Background: Reducing the gaps in health inequality at a regional level and improving health equity have been emphasized in Korea, it is essential to accurately measure the burden of disease by region. This study aimed to estimate years of life lost (YLLs) in 17 Si and Do of Korea from 1997 to 2015 and determine the trends of regional differences in health status and disease structure.

Methods: YLL was calculated by subtracting the age at death from the life expectancy. Data on the region, gender, and age-stratified cause-specific death were obtained from the Korean Statistical Information Service of Statistics Korea.

Results: Age-standardized YLLs per 100,000 population decreased by year in all regions from 1997 to 2015 by 27.4% (27.5% for men; 27.2% for women). Despite the decline in YLLs, the regions with the highest and lowest YLLs did not change between 1997 and 2015. The diseases showing regional differences were caused by injury, often classified as avoidable mortality. We also confirmed that YLLs were higher in the regions with a higher deprivation index.

Conclusion: The present study identified that YLLs differed by regions in Korea with specific causes. The findings of this study can be used by decision-makers to prioritize the reduction of regional gaps in premature deaths.

Keywords: Mortality, Premature; Population Health; Health Status; Epidemiologic Measurements
When considering the application of the results of disease burden on policymaking, the unit of estimation needs to be divided into various population groups. One of the basic variables is the regional level; however, to the best of our knowledge, cause-specific YLLs or YLDs by regional level has not been yet investigated in Korea. Several studies have analyzed regional differences in mortality\textsuperscript{2-4} or a specific disease burden.\textsuperscript{5-8} Given that with the National Health Plan 2020, reducing the gaps in health disparities at a subnational level and improving health equity have been emphasized in Korea, it is essential to accurately measure the burden of disease by region. A comparison of YLLs in different regions across a span of several years might provide helpful information to estimate health inequalities.

This study aimed to estimate YLLs in 17 administrative regions of Korea from 1997 to 2015 and determine the trends of regional differences in health status and disease structure.

METHODS

Estimation of YLLs

YLL was calculated by subtracting the age at death from the longest possible life expectancy for a person at that age. Data on the region, gender, and age-stratified cause-specific death were obtained from the Korean Statistical Information Service (KOSIS) of Statistics Korea. Disease classification was developed by the Korean National Burden of Disease Study by modifying the recently published Global Burden of Disease cause list. A total of 242 causes were included in the analysis. When the garbage code—which cannot be the cause of death—was input, the code was distributed according to the rate of the algorithm developed in a previous research\textsuperscript{9} to ensure validity. To determine the possible life expectancy, we applied standard life expectancy at each age by year and gender based on life tables, which are also available from the KOSIS. Data sources and methodology are described in detail elsewhere.\textsuperscript{9,10}

To standardize YLLs by the regional population structure, we used the direct age standardization method with the mid-year population of Korea in 2005. The cause-specific YLLs were aggregated to obtain the regional estimation by gender and age-standardized YLLs per 100,000 population and were used to rank the leading causes of burden of premature death by regions.

Variables representing the regional characteristics

We estimated YLLs by metropolitan cities and provinces, which are the biggest administrative units in Korea. In 2015, the Korean administrative district was composed of eight metropolitan cities (‘Si’ in Korean) and nine provinces (‘Do’ in Korean). The only change that occurred between 1997 and 2015 was that Sejong-si was separated into a new administrative Si from Do (Chungbuk and Chungnam) in 2012.

As variables representing the regional characteristics, we considered individual income, regional income, and deprivation index. Data on the individual and regional income of the 17 Si and Do were obtained from the KOSIS. We used the gross regional national income (GRNI) as a regional income indicator, and income per capita excluding the government and corporate income from the GRNI was used as the individual income.

We used the regional deprivation index developed in a previous study,\textsuperscript{11} which is composed of eight socioeconomic indicators: the proportion of poor residential areas, elderly
population, low level of education, low socioeconomic level, households with no car, single-family households, and women householder. The deprivation index is one of the measures for the socioeconomic status of the region, and higher index values represent higher levels of deprivation.

Ethics statement
This study was approved by the Institutional Review Board of Korea University (KU-IRB-18-EX-51-A4). Informed consent was waived by the board.

RESULTS
Table 1 shows the trends in age-standardized YLLs per 100,000 population by gender and 17 regions from 1997 to 2015. There was a decline in YLLs by year in all regions with different patterns of changes across the country (Fig. 1). The average annual changes and rate of YLLs was –257.5 (–3.19%) for men and –144.7 (–0.03%) for women. The region with the greatest annual changes was Jeonnam for both genders (Men, –411.8; Women, –200.2), and the region with the greatest annual change rate was Chungnam for men (–3.39%) and Gangwon for women (–0.03%).

The differences in the YLLs between the regions with the highest and lowest value of YLLs declined. In men, the difference in YLLs per 100,000 population between Jeonnam and Seoul—the regions with the highest and lowest values of YLLs, respectively—decreased from 6,405.2 in 1997 to 1,863.3 in 2015, and the ratio of the two regions decreased from 2.06 to 1.52. In women, the difference in YLLs per 100,000 population between regions with the highest and lowest values of YLLs was decreased from 2384.9 in 1997 (Chungnam and Seoul) to 1096.7 in 2015 (Chungbuk and Seoul). The ratio of the two regions changed from 1.56 to 1.46.

Table 1. Age-standardized YLLs per 100,000 population by region from 1997 to 2015

| Region   | Si/Do | Men  | Women |
|----------|-------|------|-------|
|          | 1997  | 2006 | 2015  | Annual changes (%) | 1997  | 2006  | 2015  | Annual changes (%) |
| Seoul    | Si    | 6,022.1 | 4,437.9 | 3,563.8 | -144.6 (–2.40) | 4,286.5 | 2,934.1 | 2,398.4 | -111.1 (–0.03) |
| Busan    | Si    | 7,677.0 | 5,233.3 | 4,232.0 | -196.7 (–2.53) | 5,010.9 | 3,673.3 | 3,040.2 | -115.9 (–0.02) |
| Daegu    | Si    | 7,807.4 | 5,280.8 | 4,401.5 | -200.3 (–2.57) | 4,867.7 | 3,313.8 | 2,779.4 | -122.8 (–0.03) |
| Incheon  | Si    | 7,667.4 | 5,345.9 | 4,282.4 | -199.1 (–2.60) | 4,927.5 | 3,489.0 | 2,777.7 | -129.4 (–0.03) |
| Gwangju  | Si    | 7,807.2 | 4,911.2 | 4,099.3 | -218.1 (–2.79) | 4,990.4 | 3,319.2 | 2,753.1 | -131.5 (–0.02) |
| Daejeon  | Si    | 7,322.6 | 5,042.4 | 4,090.9 | -219.5 (–2.66) | 4,723.9 | 3,475.7 | 2,720.2 | -117.9 (–0.02) |
| Ulsan    | Si    | 8,344.2 | 5,171.4 | 4,097.9 | -249.2 (–3.06) | 5,512.8 | 3,666.1 | 2,801.6 | -159.5 (–0.03) |
| Jeong    | Si    | -      | -      | 4,180.4 | -22.9 (–7.22)  | -      | -      | 2,815.5 | -2.5 (–0.02)  |
| Gyeonggi | Do    | 7,593.5 | 4,942.5 | 3,805.9 | -222.8 (–2.93) | 5,291.3 | 3,372.6 | 2,599.4 | -158.3 (–0.03) |
| Gangwon  | Do    | 10,889.3 | 6,915.4 | 4,993.2 | -346.8 (–3.19) | 6,362.5 | 4,013.4 | 3,063.1 | -194.1 (–0.03) |
| Chungbuk | Do    | 10,972.1 | 6,207.8 | 4,875.2 | -358.6 (–3.27) | 5,870.5 | 3,953.3 | 3,495.0 | -139.7 (–0.02) |
| Chungnam | Do    | 11,469.5 | 6,118.0 | 4,867.7 | -388.3 (–3.39) | 6,671.4 | 4,319.6 | 3,321.3 | -197.1 (–0.03) |
| Jeonbuk  | Do    | 9,908.3 | 6,301.4 | 4,686.1 | -307.2 (–3.10) | 6,273.9 | 4,428.3 | 3,248.6 | -178.0 (–0.03) |
| Jeonnam  | Do    | 12,427.3 | 7,137.1 | 5,427.2 | -411.8 (–3.31) | 6,661.0 | 4,195.9 | 3,558.1 | -200.2 (–0.02) |
| Gyeongbuk| Do    | 10,845.6 | 6,624.5 | 4,974.2 | -345.4 (–3.18) | 5,999.5 | 3,993.8 | 3,271.8 | -160.5 (–0.03) |
| Gyeongnam| Do    | 10,384.6 | 6,284.1 | 4,685.9 | -335.2 (–3.23) | 6,026.3 | 3,636.4 | 3,081.1 | -173.2 (–0.03) |
| Jeju     | Do    | 8,725.4 | 6,131.4 | 4,644.5 | -240.1 (–2.75) | 5,778.4 | 4,033.4 | 2,907.1 | -168.9 (–0.03) |
| Difference | 6,405.2 | 2,699.2 | 1,863.3 | 2,384.9 | 1,494.2 | 1,096.7 |
| Ratio    | 2.06  | 1.61  | 1.52  | 1.56  | 1.51  | 1.46

YLLs = years of life lost.

*aAnnual average change from 1997 to 2015, bdifference between the regions with the highest and the lowest changes.
Regional Differences in YLLs in Korea

Fig. 1. Regional trends in age-standardized YLLs per 100,000 population from 1997 to 2015. (A) Men, (B) Women. YLLs = years of life lost.

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The cause of premature death with respect to regional differences changed every year. Table 2 shows the 10 leading causes of YLLs, which represented the greatest differences between regions in 1997, 2006, and 2015 for men (Table 2A) and women (Table 2B). In men, the leading causes of YLLs in 1997 were accidents of motor vehicles with three or more wheels (Jeonnam, 1,443.1; Daejeon, 256.0), followed by cirrhosis of the liver (Jeonnam, 1,231.0; Seoul, 526.7) and ischemic heart disease (Busan, 831.1; Incheon, 365.4). In 2015, self-harm (Gangwon, 803.0; Sejong, 377.9) showed the greatest regional difference, followed by overexertion and strenuous movements (Sejong, 287.5; Daejeon, 32.9) and hemorrhagic and other non-ischemic strokes (Sejong, 352.1; Daejeon, 137.3). In women, acute bronchitis was the leading cause of YLLs and showed the greatest regional difference in 1997 (Chungnam, 721.3; Busan, 15.4) and 2006 (Jeonbuk, 452.9; Gwangju, 11.4). In 2015, overexertion and strenuous movements (Chungbuk: 214.7; Gangwon: 26.5) showed the greatest regional difference.

Fig. 2 illustrates the YLLs per 100,000 population in 17 Si and Do by regional characteristics. YLLs per 100,000 was significantly correlated with the deprivation index for both genders:

Table 2. Top 10 causes with the largest difference between the regions with the highest YLL and the region with the lowest YLL

| Cause                                      | 1997      | 2006      | 2015      |
|--------------------------------------------|-----------|-----------|-----------|
| Self-harm                                  | 330.4 (2.09) | 196.0 (1.44) | 425.1 (2.12) |
| Overexertion and strenuous movements       | 241.4 (1.58) | 162.8 (1.75) | 214.8 (2.56) |
| Hemorrhagic and other non-ischemic stroke  | 1,187.2 (5.64) | 202.9 (2.92) | 211.1 (5.28) |
| Motorized vehicle with three or more wheels| 704.3 (2.34) | 327.8 (2.19) | 199.0 (2.37) |
| Cirrhosis of the liver                     | 313.5 (1.80) | 301.2 (2.12) | 154.3 (1.70) |
| Liver cancer                               | 465.7 (2.27) | 289.8 (1.99) | 148.7 (1.67) |
| Epilepsy                                   | 378.8 (36.36) | 151.8 (3.52) | 125.8 (2.40) |
| Trachea, bronchus and lung cancers         | 245.0 (1.97) | 248.0 (1.96) | 188.2 (3.11) |
| Diabetes mellitus                          | 255.1 (2.13) | 189.2 (1.80) | 150.2 (1.64) |
| Stomach cancer                             | 276.4 (2.59) | 161.6 (1.32) | 116.9 (1.92) |
| Chronic obstructive pulmonary disease      | 224.4 (20.87) | 91.0 (5.79) | 188.2 (3.11) |
| Acute bronchitis                           | 224.4 (20.87) | 91.0 (5.79) | 188.2 (3.11) |
| Ovarian cancer                             | 288.3 (2.04) | 253.6 (2.30) | 118.1 (2.05) |
| Cardiomyopathy and myocarditis             | 239.1 (1.68) | 138.9 (1.65) | 116.9 (1.92) |
| Trachea, bronchus and lung cancers         | 270.4 (2.02) | 200.5 (2.25) | 90.8 (2.02) |
| Acute bronchitis                           | 705.9 (46.94) | 441.6 (39.30) | 80.0 (2.13) |
| Diabetes mellitus                          | 134.8 (2.09) | 180.8 (2.82) | 150.2 (1.64) |
| Motorized vehicle with three or more wheels| 509.1 (12.21) | 99.5 (3.30) | 90.8 (2.02) |
| Stomach cancer                             | 235.9 (2.55) | 96.2 (3.30) | 116.9 (1.92) |
| Carcinoma                                  | 155.9 (8.71) | 141.7 (2.08) | 80.0 (2.13) |

YLL = year of life lost.

The difference in and ratio of age-standardized YLLs per 100,000 population (in descending order in 2015).
the correlation coefficient ($r$) was 0.91 in men and 0.94 in women ($P < 0.001$). The higher the deprivation index, the higher the YLL, and the most vulnerable regions were Jeonnam and Gyeongbuk. There were no statistically significant correlations with the individual and regional income.

**DISCUSSION**

We estimated age-standardized YLLs and its differences in 17 Si and Do of Korean using the KOSIS data. YLLs decreased by year in all regions from 1997 to 2015. The YLLs per 100,000 population decreased from 1997 to 2015 by 27.4% (27.5% for men; 27.2% for women), and the proportion of YLLs in DALYs also decreased from 24.8% in 2007 to 17.0% in 2015. The favorable trends in YLLs are due to not only a decline in crude death rates over the last three decades but also an increase in life expectancy and an improvement in the prognosis of diseases owing to the advances in medical care. However, Jeonnam and Seoul were the
highest and lowest regions between 1997 and 2015. Identifying regional health status allows us to understand the needs for health policies. In particular, if the goal is to reduce health inequalities, monitoring changes in health status over time with a reliable and valid method is essential. However, there is a lack of studies on the burden of disease by region in Korea. Given the geographic differences in health financing and performance and the challenges faced by the Korean healthcare system, a detailed understanding of the regional variations in the causes of premature death is crucial.

Of the 242 causes of YLLs, epilepsy showed the greatest differences in YLLs between the highest and the lowest region in 2015 (difference and ratio: 150.1, 20.2 for men; 105.7, 34.15 for women), and assault by bodily force (difference and ratio: 93.2, 15.46 for men; 132.6, 57.89 for women) was one of the leading causes of YLLs. The diseases which showed geographical differences were caused by injury and often classified as avoidable mortality (or amenable mortality), which might have been preventable if timely and effective health services were provided. A study conducted in Korea reported that metropolitan regions including Seoul and Gyeonggi have shown lower avoidable mortality compared to non-metropolitan regions, including Jeonnam and the bordering regions between Gyeongnam and Gyeongbuk over the last 20 years. Therefore, the central government should develop policies at a national level to prevent such diseases and thereby reduce the gaps in health status, and cause-specific policies need to be developed by local governments of regions with a higher burden of disease.

We also confirmed that YLLs were higher in the regions with a higher deprivation index. The association between the regional deprivation index and health gaps is consistent with the findings of previous studies, which have shown that the higher the deprivation index, the worse the health status. The studies on the association between regional variables and health outcomes were mainly based on two models with an assumption that the socioeconomic characteristics of a region may affect the health of the residents, even after controlling for individual health risk factors. The first model, known as the collective resource model, assumes that individuals in wealthy areas are more likely to have access to resources. The second model, known as the local social inequality model, assumes that the socioeconomic level of the individual and the community affect health status. In other words, the health of a poor person who lives in a wealthy region will be worse than that of a poor person who lives in a poor region. This study and most of the previous studies were based on the collective resource model with an assumption that the amount of available resources in the community is measured by an integrated deprivation index and that the better the indicator, the better the health status of the community. Despite the importance of capturing the health inequalities by the region, the estimation of the differences in the burden of disease by the region has not been conducted in Korea. The findings of the present study indicate the importance of a valid and reliable deprivation index that reflects the regional socioeconomic characteristics and the health outcomes.

There are some limitations to this study. First, we considered the Korean regional composition according to the administrative district Si and Do, due to limited data availability. Most of the health policies for a population are planned and implemented at a more specific administrative level, such as Si, Gun, and Gu. Thus, specific regional levels need to be assessed in future studies, which would be more meaningful to decision makers and policy-makers of regional health. Secondly, the study applied the life expectancy of the whole Korean at each age and gender. However, the application of the life expectancy by region could provide more accurate information. Thirdly, this study used the deprivation
index developed in a previous study. In Korea, various indicators have been developed and used to measure inequalities within the community; however, studies on the deprivation index of the community have not yet been explored, and there is no social consensus on the index. When developing an indicator, there is a need to consider whether it is based on the fundamental principles of index development and limitations of available data. Researchers have applied different variables and methods of calculation in the development of an index to measure the degree of community deprivation. In other words, the practical and arbitrary choice of variables in the development of indicators provides a range of arguments, but if the variables that can reflect the local characteristics are not included, the indicator might not measure what it intends to. Therefore, it is important to develop indicators based on the fundamental principles of index development, considering the range of available data. Based on the theoretical basis of the social exclusion, this study investigated the common areas of social exclusion, substance depletion index, and adjusted developed index. However, the index used in this study was designed to assess disparities in mortality, and therefore, developing an indicator that reflects the outcomes of the burden of disease including YLL, YLD, DALY is necessary.

In conclusion, the present study found that YLLs—the index of premature death—differed by regions in Korea with specific causes. The findings of this study can be used by decision-makers to prioritize the reduction of regional gaps in premature deaths.

REFERENCES

1. Gardner JW, Sanborn JS. Years of potential life lost (YPLL)—what does it measure? Epidemiology 1990;1(4):322-9.
2. Jeong BG, Jung KY, Kim JV, Moon OR, Lee YH, Hong VS, et al. The relationship between regional material deprivation and the standardized mortality ratio of the community residents aged 15-64 in Korea. J Prev Med Public Health 2006;39(1):46-52.
3. Choi MH, Cheong KS, Cho BM, Hwang IK, Kim CH, Kim MH, et al. Deprivation and mortality at the town level in Busan, Korea: an ecological study. J Prev Med Public Health 2011;44(6):242-8.
4. Hong E, Ahn BC. Income-related health inequalities across regions in Korea. Int J Equity Health 2011;10(1):41.
5. Cheong KS, Choi MH, Cho BM, Yoon TH, Kim CH, Kim YM, et al. Suicide rate differences by sex, age, and urbanicity, and related regional factors in Korea. J Prev Med Public Health 2012;45(2):70-7.
6. Moon S, Han JH, Bae GR, Cho E, Kim B. Hepatitis A in Korea from 2011 to 2013: current epidemiologic status and regional distribution. J Korean Med Sci 2016;31(1):67-72.
7. Song HN, Go SI, Lee WS, Kim Y, Choi H, Lee US, et al. Population-based regional cancer incidence in Korea: comparison between urban and rural Areas. Cancer Res Treat 2016;48(2):789-97.
8. Kim I, Bahk I, Kim YY, Lee J, Kang HY, Lee J, et al. Prevalence of overweight and income gaps in 245 districts of Korea: comparison using the National Health Screening Database and the Community Health Survey, 2009–2014. J Korean Med Sci 2018;33(1):e3.
9. Lee YR, Kim YA, Park SY, Oh CM, Kim YE, Oh IH. Application of a modified garbage code algorithm to estimate cause-specific mortality and years of life lost in Korea. J Korean Med Sci 2016;31 Suppl 2:S121-8.
10. Kim YE, Park H, Jo MW, Oh IH, Go DS, Jung J, et al. Trends and Patterns of Burden of Disease and injuries in Korea using disability-adjusted life years. J Korean Med Sci 2019;34 Suppl 1:e75.

11. Shin YJ. Health promotion strategies and programmes development for health inequalities alleviation. Seoul: Hanyang University; 2009.

12. Lim D, Ha M, Song I. Trends in the leading causes of death in Korea, 1983-2012. J Korean Med Sci 2014;29(12):1597-603.

13. Kim AM, Park JH, Kang S, Hwang K, Lee T, Kim Y. The effect of geographic units of analysis on measuring geographic variation in medical services utilization. J Prev Med Public Health 2016;49(4):230-9.

14. Rutstein DD, Berenberg W, Chalmers TC, Child CG 3rd, Fishman AP, Perrin EB, et al. Measuring the quality of medical care. A clinical method. N Engl J Med 1976;294(11):582-8.

15. Choi MH, Yoon TH. Trends in amenable mortality to health care across the districts in Korea from 1993 to 2013. J Crit Soc Welfare 2015;(49):404-32.

16. Yun JW, Kim YJ, Son M. Regional Deprivation Index and socioeconomic inequalities related to infant deaths in Korea. J Korean Med Sci 2016;31(4):568-78.

17. Shin H, Lee S, Chu JM. Development of composite deprivation index for Korea: the correlation with standardized mortality ratio. J Prev Med Public Health 2009;42(6):392-402.

18. Singh-Manoux A. Commentary: Modelling multiple pathways to explain social inequalities in health and mortality. Int J Epidemiol 2005;34(3):638-9.