5	4	3	2	3
Lung (C33-C34)	16.9	11.3	8	3	5	5	1	4
Colon, rectum, and anus (C18-C21)	17.1	9.3	7	3	4	4	3	5
Liver (C22)	11.8	8.1	6	2	4	6	4	6
Panceras (C25)	5.7	5.5	4	1	3	9	6	7
Cervix uteri (C53)	7	2.7	4	2	2	7	8	7
Gallbladder (C23-C24)	6.4	4.6	3	1	2	8	7	9
Larynx (C32)	0	0	2	1	1	20	20	10
Esophagus (C15)	0.6	0.1	2	1	1	19	19	10
Multiple myeloma (C90)	1.5	0.9	2	1	1	18	13	10
Lip, oral cavity, and pharynx (C00-C14)	2.5	0.5	2	1	1	16	17	10
Bladder (C67)	1.7	0.6	2	1	1	17	15	10
Corpus uteri (c54-c55)	3.1	0.9	2	1	1	14	13	10
Ovary (C56)	3.7	1.6	2	1	1	13	11	10
Kidney (C64)	3.4	0.5	2	1	1	13	17	10
Brain and central nervous system (C70-C72)	2.7	1.5	2	1	1	15	12	10
Leukemia (C91-C95)	4.2	2.3	2	1	1	11	9	10
Non-Hodgkin's lymphoma (C82-C85,C96)	5.7	1.8	2	1	1	9	10	10

*Incidence, **Mortality: age-adjusted incidence and mortality standardized as mid-year population in 2005, SMCB scores: incidence score+mortality score; respective score was given that incidence and mortality were reclassified by 10 ranges using equal interval from 0 to the maximum value in 2010; †Incidence: arranged by cancer-specific incidence (1st-19th); ‡Mortality: arranged by cancer-specific mortality(1st-19th); #SMCB: arranged by SMCB scores(1st-19th); §: rearranged by SMCB scores

points for mortality. Finally, pancreatic cancer had 6 points with 2 points for incidence and 4 points for mortality.

Thyroid cancer had the highest incidence in females in 2010 with 111.5 people per 100,000 (Table 1). The rankings were in the following order: breast cancer (51.1), stomach cancer (30.3), colon cancer (17.1), and lung cancer (16.9). Age-adjusted mortalities per 100,000 people according to cancer site were lung cancer (11.3), stomach cancer (10.1), colon cancer (9.3), liver cancer (8.1), and breast cancer (6.4). The greatest cancer burden according to SMCB score was thyroid cancer with an incidence of 10 points and mortality of 1 point. Breast cancer had an incidence score of 8 points and mortality score of 3 points, which gave an SMCB score of 11 points. The SMCB scores were in the following order. Stomach cancer had 9 points with 5 points for incidence and 4 points for mortality. Lung cancer had 8 points with 3 points for incidence and 5 points for mortality. Colon cancer had 7 points with 3 points for incidence and 4 points for mortality. Thyroid cancer and breast cancer were tied for the SMCB. However, the incidence rank and mortality rank for breast cancer were 2nd and 5th, respectively, whereas the incidence rank and mortality rank for thyroid cancer were 1st and 15th, respectively. Breast cancer was ranked in the top five for both incidence and mortality. In contrast, thyroid cancer was in the top five for incidence only.

Comparison of the cancer burden by SMCB for males and females showed that stomach cancer ranked 1st in males with 20 points. Breast cancer and thyroid cancer tied for 1st in females with 11 points each. The burden of colon cancer in males also received a score of 11 points. Thus, the cancer burden in females appeared to be less than the cancer burden in males.

Annual trends for cancer burden according to sex and cancer site are presented in Figure 1. The annual cancer burden was estimated with the same standard from 2010. The burden of stomach cancer in males was the same by year. The burdens of lung cancer and liver cancer showed tendencies to decrease, whereas thyroid cancer and colon cancer showed the opposite trends. Although the burden of thyroid cancer was modest in comparison with other

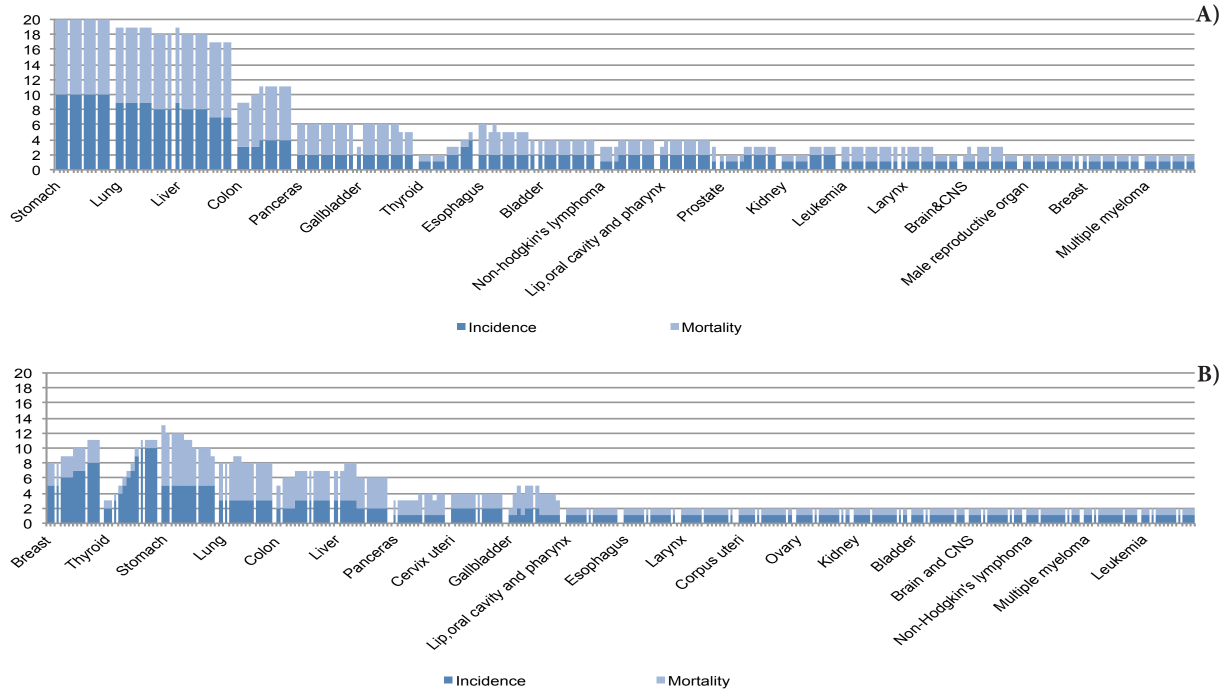

Figure 1. Annual Cancer-Specific SMCB (1999-2010) for A) Males and B) Females

Table 2. Comparison SMCB with DALY and Social-Economic Burden in 2005 and 2010

Cancer sites[§]	2005			2010	
	SMCB Scores	DALY*	Social-economic costs[‡]	SMCB Scores	DALY
Lung (C33-C34)	16	217	1,653,039	16	239
Stomach (C16)	19	245	2,377,698	15	292
Liver (C22)	14	237	2,445,189	12	254
Colon, rectum, and anus (C18-C21)	11	137	1,362,989	12	214
Thyroid (C73)	5	14	514,354	11	50
Breast (C50)	6	71	947,520	6	111
Pancreas (C25)	5	54	411,103	5	72
Gallbladder (C23-C24)	5	54	375,684	5	58
Cervix uteri (C53)	4	35	360,202	4	43
Leukemia (C91-C95)	3	52	588,505	3	52
Non-Hodgkin's lymphoma (C82-C85,C96)	2	31	382,085	3	39
Prostate (C61)	3	13	123,370	3	28
Brain and central nervous system (C70-C72)	2	37	365,667	2	39
Ovary (C56)	2	22	211,536	2	31
Esophagus (C15)	3	24	202,456	2	24
Lip, oral cavity, and pharynx(C00-C14)	2	24	111,875	2	32
Kidney (C64)	2	16	185,182	2	26
Bladder (C67)	2	16	173,258	2	26
Larynx (C32)	2	10	104,980	2	11
Multiple myeloma (C90)	2	9	98,670	2	14
Corpus uteri (C54-C55)	2	8	65,122	2	16
Male reproductive organ except prostate (C60-C63)[†]	2	1	17,336	2	2

*DALY: replaced the average of 2004 and 2006 due to not available data of 2005 (data: Park et al. the analysis and reduction strategies of cancer burden in Korea. Korean Foundation fro cancer Research, 2012), unit of DALY: person-year/one hundred thousand people); [‡]Social-economic burden: including medical care and non-medical expenses, morbidity and mortality cost (data: Kim et al. economic burden of cancer in South Korea for the year 2005. Journal of Preventive Medicine and Public Health, 2009), unit of social-economic costs: million-won; [†]Corresponds only testis cancer (C60) in DALY and social-economic burden; [§]Rearranged by SMCB scores

cancers, the burden continued to grow. The burden of colon cancer increased steadily until 2004, at which point it has been stable.

The burden of stomach cancer in females showed a tendency to decrease from 13 points in 1999 to 9 points in 2010. The burdens of breast cancer and thyroid cancer showed tendencies to increase. In particular, the growth rate for thyroid cancer burden was larger than that for breast cancer. The burden of colon cancer was not as great as that of breast cancer or thyroid cancer, but it was one of the cancers whose burden continued to increase.

SMCB was compared to two previous studies in which the annual estimated DALY by cancer site and socioeconomic costs of cancer burden were examined to validate SMCB (Table 2). The burden of lung cancer by DALY and SMCB was greatest in 2005, but the greatest socioeconomic burden by cancer site was for liver cancer. Cancer burden according to DALY, socioeconomic costs, and SMCB for the top five cancers were the same in 2005, but there were differences in the size of cancer burden. Cancer burden rankings according to SMCB scores were the following. Thyroid cancer was ranked 6th, followed by pancreatic cancer, gallbladder cancer (5 points), and cancer of the uterine cervix (4 points). Cancer burdens by socioeconomic costs were in the following order. Leukemia was 1st (588,505 million won) followed by thyroid cancer (514,354 million won) and pancreatic cancer (411,103 million won). Cancer burden by DALY ranked pancreatic cancer 1st, followed by gallbladder cancer (54 person-years) and leukemia (52 person-years). The DALY for thyroid cancer were 14 person-years, which indicated a relatively smaller burden for thyroid cancer in comparison to other methods.

The burdens of prostate cancer and leukemia by SMCB were each 3 points. However, the burdens of prostate cancer and leukemia by DALY were 13 person-years and 52 person-years, respectively. The burdens for these cancers according to socioeconomic costs were 123,770 million won and 588,505 million won, respectively. The burden of leukemia was more than four times larger. Cancer burden by SMCB was distributed by 2 points for the remaining cancers. In contrast, cancer burden by DALY was distributed from 1 person-year to 25 person-years except in non-Hodgkin's lymphoma and brain cancer. Cancer burden by socioeconomic burden was distributed from 17,336 million won to 211,536 million won.

Discussion

We compared cancer burden according to incidence and mortality with cancer burden assessed by a single measure. This single measure considered both incidence and mortality to determine the priority of these factors in epidemiologic disease burden. This study also compared SMCB with DALY and socioeconomic costs, which were estimated from previous studies, to validate development of the SMCB method. There are several discussion points regarding development of a single measure.

First, validation of the single measure should be discussed. As mentioned in the introduction of this study, cancer burden may be measured by three methods. The first method is the traditional method, which examines epidemiologic indicators, such as incidence, mortality, and prevalence. The second method is to estimate socioeconomic costs due to diseases. The final method is to measure DALY (Prüss-Üstün et al., 2003; Yoon and Bae, 2004). These three methods share the same goal of measuring cancer burden based on incidence, mortality, and prevalence. The DALY and socioeconomic methods may differ slightly, in which case comparisons can be based on DALY estimation studies (Park and Park, 2012; Park et al., 2013) and the socioeconomic costs study (Kim et al., 2009).

In the DALY estimation studies (Park and Park, 2012; Park et al., 2013), DALY were estimated as the sum of the years of life lost (YLLs), which were defined as the quantity of premature death or fatal health outcomes, and the years lived with disability (YLDs), or the quality of disabled life or non-fatal health outcomes. YLL and YLD take into consideration life expectancy, age-weighting, and discount rate by time preference. So DALY highlight premature mortality (Murthy et al., 2010).

In the socioeconomic costs study (Kim et al., 2009), total costs related to cancer were classified into direct costs and indirect costs. Directs costs included both medical and non-medical care expenses, and indirect costs consisted of morbidity, mortality, and the caregiver's time costs. Both studies estimated the years of life lost and the costs of premature death in connection with cancer burden. Indirect costs, which combine morbidity costs and mortality costs, are usually greater than direct costs if disease burden is measured in terms of socioeconomic costs. Kim's study also measured cancer-related direct costs of 3.0 trillion won (30.4%) in 2005, whereas the indirect costs were 10.7 trillion won (76.3%). In particular, , the mortality costs are much greater than the morbidity costs for cancers in which survival rates are relatively low compared with other diseases. Similarly, in the case of DALY, which are measured as the sum of YLLs and YLDs, YLLs were much larger than YLDs except in thyroid cancer. There were similar results in Park's study (Park and Park, 2012; Park et al., 2013). The mortality costs of certain diseases tend to be observed at younger ages and lower survival rates (Romeder and Mcwhinnie, 1977; Jung, 2011).

Comparison of SMCB in two studies showed that the burden of lung cancer was relatively large, and the burden of liver cancer was relatively small. Both studies determined that the burden of liver cancer was greater than that of lung cancer. This is why cancer burden by a single measure is reflected as an estimate of both incidence and mortality. However, these two studies tended to show that premature death costs were larger if cancer burden was larger. The greatest cancer burden according to SMCB and DALY in 2005 was for stomach cancer, whereas socioeconomic costs were greatest for liver cancer.

These findings may be explained by the age-specific cancer mortality in 2005 (Ministry of Health And Welfare, 2013a). Mortality from liver cancer was higher than from stomach and lung cancers in patients whose ages ranged from 40-75. Mortality rates from stomach and lung cancers were higher than those for liver cancer starting at age 75. Therefore, the premature costs and YLLs of liver cancer were larger than those for stomach and lung cancers, which affected the burden of liver cancer.

Both studies reflected early death based on cancer burden. The burden of stomach cancer was ranked at the top by DALY, and the burden of liver cancer was ranked at the top by socioeconomic costs. Unique features of each measurement method were also considered. Socioeconomic costs were estimated by considering individual characteristics, such as unemployment rates, employment rates, and average wages according to sex. DALY were estimated by taking incidence and mortality into consideration for male and female populations. The incidence and mortality rates of stomach cancer in males were 76.4 and 36.1 people per 100,000, respectively. The incidence and mortality rates of liver cancer were 49.3 and 37.5 people per 100,000, respectively, in 2005. The incidence and mortality rates of stomach cancer in females were 32.4 and 13.3 people per 100,000, respectively. The incidence and mortality rates of liver cancer were 13.2 and 9.7 people per 100,000, respectively. The incidence of stomach cancer in males was twice as high as in females, and mortality was three times higher in males versus females. The incidence and mortality of liver cancer was three times higher in males than in females. The burden of liver cancer was larger than that of stomach cancer according to socioeconomic costs, because employment rates and average wages were usually larger for males than females in Korea.

In addition, stomach cancer burden showed a significant increase annually from 1999 to 2010 in Korea according to DALY. In contrast, lung cancer burden significantly increased according to SMCB. There are two potential explanations for these findings. First, the proportion of people who are 65 years old or greater has progressed rapidly from 7.2% to 11.1% during 2000-2010. Second, the incidence and mortality rates of lung cancer were relatively higher than those for stomach cancer in aging people. Therefore, lung cancer burden was highlighted by SMCB, which equally reflected age structure.

Premature costs and YLLs were relatively small for thyroid cancer in comparison to other cancers, as the survival rate was close to 100%. DALY for thyroid cancer were as small as 14 person-years. YLDs were small, because the disability weight of thyroid cancer was low.

DALY measurements consider age-weighting and socioeconomic burden, which focus on employment and manpower of housework as features that are important to the health status of young people. DALY and socioeconomic burden have raised criticism for highlighting younger generations. In contrast, there is a feature of SMCB that reflects age structure equally. SMCB with this feature is valuable for developed countries like Korea where the survival rate increases rapidly and characteristics of chronic disease are reinforced in cancer.

In conclusion, the single measure developed in this study was based equally on incidence and mortality. This was a significant difference from the other two studies.

Development of the single measure did not involve adding incidence and mortality alone. We set a range of 10 by equal intervals based on the maximum value in the whole population, including males and females. We assigned scores according to incidence and mortality by range and added the scores. Mortality showed a tendency to be lower than incidence. If incidence and mortality were added alone, mortality would be reflected less than incidence. Thereby, we added scores for incidence and mortality by range to make the dimensions of incidence and mortality the same. We considered using both equal interval and standard deviation for determining rankings by cancer sites. The distribution was skewed to the right when distributions of incidence and mortality were examined by year and cancer site. Respective incidence and mortality were converted to logarithmic scale, and normal distributions were made. Rank was determined with the standard deviation. In comparison to equal interval, standard deviation is affected less by the maximum value. However, conversion to logarithmic scale tended to make larger values smaller and smaller values larger due to the nature of logarithmic scales. Logarithmic conversion was useful for cancers that had low incidence and low mortality. However, the disadvantage was that the actual difference between cancer sites was not adequately reflected. Cancers were concentrated on both sides of the average value. In contrast, in the case of equal intervals, the disadvantage was that these values were affected more by the maximum value. The advantage was that equal intervals reflected the actual difference.

Another consideration in developing a single measure was whether to add or multiply scores. The advantage of multiplying scores is that the burden by cancer site was dramatic. In contrast, the disadvantage is that multiplied scores are more affected by large or small values on one side, because respective scores of incidence and mortality are weighted together. However, in the case of adding scores, the disadvantage is that differences in cancer-specific burden are not dramatic. The advantage is that adding scores would adequately reflect the equivalent size of scores, which would be consistent with the original purpose.

The purpose of developing a single measure was not to compare cancers that had small cancer burdens but to determine the priority of cancer-specific burden. Therefore, equal interval reflected actual cancer-specific differences more than standard deviation, and adding scores was more suitable than multiplying scores.

The other consideration was how to determine rank for cancers with the same SMCB. For example, the burdens of breast cancer and thyroid cancer were the same in females. The score for breast cancer was 11 points with 8 points for incidence and 3 points for mortality. The score for thyroid cancer was 11 points with 10 points for incidence and 1 point for mortality. Breast cancer had a certain size for incidence and mortality. The growth rate for thyroid cancer burden was greater. We should determine whether to select a certain size for both incidence and mortality or to select a greater growth rate for cancer burden. The first purpose of this study was to judge cancer-specific burden through the average approach. In cases that had the same cancer burden, we decided that selecting a certain size for both incidence and mortality was greater. However, this does not mean that cancer burden is small. The growth of cancer burden grows rapidly each year, which is a subject to be considered as a sentinel indicator.

The limitations of this study were that a single measure was affected by the maximum value and did not differentiate between cancers that had small cancer burdens. Nevertheless, a single measure is meaningful in that it can easily be used by anyone to determine the cancer-specific burden. Furthermore, this study was meaningful, because it was the first study in which epidemiologic cancer burden was comprehensively examined with a single measure that considered both incidence and mortality.

An SMCB that reflects age structure equally is useful as an alternative indicator for policy makers, because we are currently faced with an aging society.

In conclusion, this study developed SMCB that indicated the burdens of cancers through merging incidence and mortality. DALY measurements consider age-weighting and socioeconomic burden, which focus on employment and manpower of housework as features that are important to the health status of young people.

DALY and socioeconomic burden have raised criticism for highlighting younger generations. In contrast, there is a feature of SMCB that reflects age structure equally. SMCB with this feature is valuable for developed countries like Korea where the survival rate increases rapidly and characteristics of chronic disease are reinforced in cancer. We consider that SMCB is useful for policy-makers of developed countries.

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References

Bener A, Ayub H, Kakil R, Ibrahim W (2008). Patterns of cancer incidence among the population of Qatar: a worldwide comparative study. *Asian Pac J Cancer Prev*, **9**, 19-24.

Datta K, Choudhuri M, Guha S, Biswas J (2010). Childhood cancer burden in part of eastern India- population based cancer registry data for Kolkata (1997-2004). *Asian Pac J Cancer Prev*, **11**, 1283-8.

Eser S, Yakut C, Özdemir R, et al (2010). Cancer incidence rates in Turkey in 2006: a detailed registry based estimation. *Asian Pac J Cancer Prev*, **11**, 1731-9.

Ferlay J, Shin H-R, Bray F, et al (2010). Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. *Int J Cancer*, **127**, 2893-917.

Hong WS, Kwon YS, Kwon YM, Yoo HK (2011). Content analysis of dietary lifestyle-related resreach articles from 1990 to 2009. *J Korean Home Econ Assoc*, **49**, 13-26.

Jemal A, Center MM, DeSantis C, Ward EM (2010). Global patterns of cancer incidence and mortality rates and trends. *Cancer Epidemiol Biomarkers Prev*, **19**, 1893-907.

Jung YH (2011). Measuring years of life lost due to premature death in Korea: toward estimating the burden of disease. *Ministry Health and Welfare Forum*, **11**, 66-75.

Jung YH, Ko SJ (2009). Cost of illness and health-friendly fiscal policy. *Ministry Health and Welfare Forum*, **10**, 51-61.

Kamangar F, Dores GM, Anderson WF (2006). Patterns of cancer incidence, mortality, and prevalence across five continents: defining priorities to reduce cancer disparities in different geographic regions of the world. *J Clin Oncol*, **24**, 2137-50.

Kim H, Ha JS, Park JG (2006). High temperature, heat index, and mortality in 6 major cities in South Korea. *Arch Environ Occup Health*, **61**, 265-70.

Kim JH, Hahm MI, Park EC, et al (2009). Economic burden of cancer in South Korea for the Year 2005. *J Prev Med and Public Health*, **42**, 190.

Korea Centers for Disease Control and Prevention (2013). Korea Nationa Health and Nutrition Examination Survey 2005-2011.

Kumar AV, Yeole BB (2005). Assessing cancer burden in Rural India: an analysis by cause of death statistics. *Asian Pac J Cancer Prev*, **6**, 221-3.

Li GL, Chen WQ (2009). Representativeness of population-based cancer registration in China - comparison of Urban and Rural areas. *Asian Pac J Cancer Prev*, **10**, 559-64.

Murthy NS, Nandakumar BS, Pruthvish S, George PS, Mathew A (2010). Disability adjusted life years for cancer patients in India. *Asian Pac J Cancer Prev*, **11**, 633-40.

Park EC, Park JH (2012). The analysis and reduction strategies of cancer burden in Korea. Korean foundation for cancer research: Seoul. Research Report, 155-208.

Park JH, Lee KS, Choi KS (2013). Burden of cancer in Korea during 2000-2020. *Cancer Epidemiol*, **37**, 353-9.

Prüss A, Kay D, Fewtrell L, Bartram J (2002). Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environ Health Perspect*, **110**, 537-42.

Romeder J-M, McWhinnie JR (1977). Potential years of life lost between ages 1 and 70: an indicator of premature mortality for health planning. *Int J Epidemiol*, **8**, 143-51.

Shibuya K, Mathers CD, Boschi-Pinto C, et al (2002). Global and regional estimates of cancer mortality and incidence by site: II. results for the global burden of disease 2000. *BMC Cancer*, **2**, 37-26.

Yancik R (1997). Cancer burden in the aged. *Cancer*, **80**, 1273-83.

Yoon SJ, Bae SC (2004). Current scope and perspective of burden of disease study based on health related quality of life. *J Korean Med Assoc*, **47**, 600-2.

Yoon SJ, Kim EJ, Seo HJ (2012). Quantitative Methodology fpr Health Policy Research. Book; Korea University, 12-31.