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Decomposition of socio-economic differences in life expectancy at birth by age and cause of death among 4 million South Korean public servants and their dependents

Young-Ho Khang,[1] Seungmi Yang,[2] Hong-Jun Cho,[3] Kyunghee Jung-Choi[4] and Sung-Cheol Yun[5]*

[1]Department of Preventive Medicine, University of Ulsan College of Medicine, Seoul, Korea, [2]Department of Epidemiology, Biostatistics, and Occupational Health, McGill University, Montreal, Quebec, Canada, [3]Department of Family Medicine, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea, [4]Department of Preventive Medicine, Ewha Womans University School of Medicine, Seoul, Korea and [5]Department of Clinical Epidemiology and Biostatistics, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

*Corresponding author. Department of Clinical Epidemiology and Biostatistics, Asan Medical Center, University of Ulsan College of Medicine, 388-1 Pung-nap 2dong, Songpa-gu, Seoul 138-736, Korea. E-mail: ysch97@amc.seoul.kr

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Background Differences in life expectancy at birth across social classes can be more easily interpreted as a measure of absolute inequalities in survival. This study quantified age- and cause-specific contributions to life expectancy differences by income among 4 million public servants and their dependents in South Korea (9.1% of the total Korean population).

Methods Using 9-year mortality follow-up data (208 612 deaths) on 4 055 150 men and women aged 0–94 years, with national health insurance premiums imposed proportionally based on monthly salary as a measure of income, differences in life expectancy at birth by income were estimated by age- and cause-specific mortality differences using Arriaga's decomposition method.

Results Life expectancy at birth gradually increased with income. Differences in life expectancy at birth between the highest and the lowest income quartile were 6.22 years in men and 1.74 years in women. Mortality differentials by income among those aged $\geqslant$50 years contributed most substantially (80.4% in men and 85.6% in women) to the socio-economic differences in life expectancy at birth. In men, cancers (stomach, liver and lung), cardiovascular diseases (stroke), digestive diseases (liver cirrhosis) and external causes (transport accidents and suicide) were important contributors to the life expectancy differences. In women, the contribution of ill-defined causes was most important. Cardiovascular diseases (stroke and hypertensive disease) and external causes (transport accidents and suicide) also contributed to the life expectancy differences in women while the contributions of cancers and digestive diseases were minimal.

Conclusions Reductions in socio-economic differentials in mortality from stroke and external causes (transport accidents and suicide) among middle-aged and older men and women would significantly contribute to

equalizing life expectancy among income groups. Policy efforts to reduce mortality differentials in major cancers (stomach, liver and lung) and liver cirrhosis are also important for eliminating Korean men's socio-economic inequalities in life expectancy.

Keywords Life expectancies, socio-economic differences, South Korea, Asia, cause of death, mortality

Introduction

Understanding cause-specific contributions to absolute inequalities in total mortality provides valuable information when planning health policies to reduce health inequalities. Several attempts have been made in Western countries to quantify the cause-specific contributions to the socio-economic differences in all-cause mortality and disability-free life expectancy.[1–3]

Life expectancy at birth is a summary index for mortality at all ages. Differences in life expectancy at birth across social classes can be more easily interpreted as a measure for absolute inequalities in survival.[4] Decomposing differences in life expectancy at birth using age- and cause-specific mortality information is a useful way to understand the underlying mechanisms of the observed inequalities in life expectancy.[5] However, only a limited number of investigations have been made regarding age- and cause-specific contributions to socio-economic differentials in life expectancy.[6–9] Two studies from the USA and Australia quantified cause-specific contributions to life expectancy differences among educational classes[6] and between indigenous and non-indigenous populations.[9] Two other studies from the USA and Finland presented age- and cause-specific decompositions of changes in life expectancy at certain ages within adulthood by education.[7,8] However, investigations into age- and cause-specific contributions to differences in life expectancy at birth by socio-economic position (SEP) are rare.

The magnitude of cause-specific contributions to socio-economic differentials in life expectancy may vary among countries with different cause-of-death structures. For example, in Northern European countries and the USA, a significant proportion of socio-economic differences in life expectancy can be explained by ischaemic heart disease as a major leading cause.[1,2,10] However, ischaemic heart disease accounts for only a small part of total mortality in many Asian countries including South Korea (hereafter 'Korea').[11,12] Stroke, stomach cancer, liver disease and cancer and lung cancer are more frequent causes of death in Korea[12] and can significantly contribute to absolute socio-economic differentials in mortality.[13]

In Korea, the system of levying an insurance premium for national health insurance can provide an opportunity to present income differences in life expectancy at birth, because the level of the national health insurance premium imposed is proportional to the monthly salary of the head of the household. Using this information and the linkage to mortality data using unique personal identification numbers (PIDs), this study aimed to quantify age- and cause-specific contributions to differences in life expectancy at birth by income level among 4 million Koreans.

Materials and methods

Data

The public servants' health insurance beneficiary data of Korea include all government employees, primary and secondary school teachers and their dependents. In this study, we used the beneficiary data constructed at the end of 1994. It included 1 171 153 public servants (830 488 men and 340 665 women) and their 2 883 997 dependents (1 135 551 men and 1 748 446 women), accounting for 9.1% of the total Korean population in 1994. Figure 1 shows the number and age distribution of study subjects and of the entire Korean population in 1994 by gender, indicating the study subjects to be older than the total Korean population. These health insurance data were individually linked to mortality data of the Korea National Statistical Office (NSO) between January 1995 and December 2003 using 13-digit PIDs. By law, all deaths of Koreans must be reported to the NSO within a month of their occurrence. Death certificate data of the NSO are known to be 100% complete for deaths at all ages except infants.[14] When a public servant or his/her dependent emigrates, follow-up via death certificate data may be impossible. However, the number of emigrants from Korea is negligible.[12] The completeness of infantile death registration is suboptimal because neonatal deaths may not be reported to the NSO when a baby dies before the birth is reported.[15] The proportion of physician-certified deaths, the most important factor in improving the accuracy of cause-of-death information,[16,17] was 70.5% in men and 62.7% in women in our data. This proportion decreased among older decedents. For example, the proportions of physician-certified deaths at age $\leqslant 64$ were 83.1% for men and 81.7% for women but the corresponding figures among those aged $\geqslant 65$ years were 59.7 and 56.6%, respectively. However, the ascertained causes

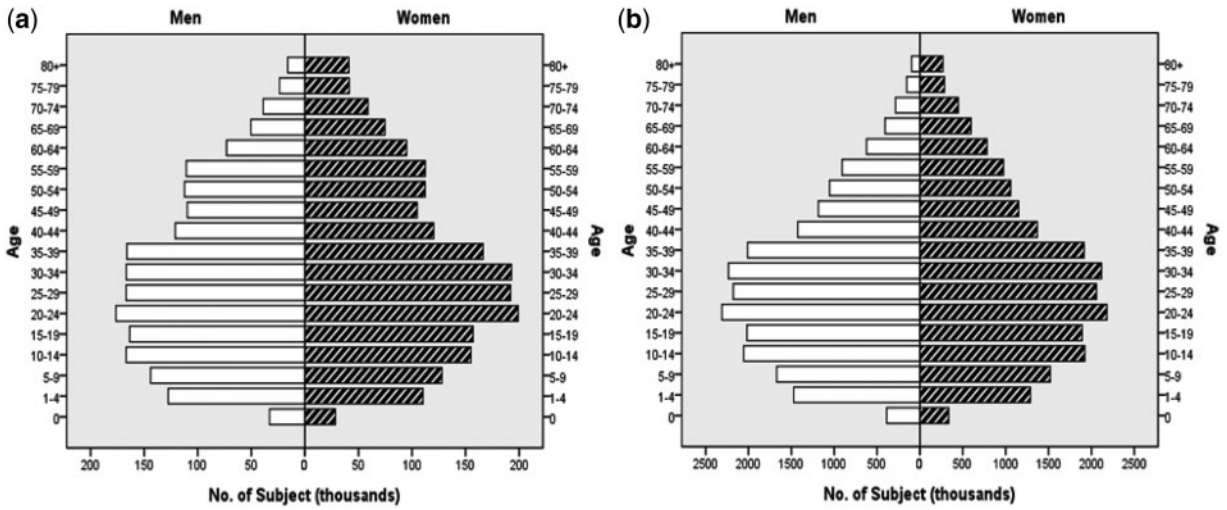

Figure 1 Number and age distribution of (a) study subjects (1 966 039 men and 2 089 111 women) and (b) the entire Korean population in 1994 (22 472 000 men and 22 169 000 women). Total Korean population data were from the National Statistical Office's population estimates for 1994

of death from death certificates is fairly accurate, as a prior study has reported 72.4% accuracy of the causes of death among non-external causes compared with medical service utilization data.[18] Moreover, the study has shown no significant difference in the accuracy level by income.

Of 4 055 150 men and women aged 0–94, a total of 208 612 men and women died during the 9-year mortality follow-up. The date and cause of death were obtained from mortality data of the NSO. Causes of death were identified per the International Classification of Disease, 10th Revision (ICD-10) codes.

Since the beneficiary data have been collected routinely in the national health insurance system, study subjects' consent for this study was not specifically obtained. This study was approved by the Asan Medical Center Institutional Review Board, Seoul, Korea.

SEP

The premium level of national health insurance was used as a measure for income. Health insurance premiums in the public servants' health insurance of Korea are proportionally imposed based on the monthly salary of the public servant and thus directly reflect individual income. This income level was also used as the SEP indicator for public servants' dependents. Using a total of 53 premium levels initially used for the health insurance, we classified the income levels into 5-year age-specific (except ages <1, 1–4 and $\geqslant 80$ years) quartiles based on the age-specific cumulative distribution of subjects by the premiums. Several prior Korean studies have used the national health insurance premium as an SEP indicator.[18–21]

Statistical analysis

Using a person-year approach, 1-year probabilities of death for single years of attained age were calculated for each income group. No smoothing of the probabilities was undertaken because of the large sample size. Life tables were constructed using the 1-year probabilities of death to estimate life expectancy at birth by income groups. Estimated life expectancies were compared among income groups. Using Arriaga's decomposition method,[22,23] age- and cause-specific contributions to life expectancy differences between the highest and the lowest income quartiles were estimated. This decomposition method estimates the contribution of mortality differentials for each age group and cause to the total differences in life expectancy at birth by income. The sum of the cause-specific contributions to the income differentials in life expectancy at birth for a given age is equal to the total contribution for that age, and the total differences in life expectancy at birth by income is the sum of the age- and cause-specific components.

Results

As shown in Table 1, this study contained 35 574 268 person-years of follow-up. The average length of follow-up was 8.8 years. Of 208 612 deaths, 51.5% ($n = 108\,104$) were of males. The average life expectancy at birth was 72.55 for men and 80.12 for women (gender difference = 7.57). This average life expectancy at birth corresponds to the 2001 life expectancy at birth in Korea (72.82 for men and 80.04 for women).[24] Table 1 also shows differences in life expectancy at birth by income. A graded pattern of differentials by income was found in both men and women. The difference between the highest and lowest income quartile was 6.22 years in men and 1.74 years in women, indicating greater differentials in men than women.

Table 1 Number of subjects, person-years, number of deaths and life expectancy at birth according to income quartile among Korean public servants' health insurance beneficiaries

Income class	No. of subjects	Person-years	No. of deaths	Life expectancy at age 0	Life expectancy difference
Men	1 966 039	17 213 003	108 104	72.55	
I (highest)	487 314	4 283 122	23 183	75.42	Reference
II	505 972	4 442 057	25 197	73.82	1.60
III	479 901	4 197 026	27 365	71.76	3.66
IV (lowest)	492 852	4 290 797	32 359	69.20	6.22
Women	2 089 111	18 361 265	100 508	80.12	
I (highest)	532 820	4 692 901	23 601	80.85	Reference
II	500 632	4 398 249	24 545	80.43	0.42
III	530 604	4 661 799	25 771	80.03	0.82
IV (lowest)	525 055	4 608 316	26 591	79.11	1.74

Table 2 presents age-standardized cause-specific mortality rates by income quartile and mortality rate ratios (RRs) between the highest and lowest income quartile among men and women. RRs for most causes of death were greater among men than women. RRs for colorectal cancer, ischemic heart disease (in men and women), prostatic cancer (in men), biliary tract/gall bladder cancer, pancreatic cancer, breast cancer and ovarian cancer (in women) were recorded at <1.

Table 3 shows the contribution in years by each age group to life expectancy differences between the highest and lowest income quartile among men and women. The absolute magnitude of age-specific contributions to the life expectancy difference (year contribution in Table 3) was greater in men than in women across all age groups except age 0. Of the total differences between the highest and the lowest income quartile, mortality differences by income among older generations made greater contributions to life expectancy differences than among younger generations in both men and women. Mortality differentials among those aged $\geqslant 50$ years contributed 5.01 years in men and 1.47 years in women to the total differences in life expectancy between the highest and the lowest income quartile, accounted for 80.4 and 85.6% of the total differences in men and women, respectively. Contributions by those aged $\geqslant 65$ years were 2.6 years (41.6%) in men and 1.04 years (59.8%) in women, indicating that contributions by the elderly were greater in women than men.

Table 4 presents contributions to the total life expectancy differences between the highest and lowest income quartile by causes of death. In men, cancers, cardiovascular diseases, digestive diseases and external causes were four major broad causes contributing 4.54 years (73.2%) to the life expectancy difference between the highest and lowest income quartiles. However, the contribution of ill-defined causes was most important (1.05 years, 60.3%) in women. Cardiovascular diseases and external causes also contributed to the life expectancy differences for women by 0.66 years, accounting for 37.6%, whereas the contributions of cancers and digestive diseases were minimal.

Table 4 also shows the contributions by detailed cause. Stomach cancer, liver cancer and lung cancer were the three leading cancers in men (see number of deaths in Table 4) and accounted for the greatest proportion of the contributions by all cancers. However, this was not true for women. Although these three cancers also constituted major leading cancers in women, their contributions to life expectancy differences were meagre. Even if the magnitudes of the contributions are minimal, colorectal cancer and prostate cancer contributed negatively to the differences in life expectancy in men. For women, cancers in general made negative contributions to the socio-economic differences in life expectancy, mainly by colorectal, biliary tract/gall bladder, pancreatic, breast and ovarian cancers. Of cardiovascular diseases, stroke was the leading cause of death in both men and women (see number of deaths in Table 4) and accounted for the largest proportion of contributions by cardiovascular diseases in both sexes. In women, the contribution by hypertensive disease was also substantial. In contrast, ischaemic heart disease negatively contributed to the life expectancy differentials in both men and women. Of external causes, transport accidents and suicide were the two major causes accounting for the largest number of externally caused deaths as well as the largest number of contributions by external causes to the life expectancy differences. Other causes such as tuberculosis, diabetes, dementia, chronic lower respiratory disease and liver cirrhosis positively contributed to life expectancy differences by income in both men and women.

Table 2 Age-standardized cause-specific mortality rates by income groups and mortality RRs between the highest (I) and lowest income quartile (IV)

Causes of death	Men					Women				
	I	II	III	IV	IV/I (RR)	I	II	III	IV	IV/I (RR)
Infectious diseases	10.3	11.8	13.1	17.6	1.72	8.0	8.3	7.6	9.0	1.12
Tuberculosis	6.4	7.2	8.1	11.6	1.81	3.2	4.0	3.6	4.5	1.41
Other infectious	3.8	4.6	5.1	6.0	1.56	4.8	4.4	4.0	4.4	0.92
Cancers	163.8	184.2	201.1	213.9	1.31	99.1	99.3	101.2	98.2	0.99
Stomach cancer	33.9	38.5	44.3	45.9	1.35	19.5	20.3	21.6	21.6	1.11
Colorectal cancer	13.1	12.7	11.4	12.0	0.92	10.4	10.1	9.8	9.8	0.94
Liver cancer	29.7	35.1	39.0	43.4	1.46	10.6	11.0	11.4	11.5	1.08
Biliary tract/gall bladder cancer	7.3	8.3	8.7	8.9	1.21	6.9	6.9	6.4	5.8	0.84
Pancreatic cancer	7.7	8.2	8.9	8.8	1.14	6.1	5.5	6.3	5.2	0.85
Lung cancer	34.1	40.1	45.9	50.0	1.47	13.7	12.7	13.6	14.1	1.03
Breast cancer	–	–	–	–	NA	5.8	5.6	5.0	4.8	0.83
Ovarian cancer	–	–	–	–	NA	3.1	2.7	2.5	2.2	0.70
Prostatic cancer	4.1	3.8	3.6	3.0	0.74	–	–	–	–	NA
Other cancers	33.9	37.6	39.2	41.9	1.24	22.9	24.4	24.6	23.3	1.02
Endocrine diseases	21.5	25.3	25.7	28.9	1.34	26.9	28.5	27.4	29.2	1.09
Diabetes	20.4	24.1	24.3	27.2	1.33	25.1	26.8	25.4	26.9	1.07
Other endocrine	1.1	1.3	1.4	1.7	1.53	1.8	1.7	1.9	2.3	1.29
Mental and nervous diseases	15.4	14.7	16.1	20.4	1.33	27.1	25.2	25.1	27.1	1.00
Dementia	7.7	7.6	8.4	9.4	1.21	19.7	18.6	18.8	20.5	1.04
Other mental and nervous	7.6	7.1	7.7	11.0	1.44	7.4	6.6	6.3	6.6	0.88
Cardiovascular diseases	125.0	135.2	152.9	166.4	1.33	147.5	157.9	162.4	171.5	1.16
Hypertensive disease	8.3	9.9	12.5	12.4	1.49	13.8	16.3	17.7	19.3	1.40
Ischaemic heart disease	25.6	24.5	27.7	24.4	0.95	21.6	22.2	19.9	18.4	0.85
Stroke	73.3	80.3	90.3	103.2	1.41	90.2	95.6	100.2	107.2	1.19
Other cardiovascular	17.7	20.5	22.4	26.4	1.49	22.0	23.7	24.7	26.6	1.21
Respiratory diseases	36.5	39.5	45.0	49.9	1.37	27.9	29.3	30.1	32.9	1.18
Chronic lower respiratory disease	19.7	23.0	26.7	29.4	1.49	14.7	16.7	18.1	21.4	1.45
Other respiratory	16.8	16.6	18.4	20.6	1.23	13.2	12.6	12.0	11.6	0.88
Digestive diseases	23.9	29.1	40.2	59.1	2.47	17.2	17.0	18.9	19.8	1.15
Liver cirrhosis	12.2	14.6	21.8	34.3	2.81	6.7	5.9	7.4	7.4	1.10
Other digestive	11.7	14.5	18.4	24.8	2.12	10.5	11.1	11.5	12.5	1.19
External causes	46.8	55.4	71.0	98.9	2.11	31.1	32.2	34.3	39.6	1.27
Transport accident	20.2	26.4	33.5	46.8	2.32	11.4	12.4	12.9	15.2	1.34
Suicide	9.6	11.3	14.4	21.2	2.20	6.8	7.0	7.8	9.1	1.33
Other external causes	17.0	17.8	23.0	30.9	1.82	12.9	12.8	13.6	15.3	1.19
Ill-defined causes	55.7	63.5	72.7	87.6	1.57	95.0	111.7	123.8	142.3	1.50
Residual	16.6	17.9	19.8	20.8	1.25	25.4	24.2	23.0	23.6	0.93
Total	515.6	576.7	657.6	763.6	1.48	505.3	533.7	553.7	593.2	1.17

Age-standardized mortality rates were calculated by the direct standardization method using total study population as the reference population. Mortality RRs were computed as the ratio of mortality rate in the lowest income quartile (IV) divided by the rate in the highest income quartile (I). NA, not available.

Table 3 Age-specific contributions (years, %) to the life expectancy gap between the highest income quartile and the lowest income quartile

Age groups	Men		Women	
	Years	%	Years	%
0	–0.01	–0.1	0.00	0.2
1–4	0.03	0.4	0.01	0.6
5–9	0.06	0.9	0.00	–0.2
10–14	0.03	0.6	0.00	0.3
15–19	0.09	1.4	0.03	1.8
20–24	0.08	1.3	0.00	0.3
25–29	0.03	0.5	–0.02	–0.9
30–34	0.01	0.2	0.00	−0.2
35–39	0.11	1.8	0.02	1.3
40–44	0.27	4.4	0.08	4.5
45–49	0.52	8.3	0.12	6.7
50–54	0.66	10.6	0.13	7.6
55–59	0.83	13.4	0.15	8.3
60–64	0.92	14.8	0.17	9.9
65–69	0.73	11.7	0.17	10.0
70–74	0.69	11.1	0.25	14.2
75–79	1.03	16.5	0.37	21.1
⩾80	0.15	2.3	0.25	14.5
Total	6.22	100.0	1.74	100.0

Discussion

In this study, we quantified age- and cause-specific contributions to socio-economic life expectancy differences using Arriaga's decomposition method. Although socio-economic differences in life expectancy have been reported in multiple studies,[4,25–32] decomposing life expectancy differences by both age and cause-of-death has rarely been performed. Although studies on the decomposition of educational inequalities in life expectancy exist,[6–8] these studies did not present inequalities in life expectancy at birth due to the inapplicability of SEP information to children. Socio-economic mortality inequalities across whole age groups have been examined in prior studies,[33,34] but explaining socio-economic inequalities in life expectancy at birth by the decomposition method can inform us about the extent to which specific ages and causes make direct contributions to observed absolute differentials in mortality.

A vital registration system that records 100% of deaths and complete coverage of unique identifiers (here PIDs) for linkage to mortality data are required to use individually linked mortality data for exploring socio-economic differences in life expectancy at birth. Of all Korean death certificates for ages ⩾1 between 1995 and 2003 ($N = 2\,177\,649$), the percentage without PIDs was 0.79%, based on our detailed analysis of death certificate data. Infantile death registration is known to be incomplete in Korea.[15,35] The infant mortality rate has been estimated at 7.7 per 1000 live births in 1996 based on the 'complete' data combining death certificate data with national health insurance and crematorium data.[15] When we used this infant mortality rate, the life expectancies for men and women were 71.96 and 79.52 years, respectively, 0.52–0.86 years smaller than those reported in this study (72.82 for men and 80.04 for women). We also performed a sensitivity analysis for the socio-economic differences in life expectancy at birth based on these infant mortality rates. Using the estimated infant mortality rates and the greatest cause-specific mortality RR (2.81 for liver cirrhosis in men and 1.50 for ill-defined causes in women) reported in Table 2, we performed a sensitivity analysis (see Note in Supplementary Table 1; Supplementary data are available at *IJE* online) and found that the infant mortality rate might meaningfully contribute to socio-economic differentials in life expectancy (8.0% in men and 12.2% in women). However, considering the steady decline in the estimated infant mortality rate (6.2 in 1999 and 5.3 in 2002)[35] and our assumption on the mortality RR (the highest RR found in cause-specific analysis was used), this scenario would be extreme.

This study employed national health insurance premiums as a maker of income, as used in many prior Korean studies.[18–21] Given that Korea has (i) national health insurance covering the whole population, (ii) an individual linkage system using unique PIDs and (iii) a surveillance system for deaths, cancers and other diseases, this socio-economic marker provides a unique opportunity to monitor population health disparities, overcoming the lack of socio-economic information in routinely collected data.[36] In this study, we used 9-year mortality follow-up data linked with baseline income data from 1994. Considering the possibility of changes in individual income during the follow-up period, we examined the age- and cause-specific contributions using data with a shorter (4-year) mortality follow-up period (1995–98) and found similar results (see Supplementary Tables 2 and 3; Supplementary data are available at *IJE* online). A prior Korean study has also demonstrated that class mobility is limited, particularly among the lower social classes of civil servants.[37]

Results of this study presented graded differentials in life expectancy by income in both genders but a less steep gradient in women. The life expectancy differences between the highest and the lowest income quartile were 6.22 years in men and 1.74 years in women. This gender difference is consistent with prior studies reporting that socio-economic gaps in life expectancy were greater in men.[4,8,25,26,28] Several Western studies have also indicated that absolute inequalities in total mortality (i.e. risk differences among social classes) were smaller in women

Table 4 Cause-specific contributions (years, %) to the life expectancy gap between the highest income quartile and the lowest income quartile

Causes of death (ICD-10 codes)	Men			Women		
	No. of deaths	Years	%	No. of deaths	Years	%
Infectious diseases (A00–B99)	2273	0.19	3.1	1517	0.02	1.0
Tuberculosis (A15–A19)	1431	0.14	2.2	708	0.03	1.7
Other infectious	842	0.05	0.9	809	–0.01	–0.6
Cancers (C00–C97)	32 850	1.15	18.5	18 312	–0.11	–6.1
Stomach cancer (C16)	6987	0.29	4.6	3823	0.03	1.8
Colorectal cancer (C18–C21)	2124	–0.05	–0.9	1852	–0.02	–1.4
Liver cancer (C22)	6343	0.35	5.6	2047	0.01	0.6
Biliary tract/gall bladder cancer (C23–C24)	1428	0.03	0.5	1199	–0.03	–1.8
Pancreatic cancer (C25)	1447	0.02	0.3	1068	–0.03	–1.5
Lung cancer (C34)	7317	0.39	6.3	2489	0.00	–0.1
Breast cancer (C50)	–	0.00	0.0	979	–0.03	–1.8
Ovarian cancer (C56)	–	0.00	0.0	483	–0.03	–1.5
Prostatic cancer (C61)	632	–0.04	–0.6	–	0.00	0.0
Other cancers	6572	0.17	2.8	4372	–0.01	–0.4
Endocrine diseases (E00–E88)	4368	0.17	2.7	5145	0.04	2.2
Diabetes (E10–E14)	4137	0.16	2.5	4790	0.03	1.5
Other endocrine	231	0.01	0.2	355	0.01	0.6
Mental and nervous diseases (F00–G99)	2866	0.12	1.9	4807	–0.01	–0.7
Dementia (F00–F03, G30)	1429	0.03	0.5	3573	0.01	0.7
Other mental and nervous	1437	0.09	1.4	1234	–0.02	–1.4
Cardiovascular diseases (I00–I99)	24 945	0.94	15.2	29 387	0.47	26.9
Hypertensive disease (I10–I13)	1852	0.10	1.6	3078	0.12	6.8
Ischaemic heart disease (I20–I25)	4412	–0.08	–1.3	3779	–0.08	–4.8
Stroke (I60–I69)	14 935	0.71	11.3	18 071	0.34	19.5
Other cardiovascular	3746	0.22	3.5	4459	0.09	5.4
Respiratory diseases (J00–J98)	7355	0.31	4.9	5527	0.10	6.0
Chronic lower respiratory disease (J40–J47)	4242	0.23	3.8	3261	0.15	8.3
Other respiratory	3113	0.07	1.2	2266	–0.04	–2.4
Digestive diseases (K00–K92)	6515	0.97	15.6	3348	0.05	3.0
Liver cirrhosis (K74)	3537	0.62	9.9	1261	0.01	0.6
Other digestive	2978	0.36	5.7	2087	0.04	2.4
External causes (V01–Y89)	11 682	1.48	23.8	6299	0.19	10.7
Transport accidents (V01–V99)	5446	0.76	12.2	2387	0.08	4.9
Suicide (X60–X84)	2428	0.33	5.4	1402	0.05	2.9
Other external causes	3808	0.39	6.3	2510	0.05	2.9
Ill-defined causes (R00–R99)	12 018	0.79	12.8	21 739	1.05	60.3
Residual	3232	0.08	1.4	4427	–0.06	–3.2
Total	108 104	6.22	100.0	100 508	1.74	100.0

The negative contribution means that mortality rate from a certain cause is greater in the highest income quartile than the lowest income quartile.

than men.[1,2] Recent Korean studies examining absolute differentials in mortality showed male dominance in absolute socio-economic mortality differences among both children and adults.[13] The use of public servants' income as an SEP indicator might have produced greater inequality in men than women.[38–40]

Results of age-specific decomposition in this study revealed that middle- and old-age groups were mostly

responsible for the life expectancy differences in both men and women. More than 80% of total life expectancy differences were due to mortality differentials among those aged ⩾50 years, and contributions by older age were more prominent in women than men. As chronic diseases affecting middle aged or older individuals become major causes of death, mortalities in the middle aged and older consequently account for most of the life expectancy differences by period, gender and SEP. A prior Korean study reported that most of the life expectancy increases during previous decades were attributed to the contributions by middle and old age groups.[14] Most of the gender differences in life expectancy were also due to mortality among the middle and old age groups.[41–43] In addition, a recent US study showed that >60% of the increase in life expectancy differences by education came from increasing mortality gaps among those aged ⩾65 years.[8]

Our decomposition analysis showed that major leading causes of death substantially contributed to life expectancy differentials, in particular among men. In Korean men, the five leading causes of death (see the number of male deaths in Table 4) were three cancers (stomach, liver and lung), stroke and transport accidents. These five causes of death accounted for 38% of total deaths and also explained 40% of income differences in life expectancy at birth in men. However, the contributions of the three cancers as well as liver disease were minimal in women. This gender difference may be partly attributable to gendered health behaviours such as cigarette smoking (for lung cancer) and alcohol consumption (for liver cancer and disease). In women, stroke was the leading cause of death, accounting for 18% of total female deaths, and explained ~20% of life expectancy inequalities. The corresponding figures in men were 14 and 11%, respectively. Considering the great contribution by ill-defined causes (~60%) and the fact that some of the vague causes would be stroke, the actual contribution by stroke may be >20% in women. A prior Korean study showed that stroke was the most frequent cause of death in explaining absolute mortality inequalities by education, occupational class and income among women aged 45–79.[13] Prior Korean studies have shown that high blood pressure and early life conditions are closely related to stroke and the relationships were stronger in hemorrhagic stroke than ischemic stroke.[44,45] Of all stroke deaths, the proportion of haemorrhagic stroke has been relatively greater in Korea than in Western countries.[46] Hypertension prevalence was also patterned by SEP in Korea.[18,20] Thus, socio-economic inequalities in both early life exposures and current hypertension treatment may have contributed to the large contributions of stroke to socio-economic differences in life expectancy in Korea.

Results of our study differed from other studies regarding the contribution of ischemic heart disease. A prior US study indicated that ischemic heart disease was the leading contributor to explain educational differences in life expectancy at age 25.[6] Another US study also revealed the importance of ischemic heart disease in eliminating disparities in potential life-years lost.[47] However, the contribution of ischemic heart disease was negative among both men and women in our study. Prior Korean studies presented a neutral or positive association between SEP and ischaemic heart disease mortality.[12,13,18] This may be related to the delayed epidemiologic transition in ischaemic heart disease associated with the recent westernization of food consumption (e.g. animal fat intake) and other cardiovascular risk factors.[10,14] It is also possible that the prevalent view that ischemic heart disease is a disease of the affluent may have influenced laypeople's report of cause of death.[48]

In this study, while many causes of death positively contributed to the income differences in life expectancy at birth, some cancers such as colorectal cancer (in both men and women), prostate cancer (in men), and biliary tract/gall bladder, pancreatic, breast and ovarian cancers (in women) negatively contributed. Prior studies have reported the positive relationship of SEP with several cancers including breast, prostate and colorectal cancers in Korea.[12,18,21] Incidence of pancreatic and gall bladder cancers was inversely related to income but the relationship was weaker in women than men.[21] Why the biliary tract/gall bladder and pancreatic cancer mortalities were greater in the highest income quartile than the lowest in women is uncertain. Meanwhile, the positive relationships between SEP and some cancers suggest that no single factor such as cigarette smoking can explain cancer occurrence and its socio-economic distribution.[49]

Besides incomplete infantile death data discussed above, this study has other limitations. First, public servants' health insurance premium levels were used as SEP for their dependents including spouse (mostly homemakers), children and elders. However, this might have resulted in the underestimation of inequalities in life expectancy, particularly among women, considering (i) the great contribution by old age (i.e. mostly elderly dependents of the insurance holder) to the life expectancy inequalities and (ii) male dominance in the number of public servants. In addition, life expectancy inequalities are likely to be underestimated due to the exclusion of socially disadvantaged groups (such as people in institutions and in public assistance programs) with elevated mortality risks. Secondly, ill-defined causes accounted for 11.1% (12 018/108 104) and 21.6% (21 739/100 508) of total deaths (see Table 4) among men and women, respectively, and their contributions to total differentials in life expectancy were substantial, especially among women. According to a community survey using interviews for the next of kin or neighbour

and medical records prior to death, however, cardiovascular disease accounted for the largest proportion of ill-defined causes and the distribution of the actual causes identified for ill-defined causes was similar to the distribution of registered causes in death certificates.[16]

This study also has considerable strengths. First, we used individually linked mortality follow-up data, which is free of numerator–denominator bias. Our data, including over 200 000 deaths from 4 million people covering the whole population of public servants and their dependents in 1994, presented stable statistics for life expectancy at birth and decomposition results on detailed causes of death. Secondly, our study examined socio-economic differences in life expectancy at birth. As discussed earlier, most previous studies examined inequalities in life expectancy at certain adulthood ages by education, [6,8,26–28,30,31] occupational class, [7,25,29] and/or income class[30] due to the inapplicability of these SEPs to infants and children. When life expectancy at birth was investigated, studies employed geographic deprivation indices as a measure for SEP.[4,32] Thirdly, to the best of our knowledge, no prior studies have presented the age-specific contributions of socio-economic differences in life expectancy, indicating the relative importance of middle or old age groups in explaining life expectancy inequalities.

In conclusion, reductions in socio-economic differentials in mortality from stroke and external causes (transport accidents and suicide) among middle-aged and older men and women could significantly contribute to equalizing life expectancy among income groups. Policy efforts to reduce mortality differentials resulting from major cancers (stomach, liver and lung) and liver cirrhosis are also important for eliminating inequalities by SEP in Korean men.

Supplementary data

Supplementary data are available at *IJE* online.

Conflict of interest: None declared.

KEY MESSAGES

- Using 9-year mortality follow-up data (208 612 deaths) on 4 055 150 men and women aged 0–94 years, with national health insurance premiums imposed proportionally, based on monthly salary as a measure for income, differences in life expectancy at birth by income were estimated by age- and cause-specific mortality difference using Arriaga's decomposition method.
- Mortality differentials by income among those aged $\geqslant$50 years contributed most substantially (>80% in men and women) to socio-economic differences in life expectancy at birth.
- In men, cancers (stomach, liver and lung), cardiovascular diseases (stroke), digestive diseases (liver cirrhosis) and external causes (transport accidents and suicide) were important contributors to life expectancy differences.
- Cardiovascular diseases (stroke and hypertensive disease) and external causes (transport accidents and suicide) contributed to the life expectancy differences in women whereas the contributions of cancers and digestive diseases were minimal.

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