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Trends in Healthy Life Expectancy (HALE) and Disparities by Income and Region in Korea (2008–2020): Analysis of a Nationwide Claims Database

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ABSTRACT

Background: Healthy life expectancy is a well-recognized indicator for establishing health policy goals used in Korea's Health Plan. This study aimed to explore Koreans' healthy life expectancy and its gender, income, and regional disparities from 2008 to 2020.

Methods: This study was conducted on the entire population covered by health insurance and medical aid program in Korea. The incidence-based "years lived with disability" for 260 disease groups by gender, income level, and region was calculated employing the methodology developed in the Korean National Burden of Disease Study, and it was used as the number of healthy years lost to calculate health-adjusted life expectancy (HALE).

Results: Koreans' HALE increased from 68.89 years in 2008 to 71.82 years in 2020. Although the gender disparity in HALE had been decreasing, it increased to 4.55 years in 2020. As of 2020, 5.90 years out of 8.67 years of the income disparity (Q5–Q1) in HALE were due to the disparity between Q1 and Q2, the low-income groups. Income and regional disparities in HALE exhibited an increasing trend, and these disparities were higher in men than in women.

Conclusion: A subgroup with a low health level was identified through the HALE results, and it was confirmed that improving the health level of this population can reduce health inequalities and improve health at the national level. Further exploration of the HALE calculation methodology may help in the development of effective policies such as prioritizing interventions for health risk factors.

Keywords: Health-Adjusted Life Expectancy; Health Equality; Years Lived with Disability; Income; Region

INTRODUCTION

Healthy life expectancy is the average number of years that a person can expect to live in good health, considering age-specific mortality and morbidity.¹ It refers to the periods in which disease-related disability, dysfunction, or decreased health-related quality of life

Author Contributions

Conceptualization: Jung YS, Kim YE, Ock M, Yoon SJ. Data curation: Jung YS, Kim YE. Formal analysis: Jung YS. Investigation: Ock M. Methodology: Kim YE, Ock M, Yoon SJ. Validation: Yoon SJ. Visualization: Jung YS. Writing - original draft: Jung YS. Writing - review & editing: Kim YE, Ock M, Yoon SJ.

are reflected in life expectancy.² Life expectancy alone cannot comprehensively assess the health of a population. Longevity and the consequential need to maintain health have become global health policy problems; hence, calculation of healthy life expectancy as a population health indicator is garnering interest.³ Furthermore, healthy life expectancy is an easy-to-understand indicator for policymakers and the general public and is useful for establishing quantitative policy goals, thus making it a standard summary measure of population health at international and national levels.⁴ Depending on the precise definition and estimation method of health or dysfunction levels, healthy life expectancy can include the following types: disability-free life expectancy, disease-free life expectancy, health-adjusted life expectancy (HALE) (or disability-adjusted life expectancy), and quality-adjusted life expectancy (QALE).² Among these, HALE is calculated using “years lived with disability” (YLD), which constitute disability-adjusted life-years, and age-specific mortality.¹ Since the disability level for each disease is evaluated using the disability weight (DW) on a scale of 0 to 1 when YLD is calculated, YLD-based HALE can estimate healthy life expectancy more accurately than other indicators.² The World Health Organization (WHO) has used HALE as a measure of the average level of health of the populations of member states in its annual reports.⁵ Its calculation of HALE was based on YLD, as reported in the Global Burden of Disease (GBD) study by the Institute for Health Metrics and Evaluation (IHME).⁶

Healthy life expectancy is used to establish targets in national health strategies or plans and it is monitored in the United Kingdom, Canada, South Australia, and the United States.⁴ The National Health Plan of Korea includes the general goals of extending healthy life expectancy and promoting health equity,⁷ and healthy life expectancy has been designated as a monitorable target. Promoting health equity was added to the general goals of the National Health Plan to emphasize health promotion support for health-vulnerable groups. However, considering the diversity of application targets and scope, no single indicator could explain the level of health equity. Nevertheless, as it became possible to measure the gap in healthy life expectancy by income and region using the Korean HALE, starting from the fifth National Health Plan (HP 2030), the target value for promoting health equity was also selected for the first time using healthy life expectancy.

The data source for HP 2030 to establish healthy life expectancy targets was changed from the existing WHO's HALE data to the Korean HALE data obtained from the Korean National Burden of Disease study (KNBD),^{8,9} owing to limitations in evaluating the achievement of policy outcomes using the WHO's HALE. The epidemiological indicators used to calculate YLD in the IHME's GBD study were obtained through “estimation” based on published papers, hospital discharge data, other surveys, etc., and a meta-regression method¹⁰; hence, ensuring consistency and accuracy were problematic. In addition, the input data of the GBD study may not be ideal for use by stakeholders at a national level,¹¹ and irregularities in the HALE calculation cycle and difficulty in using indicators for health equality have served as a background for data changes.⁹ Therefore, directly calculating Koreans' HALE using data-driven YLD enabled the easy establishment of national policy targets and monitoring of national health levels. In particular, income and regional indicators could be developed from the perspective of health equality.

The current HALE of Koreans is based on data available until 2018.⁹ The health level of the Korean population needs to be continuously monitored through annual HALE evaluations. Moreover, the coronavirus disease 2019 (COVID-19) pandemic and the subsequent countermeasures have significantly impacted healthcare use patterns and reduced access to prevention and treatment services.¹² Against this background, the present study was

conducted to examine the health level and health equality of the Korean population from 2008 to 2020 by using the YLD-based HALE.

METHODS

Study design and data sources

In this study, the HALE of the Korean population was computed using Sullivan's method using YLD,¹³ similar to the methodology used by the WHO and IHME.^{1,6} In this method, HALE is expressed as the difference between life expectancy calculated using age-specific population and mortality rates and YLD-derived years of healthy life lost. Therefore, the population size, number of deaths, and YLD values are required to calculate HALE. The data sources required for each step are elucidated below.

The first step of calculating life expectancy requires population and mortality rate data. In this study, YLD was calculated using the National Health Insurance Service (NHIS) claims data¹⁴; hence, the same data were used in life expectancy computation. The Korean health security system provides health care coverage for all citizens through National Health Insurance (NHI), a social insurance, and Medical Aid (MA) program, a public assistance scheme. At the end of 2022, 52.93 million people were covered by the health security system, of which NHI accounted for 97.1% and MA for 2.9%.¹⁵ Accordingly, the study population comprised Korean nationalities covered by the health security system and residing in Korea. In this study, the population was defined as “population covered by the NHI and MA program” and deaths as “those who were suspended from receiving eligibility due to death in the qualification and contribution data.” The NHIS claims database contains personal information such as demographics, types of qualifications, insurance premiums, principal diagnosis, date of medical care commencement, days of medical care, medical treatment (procedure), surgery, and detailed statements of prescriptions, excluding uninsured services.¹⁶ Therefore, in the second step of YLD calculation, the NHIS claims data were used to calculate the prevalence and incidence of diseases, which are the main input values. Excluding those who excepted insurance premium and household members' information, the data of 50,658,240 people (approximately 97.24% of the entire population, as of 2020) were analyzed. In case of injuries, epidemiological indicators by year were obtained from the Korean National Hospital Discharge In-depth Injury Survey (KNHDIS) conducted by the Korea Disease Control and Prevention Agency.¹⁷ Publication of the KNHDIS data for 2020 was delayed; hence, the 2019 data were used for calculating YLDs for injuries. In addition, the cause of death from Statistics Korea was used for YLD calculation.¹⁸

Causes of diseases and injuries

In this study, the causes of diseases and injuries were organized in a four-level classification hierarchy and were collectively exhaustive and mutually exclusive.¹⁹ At level 1, the highest level, all causes were broadly classified into three categories: communicable, maternal, neonatal, and nutrition diseases; non-communicable diseases; and injuries. These are broken down into 21 level 2 causes with further disaggregation into 260 levels 3 and 4 causes. The list of causes is shown in the **Supplementary Table 1**. To prevent overestimation and calculate valid prevalent and incident cases using the claims data, we applied criteria for each cause based on the number of hospitalizations and outpatient visits (1–5 times) for each cause. Additionally, to calculate the number of incident cases, we applied a washout period of at least one year to a maximum of five years.²⁰

Calculation of YLD

YLD was calculated by applying an incidence-based approach and multiplying the number of incident cases, average duration, and the assigned DW for 260 disease groups; it was used as the number of healthy years lost when calculating HALE.²¹ Duration of disease and average age of disease onset were estimated using the WHO's DISMOD II software, and in cases of infectious diseases, such as influenza, they were directly calculated using the NHIS claims data. DWs calculated for Koreans were used as well,^{22,23} and the DW values applied for each cause are presented in the **Supplementary Table 1**. In this study, an age-weighting rate of 4.0% and a time discount of 3.0% were applied when calculating YLDs.²⁴ Except for some variations in data sources, the specific methodology for calculating YLD was based on the KNBD study.^{20,25} The sum of YLD was independently calculated for the disease groups.⁹ Therefore, subsequently, the decrease in YLD due to comorbidities must be factored into the equation, because the maximum number of years of health lost in a year is 1; hence, the Monte-Carlo simulation was used to estimate the loss and calculate HALE.⁹

Calculation of HALE by income level and region

The income disparity in HALE was examined using the health insurance premium variable. Since insurance premium is based on wages and incomes of the insured, it was adopted as a proxy indicator to calculate the population's income. The income level was determined using equivalized annual household income based on insurance premiums. For MA beneficiaries, their insurance premiums were considered zero. Consequently, the income level was divided into quintiles for the entire population. To examine regional disparities in HALE, 250 regions were classified into 67 cities ("Si"), 114 counties ("Gun"), and 69 districts ("Gu"). To calculate HALE by income level and region, we extracted epidemiological indicators for each individual group from the NHIS claims and KNHDIS data, calculated the YLD rate, and applied it to HALE calculation. However, as income levels could not be confirmed from the KNHDIS data, which is the main data source for injury epidemiological indicators, prevalence and incidence distributions by income level were obtained from the Korea Community Health Survey. By applying this distribution to the YLD calculation result, YLDs for injuries were allocated according to income levels.

Statistical analysis

The HALE was calculated annually from 2008 to 2020 according to gender, income level, and region. When examining regional disparities in HALE, the difference between the 95th and 5th percentiles was considered to minimize outlier influence. The SAS version 9.4 (SAS Institute, Cary, NC, USA) was used for statistical analysis.

Ethics statement

This study was approved by the Institutional Review Board (IRB) of Korea University (IRB No. KUIRB-2022-0093-01). Informed consent was waived by the board.

RESULTS

Annual HALE (2008–2020) by gender and income level

In 2020, the HALE in Korea was 71.82 years, an increase of 2.93 years from 2008 (68.89 years). From 2008 to 2019, it increased by an average of 0.15 years/year, and from 2019 to 2020, by 1.25 years. In 2020, the HALE for men and women were 69.43 and 73.98 years, respectively, exhibiting a difference of 4.55 years. The 12-year trend from 2008 to 2020

revealed that the HALE for men increased by an average of 0.18 years/year, from 2008 (66.47 years) to 2019 (68.40 years), and increased by 1.03 years between 2019 and 2020, whereas the HALE for women increased by an average of 0.14 years/year, from 2008 (71.00 years) to 2019 (72.50 years), and increased by 1.48 years, from 2019 to 2020. The gender disparity in HALE exhibited a decreasing trend, from 4.53 years in 2008 to 4.10 years in 2019, and subsequently increased by 0.45 years in 2020 compared with the previous year. Regarding income-wise HALE, a higher income level indicated a higher HALE. The disparity in HALE between Q1, the lowest income level, and Q5, the highest, decreased from 7.94 years in 2008 to 6.72 years in 2012 and subsequently increased to 8.67 years in 2020. The disparity in HALE between Q1 and Q2 was 5.70 years in 2008 and 5.90 years in 2020. Regarding the trend in income-wise HALE from 2008 to 2019, it increased by 0.13 years/year in Q1, 0.13 years/year in Q2, 0.21 years/year in Q3, 0.16 years/year in Q4, and 0.15 years/year in Q5. Moreover, from 2019 to 2020, a higher income level resulted in a higher increase in HALE (Q1: 0.97 years, Q2: 1.17 years, Q3: 1.25 years, Q4: 1.46 years, and Q5: 1.47 years) (Table 1).

Income-wise HALE for men and women

Income-wise HALE for men and women exhibited an increasing trend from 2008 to 2020 in all income levels for both genders. For men, HALE in Q1 increased by 0.13 years on average, from 61.09 in 2008 to 62.50 in 2019, and HALE in Q5 increased by 0.18 years on average, from 69.73 in 2008 to 71.76 in 2019. Furthermore, from 2019 to 2020, it increased by 0.61 years in Q1, 1.02 years in Q2, 1.11 years in Q3, 1.26 years in Q4, and 1.34 years in Q5. For women, HALE in Q1 increased by 0.15 years on average, from 66.60 in 2008 to 68.23 in 2019, and HALE in Q5 increased by 0.12 years on average, from 73.29 in 2008 to 74.60 in 2019. Furthermore, from 2019 to 2020, it increased by 1.42 years in Q1, 1.32 years in Q2, 1.38 years in Q3, 1.63 years in Q4, and 1.63 years in Q5. The disparity in HALE between Q1 and Q5 was larger for men than for women in all years. In men, the income disparity in HALE decreased from 8.64 years in 2008 to 7.64 years in 2012, and subsequently, increased to 9.99 years in 2020. In particular, from 2019 to 2020, it increased by 0.73 years. For women, income disparity in HALE decreased from 6.70 years in 2008 to 5.25 years in 2012 and subsequently increased to 6.58 in 2020 (Fig. 1).

Regional distribution of HALE

Calculation of HALE according to 250 regions revealed that regions with high HALE were concentrated in Seoul, Gyeonggi, and other metropolitan areas. Notably, 89 regions had a higher HALE than the national HALE of 71.82 years and 161 regions had a lower HALE (Fig. 2). The disparity in HALE between the 95th and 5th percentile regions increased by 1.31 years

Table 1. Annual health-adjusted life expectancy by gender and income level in Korea (2008–2020)^a

Characteristics	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Overall population	68.89	69.05	69.16	69.20	68.97	69.69	70.10	70.59	70.56	70.78	70.43	70.58	71.82
Gender													
Men	66.47	66.69	66.78	66.77	66.66	67.36	67.82	68.35	68.33	68.58	68.25	68.40	69.43
Women	71.00	71.09	71.24	71.32	71.00	71.72	72.08	72.54	72.49	72.72	72.37	72.50	73.98
Difference (Women–Men)	4.53	4.40	4.46	4.54	4.34	4.36	4.26	4.20	4.16	4.14	4.12	4.10	4.55
Income level													
Q1 (Lowest)	63.82	64.06	64.53	64.72	64.76	65.25	65.58	66.00	65.78	66.03	65.24	65.25	66.22
Q2	69.52	69.53	69.43	69.42	69.25	70.03	70.37	70.80	70.89	71.10	70.81	70.95	72.12
Q3	69.61	69.61	69.81	69.94	69.56	70.25	70.73	71.30	71.40	71.59	71.48	71.90	73.15
Q4	70.39	70.66	70.59	70.63	70.33	71.08	71.47	72.00	71.98	72.21	72.10	72.12	73.58
Q5 (Highest)	71.76	72.01	72.00	71.80	71.48	72.39	72.93	73.44	73.37	73.58	73.28	73.41	74.88
Difference (Q5–Q1)	7.94	7.95	7.47	7.08	6.72	7.14	7.35	7.44	7.58	7.55	8.04	8.17	8.67

^aValues are presented as years.

from 4.88 years in 2008 to 6.19 years in 2020. By gender, the regional disparity in HALE increased by 0.96 years from 5.93 years in 2008 to 6.89 years in 2020 in men and by 0.41

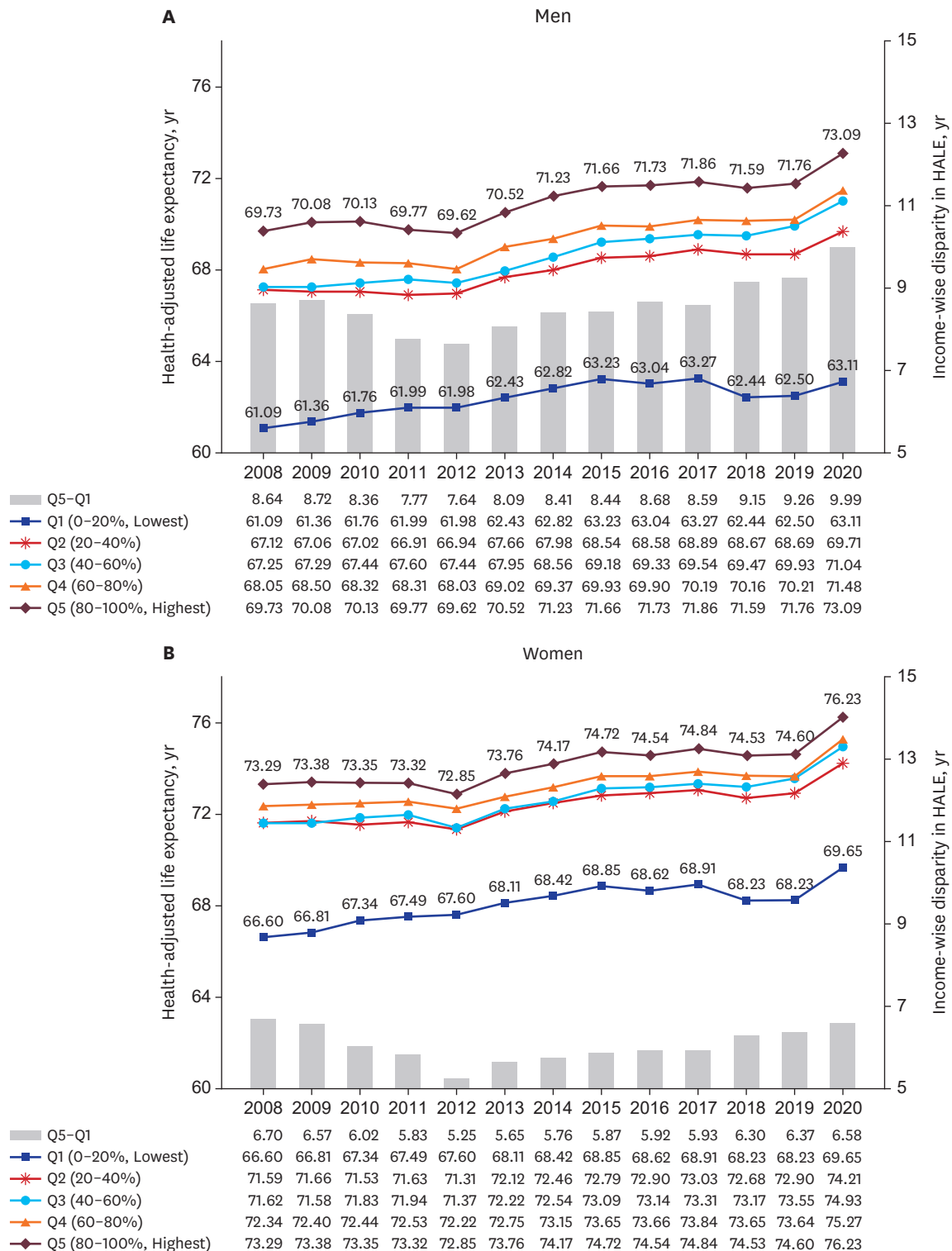


Fig. 1. Income-wise HALE for men and women in Korea (2008–2020) (unit: years). **(A)** Income-wise HALE for men **(B)** Income-wise HALE for women. HALE = health-adjusted life expectancy.

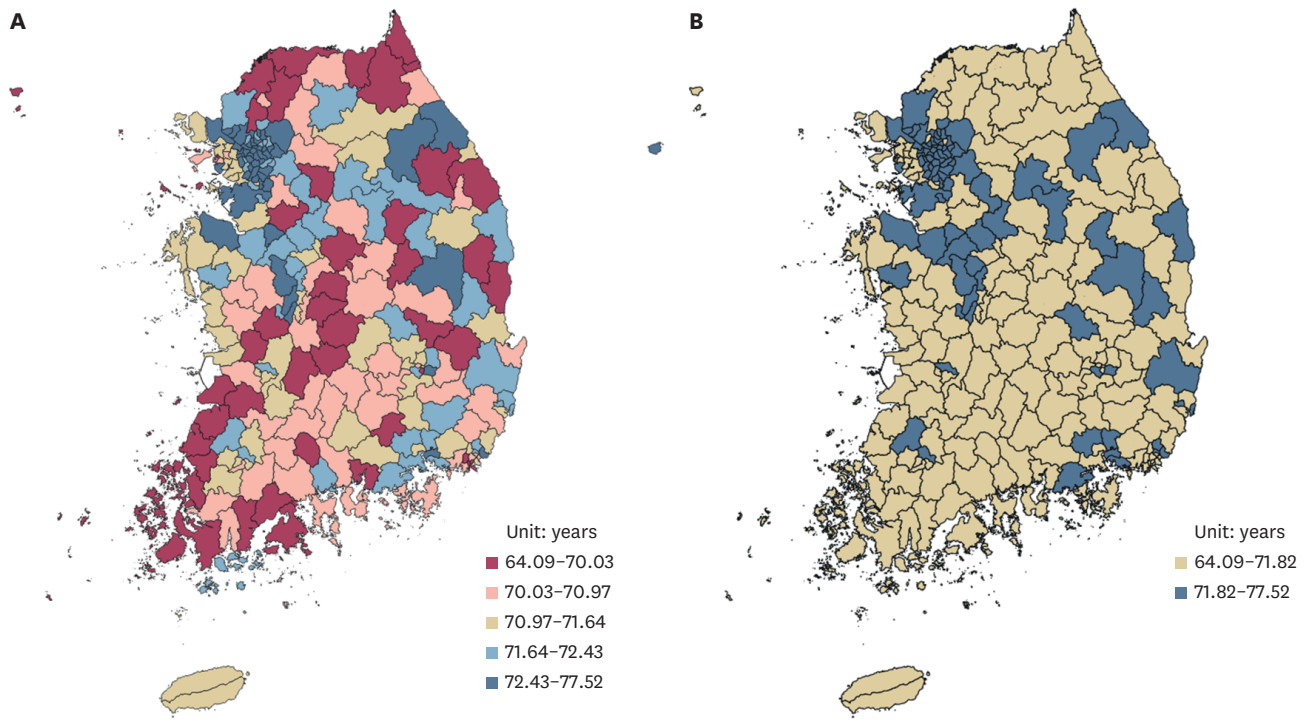


Fig. 2. Regional HALE in Korea in 2020 (unit: years). (A) Regional quintile division according to regional HALE. (B) Regional median division according to national HALE (71.82 years).

HALE = health-adjusted life expectancy.

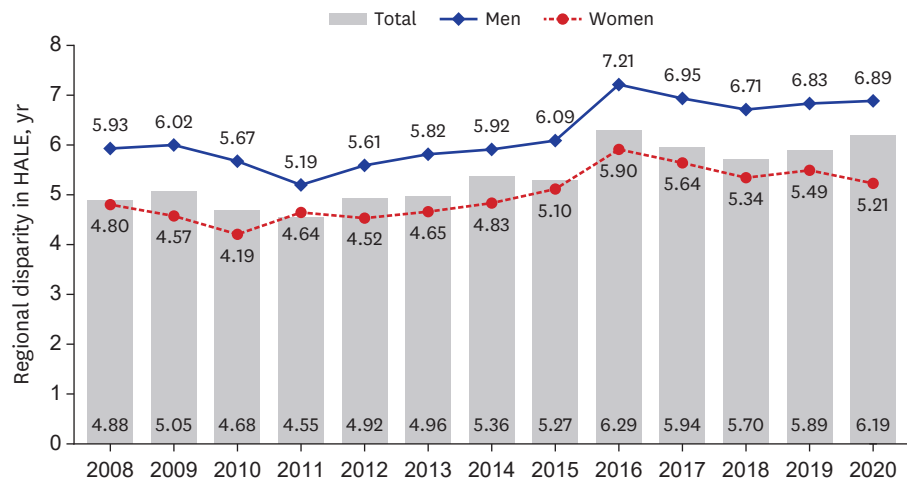


Fig. 3. Trends in regional disparities (95th and 5th percentile) in HALE in Korea (2008–2020) (unit: years). HALE = health-adjusted life expectancy.

years from 4.80 years in 2008 to 5.21 years in 2020 in women. The regional disparity in HALE slightly increased and decreased annually, and in particular, it exhibited a decreasing trend from 2016, although it displayed a tendency to increase over a 12-year period (Fig. 3).

Difference between life expectancy and HALE

We examined “years lived with poor health” through the difference between life expectancy calculated using population and mortality rates and HALE. The difference between life

Table 2. Annual life expectancy by gender and income level in Korea (2008–2020)^a

Characteristics	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Overall population	80.83	81.28	81.44	81.83	82.03	82.55	82.98	83.20	83.49	83.86	83.82	84.40	84.55
Gender													
Men	77.32	77.78	77.92	78.32	78.62	79.18	79.65	79.95	80.29	80.72	80.73	81.30	81.48
Women	84.04	84.47	84.68	85.04	85.17	85.63	86.02	86.16	86.41	86.74	86.67	87.26	87.39
Income level													
Total													
Q1 (Lowest)	76.82	77.27	77.61	78.04	78.21	78.64	79.01	79.26	79.30	79.74	79.15	79.53	79.49
Q2	81.13	81.48	81.57	81.96	82.12	82.73	83.18	83.29	83.72	84.10	84.14	84.72	84.78
Q3	81.33	81.70	81.93	82.35	82.47	83.07	83.49	83.79	84.24	84.54	84.73	85.50	85.65
Q4	81.96	82.49	82.53	82.92	83.29	83.69	84.14	84.34	84.68	85.04	85.26	85.83	86.18
Q5 (Highest)	83.48	83.98	84.04	84.35	84.57	85.14	85.62	85.87	86.11	86.47	86.56	87.14	87.43
Men													
Q1 (Lowest)	72.59	73.11	73.41	73.98	74.15	74.60	74.98	75.34	75.40	75.84	75.23	75.67	75.54
Q2	77.54	77.83	77.94	78.34	78.58	79.21	79.69	79.96	80.41	80.92	81.06	81.60	81.77
Q3	78.00	78.25	78.47	78.88	79.18	79.78	80.22	80.65	81.16	81.49	81.78	82.53	82.80
Q4	78.63	79.26	79.21	79.60	80.02	80.63	81.05	81.32	81.66	82.16	82.50	83.05	83.43
Q5 (Highest)	80.70	81.27	81.31	81.55	81.92	82.49	83.20	83.32	83.76	84.09	84.21	84.75	85.12
Women													
Q1 (Lowest)	81.18	81.58	81.96	82.23	82.40	82.79	83.19	83.31	83.39	83.84	83.36	83.72	83.85
Q2	84.40	84.83	84.92	85.31	85.43	85.98	86.39	86.37	86.75	87.02	86.95	87.56	87.51
Q3	84.31	84.82	85.05	85.49	85.47	86.05	86.43	86.62	86.99	87.26	87.35	88.16	88.18
Q4	84.87	85.31	85.45	85.82	86.15	86.35	86.81	86.95	87.28	87.55	87.63	88.22	88.51
Q5 (Highest)	85.75	86.13	86.25	86.62	86.71	87.27	87.57	87.90	88.00	88.38	88.46	89.03	89.28

^aValues are presented as years.

expectancy and HALE increased by 0.78 years from 11.95 years (2008) to 12.72 years (2020). By gender, it increased by 1.19 years, from 10.85 years (2008) to 12.05 years (2020) in men, and by 0.37 years, from 13.04 years (2008) to 13.41 years (2020) in women.

Regarding income, in all income quintiles, the difference between life expectancy and HALE decreased in 2020 compared with that in the previous year. As of 2020, 13.27 years in Q1 and 12.54 years in Q5 were “years lived with poor health.” By income and gender, as of 2020, the difference was 12.43 years in Q1 and 12.02 years in Q5 in men, displaying no significant difference in income. Conversely, in the case of women, it was 14.20 years in Q1 and 13.05 years in Q5, displaying an intergroup difference of 1.14 years (Table 2).

DISCUSSION

In this study, we examined the healthy life expectancy of the Korean population by calculating YLD-based HALE from 2008 to 2020 and the trends of the disparities in HALE by gender, income level, and region. Overall, HALE increased from 2008 to 2020; however, in 2020, when the use of medical care decreased owing to COVID-19,¹² HALE increased considerably compared with that in the previous year and trends. Therefore, “years lived with poor health,” or the disparity between life expectancy and HALE, which has been continuously increasing since 2015, decreased in 2020 compared with previous years. This trend was examined for both men and women and for all income quintiles. Since the outbreak of COVID-19, most countries have recommended and implemented non-pharmaceutical interventions (NPI), such as mask-wearing, hand washing, and social distancing, to prevent the spread of the disease. The Korean government has been implementing NPI since February 2020, and the NPI policy has also reduced the incidence of other diseases with similar transmission modes as severe acute respiratory syndrome coronavirus 2.²⁶ The effectiveness of these

measures in preventing respiratory infections has been reported in several studies,^{27,28} and NPI implementation appears to have reduced healthcare utilization and increased HALE in 2020. Moreover, in 2020, gender and income disparities in HALE increased substantially compared with those in the previous year. The HALE for women was consistently higher than that for men, confirming the existence of gender inequality in HALE. A higher HALE with higher income level was observed for both men and women. The disparity in HALE between Q1 and Q5 exhibited an increasing trend, and the income disparity in HALE was much larger for men than for women in all years. In addition, the regional disparity in HALE exhibited an increasing trend, and it was larger in men than in women. In terms of health inequality, our findings confirmed that the health levels of men are more sensitive to socioeconomic and regional influences than those of women.

Although women's year-wise HALE was higher than that of men, it increased faster in men than in women from 2008 to 2019. However, in 2020, as the decrease in medical use due to reduced medical access was more in women than in men,^{29,30} women's HALE showed a notable increase compared with that of men within a year. Therefore, the gender disparity in HALE, which exhibited a decreasing trend since 2013, increased considerably in 2020 compared with that in the previous year. In general, women's longevity paradoxically increases morbidity and disability; hence, they use more healthcare services than men.^{31,32} Although gender-specific health disparities are attributable to physical and mental illnesses caused by pregnancy, childbirth, and menopause, women bear the primary burdens of housework, child care, and other family care responsibilities.³³ Family care and work activities worsen women's stress and health, and hence a lower rate of increase in HALE than that in men was observed. However, as the HALE of women markedly increased in 2020, the "years lived with poor health" in women decreased significantly compared with those in men (men: 0.85-year decrease vs. women: 1.35-year decrease). As of 2020, the difference in life expectancy between men and women was 5.91 years, while the difference in HALE was only 4.55 years, confirming that women live relatively longer, although unhealthily, than men. Furthermore, as the rate of increase in HALE for both men and women did not catch up with the rate of increase in life expectancy, the number of "years lived with poor health" was gradually increasing.

According to the income-wise HALE calculation results, the HALE of Q1 was notably lower than that of other quintiles. As of 2020, 5.90 years out of 8.67 years of the income disparity (Q5–Q1) in HALE were due to the disparity between Q1 and Q2, the lower income group, suggesting the urgent need for intensive management of the lowest-income group. The considerably larger income disparity in HALE in men than in women confirmed that the inequality in HALE according to income level was greater in men than in women. Moreover, the rate of increase in HALE was not higher in the high-income groups (Q4 and Q5) than in the low-income groups (Q1 and Q2) in women. Conversely, the increase in the rate of HALE in the low-income groups (Q1 and Q2) was lower than that of other quintiles in men, indicating that the disparity in HALE is deepening. In addition, between 2019 and 2020, HALE increased more with higher income levels in men, and because men with the lowest income were unable to significantly reduce their medical use despite COVID-19 (Q1: 0.61 years increase vs. Q5: 1.34 years increase), health inequality between men's income levels intensified over the course of a year.

Our study results confirmed that raising the health level of the lowest-income group can reduce the income disparity and improve the HALE nationally. Thorough identification of

the target population and intensive management are required, and healthcare policies for the underprivileged need to be formulated. Several studies have revealed a high prevalence of various health risk factors, such as smoking, high-risk drinking, and physical inactivity, in low-income groups³⁴⁻³⁷ and income disparities in the prevalence of multiple health risk factors.³⁸ To effectively manage these risk factors, a follow-up study is needed to evaluate the attributable YLD due to each risk factor by calculating the population attributable fraction (PAF) that quantifies the contribution to YLD of these health risk factors in the low-income group. The results of such a study can be used to clearly capture intervention targets (e.g., risk factors or age groups) to reduce health inequality by preparing effective policies. In particular, since the income disparity is evident and progressively worse in men compared with women, intensive research is needed to establish intervention priorities and prepare preventive measures targeting men with low incomes.

The results of the analysis between life expectancy and HALE revealed income inequality in “years lived with poor health” in women. No significant difference was observed in men; however, the period of living with poor health was longer in Q1 than in other quintiles in women, possibly because the income disparity in life expectancy was not large compared with the income disparity in HALE.

Regions with a high HALE were concentrated in the metropolitan area, and the regional disparity in HALE exhibited an increasing trend. The yearly regional disparity in HALE was larger in men than in women, and the rate of increase in the disparity was more rapid in men than in women. Environmental factors affect large groups sharing common living or working spaces³⁹; therefore, health is influenced by individual characteristics and the physical and social environmental factors.³⁹ For example, while physical environment and social support, such as improvement of the neighborhood environment⁴⁰ and the local government's healthy city policy,⁴¹ improve health, factors such as decreased access to health care services lower health levels.^{42,43} This correlation between the contextual environment and health level indicates that inter-regional physical and socio-environmental disparities can lead to regional disparities in HALE. A domestic study found that QALE demonstrated a relatively close correlation with neighborhood-level socioeconomic characteristics (regional deprivation index and Gini index) and current smoking prevalence.⁴⁴ Eventually, regional health inequality occurs because health risk factors are spatially unequally distributed according to geographical contexts, such as healthcare accessibility and social and environmental characteristics.⁴⁵ In particular, since high-quality medical resources are concentrated in the Seoul metropolitan area,⁴⁶ the imbalance of resources between metropolitan and non-metropolitan areas continues, raising concerns about regional health disparities. The results of the present study are not sufficient to identify the specific mechanism by which regional characteristics, such as the distribution of medical resources, affect HALE; hence, further research is needed to clarify the relationship between regional characteristics and HALE and to provide the basis for preparing countermeasures, such as preferential distribution of medical resources to areas with low HALE or the planning and establishment of various public services.

We compared the results of this study with the results of the WHO's HALE. The WHO reported that Korea's HALE in 2019 was 73.1 years (71.3 and 74.7 years for men and women, respectively),⁴⁷ whereas, in this study, it was calculated as 70.58, 68.40, and 72.50 years for the whole population, men, and women, respectively, thus revealing a difference in the calculation results. This discrepancy may be due to methodological differences because

the YLD was calculated by applying a prevalence-based approach in the GBD study²¹ and it was obtained through “estimation” using epidemiological indicators. The WHO’s HALE is a useful indicator for cross-country comparisons; however, the HALE results are linked and updated based on the GBD study; hence, its use within individual countries is limited. Moreover, to date, the HALE that was updated after December 2020 is ambiguous. Therefore, to establish and evaluate health policy within Korea, the HALE should be periodically calculated through a self-developed methodology using actual medical use data. Although HALE is already being used in Korea’s Health Plan as an indicator to monitor the achievement of health goals, it can be used in other health policies and even other areas.

This study has some limitations. First, when computing the YLD for the HALE calculation in 2020, although DW reflecting COVID-19 was applied, COVID-19 was not included as a cause. The methodology of future studies should be improved to reflect this aspect in the disease classification system of the KNBD study while monitoring the progress of COVID-19. Moreover, since YLD, which is the basis for HALE calculation, was measured using the national medical use database, a short-term decrease in YLD and increase in HALE were expected. However, the long-term effects of COVID-19 are yet to be understood; hence, the consequences of this phenomenon require careful interpretation with long-term monitoring, which is beyond the scope of this study. Second, the list of 260 causes included in this study was developed to suit the domestic situation based on the cause classification system verified in the GBD study, but it does not cover all diseases. Therefore, although the impact on healthy life expectancy was minimal, there is a possibility of slight underestimation. In this regard, future research should attempt to improve the cause classification system along with the inclusion of COVID-19. Third, when calculating HALE for a small region, some outliers occurred due to the lack of population and mortality rate data in that region. Therefore, further research is needed to develop a methodology for calculating HALE in small areas or to prepare alternatives for classifying regional units. Last, although HALE was measured based on claims data and reflected the actual medical use, it only reflected people who used formal medical care. To overcome these methodological limitations, continued efforts are warranted to improve the accuracy of disease prevalence and incidence estimates. In addition, the results of this study are not sufficient to identify the mechanisms underlying the effect of gender, region, and income level on health inequality, thus underscoring the need for additional related research.

In conclusion, this study contributes to the understanding of the health level of Koreans by identifying the trends in healthy life expectancy and the health disparities by gender, income level, and region, from 2008 to 2020, using HALE, a summary measure of population health. The results of 2020, when COVID-19 first occurred, were different compared with those of previous years. The pandemic era necessitates the consideration of the current situation when interpreting the results. Owing to limitations in available data, we calculated HALE up to 2020; however, the increasing and decreasing trends must be continuously observed after the accumulation of more time series data. Moreover, the use of HALE must be expanded to include exploring other variables that can better reflect health inequalities or developing scenarios to increase the HALE by using risk factor-specific attributable YLD through PAF estimation and application.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

The cause hierarchy and disability weight values applied for each cause

REFERENCES

1. GBD 2017 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018;392(10159):1859–922. [PUBMED](#) | [CROSSREF](#)
2. Kim YE, Jung YS, Ock M, Yoon SJ. A review of the types and characteristics of healthy life expectancy and methodological issues. *J Prev Med Public Health* 2022;55(1):1–9. [PUBMED](#) | [CROSSREF](#)
3. Jagger C. Trends in life expectancy and healthy life expectancy. In: *Future of an Ageing Population: Evidence Review*. London, UK: Foresight, Government Office for Science; 2015.
4. Stiefel MC, Perla RJ, Zell BL. A healthy bottom line: healthy life expectancy as an outcome measure for health improvement efforts. *Milbank Q* 2010;88(1):30–53. [PUBMED](#) | [CROSSREF](#)
5. Hyder AA, Puvanachandra P, Morrow RH. Measuring the health of populations: explaining composite indicators. *J Public Health Res* 2012;1(3):222–8. [PUBMED](#) | [CROSSREF](#)
6. World Health Organization. *WHO Methods for Life Expectancy and Healthy Life Expectancy. Global Health Estimates Technical Paper WHO/HIS/HSI/GHE*. Geneva, Switzerland: World Health Organization; 2014.
7. Oh Y. The National Health Plan 2030: its purpose and directions of development. *J Prev Med Public Health* 2021;54(3):173–81. [PUBMED](#) | [CROSSREF](#)
8. Yoon SJ. *A Study on the Development of a Platform for Measuring the Health Life Expectancy of Koreans for Realization of Precision Public Health*. Seoul, Korea: Korea University; 2020.
9. Kim YE, Jung YS, Ock M, Park H, Kim KB, Go DS, et al. The gaps in health-adjusted life years (HALE) by income and region in Korea: a national representative bigdata analysis. *Int J Environ Res Public Health* 2021;18(7):3473. [PUBMED](#) | [CROSSREF](#)
10. Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380(9859):2163–96. [PUBMED](#) | [CROSSREF](#)
11. Haneef R, Schmidt J, Galloway A, Devleeschauwer B, Grant I, Rommel A, et al. Recommendations to plan a national burden of disease study. *Arch Public Health* 2021;79(1):126. [PUBMED](#) | [CROSSREF](#)
12. Cho KS. Changes in infectious diseases, health behaviors, and medical uses during COVID-19 pandemic in the Republic of Korea, 2020. *Public Health Wkly Rep* 2021;39(39):2750–64.
13. Sullivan DF. A single index of mortality and morbidity. *HSMHA Health Rep* 1971;86(4):347–54. [PUBMED](#) | [CROSSREF](#)
14. National Health Insurance Sharing Service. Customized DB. <https://nhiss.nhis.or.kr/bd/ab/bdaba000eng.do>. Updated 2023. Accessed July 23, 2023.
15. Ministry of Health and Welfare (KR). Workplans. https://www.mohw.go.kr/react/policy/index.jsp?PAR_MENU_ID=06&MENU_ID=06320103&PAGE=3&topTitle=. Updated 2023. Accessed July 22, 2023.
16. Song SO, Jung CH, Song YD, Park CY, Kwon HS, Cha BS, et al. Background and data configuration process of a nationwide population-based study using the Korean National Health Insurance system. *Diabetes Metab J* 2014;38(5):395–403. [PUBMED](#) | [CROSSREF](#)
17. Korea Disease Control and Prevention Agency. Request for raw data. <https://www.kdca.go.kr/injury/biz/injury/recsroom/rawDta/rawDtaDwldMain.do>. Updated 2023. Accessed July 23, 2023.
18. MicroData Integrated Service. Download data for public use. https://mdis.kostat.go.kr/dwnlSvc/ofrSurvSearch.do?curMenuNo=UI_POR_P9240. Updated 2023. Accessed July 23, 2023.
19. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017;390(10100):1211–59. [PUBMED](#) | [CROSSREF](#)
20. 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. [PUBMED](#) | [CROSSREF](#)

21. Kim YE, Jung YS, Ock M, Yoon SJ. DALY estimation approaches: understanding and using the incidence-based approach and the prevalence-based approach. *J Prev Med Public Health* 2022;55(1):10-8. [PUBMED](#) | [CROSSREF](#)
22. Kim YE, Jo MW, Park H, Oh IH, Yoon SJ, Pyo J, et al. Updating disability weights for measurement of healthy life expectancy and disability-adjusted life year in Korea. *J Korean Med Sci* 2020;35(27):e219. [PUBMED](#) | [CROSSREF](#)
23. Im D, Mahmudah NA, Yoon SJ, Kim YE, Lee DH, Kim YH, et al. Updating disability weights for causes of disease: adopting an add-on study method. *J Prev Med Public Health* 2023;56(4):291-302. [PUBMED](#) | [CROSSREF](#)
24. Yoon J, Oh IH, Seo H, Kim EJ, Gong YH, Ock M, et al. Disability-adjusted life years for 313 diseases and injuries: the 2012 Korean burden of disease study. *J Korean Med Sci* 2016;31 Suppl 2 (Suppl 2):S146-57. [PUBMED](#) | [CROSSREF](#)
25. Jung YS, Kim YE, Park H, Oh IH, Jo MW, Ock M, et al. Measuring the burden of disease in Korea, 2008–2018. *J Prev Med Public Health* 2021;54(5):293-300. [PUBMED](#) | [CROSSREF](#)
26. Ahn JG. Epidemiological changes in infectious diseases during the coronavirus disease 2019 pandemic in Korea: a systematic review. *Clin Exp Pediatr* 2022;65(4):167-71. [PUBMED](#) | [CROSSREF](#)
27. Huh K, Kim YE, Ji W, Kim DW, Lee EJ, Kim JH, et al. Decrease in hospital admissions for respiratory diseases during the COVID-19 pandemic: a nationwide claims study. *Thorax* 2021;76(9):939-41. [PUBMED](#) | [CROSSREF](#)
28. Mun SK, Yang BR, Chang M. Changes in respiratory diseases in South Korea during the COVID-19 pandemic: an interrupted time series study. *BMJ Glob Health* 2021;6(12):e006912. [PUBMED](#) | [CROSSREF](#)
29. Bamba C, Albani V, Franklin P. COVID-19 and the gender health paradox. *Scand J Public Health* 2021;49(1):17-26. [PUBMED](#) | [CROSSREF](#)
30. Frederiksen B, Ranji U, Salganicoff A, Long M. *Women's Experiences With Health Care During the COVID-19 Pandemic: Findings From the KFF Women's Health Survey*. San Francisco, CA, USA: Kaiser Family Foundation; 2021.
31. Nathanson CA. Illness and the feminine role: a theoretical review. *Soc Sci Med (1967)* 1975;9(2):57-62. [PUBMED](#) | [CROSSREF](#)
32. Verbrugge LM. Gender and health: an update on hypotheses and evidence. *J Health Soc Behav* 1985;26(3):156-82. [PUBMED](#) | [CROSSREF](#)
33. Mussida C, Patimo R. Women's family care responsibilities, employment and health: a tale of two countries. *J Fam Econ Issues* 2021;42(3):489-507. [PUBMED](#) | [CROSSREF](#)
34. Chang Y, Cho S, Kim I, Bahk J, Khang YH. Trends in inequality in cigarette smoking prevalence by income according to recent anti-smoking policies in Korea: use of three national surveys. *J Prev Med Public Health* 2018;51(6):310-9. [PUBMED](#) | [CROSSREF](#)
35. Choe SA, Yoo S, JeKarl J, Kim KK. Recent trend and associated factors of harmful alcohol use based on age and gender in Korea. *J Korean Med Sci* 2018;33(4):e23. [PUBMED](#) | [CROSSREF](#)
36. Kim IG, So WY. The relationship between household income and physical activity in Korea. *J Phys Ther Sci* 2014;26(12):1887-9. [PUBMED](#) | [CROSSREF](#)
37. Kim YM, Jung-Choi K. Socioeconomic inequalities in health risk factors in Korea. *J Korean Med Assoc* 2013;56(3):175-83. [CROSSREF](#)
38. Jung YH. Network analysis of complex health risk factors and chronic diseases. *Health Welf Issue Focus* 2014;254:1-8.
39. Woolf SH, Aron L; National Research Council. Physical and social environmental factors. In: *US Health in International Perspective: Shorter Lives, Poorer Health*. Washington, D.C., USA: National Academies Press; 2013.
40. Mohnen SM, Schneider S, Droomers M. Neighborhood characteristics as determinants of healthcare utilization - a theoretical model. *Health Econ Rev* 2019;9(1):7. [PUBMED](#) | [CROSSREF](#)
41. Goldstein G. A healthy city is a better city. *World Health* 1996;49(1):4-6.
42. Okoro CA, Dhingra SS, Li C. A triple play: psychological distress, physical comorbidities, and access and use of health services among U.S. adults with disabilities. *J Health Care Poor Underserved* 2014;25(2):814-36. [PUBMED](#) | [CROSSREF](#)
43. Zhang X, Dupre ME, Qiu L, Zhou W, Zhao Y, Gu D. Urban-rural differences in the association between access to healthcare and health outcomes among older adults in China. *BMC Geriatr* 2017;17(1):151. [PUBMED](#) | [CROSSREF](#)
44. Lim D, Bahk J, Ock M, Kim I, Kang HY, Kim YY, et al. Income-related inequality in quality-adjusted life expectancy in Korea at the national and district levels. *Health Qual Life Outcomes* 2020;18(1):45. [PUBMED](#) | [CROSSREF](#)
45. Fayet Y, Praud D, Fervers B, Ray-Coquard I, Blay JY, Ducimetiere F, et al. Beyond the map: evidencing the spatial dimension of health inequalities. *Int J Health Geogr* 2020;19(1):46. [PUBMED](#) | [CROSSREF](#)

46. Hong E, Ahn BC. Income-related health inequalities across regions in Korea. *Int J Equity Health* 2011;10(1):41. [PUBMED](#) | [CROSSREF](#)
47. World Health Organization. Healthy life expectancy (HALE) at birth (years). <https://www.who.int/data/gho/data/indicators/indicator-details/GHO/gho-ghe-hale-healthy-life-expectancy-at-birth>. Updated 2023. Accessed August 1, 2023.