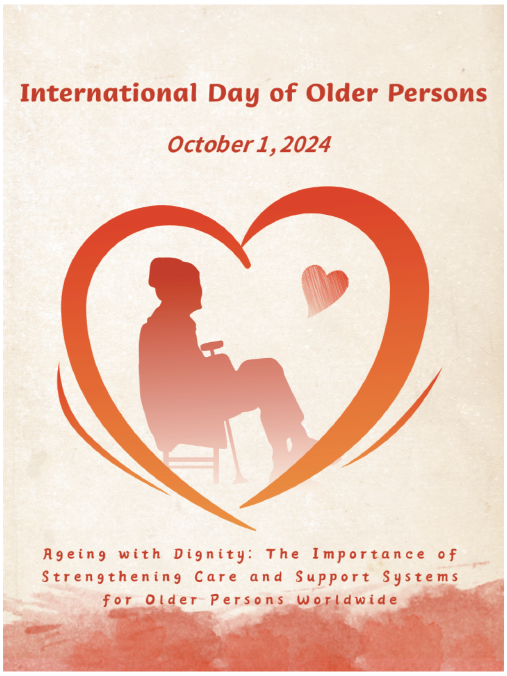
ISSN 2096-7071 (Print)
ISSN 2096-3101 (Online)
CN 10-1629/R1

CHINA CDC WEEKLY

Vol. 6 No. 39 Sept. 27, 2024

CCDC weekly

中国疾病预防控制中心周报



Preplanned Studies

ISSN 2096-7071

China CDC Weekly

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Preplanned Studies

Differential Impact of Fertility on Health-Adjusted Life Expectancy of Older Adults Across Countries of Various Levels of Socio-Demographic Index — Worldwide, 1995–2019

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Summary

What is already known about this topic?

Health-adjusted life expectancy (HALE) is a crucial indicator of global health, which is strongly correlated with the socio-demographic index (SDI) and population dynamics.

What is added by this report?

This study revealed that the correlation between total fertility rate (TFR) and HALE of older adults varies across countries with different SDI levels, offering valuable insights for the development of more targeted health promotion programs and interventions.

What are the implications for public health practice?

Different health interventions should be tailored to countries with different levels of SDI. In countries with both low fertility rates and low SDI, advanced measures are needed to address the challenge of an aging population that may live longer but face poorer health in the future.

Health-adjusted life expectancy (HALE) is a widely recognized metric that captures both mortality and non-fatal health outcomes. Over the past few decades, global HALE has increased substantially and is strongly correlated with the socio-demographic index (SDI) (*1*–*2*). However, apart from social development indicators, the impact of population dynamics is often overlooked in studies of factors influencing HALE. Fertility rate, as a crucial element, may have a complex effect on HALE among older adults. Despite HALE increasing globally, the relationship between fertility rate and HALE, particularly among older adults in countries at varying development levels, remains underexplored. Exploring these issues is vital for formulating policies to promote the health and longevity of older populations in the context of low fertility. Therefore, this study analyzed country-level panel data from 1995 to 2019 to examine the impact of fertility rate on HALE at age 65, adjusting for socioeconomic factors and considering different SDI country groupings.

A country-level panel database spanning 1995 to 2019 was constructed using indicators of HALE, total fertility rate (TFR), human resources for health (HRH), gross domestic product (GDP) per capita, and total health spending (THS) per GDP from GBD Results (*3*). Data from Our World in Data (*4*), including average years of schooling, population density, and the percentage of the population living in urban areas, were also incorporated. After addressing missing values, 191 of 204 countries and territories were included in the analytical sample, yielding 4,625 observations. The impact of TFR on HALE was estimated using generalized estimating equations (GEE) with Gaussian distributions, considering HALE as the dependent variable and controlling for time effects. In both univariate and multivariate analyses, the quadratic term of TFR was incorporated, as the fitting analysis based on the scatter plot indicated a nonlinear relationship between TFR and HALE (Figure 1). Among covariates, HRH, per capita GDP, THS per GDP, and population density were log-transformed to control for skewness.

Countries were ranked and divided equally into three groups based on their 1995 country-level SDI. SDI is a composite measure of development status, calculated as the geometric mean of three indices, each scaled from 0 to 1: total fertility rate among women younger than 25 years, mean years of education among individuals aged 15 years and older, and lag-distributed income per capita. SDI is highly correlated with health outcomes, with a score of 0 representing the lowest theoretical level of development relevant to health and a score of 1 representing the highest. Multivariate GEE models stratified by SDI groups were then estimated. Given that SDI development trends between 1995 and 2019 varied across countries, leading to SDI grouping

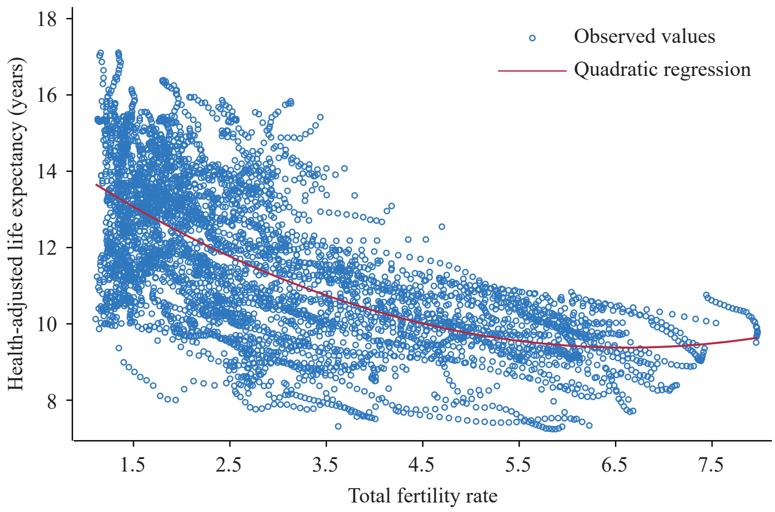

FIGURE 1. Scatter plot of TFR and HALE at age 65 across 191 countries, 1995–2019.
Note: A quadratic smoothing method was applied to fit the scatter plot.
Abbreviation: TFR=total fertility rate; HALE=health-adjusted life expectancy.

changes for some countries during this period, the following analysis was conducted. The sample was re-examined, revealing SDI grouping changes in 23 countries during the study period, representing 12.04% of the total sample. The multivariable GEE model was then re-estimated using the 2019 SDI groupings; the main results were unchanged. All computations were performed using STATA 17.0 (StataCorp LLC, College Station, TX, USA).

The estimated results from the GEE models are presented in Table 1. In the univariable model, TFR and all other socioeconomic indicators were statistically significant predictors of HALE. Specifically, HALE tended to increase linearly with decreasing TFR, as the quadratic term for TFR was not statistically significant (TFR: β=−0.48, P<0.001; TFR squared: β=−0.01, P=0.102). Considering other variables, for every 10% increase in HRH density, per capita GDP, and THS per GDP, HALE increased by 0.16 years, 0.14 years, and 0.07 years, respectively. Additionally, a 5-year increase in average years of schooling was associated with a 1.5-year increase in HALE.

In the multivariable analyses, after controlling for confounding variables, a significant quadratic relationship was observed between TFR and HALE (TFR: β=−0.71, P<0.001; TFR squared: β=0.05, P<0.001). As shown in Figure 2A, as TFR decreased, HALE accelerated after maintaining stability, consistent with the overall trend described by the observed values (Figure 1). Moreover, when compared to the univariable models, the results revealed that the effect sizes for GDP per capita and THS per GDP decreased, while the estimated coefficient for HRH and education remained stable (log HRH: β=1.21, P<0.001; log per capita GDP: β=0.19, P<0.001; log THS per GDP: β=−0.01, P=0.746; average years of schooling: β=0.32, P<0.001).

Stratified analyses by SDI groups revealed distinct correlations between TFR and HALE among older adults. In low-SDI countries, HALE increased with rising TFR up to 4. Beyond this threshold, further increases in TFR were associated with a decline in HALE (Figure 2B). Conversely, in the middle- and high-SDI countries, increasing TFR did not reduce HALE. A monotonically upward trend was even observed in high-SDI countries (Figure 2C and D).

DISCUSSION

In the context of promoting improvements in development as an essential strategy for global health, this study further explored the impact of TFR on HALE of the older population among country clusters with different SDI, which will contribute to our understanding of the correlation between TFR and healthy longevity at varying levels of socioeconomic development, as well as to the development of more targeted health promotion programs and interventions.

Although some studies have identified a negative correlation between HALE and TFR (*5–6*), these studies primarily focused on HALE at birth and did not explore differences in correlation patterns between regions with varying levels of social development. This study conducted a comprehensive analysis of the

TABLE 1. Correlation of TFR and social development indicators with HALE at age 65 across different SDI country groups, 1995–2019.

Variables	Univariable model	Multivariable model			
	All	All	Low SDI†	Middle SDI†	High SDI†
TFR	−0.48* (−0.59, −0.36)	−0.71* (−0.82, −0.60)	0.37* (0.20–0.53)	−0.64* (−0.98, −0.30)	−1.41* (−1.85, −0.98)
TFR squared	−0.01 (−0.02, 0)	0.05* (0.04, −0.06)	−0.05* (−0.07, −0.04)	0.11* (0.06, 0.16)	0.57* (0.46, 0.67)
Log HRH (workers per 10,000 population)	1.61* (1.56, 1.66)	1.21* (1.08, 1.33)	1.16* (0.98, 1.33)	0.38 (−0.12, 0.65)	1.66* (1.50, 1.82)
Log per capita GDP (2021 PPP)	1.39* (1.34, 1.44)	0.19* (0.10, 0.29)	0.64* (0.51, 0.76)	0.11 (−0.08, 0.29)	0.34* (0.21, 0.48)
Log THS per GDP	0.67* (0.57, 0.76)	−0.01 (−0.10, 0.07)	−0.04 (−0.14, 0.06)	0.25 (−0.41, 0.09)	0.88* (0.74, 1.01)
Average years of schooling (years)	0.30* (0.29, 0.31)	0.32* (0.30, 0.33)	0.25* (0.23, 0.27)	0.29* (0.26, 0.32)	0.23* (0.21, 0.26)
Percentage of urban population (%)	0.08* (0.08, 0.08)	0 (0, 0.01)	−0.01 (−0.01, 0)	0.02* (0.01, 0.03)	0.02* (0.01, 0.03)
Log population density (people per km^2)	1.97* (1.87, 2.06)	0.65* (0.54, 0.76)	0.43* (0.26, 0.60)	0.39* (0.17, 0.61)	1.35* (1.19, 1.51)
Number of countries	191	191	63	64	64
Observations	4,625	4,625	1,527	1,548	1,550

Note: 95% confident intervals are bracketed below coefficient estimates.

Abbreviation: TFR=total fertility rate; HALE=health-adjusted life expectancy; SDI=socio-demographic index; HRH=human resources for health; GDP=gross domestic product; PPP=purchasing power parity; THS=total health spending.

* $P<0.05$.

† Low SDI countries: 0.08–0.69; Middle SDI countries: 0.42–0.81; High SDI countries: 0.60–0.93.

impact of TFR on health and longevity through HALE for the first time. The key finding is that the decline in TFR promotes an overall upward trend in HALE among the older population globally, which is also evident in low-SDI countries when TFR exceeds approximately 4. However, this relationship weakens in middle-SDI countries and reverses in high-SDI countries, where HALE decreases as TFR declines. For instance, Japan, a high-SDI country, exemplifies the challenges posed by low fertility rates. Japan faces significant health and economic burdens due to bottom-up aging, driven by a combination of low fertility, high life expectancy, and demographic shifts. This is reflected in the widening gap between life expectancy and healthy life years, despite ongoing increases in overall life expectancy (*7*). In summary, the study findings suggest that while the trend of declining TFR may support healthy aging in less developed countries, different strategies may be required in more developed countries, where this decline could pose health and economic challenges.

Considering other socioeconomic indicators, the study confirmed the critical role of education in promoting population health, demonstrating similar effect sizes across SDI groups. This suggests that increasing educational attainment remains an effective measure for healthy aging (*8*). Furthermore, a strong association between higher levels of healthcare resources and HALE among older adults was consistent with previous analyses (*9*). However, stratified analyses revealed that the influence of HRH in middle-SDI countries was no longer significant. Similar results were reported in a study examining the correlation between health system performance measured by the Healthcare Access and Quality Index and HALE at age 70 (*2*). Finally, the study results indicated that regardless of SDI grouping, the contribution of economic level to HALE was significantly reduced in multivariate models. A cluster analysis of 22 Western Pacific countries showed that, although GDP per capita in developed countries was five times higher than in the least developed countries, HALE at age 70 was similar across groups, potentially due to comparable THS per GDP (*10*).

The public health implications of these findings are substantial. In low-SDI countries, efforts should focus on fertility rate management and improving education systems to enhance health literacy, which can contribute to better health outcomes in older adults. Conversely, in middle- and high-SDI countries, TFR should be maintained within a reasonable range. In addition to controlling TFR, improving healthcare quality, expanding access to care, and strengthening social support systems are crucial to ensuring that longer lifespans yield better health outcomes.

This analysis shares the limitations of the GBD 2019 publications (*11*), including difficulties identifying sources of uncertainty, delays in data

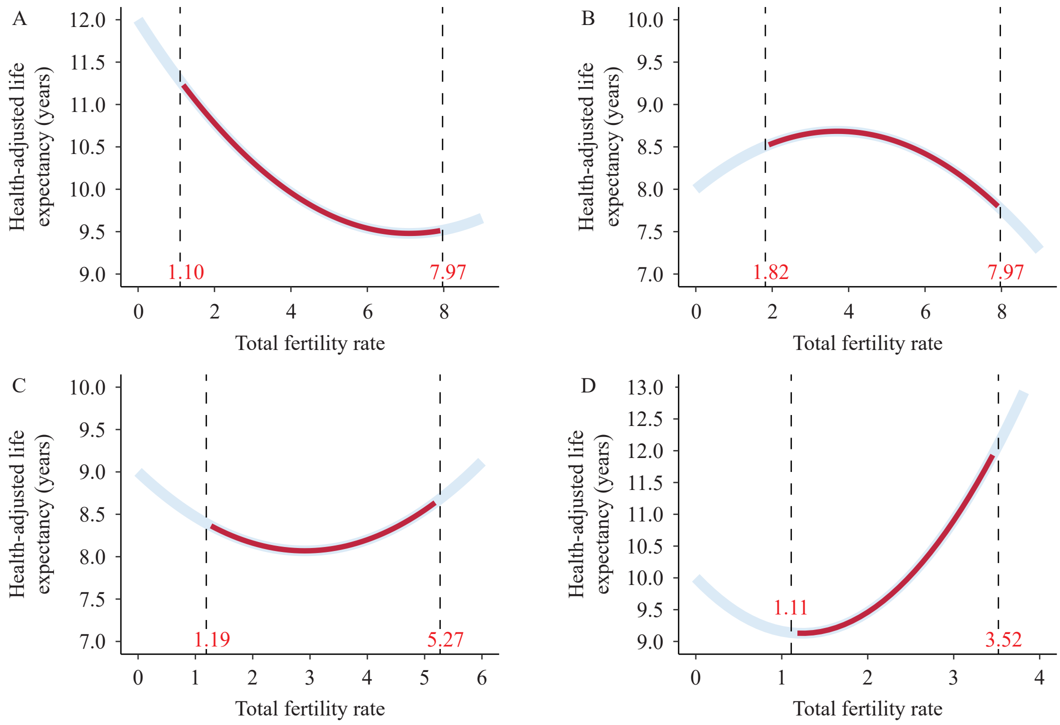

FIGURE 2. Estimated trends of HALE at age 65 based on observed TFR across different SDI country groups, 1995–2019. (A) Total countries; (B) Low SDI countries; (C) Middle SDI countries; (D) High SDI countries.

Note: The numbers in red in each figure show the range of observed TFR values in each SDI country group, and the corresponding predicted HALE values are also marked using red curves.

Abbreviation: HALE=healthy-adjusted life expectancy; TFR=total fertility rate; SDI=socio-demographic index.

availability, variability in coding practices, and other biases. Additionally, this study did not include other important socioeconomic indicators that may affect older adult health, such as the status of women (*1*), due to limited data availability. Furthermore, because TFR is a component of SDI, its inclusion as both a covariate and part of the stratifying indicator requires careful interpretation. By including TFR as a separate independent variable in our models, we isolated its direct effect on HALE, independent of its contribution to SDI. This strategy helps avoid conflating the direct effect of TFR on HALE with its indirect influence through SDI. Nevertheless, stratifying by SDI remains pivotal because it encompasses a broader socioeconomic and demographic context. While TFR affects HALE directly and indirectly through SDI, our model adjustments clarify that the observed patterns reflect more than just the fertility component of SDI. This underscores the importance of considering the broader socioeconomic landscape when interpreting the relationship between fertility rates and HALE across different developmental contexts.

In conclusion, based on the long-span country-level panel data, this study identified various patterns of correlation between TFR and HALE at different levels of SDI, and these effects are independent of other socioeconomic indicators that may influence HALE. Given the finding that HALE decreases with declining TFR in high-SDI countries, low- and middle-SDI countries with the potential for future development should invest more in health capital to prepare for the future health challenges of aging populations. Additionally, countries currently experiencing low fertility rates but still at lower levels of socioeconomic development should adopt a range of additional cost-effective socioeconomic measures to ensure a balanced improvement in both health and longevity.

Conflicts of interest: The authors have no conflicts of interest to disclose.

Funding: Supported by the National Key Research and Development Program of China (No. 2022YFC3600800), the Peking Union Medical College Education Foundation, the Chinese Academy of Medical Sciences Basic Fund-Talent Introduction and Development Project (NO. 2023-RC330-01), Population and Aging Health Science Program (WH10022023035), and the Postdoctoral Fellowship Program of CPSF under Grant Number GZC20240155.

doi: 10.46234/ccdcw2024.207

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Submitted: July 31, 2024; Accepted: September 17, 2024

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Preplanned Studies

Trends and Distribution of Life Expectancy and Health-Adjusted Life Expectancy — Asia-Pacific Region, 1990–2021

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Summary

What is already known about this topic?

The Asia-Pacific region is the most populous and diverse globally, encompassing nations with both the longest and shortest life expectancies (LE). However, less is known about the health-adjusted life expectancy (HALE) situation in this region.

What is added by this report?

This study found diversity in the levels and trends of HALE among countries in the Asia-Pacific region, with HALE in 2021 ranging from 49.87 years in Afghanistan to 74.96 years in Singapore. The largest HALE increase from 1990 to 2021 was observed in the Lao People's Democratic Republic and the smallest in Fiji. HALE continually increased as SDI increased, but different patterns of HALE across countries varied by SDI level.

What are the implications for public health practice?

The diversity among these countries provides a prerequisite and scientific basis for promoting the achievement of health goals in the Asia-Pacific region through multilateral and bilateral cooperation.

In recent decades, global total life expectancy (LE) has increased rapidly, from 65.49 years in 1990 to 71.74 in 2021, but the corresponding health-adjusted life expectancy (HALE) has grown relatively slowly, or even stagnated, from 57.05 years in 1990 to 62.20 years in 2021 (*1*). Although significant progress has been made in understanding and eliminating fatal diseases, research on the impact of mild and non-fatal diseases on lifespan has lagged. In the context of rapid population aging and health transitions, delaying the onset of functional impairment and shortening the period of dependency are critical to improving quality of life. Enhancing HALE, focusing more on quality of life, and narrowing the gap between LE and HALE are the common goal in the global health field.

The Asia-Pacific region is the most populous and diverse region in the world. It includes populous countries such as China, India, and Bangladesh, and also nations with the longest LE, such as Japan, Singapore, and the Republic of Korea. The region also includes areas like Afghanistan, which faces severe political and cultural conflicts and health threats, as well as regions like Fiji, which is threatened by metabolic and chronic diseases, and Papua New Guinea, with threats from communicable diseases, such as malaria. Analyzing the geographic distribution and trends in HALE in the Asia-Pacific region can reveal health disparities between different countries and regions, helping to understand the impact of various social, economic, cultural, and environmental factors on health. This study analyzed the distribution of HALE in different countries within the Asia-Pacific region, as well as trends in HALE changes from 1990 to 2021. Additionally, it examines the distribution of HALE and its changing trends across different SDI regions. The research results can provide references for contributing to the realization of the Putrajaya Vision of the Asia-Pacific region, including through the Aotearoa Plan of Action of "fostering quality growth that brings palpable benefits and greater health and wellbeing to all" and "preventing, detecting, responding to, and recovering from, pandemics."

Data on LE and HALE were obtained from the Global Burden of Disease Study (GBD) 2021 (https://vizhub.healthdata.org/gbd-results/). GBD 2021 provided a standardized and comprehensive assessment of the global burden of 371 diseases and injuries in 204 countries and territories, using data sources identified from vital registration, verbal autopsy, registry, survey, police, and surveillance data across all countries and territories (*2*). This study focused on LE and HALE across the Asia-Pacific region and selected 29 major countries for analysis [data for China did not include Hong Kong Special Administrative Region (SAR), Macau SAR, or Taiwan, China] (*3*). LE was calculated using life tables, and HALE was estimated using Sullivan's method (*4*), one of the most widely used methods to compute HALE. Although criticized for excluding the possibility of recovering from disability to health, Sullivan's method can produce reliable estimations of health expectancy if no sudden or significant health events occur (*5*).

The estimated annual percentage change (EAPC) was determined using linear regression, formulated as $y=\alpha+\beta x+\varepsilon$, where x=year and y=ln(rate). The EAPC was calculated using the formula $100\times(e^{\beta}-1)$. LE and HALE were considered to increase if the EAPC value and the lower limit of the 95% confidence interval (*CI*) were above 0. Conversely, LE and HALE were considered to decrease if the EAPC value and the upper limit of the 95% *CI* were below 0. Otherwise, LE and HALE were considered stable over time. A joinpoint regression model with natural log-transformed rates was used to analyze the LE and HALE of the 29 countries between 1990 and 2021. A grid search method (GSM) and Monte Carlo permutation test were used to distinguish periods. This analysis was performed using the Joinpoint Regression Program (v4.9.10, Statistical Research and Applications Branch, National Cancer Institute, Washington, USA) (*6*–*7*). The sociodemographic index (SDI) is a socioeconomic indicator scored from 0 (worst) to 1 (best), measured by the total fertility rate of the population aged under 25 (TFU25), the average educational attainment of the population aged 15 and over (EDU15+), and the lag distribution of per capita income. Loess regression was employed to examine the association between LE or HALE and SDI. Data analysis and visualization were carried out using R version 4.3.3 (R Core Team, Vienna, Austria, 2024).

Across the Asia-Pacific region, LE at birth in 2021 ranged from 58.23 years [95% uncertainty interval (*UI*): 56.25, 60.27] in Afghanistan to 85.70 years (95% *UI*: 85.50, 85.90) in Singapore. HALE at birth in 2021 ranged from 49.87 years (95% *UI*: 46.94, 52.24) in Afghanistan to 74.96 years (95% *UI*: 71.74,77.63) in Singapore. Afghanistan was the only country with LE at birth less than 60 years and HALE at birth less than 50 years in 2021. Five countries, including Singapore, Japan, the Republic of Korea, Australia, and New Zealand, had LEs above 80 years and HALEs above 70 years in 2021. Afghanistan, Papua New Guinea, Pakistan, and Fiji had the lowest LE and HALE in 2021. According to EAPC, LE and HALE at birth increased significantly from 1990 to 2021 in all the studied countries. The largest LE increase was observed in the Lao People's Democratic Republic (EAPC=0.93, 95% *CI*: 0.89, 0.97), and the smallest in the Philippines (EAPC=0.08, 95% *CI*: 0.04, 0.11). The largest HALE increase was observed in the Lao People's Democratic Republic (EAPC=0.93, 95% *CI*: 0.89, 0.97), and the smallest in Fiji (EAPC=0.09, 95% *CI*: 0.07, 0.12). In addition, the EAPCs of HALE in the countries with the lowest LE and HALE were 0.58 (95% *CI*: 0.50, 0.66) for Afghanistan, 0.22 (95% *CI*: 0.19–0.25) for Papua New Guinea, and 0.25 (95% *CI*: 0.21, 0.29) for Pakistan (Table 1).

The Joinpoint regression analysis revealed that nearly all countries experienced increases in LE and HALE at birth from 1990 to 2021, with the average annual percentage change (AAPC) above zero. Exceptions included the Philippines, Fiji, and the Democratic People's Republic of Korea (DPRK) for LE, and Fiji and the DPRK for HALE (Figure 1). The patterns of change in LE and HALE in Asia-Pacific countries between 1990 and 2021 can be broadly categorized as: 1) continuous increases, such as in China, Bhutan, and Australia; 2) declines in the first few years followed by upward trends and subsequent declines in the last few years, such as in Fiji, Mongolia, and Pakistan; and 3) upward trends for most of the period followed by downward trends in the last few years, such as in Cambodia, Bangladesh, and Viet Nam (Table 2).

Figure 2 shows the association between LE and HALE at birth and SDI across Asia-Pacific countries in 2021. In the Asia-Pacific region, LE and HALE at birth continually increased as SDI increased, although the rate of increase slowed around an SDI of 0.6. Based solely on SDI, LE and HALE at birth were much higher than expected in Maldives and lower in Fiji (Figure 2A and C). Regarding HALE, among the four Asia-Pacific countries with the lowest SDI, three (Afghanistan, Nepal, and Papua New Guinea) showed an inverted-U-curve pattern, while one country (Timor-Leste) experienced increasing HALE at birth. There were three different patterns in low-middle SDI and middle SDI quintile countries: an inverted-U-curve in four countries (India, Pakistan, Philippines, and Indonesia), a U-curve pattern in four countries (DPRK, Fiji, Mongolia, and Thailand), and an increasing growth pattern in seven countries (Bangladesh, Bhutan, Cambodia, Lao People's Democratic Republic, Myanmar, Maldives, and Viet Nam). Of the countries with high-middle SDI, three (China, Malaysia, and Sri Lanka) exhibited an increasing pattern, while one country (Iran) showed an inverted-U-curve pattern. Of the six countries with the highest SDI, all (Australia, New Zealand, Japan, Republic of Korea, Singapore, and Brunei Darussalam)

TABLE 1. LE and HALE at birth in 2021 and EAPC of LE and HALE between 1990 and 2021 in Asia-Pacific countries.

Country	LE in 2021	HALE in 2021	EAPC of LE, 1990−2021 (95% *CI*)	EAPC of HALE, 1990−2021 (95% *CI*)
Afghanistan	58.23	49.87	0.58 (0.50, 0.66)	0.58 (0.50, 0.66)
Australia	83.41	70.79	0.27 (0.26, 0.29)	0.23 (0.22, 0.24)
Bangladesh	72.26	62.45	0.73 (0.67, 0.79)	0.72 (0.66, 0.78)
Bhutan	73.74	63.93	0.70 (0.65, 0.76)	0.69 (0.64, 0.75)
Brunei Darussalam	76.60	66.90	0.22 (0.19, 0.25)	0.19 (0.16, 0.22)
Cambodia	68.19	60.02	0.70 (0.65, 0.74)	0.73 (0.68, 0.78)
China	77.58	68.56	0.48 (0.46, 0.49)	0.45 (0.44, 0.47)
DPRK	73.27	65.25	0.40 (0.21, 0.58)	0.40 (0.21, 0.58)
Fiji	66.10	58.21	0.11 (0.08, 0.13)	0.09 (0.07, 0.12)
India	68.75	59.14	0.49 (0.46, 0.52)	0.51 (0.48, 0.54)
Indonesia	69.51	61.57	0.31 (0.28, 0.34)	0.33 (0.30, 0.36)
The Islamic Republic of Iran	74.37	63.82	0.38 (0.33, 0.43)	0.35 (0.30, 0.40)
Japan	85.15	73.84	0.23 (0.22, 0.24)	0.21 (0.20, 0.21)
Lao People's Democratic Republic	67.78	60.09	0.93 (0.89, 0.97)	0.93 (0.89, 0.97)
Malaysia	72.87	64.01	0.12 (0.09, 0.15)	0.12 (0.09, 0.14)
Maldives	79.41	69.33	0.68 (0.62, 0.74)	0.66 (0.60, 0.72)
Mongolia	70.05	61.28	0.50 (0.47, 0.53)	0.48 (0.45, 0.51)
Myanmar	67.63	59.59	0.80 (0.73, 0.88)	0.80 (0.73, 0.87)
Nepal	68.38	58.98	0.62 (0.53, 0.71)	0.64 (0.55, 0.72)
New Zealand	82.44	70.14	0.29 (0.27, 0.31)	0.27 (0.25, 0.29)
Pakistan	64.96	56.22	0.26 (0.22, 0.30)	0.25 (0.21, 0.29)
Papua New Guinea	63.49	55.91	0.21 (0.18, 0.24)	0.22 (0.19, 0.25)
Philippines	68.27	60.17	0.08 (0.04, 0.11)	0.11 (0.07, 0.14)
Republic of Korea	83.23	72.05	0.51 (0.48, 0.53)	0.45 (0.43, 0.47)
Singapore	85.70	74.96	0.43 (0.42, 0.44)	0.39 (0.38, 0.40)
Sri Lanka	76.60	66.27	0.35 (0.30, 0.41)	0.32 (0.27, 0.37)
Thailand	76.28	66.54	0.38 (0.33, 0.42)	0.36 (0.32, 0.40)
Timor-Leste	68.58	60.14	0.58 (0.48, 0.68)	0.62 (0.52, 0.72)
Viet Nam	74.00	65.61	0.20 (0.19, 0.22)	0.22 (0.20, 0.24)

Abbreviation: LE=life expectancy; HALE=health-adjusted life expectancy; EAPC=estimated annual percentage change; DPRK=Democratic People's Republic of Korea.

experienced a growth pattern (Figure 2D). Similarly, LE also exhibited a comparable association with SDI across these countries in the Asia-Pacific region.

DISCUSSION

We found that LE and HALE ranges varied significantly across countries in the Asia-Pacific region, with regional HALE in 2021 ranging from 49.87 to 74.96 years. HALEs in Pakistan and Afghanistan were below 60 years, with conflicts leading to substantial declines in LE and HALE or causing severe economic setbacks. Studies suggest that these countries may require several years or even decades to return to pre-conflict development levels (*8*). Papua New Guinea, Nepal, and other regional areas currently have relatively low HALEs associated with threats such as local infectious and non-communicable diseases. Moreover, HALE trends in the Asia-Pacific region show regional disparities. Regions experiencing rapid HALE increases include Myanmar and Laos, where progress in combating diseases like diarrhea, tuberculosis, lower respiratory infections, HIV/AIDS, and measles is likely the most significant factor contributing to rising HALE in these areas (*2*). Some countries, like Fiji and Mongolia, experienced

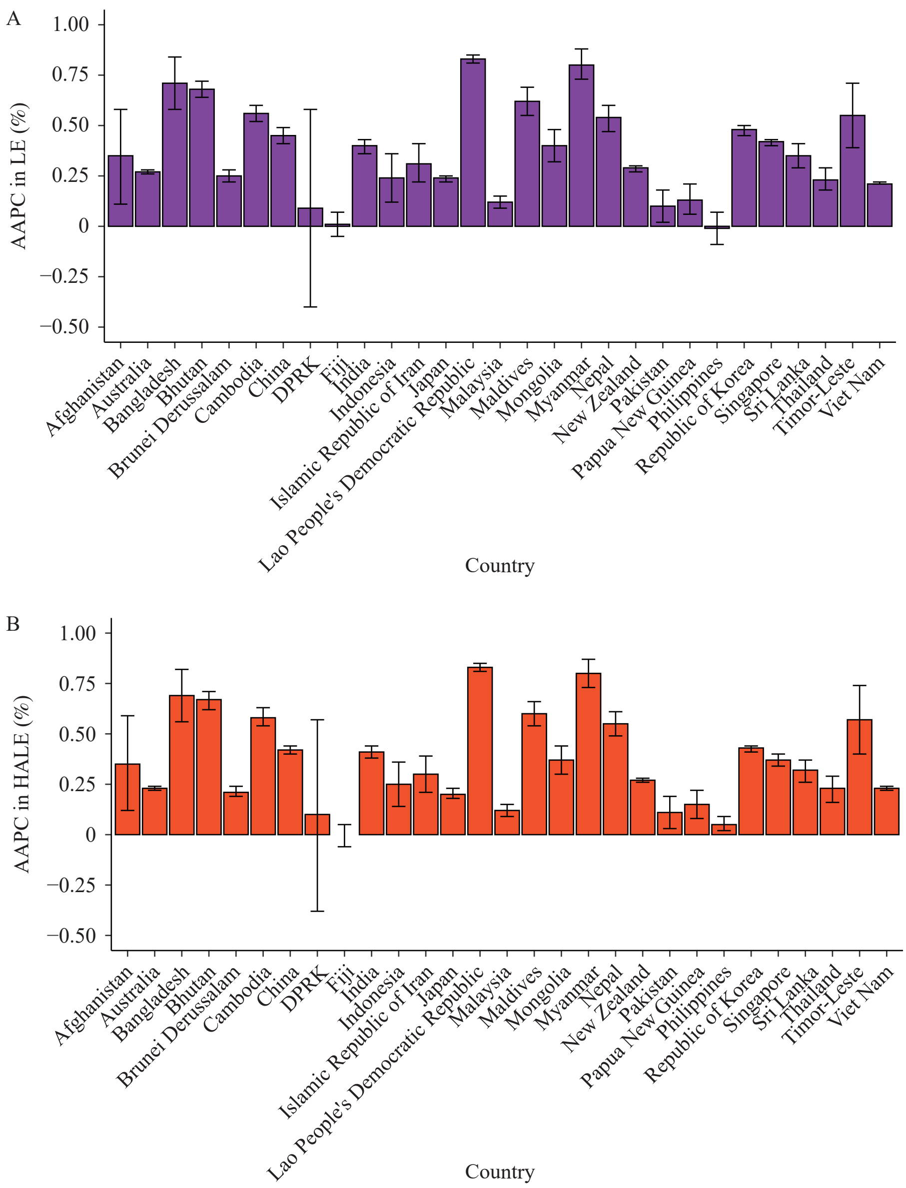

FIGURE 1. Joinpoint analysis of LE (A) and HALE (B) in individuals at birth across Asia-Pacific countries, 1990 to 2021.
Abbreviation: AAPC=average annual percent change; LE=life expectancy; HALE=health-adjusted life expectancy; DPRK=Democratic People's Republic of Korea.

declining LE and HALE in the early 1990s, followed by gradual increases by the mid-to-late 1990s, possibly related to local economic development, public health standards, and infectious disease control. This suggests that, with socioeconomic development, countries with currently lower LE, HALE, or SDI can also gradually increase their LE and HALE. Furthermore, this study found that most countries experienced LE and HALE declines starting in 2019 or 2020, likely due to the impact of the COVID-19 pandemic. Against this backdrop, China managed to maintain increasing LE and HALE, indicating that the Chinese government's experience in dealing with pandemics is worth learning from (*9*).

We observed that HALE rises with increasing socio-demographic index (SDI) levels. However, the rate of HALE increase differs between regions with higher and lower SDI levels. In regions with higher SDI levels, HALE tends to increase more rapidly with rising SDI, while in lower SDI regions, although HALE is increasing, the rate of increase is slowing. This discrepancy may be attributed to factors such as better healthcare coverage, improved sanitation and hygiene practices, higher levels of education, and increased awareness of preventive health measures in regions with higher SDI levels (*10*). Conversely, regions with lower

TABLE 2. Joinpoint analysis of LE and HALE at birth across Asia-Pacific countries, 1990 to 2021.

Categories	location	Years		Total study period		Period 1		Period 2		Period 3		Period 4		Period 5		Period 6	
		1990	2021	AAPC (%)	95% *CI*	Years	APC (%)	Years	APC (%)	Years	APC (%)	Years	APC (%)	Years	APC (%)	Years	APC (%)
LE at birth	Afghanistan	52.47	58.23	0.35*	(0.11, 0.58)	1990−1995	0.64*	1995−1998	−0.76	1998−2012	1.01*	2012−2019	0.13	2019−2021	−2.53*	−	−
	Australia	76.84	83.41	0.27*	(0.26, 0.28)	1990−2006	0.36*	2006−2021	0.18*	−	−	−	−	−	−	−	−
	Bangladesh	58.91	72.26	0.71*	(0.58, 0.84)	1990−1994	1.67*	1994−2017	0.74*	2017−2021	−0.43	−	−	−	−	−	−
	Bhutan	60.16	73.74	0.68*	(0.64, 0.72)	1990−2004	0.98*	2004−2012	0.65*	2012−2021	0.25*	−	−	−	−	−	−
	Brunei Darussalam	71.20	76.60	0.25*	(0.22, 0.28)	1990−1996	0.48*	1996−2009	0.30*	2009−2016	−0.10*	2016−2021	0.34*	−	−	−	−
	Cambodia	57.45	68.19	0.56*	(0.52, 0.60)	1990−1999	0.40*	1999−2010	1.03*	2010−2019	0.43*	2019−2021	−0.70*	−	−	−	−
	China	67.67	77.58	0.45*	(0.41, 0.49)	1990−1999	0.49*	1999−2004	0.38*	2004−2007	0.85*	2007−2010	0.37*	2010−2015	0.53*	2015−2021	0.22*
	DPRK	69.88	73.27	0.09	(−0.40, 0.58)	1990−2000	−1.64	2000−2004	3.86*	2004−2021	0.24	−	−	−	−	−	−
	Fiji	66.26	66.10	0.01	(−0.05, 0.07)	1990−1997	−0.11*	1997−2019	0.17*	2019−2021	−1.32*	−	−	−	−	−	−
	India	60.80	68.75	0.40*	(0.36, 0.43)	1990−1998	0.46*	1998−2002	0.81*	2002−2019	0.46*	2019−2021	−1.25*	−	−	−	−
	Indonesia	64.01	69.51	0.24*	(0.12, 0.36)	1990−2019	0.34*	2019−2021	−1.15	−	−	−	−	−	−	−	−
	The Islamic Republic of Iran	67.51	74.37	0.31*	(0.22, 0.41)	1990−1992	1.91*	1992−2019	0.40*	2019−2021	−2.39*	−	−	−	−	−	−
	Japan	79.35	85.15	0.24*	(0.22, 0.25)	1990−2002	0.30*	2002−2021	0.20*	−	−	−	−	−	−	−	−
	Lao People's Democratic Republic	52.52	67.78	0.83*	(0.81, 0.85)	1990−1999	0.98*	1999−2012	1.08*	2012−2019	0.58*	2019−2021	−0.54*	−	−	−	−
	Malaysia	72.12	72.87	0.12*	(0.09, 0.15)	1990−2021	0.12*	−	−	−	−	−	−	−	−	−	−
	Maldives	65.67	79.41	0.62*	(0.55, 0.69)	1990−2007	0.94*	2007−2019	0.38*	2019−2021	−0.64	−	−	−	−	−	−
	Mongolia	62.51	70.05	0.40*	(0.32, 0.48)	1990−1995	−0.21	1995−2019	0.57*	2019−2021	−0.20	−	−	−	−	−	−
	Myanmar	55.06	67.63	0.80*	(0.73, 0.88)	1990−2021	0.80*	−	−	−	−	−	−	−	−	−	−
	Nepal	57.98	68.38	0.54*	(0.47, 0.60)	1990−2001	1.19*	2001−2006	0.67*	2006−2019	0.33*	2019−2021	−2.01*	−	−	−	−
	New Zealand	75.50	82.44	0.29*	(0.27, 0.30)	1990−2007	0.37*	2007−2021	0.19*	−	−	−	−	−	−	−	−
	Pakistan	62.50	64.96	0.10*	(0.02, 0.18)	1990−1997	−0.18*	1997−2019	0.38*	2019−2021	−1.90*	−	−	−	−	−	−
	Papua New Guinea	61.42	63.49	0.13*	(0.06, 0.21)	1990−1996	0.46*	1996−2006	0.10*	2006−2019	0.33*	2019−2021	−1.92*	−	−	−	−
	Philippines	68.45	68.27	−0.01	(−0.09, 0.07)	1990−2019	0.11*	2019−2021	−1.75*	−	−	−	−	−	−	−	−
	Republic of Korea	71.97	83.23	0.48*	(0.45, 0.50)	1990−1992	0.74*	1992−2003	0.56*	2003−2007	0.67*	2007−2015	0.44*	2015−2019	0.29*	2019−2021	−0.07
	Singapore	75.59	85.70	0.42*	(0.40, 0.43)	1990−2015	0.44*	2015−2021	0.30*	−	−	−	−	−	−	−	−
	Sri Lanka	69.62	76.60	0.35*	(0.29, 0.41)	1990−2021	0.35*	−	−	−	−	−	−	−	−	−	−
	Thailand	71.02	76.28	0.23*	(0.18, 0.29)	1990−1996	−0.12*	1996−2004	0.34*	2004−2012	0.74*	2012−2019	0.15*	2019−2021	−0.85*	−	−
	Timor−Leste	59.30	68.58	0.55*	(0.39, 0.71)	1990−2008	0.89*	2008−2021	0.08	−	−	−	−	−	−	−	−
	Viet Nam	69.36	74.00	0.21*	(0.21, 0.22)	1990−2000	0.40*	2000−2010	0.09*	2010−2019	0.23*	2019−2021	−0.18*	−	−	−	−

Continued

Categories	location	Years 1990	Years 2021	Total study period AAPC (%)	Total study period 95% *CI*	Period 1 Years	Period 1 APC (%)	Period 2 Years	Period 2 APC (%)	Period 3 Years	Period 3 APC (%)	Period 4 Years	Period 4 APC (%)	Period 5 Years	Period 5 APC (%)	Period 6 Years	Period 6 APC (%)
HALE at birth	Afghanistan	44.86	49.87	0.35*	(0.12, 0.59)	1990−1995	0.65*	1995−1998	−0.76	1998−2012	1.01*	2012−2019	0.12	2019−2021	−2.41*	−	−
	Australia	65.97	70.79	0.23*	(0.22, 0.24)	1990−2005	0.29*	2005−2021	0.17*	−	−	−	−	−	−	−	−
	Bangladesh	51.02	62.45	0.69*	(0.56, 0.82)	1990−1995	1.53*	1995−2018	0.71*	2018−2021	−0.87	−	−	−	−	−	−
	Bhutan	52.36	63.93	0.67*	(0.62, 0.71)	1990−2004	0.95*	2004−2012	0.66*	2012−2021	0.25*	−	−	−	−	−	−
	Brunei Darussalam	62.88	66.90	0.21*	(0.19, 0.24)	1990−1996	0.44*	1996−2009	0.28*	2009−2016	−0.09*	2016−2021	0.21*	−	−	−	−
	Cambodia	50.20	60.02	0.58*	(0.54, 0.63)	1990−1999	0.42*	1999−2008	1.09*	2008−2012	0.77*	2012−2019	0.41*	2019−2021	−0.68*	−	−
	China	60.32	68.56	0.42*	(0.40, 0.44)	1990−1998	0.49*	1998−2004	0.41*	2004−2007	0.77*	2007−2015	0.44*	2015−2021	0.15*	−	−
	DPRK	62.28	65.25	0.10	(−0.38, 0.57)	1990−2000	−1.59	2000−2004	3.86*	2004−2021	0.23	−	−	−	−	−	−
	Fiji	58.51	58.21	0.00	(−0.06, 0.05)	1990−1997	−0.11*	1997−2019	0.16*	2019−2021	−1.36*	−	−	−	−	−	−
	India	52.08	59.14	0.41*	(0.38, 0.44)	1990−1998	0.48*	1998−2002	0.79*	2002−2019	0.49*	2019−2021	−1.23*	−	−	−	−
	Indonesia	56.46	61.57	0.25*	(0.14, 0.36)	1990−2019	0.36*	2019−2021	−1.30	−	−	−	−	−	−	−	−
	The Islamic Republic of Iran	58.15	63.82	0.30*	(0.21, 0.39)	1990−1992	1.96*	1992−2019	0.37*	2019−2021	−2.19*	−	−	−	−	−	−
	Japan	69.45	73.84	0.20*	(0.18, 0.23)	1990−2004	0.25*	2004−2011	0.13*	2011−2018	0.26*	2018−2021	0.03	−	−	−	−
	Lao People's Democratic Republic	46.55	60.09	0.83*	(0.81, 0.85)	1990−1999	0.99*	1999−2012	1.07*	2012−2019	0.57*	2019−2021	−0.56*	−	−	−	−
	Malaysia	63.22	64.01	0.12*	(0.09, 0.15)	1990−2021	0.12*	−	−	−	−	−	−	−	−	−	−
	Maldives	57.65	69.33	0.60*	(0.54, 0.66)	1990−2007	0.93*	2007−2019	0.36*	2019−2021	−0.71	−	−	−	−	−	−
	Mongolia	55.03	61.28	0.37*	(0.30, 0.44)	1990−1995	−0.18	1995−2019	0.55*	2019−2021	−0.34	−	−	−	−	−	−
	Myanmar	48.63	59.59	0.80*	(0.73, 0.87)	1990−2021	0.80*	−	−	−	−	−	−	−	−	−	−
	Nepal	49.77	58.98	0.55*	(0.49, 0.61)	1990−2000	1.19*	2000−2006	0.74*	2006−2019	0.37*	2019−2021	−2.02*	−	−	−	−
	New Zealand	64.50	70.14	0.27*	(0.26, 0.28)	1990−2006	0.38*	2006−2021	0.15*	−	−	−	−	−	−	−	−
	Pakistan	54.05	56.22	0.11*	(0.03, 0.19)	1990−1997	−0.14	1997−2019	0.35*	2019−2021	−1.72*	−	−	−	−	−	−
	Papua New Guinea	53.82	55.91	0.15*	(0.08, 0.22)	1990−1996	0.46*	1996−2006	0.13*	2006−2019	0.32*	2019−2021	−1.74*	−	−	−	−
	Philippines	59.67	60.17	0.05*	(0.02, 0.09)	1990−1995	0.46*	1995−2019	0.11*	2019−2021	−1.61*	−	−	−	−	−	−
	Republic of Korea	63.23	72.05	0.43*	(0.41, 0.44)	1990−1992	0.71*	1992−2008	0.53*	2008−2019	0.34*	2019−2021	−0.23*	−	−	−	−
	Singapore	66.86	74.96	0.37*	(0.34, 0.40)	1990−2011	0.42*	2011−2019	0.34*	2019−2021	0.02	−	−	−	−	−	−
	Sri Lanka	61.00	66.27	0.32*	(0.26, 0.37)	1990−2021	0.32*	−	−	−	−	−	−	−	−	−	−
	Thailand	62.03	66.54	0.23*	(0.16, 0.29)	1990−1996	−0.09	1996−2004	0.34*	2004−2009	0.80*	2009−2014	0.41*	2014−2019	0.07	2019−2021	−0.72*
	Timor−Leste	51.65	60.14	0.57*	(0.40, 0.74)	1990−2010	0.86*	2010−2021	0.04	−	−	−	−	−	−	−	−
	Viet Nam	61.28	65.61	0.23*	(0.22, 0.24)	1990−2000	0.44*	2000−2011	0.12*	2011−2019	0.22*	2019−2021	−0.21*	−	−	−	−

Note: "−" means no joinpoints identified.
Abbreviations: AAPC=average annual percent change; APC=annual percent change; LE=life expectancy; HALE=health-adjusted life expectancy; DPRK=Democratic People's Republic of Korea.
* Statistically significant at a two-tailed $P<0.05$.

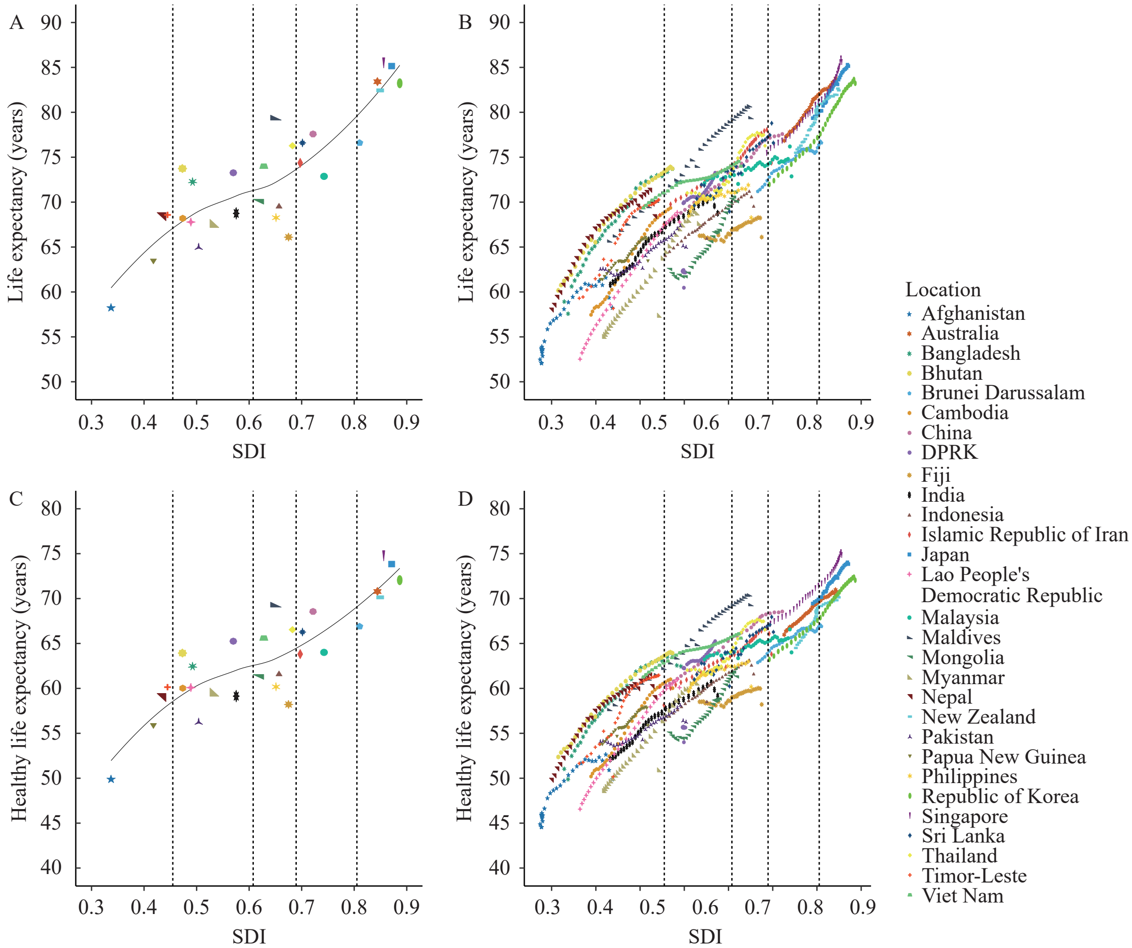

FIGURE 2. Life expectancy (LE) and health-adjusted life expectancy (HALE) at birth across Asia-Pacific countries by SDI, 1990–2021. (A) LE, 2021; (B) LE, 1990–2021; (C) HALE, 2021; (D) HALE, 1990–2021.
Abbreviation: LE=life expectancy; HALE=health-adjusted life expectancy; SDI=sociodemographic index; DPRK=Democratic People's Republic of Korea.

SDI levels may face challenges such as limited healthcare coverage, a higher prevalence of infectious diseases, and malnutrition, which, despite efforts to enhance healthcare services and public health interventions, result in a slower rate of HALE increase.

This study has some limitations. First, the scarcity of primary data might affect the representativeness of the data. Second, the uncertainty estimates were similarly wide across countries, suggesting a heavy reliance on modeling.

In summary, this study analyzed the geographic distribution of LE and HALE, along with their changing trends over time and in relation to SDI levels in the Asia-Pacific region. This study found diversity in the levels and trends of LE and HALE among countries in the Asia-Pacific region, highlighting significant HALE disparities across areas. In 2021, the maximum HALE difference in the region reached 25.09 years, suggesting that achieving health equity goals within the Asia-Pacific framework continues to pose substantial challenges. Increased global health cooperation and assistance are urgently needed to address this considerable gap. Utilizing multilateral global health cooperation frameworks in the Asia-Pacific region, such as APEC, ASEAN, and the Lancang-Mekong Cooperation, is essential to facilitate the implementation of health development roadmaps and action plans. These represent critical governance strategies for reducing health inequalities and enhancing health outcomes in the Asia-Pacific region.

Conflicts of interest: No conflicts of interest.

Funding: Supported by the National Key Research and Development Program of China (No. 2022YFC3600800) and Population and Aging Health Science Program (WH10022023035).

doi: 10.46234/ccdcw2024.208

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Submitted: July 26, 2024; Accepted: September 12, 2024

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Preplanned Studies

A Global Decomposition Analysis of the Effect of Population Aging on Disability-Adjusted Life Years Associated with Cardiovascular Disease — 204 Countries and Territories, 1990–2021

Na Sun[1]; Xiaocan Jia[1]; Xuezhong Shi[1]; Feng Jiang[2]; Chaojun Yang[1]; Yongli Yang[1,#]

Summary

What is already known about this topic?

The influence of population aging on the disability-adjusted life years (DALYs) associated with cardiovascular disease (CVD) is acknowledged, yet the magnitude of this impact remains unclear.

What is added by this report?

This research quantified the influence of population aging on CVD DALYs from 1990 to 2021 through decomposition analysis. The findings revealed that the proportion of DALYs attributable to aging varied widely, ranging from −77.0% to 148.9% across 204 countries. There was significant variation in the attributed DALY proportions among different countries or territories and types of CVD. Ischemic heart disease and stroke emerged as the leading contributors to DALYs influenced by aging.

What are the implications for public health practice?

Globally, the association of population aging with increased CVD DALYs underscores the critical need for enhancing health systems to cater to the needs of older adults. Mitigating the burden of CVD DALYs linked to demographic aging can be achieved by investing in resources and adjusting fertility policies.

Cardiovascular disease (CVD) is a major cause of premature mortality and a significant factor in escalating healthcare costs. With the lower birth rates and increased life expectancy, population aging and it's associated CVD burden have emerged as a critical social challenge. This study sought to systematically assess the effect of population aging on the disability-adjusted life years (DALYs) associated with CVD, utilizing data from the Global Burden of Disease Study (GBD) 2021. The findings reveal that global DALYs for CVD reached 428.3 million in 2021, marking a 44.0% increase since 1990, largely driven by aging populations. Notably, the impact of population aging on DALYs varied significantly across different countries, territories, and types of CVD. Public health professionals are urged to focus on tailored preventive and treatment strategies to address the impending challenges of population aging and its influence on CVD burden.

Data were obtained from the GBD 2021 online database (http://ghdx.healthdata.org/gbd-results-tool), encompassing DALYs, age-standardized DALY rate (ASDR), and population sizes spanning 1990 to 2021. Age-standardized rates facilitated the comparison of DALY rates across nations or regions with diverse age structures and demographic profiles. The analysis included a total of 204 countries and territories, categorized into five socio-demographic index (SDI) regions (high, high-middle, middle, low-middle, and low) (*1*).

The average annual percent change (AAPC) was determined using Joinpoint regression analysis to evaluate trends in ASDR (*2*). A decomposition method was utilized to assess the variations in DALYs due to population growth, aging, and changes in age-specific DALY rates (*3*). Both the absolute and relative contributions of these three factors to the alterations in DALYs were computed, using 1990 as a baseline. In countries where DALYs increases were linked to population aging, ratios of DALYs ascribed to changes in DALY rates (R_1) and to population growth (R_2) were separately calculated in comparison to those due to population aging. Comprehensive methodologies for data correction are provided in the Supplementary Material (available at https://weekly.chinacdc.cn/). All processes of data handling, analytical procedures, and the production of graphical content were conducted using R (version 4.1.3, Development Core Team, Vienna, Austria).

In 2021, the global burden of CVD amounted to approximately 428.3 million DALYs, with a 95% uncertainty interval (*UI*) of 403.7 to 453.7 million. The ASDR was 5,055.9 per 100,000 individuals (95% *UI*: 4,759.5, 5,359.2). From 1990 to 2021, there was a 1.3% decrease in the global ASDR for CVD [95% confidence interval (*CI*): −1.4%, −1.2%], despite a 44.0% increase in the global DALYs attributed to CVD. Among various SDI quintiles, DALYs consistently increased in all but the high SDI quintile. Notably, ASDR declined across all SDI categories, with the most pronounced decrease occurring in the high SDI quintile.(Figure 1 and Table 1). Rheumatic heart disease experienced the sharpest decrease in ASDR, with an AAPC of −2.5% (95% *CI*: −2.5%, −2.4%) (Table 1).

Since 1990, global DALYs attributable to population aging have gradually increased, reaching 138.2 million by 2021. Over the same timeframe, population growth accounted for an additional 144.2 million DALYs, while changes in DALY rates led to a reduction of 151.7 million DALYs (Figure 2A and Table 2). The impact of these three determinants varied significantly across different regions and countries (Table 2 and Supplementary Table S1, available at https://weekly.chinacdc.cn/). From 1991 to 2021, the percentage of DALYs linked to population aging rose globally and across most SDI quintiles, with figures ranging from 2.9% in the lowest SDI countries to 79.0% in middle SDI countries (Figure 2B). The extent of total DALYs changes due to population aging varied widely from −77.0% in Afghanistan to 148.9% in the United Arab Emirates, with 174 countries or territories recording an increase in DALYs attributed to aging (Supplementary Table S1). IHD and stroke were the conditions most affected by aging, with 42 countries noting more than a 25% increase in IHD

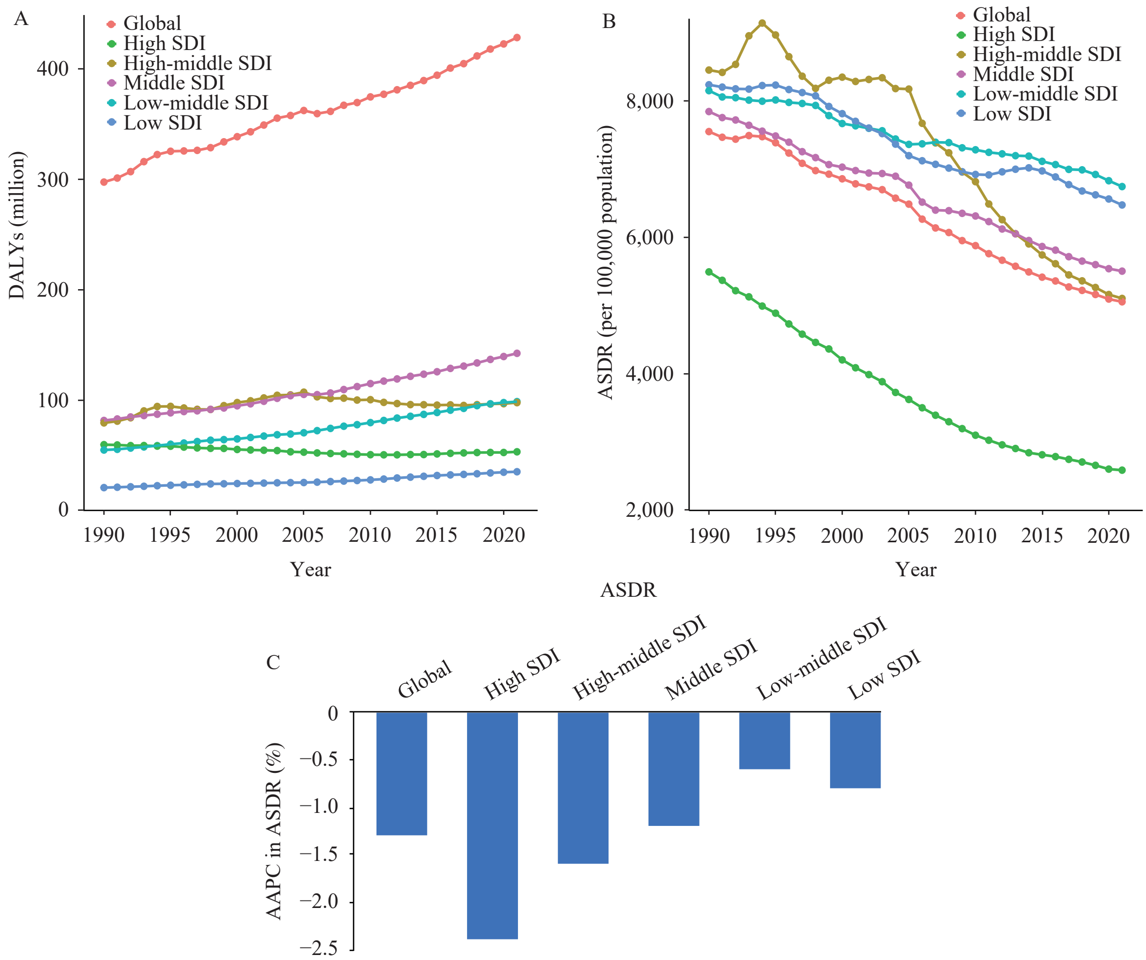

FIGURE 1. Global DALYs and ASDR of CVD from 1990 to 2021. (A) DALYs across various SDI regions. (B) ASDR across different SDI regions. (C) AAPC in ASDR.

Abbreviation: DALYs=disability-adjusted life years; ASDR=age-standardized DALY rate; CVD=cardiovascular disease; SDI=socio-demographic index; AAPC=average annual percent change.

TABLE 1. DALYs cases and the ASDR for CVD from 1990 to 2021.

Characteristics	1990		2021		1990–2021
	DALYs cases No. ×10[4] (95% *UI*)	ASDR per 100,000 No. (95% *UI*)	DALYs cases No. ×10[4] (95% *UI*)	ASDR per 100,000 No. (95% *UI*)	AAPC No. (95% *CI*)
Global	29,750.7 (28,460.1, 30,934.6)	7,550.2 (7,181.5, 7,862.0)	42,832.7 (40,368.4, 45,371.2)	5,055.9 (4,759.5, 5,359.2)	−1.3 (−1.4, −1.2)
SDI					
High	5,984.0 (5,651.8, 6,203.0)	5,494.2 (5,185.5, 5,700.0)	5,338.5 (4,835.2, 5,708.6)	2,588.8 (2,388.0, 2,762.8)	−2.4 (−2.5, −2.4)
High-middle	7,955.2 (7,549.6, 8,296.2)	8,451.9 (8,001.6, 8,819.2)	9,787.9 (8,980.2, 10,573.9)	5,105.1 (4,685.7, 5,507.5)	−1.6 (−1.8, −1.3)
Middle	8,173.6 (7,673.6, 8,708.0)	7,843.6 (7,348.3, 8,338.5)	14,251.9 (13,208.1, 15,296.2)	5,505.1 (5,088.9, 5,901.3)	−1.2 (−1.3, −1.0)
Low-middle	5,500.8 (5,143.9, 5,804.8)	8,149.9 (7,607.7, 8,594.9)	9,878.8 (9,203.1, 10,563.6)	6,744.4 (6,289.1, 7,198.7)	−0.6 (−0.7, −0.5)
Low	2,096.8 (1,907.1, 2,295.2)	8,236.3 (7,566.5, 8,920.5)	3,533.5 (3,184.7, 3,911.8)	6,474.7 (5,883.2, 7,124.5)	−0.8 (−0.9, −0.7)
Type of CVD					
Aortic aneurysm	188.4 (178.4, 200.7)	48.8 (6.0, 51.8)	310.8 (285.7, 335.4)	36.5 (33.5, 39.5)	−0.9 (−1.0, −0.8)
Atrial fibrillation and flutter	335.9 (271.5, 414.2)	100.8 (82.8, 122.6)	835.9 (697.1, 1,013.3)	101.4 (84.9, 122.4)	0.0 (0.0, 0.1)
Cardiomyopathy and myocarditis	857.4 (765.6, 942.4)	195.0 (175.9, 211.1)	1,165.4 (1,070.8, 1,262.6)	142.2 (130.6, 154.1)	−1.0 (−1.4, −0.6)
Endocarditis	133.4 (105.6, 150.9)	28.3 (23.3, 31.6)	207.6 (182.7, 230.9)	25.6 (22.3, 28.4)	−0.3 (−0.4, −0.2)
Hypertensive heart disease	1,547.4 (1,231.1, 1,731.2)	406.5 (328.9, 452.2)	2,546.2 (2,149.3, 2,804.8)	301.6 (255.1, 332.1)	−1.0 (−1.0, −0.9)
Ischemic heart disease	11,916.3 (11,454.8, 12,345.5)	3,107.6 (2,966.5, 3,222.7)	18,836.1 (17,703.7, 19,815.4)	2,212.2 (2,075.5, 2,327.6)	−1.1 (−1.2, −0.9)
Non-rheumatic valvular heart disease	179.2 (164.6, 196.7)	49.3 (45.3, 54.2)	323.8 (293.4, 359.4)	39.7 (35.8, 44.1)	−0.7 (−0.8, −0.6)
Other cardiovascular and circulatory diseases	664.2 (564.7, 766.9)	147.5 (128.0, 169.5)	998.6 (838.6, 1,210.7)	121.5 (102.6, 145.8)	−0.6 (−0.7, −0.5)
Lower extremity peripheral arterial disease	91.3 (75.5, 118.0)	26.6 (22.3, 33.8)	155.8 (126.7, 204.6)	18.6 (15.2, 24.2)	−1.2 (−1.5, −0.9)
Rheumatic heart disease	1,628.0 (1,370.7, 1,917.7)	347.5 (292.5, 409.6)	1,342.6 (1,151.7, 1,578.0)	162.1 (139.1, 190.5)	−2.5 (−2.5, −2.4)
Stroke	12,140.5 (11,472.2, 12,762.5)	3,079.0 (2,893.6, 3,237.3)	16,045.7 (14,778.1, 17,164.3)	1,886.2 (1,739.0, 2,017.9)	−1.6 (−1.7, −1.5)

Abbreviation: CVD=cardiovascular disease; SDI=socio-demographic index; DALYs=disability-adjusted life years; ASDR=age standardized DALY rate; *UI*=uncertainty interval; *CI*=confidence interval; AAPC=average annual percent change.

DALYs and 36 countries observing a similar increase for stroke DALYs. Notably, the rise in DALYs related to aging between 1990 and 2021 was less than 5.0% for most diseases (Table 3).

Globally, the reduction in total CVD DALYs due to decreased DALY rates (−151.7 million) surpassed the increase caused by population aging (138.2 million) from 1990 to 2021, with an R_1 value of −1.1. R_1 values varied, with −1.7 in high SDI regions and −14.7 in low SDI regions (Figure 2 and Table 2). Out of 174 countries that saw an increase in DALYs due to population aging, 103 recorded R_1 values of ≤ -1, 64 reported values between −1 and 0, and 7 had values greater than 0 (Supplementary Table S1). On a global scale, the increase in DALYs due to population growth was greater than that due to aging (Figure 2). Among the countries studied, 1 had R_2 values of ≤ -1, 33 ranged between −1 and 0, and 140 had R_2 values greater than 0. R_2 values ranged from −1.0 in Georgia to 353.6 in Democratic Republic of the Congo (Supplementary Table S1).

DISCUSSION

This study examined the burden of CVD and its trends from 1990 to 2021, concentrating on the changes in DALYs that resulted from population aging, using a decomposition method. During this period, the global ASDR decreased by 1.3%, whereas the global DALYs attributable to total CVD increased by 44.0%. Significant variations in DALY changes associated with population aging were observed across SDI categories, regions, countries, and types of CVD. Given the influence of population aging on the escalating burden of CVD, there was an urgent need for increased investments in healthcare infrastructure, enhancements

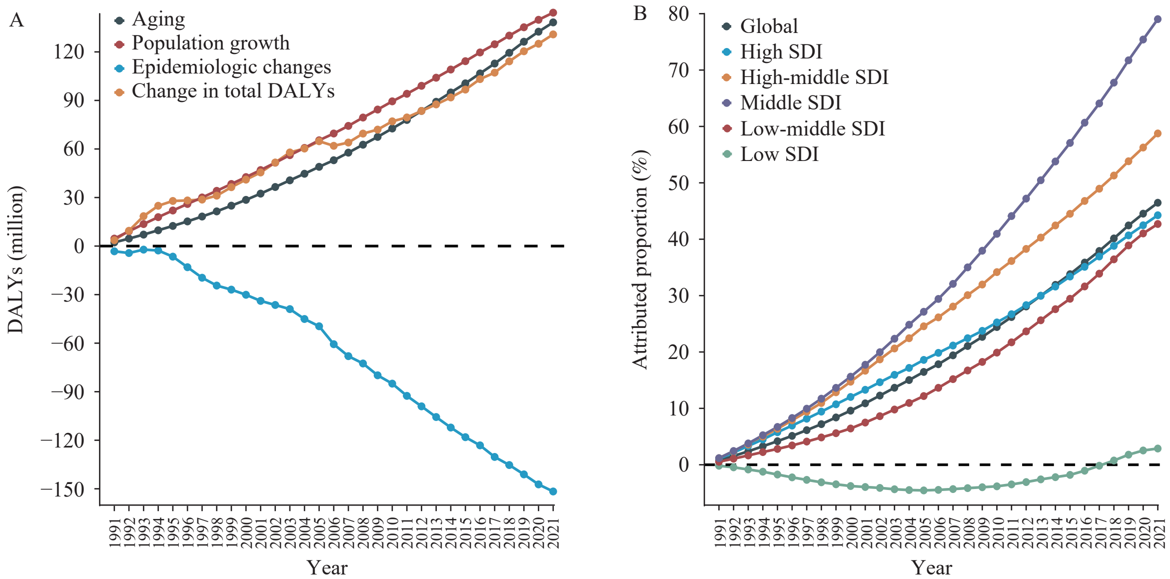

FIGURE 2. Changes in DALYs attributed to population aging, population growth, and DALY rate changes. (A) Global DALYs changes associated with population aging, population growth, and DALY rate changes from 1990 to 2021. (B) Proportion of DALYs associated with population aging globally and by SDI, 1990–2021.

Note: A decomposition analysis was conducted using the number of DALYs in 1990 as the reference year. The attributable proportion of DALYs was calculated as the number of DALYs due to population aging divided by the total DALYs in 1990, then multiplied by 100%.

Abbreviation: DALYs=disability-adjusted life years; SDI=socio-demographic index.

in screening and early intervention programs for high-risk elderly populations, and the implementation of public health education campaigns to foster awareness and encourage healthy lifestyles.

The analysis highlighted global disparities in the burden and trends of CVD. ASDRs had declined in most countries, whereas DALYs saw an increase from 1990 to 2021. For example, China witnessed a 58.5% surge in CVD-related DALYs, escalating from 63.2 million in 1990 to 100.2 million in 2021. This rise was linked to rapid economic transformation, industrialization, urbanization, and globalization in developing nations over the past 32 years. These developments markedly altered lifestyles and diets, consequently contributing to the increase in CVD. Simultaneously, China had advanced the standardization of clinical pathways for major CVDs, which shortened hospital stays, improved the quality of care, enhanced treatment effectiveness, and significantly boosted patient survival rates (*4*). These advancements provide valuable experience for the development of CVD prevention and control strategies in China, underscoring the importance of comprehensive reforms in healthcare systems, social security, and risk factor management.

Population aging correlates with a consistent increase in DALYs, which is mainly due to higher DALY rates among the elderly and an expanding older population segment. Aging results in a gradual decline in physiological integrity, diminished function, and an elevated vulnerability to diseases and mortality in older age groups. Although social advancements and enhancements in healthcare services have extended life expectancy, the effects of population aging differ significantly by region and country. Regions with higher SDI benefit from superior education, healthcare systems, and policy priorities, facilitating more efficient management of disease burdens. Conversely, regions with lower SDI, which are hampered by inadequate healthcare infrastructure, find it challenging to effectively mitigate disease burdens. As low-income countries progress, they encounter challenges linked to population aging and should draw lessons from the experiences of high-income nations (e.g., equitable healthcare, drug availability, and fertility policies) to allocate resources towards proven health interventions that promote healthy aging (*5*).

Despite the challenges posed by an aging population, the increase in DALYs for total CVD and specific categories has been mitigated by decreasing DALY rates over time. This favorable outcome likely results from reduced risk-attribution rates that

TABLE 2. Comparative contributions of change in DALY rates and population growth versus population aging to the change in the number of CVD DALYs between 1990 and 2021.

Characteristics	Population aging No. $\times10^4$	Population growth No. $\times10^4$	DALY rate change No. $\times10^4$	R_1	R_2
Total	13,824.4	14,424.3	−15,166.7	−1.1	1.0
Types of CVD					
Aortic aneurysm	74.3	122.2	−74.2	−1.0	1.6
Atrial fibrillation and flutter	148.1	349.4	2.6	0.0	2.4
Cardiomyopathy and myocarditis	221.9	399.8	−313.8	−1.4	1.8
Endocarditis	28.9	65.3	−19.9	−0.7	2.3
Hypertensive heart disease	659.7	1,001.0	−661.9	−1.0	1.5
Ischemic heart disease	4,645.6	7,587.6	−5,313.5	−1.1	1.6
Non-rheumatic valvular heart disease	86.4	120.9	−62.4	−0.7	1.4
Other cardiovascular and circulatory diseases	177.3	321.0	−163.9	−0.9	1.8
Lower extremity peripheral arterial disease	20.0	90.1	−45.6	−2.3	4.5
Rheumatic heart disease	283.8	623.0	−1,192.1	−4.2	2.2
Stroke	5,523.8	5,676.4	−7,295.0	−1.3	1.0
SDI					
High	2,648.1	1,324.1	−4,617.8	−1.7	0.5
High-middle	4,674.5	1,877.7	−4,719.5	−1.0	0.4
Middle	6,459.7	3,959.1	−4,340.6	−0.7	0.6
Low-middle	2,348.9	3,776.3	−1,747.2	−0.7	1.6
Low	60.3	2,260.6	−884.2	−14.7	37.5
Region					
East Asia	6,540.8	1,671.1	−4,384.5	−0.7	0.3
Southeast Asia	1,562.5	1,294.5	−682.1	−0.4	0.8
Oceania	9.4	41.6	−10.3	−1.1	4.4
Central Asia	126.3	189.0	−140.8	−1.1	1.5
Central Europe	732.9	−115.0	−925.2	−1.3	−0.2
Eastern Europe	1,020.3	−269.1	−730.7	−0.7	−0.3
High-income Asia Pacific	742.2	58.5	−788.5	−1.1	0.1
Australasia	55.4	53.1	−128.2	−2.3	1.0
Western Europe	1,093.5	350.5	−2,408.9	−2.2	0.3
Southern Latin America	98.1	91.7	−231.3	−2.4	0.9
High-income North America	657.7	539.0	−1,124.7	−1.7	0.8
Caribbean	95.3	71.6	−81.8	−0.9	0.8
Andean Latin America	55.9	73.7	−76.4	−1.4	1.3
Central Latin America	384.1	270.0	−213.4	−0.6	0.7
Tropical Latin America	508.3	349.3	−627.9	−1.2	0.7
North Africa and Middle East	913.9	1,675.2	−1,425.4	−1.6	1.8
South Asia	2,552.3	3,599.6	−1,353.4	−0.5	1.4
Central Sub−Saharan Africa	−2.0	293.5	−93.9	−	−
Eastern Sub−Saharan Africa	27.6	685.0	−313.4	−11.4	24.8
Southern Sub−Saharan Africa	70.6	102.1	−2.6	0.0	1.4
Western Sub−Saharan Africa	−104.4	982.1	−322.7	−	−

Note: In countries where population aging corresponded with a rise in DALYs from 1990 to 2021, we calculated R_1 and R_2. R_1 was determined by the equation "DALYs attributed to changes in DALY rate / DALYs attributed to population aging," while R_2 was computed as "DALYs attributed to population growth / DALYs attributed to population aging."

Abbreviation: CVD=cardiovascular disease; SDI=socio-demographic index; DALYs=disability-adjusted life years.

TABLE 3. Number of countries and territories with different increases in cause-specific proportions of DALYs associated with population aging between 1990 and 2021.

Cause of cardiovascular diseases DALYs	Increase in attributed proportion of DALYs (number of countries/territories)					
	1.0%–5.0%	5.1%–10.0%	10.1–15.0%	15.1–20.0%	20.1–25.0%	≥25.1%
Ischemic heart disease	16	25	23	35	22	42
Stroke	14	29	33	34	30	36
Hypertensive heart disease	97	20	2	0	0	0
Atrial fibrillation and flutter	43	0	0	0	0	0
Cardiomyopathy and myocarditis	62	1	0	0	0	0
Other cardiovascular and circulatory diseases	60	2	0	0	0	0
Rheumatic heart disease	30	1	0	0	0	0
Aortic aneurysm	14	0	0	0	0	0
Non-rheumatic valvular heart disease	18	0	0	0	0	0
Lower extremity peripheral arterial disease	0	0	0	0	0	0
Endocarditis	1	0	0	0	0	0

Note: The attributed proportion was calculated as the number of DALYs attributed to population aging for each cause of DALYs between 1990 and 2021 divided by total DALYs in 1990 ×100%. Countries and territories with an attribution rate of <1.0% were ignored.
Abbreviation: DALYs=disability-adjusted life years.

effectively counterbalance the DALYs increase due to aging. This reflects advancements in the prevention and control of diseases such as stroke and peripheral artery disease (*6*). However, progress has been uneven across different disease categories. To sustain these gains, significant investments are necessary to improve disease monitoring, early warning systems, and healthcare infrastructure, especially in regions where the effects of population aging surpass the reductions in DALY rates. It is crucial to implement continuous, cost-effective interventions and policies to meet the 2030 goal of a ≥30% reduction in premature noncommunicable disease mortality (*7*). Enhancing primary prevention through better control of risk factors, improving access to early screening and diagnosis for timely treatment, and strengthening healthcare capacity, particularly in primary healthcare services, are essential steps.

This study is subject to some limitations. First, the findings were contingent on the quality of DALYs and population estimates from the GBD 2021, which might be subject to bias stemming from variations in population-based studies and access to CVD diagnostics across different countries. Second, factors such as increasing life expectancy and declining fertility rates were not examined due to data constraints, although these are known to be associated with the rising burden of DALYs due to population aging. Lastly, our methodology only incorporated three variables and did not account for additional factors like lifestyle and healthcare accessibility.

In conclusion, the global burden of CVD has been profoundly influenced by demographic shifts. From 1990 to 2021, the global burden of CVD DALYs increased due to population aging, with variations observed across SDI levels, regions, countries, and types of CVD. Notably, significant reductions in DALY rates in certain regions largely mitigated the increases. Addressing the impact of aging populations requires collaborative efforts from stakeholders, policymakers, and researchers. Strategies may include promoting healthy lifestyles, adjusting fertility policies, enhancing healthcare access, and implementing interventions aimed at reducing CVD risk factors among the elderly.

Conflicts of interest: No conflicts of interest

Funding: Supported by the National Natural Science Foundation of China (82073670) and the Humanities and Social Science Fund of the Ministry of Education (23YJAZH178).

doi: 10.46234/ccdcw2024.209

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Submitted: November 06, 2023; Accepted: March 24, 2024

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SUPPLEMENTAL MATERIAL

A positive contribution indicated an increase in overall DALYs, while a negative contribution signified a decrease. In nations where population aging correlated with higher DALYs from 1990 to 2021, we determined the ratio (R_1) of DALYs resulting from changes in DALY rates to those due to population aging to evaluate their relative impacts on the total DALYs. An R_1 value less than -1 implies that decreases in DALY rates had a greater impact on reducing total DALYs compared to the increase caused by population aging; an R_1 value of −1 means the impacts of DALY rate reductions and population aging are balanced; an R_1 value between −1 and 0 indicates that the effect of DALY rate reductions is lesser than that of population aging; an R_1 value greater than 0 indicates that both changes in DALY rates and population aging contributed to increases in DALYs during that period. Furthermore, to assess the relative contributions of population growth versus population aging on changes in total DALYs, the ratio (R_2) of DALYs attributed to population growth vs. those attributed to population aging was calculated.

SUPPLEMENTARY TABLE S1. Proportion of DALYs associated with population aging and comparative contributions from 1990 to 2021 across 204 countries and territories.

Characteristics	DALYs in 1990 No.×10^4	Population aging No. ×10^4	Population growth No. ×10^4	DALY rate change No. ×10^4	Proportion of DALYs attributed to population aging (%)	R_1	R_2
Afghanistan	123.8	−95.3	176.0	−59.2	−77.0	–	–
Albania	15.6	20.7	−4.6	−7.9	132.4	−0.4	−0.2
Algeria	120.2	88.0	93.2	−92.4	73.2	−1.1	1.1
American Samoa	0.2	0.2	0.0	0.0	82.2	0.0	0.0
Andorra	0.2	0.1	0.1	−0.2	84.2	−2.0	1.0
Angola	44.0	−1.7	79.6	−29.1	−3.9	–	–
Antigua and Barbuda	0.4	0.1	0.2	−0.2	27.1	−2.0	2.0
Argentina	221.4	53.0	67.8	−162.5	23.9	−3.1	1.3
Armenia	23.6	16.3	−3.4	−10.8	69.0	−0.7	−0.2
Australia	98.7	47.0	43.6	−106.6	47.7	−2.3	0.9
Austria	70.3	21.3	9.0	−54.0	30.3	−2.5	0.4
Azerbaijan	55.3	23.3	24.7	−22.7	42.2	−1.0	1.1
Bahamas	1.2	0.8	0.7	−0.6	69.0	−0.8	0.9
Bahrain	2.1	1.7	3.7	−3.6	83.4	−2.1	2.2
Bangladesh	515.9	400.6	292.0	−310.3	77.7	−0.8	0.7
Barbados	1.6	0.6	0.3	−0.8	39.6	−1.3	0.5
Belarus	123.9	44.9	−15.4	−9.0	36.3	−0.2	−0.3
Belgium	71.6	20.6	8.6	−57.2	28.8	−2.8	0.4
Belize	0.5	0.2	0.7	−0.3	45.9	−1.5	3.5
Benin	16.0	−1.7	24.6	−6.6	−10.6	–	–
Bermuda	0.5	0.3	0.0	−0.4	76.9	−1.3	0.0
Bhutan	1.9	1.6	0.5	−0.9	82.2	−0.6	0.3
Bolivia	25.1	11.1	19.2	−20.7	44.2	−1.9	1.7
Bosnia and Herzegovina	31.8	27.4	−10.8	−14.8	86.2	−0.5	−0.4
Botswana	4.7	2.3	3.7	−3.0	49.3	−1.3	1.6
Brazil	688.7	502.8	337.8	−622.4	73.0	−1.2	0.7
Brunei Darussalam	0.9	0.6	0.7	−0.8	73.4	−1.3	1.2
Bulgaria	149.1	73.1	−36.2	−52.0	49.0	−0.7	−0.5
Burkina Faso	31.4	−3.6	39.6	−5.9	−11.4	–	–

Continued

Characteristics	DALYs in 1990 No.×10[4]	Population aging No. ×10[4]	Population growth No. ×10[4]	DALY rate change No. ×10[4]	Proportion of DALYs attributed to population aging (%)	R_1	R_2
Burundi	28.1	−2.9	29.1	−20.3	−10.2	–	–
Cabo Verde	1.3	0.3	0.8	0.0	25.3	0.0	2.7
Cambodia	45.3	30.1	32.2	−24.6	66.6	−0.8	1.1
Cameroon	35.8	−3.2	68.6	−5.8	−8.9	–	–
Canada	147.4	77.9	50.6	−132.2	52.8	−1.7	0.6
Central African Republic	14.9	−0.3	13.4	−4.2	−2.2	–	–
Chad	23.0	−11.1	39.1	−0.5	−48.3	–	–
Chile	48.7	34.4	19.9	−47.3	70.6	−1.4	0.6
China	6,325.4	6,367.8	1,615.9	−4,288.3	100.7	−0.7	0.3
Colombia	105.0	97.2	57.6	−104.4	92.5	−1.1	0.6
Comoros	1.7	0.9	1.1	−1.0	48.8	−1.1	1.2
Congo	13.2	2.7	14.8	−7.3	20.1	−2.7	5.5
Cook Islands	0.1	0.1	0.0	−0.1	81.9	−1.0	0.0
Costa Rica	7.6	7.1	4.9	−6.0	92.9	−0.8	0.7
Cote d'Ivoire	38.3	10.7	49.3	−10.7	27.8	−1.0	4.6
Croatia	53.2	32.2	−7.1	−41.3	60.6	−1.3	−0.2
Cuba	64.3	45.0	2.9	−33.2	70.1	−0.7	0.1
Cyprus	5.1	3.8	3.4	−7.2	74.5	−1.9	0.9
Czechia	139.7	52.2	3.8	−114.4	37.3	−2.2	0.1
North Korea	126.5	83.9	45.5	−5.8	66.3	−0.1	0.5
Democratic Republic of the Congo	145.6	0.5	176.8	−50.7	0.4	−101.4	353.6
Denmark	48.1	9.9	4.9	−41.0	20.5	−4.1	0.5
Djibouti	1.1	0.9	2.5	−0.6	81.9	−0.7	2.8
Dominica	0.4	0.2	0.0	−0.1	40.3	−0.5	0.0
Dominican Republic	24.7	19.3	16.9	−2.9	78.0	−0.2	0.9
Ecuador	26.6	17.1	22.1	−18.3	64.2	−1.1	1.3
Egypt	530.0	90.4	417.3	−295.9	17.1	−3.3	4.6
El Salvador	14.9	8.4	3.5	−6.9	56.7	−0.8	0.4
Equatorial Guinea	2.3	−0.8	4.2	−2.2	−33.7	–	–
Eritrea	13.7	4.1	11.8	−7.8	30.0	−1.9	2.9
Estonia	22.0	9.1	−3.2	−16.5	41.6	−1.8	−0.4
Eswatini	2.4	0.9	1.2	0.0	38.5	0.0	1.3
Ethiopia	183.9	10.8	159.2	−156.4	5.9	−14.5	14.7
Fiji	5.4	3.0	1.3	−1.7	56.6	−0.6	0.4
Finland	48.0	22.2	4.5	−39.1	46.3	−1.8	0.2
France	321.5	142.9	43.7	−240.9	44.5	−1.7	0.3
Gabon	5.1	−0.1	3.8	−1.8	−1.1	–	–
Gambia	3.2	0.7	4.8	−0.1	22.1	−0.1	6.9
Georgia	71.1	24.2	−24.5	−28.4	34.1	−1.2	−1.0
Germany	785.9	279.1	45.5	−593.7	35.5	−2.1	0.2
Ghana	69.5	16.2	83.3	−33.6	23.4	−2.1	5.1

Continued

Characteristics	DALYs in 1990 No.×10⁴	Population aging No. ×10⁴	Population growth No. ×10⁴	DALY rate change No. ×10⁴	Proportion of DALYs attributed to population aging (%)	R_1	R_2
Greece	83.4	51.1	−1.8	−59.4	61.3	−1.2	0.0
Greenland	0.3	0.2	0.0	−0.3	63.8	−1.5	0.0
Grenada	0.6	0.2	0.1	−0.3	27.4	−1.5	0.5
Guam	0.6	0.7	0.1	−0.3	111.0	−0.4	0.1
Guatemala	18.9	12.8	17.0	−14.1	68.0	−1.1	1.3
Guinea	28.6	−8.8	30.4	−4.3	−30.6	−	−
Guinea−Bissau	5.7	−0.5	5.2	−1.9	−8.2	−	−
Guyana	5.6	2.9	−0.1	−2.9	51.9	−1.0	0.0
Haiti	51.3	6.3	46.3	−24.3	12.3	−3.9	7.3
Honduras	12.6	8.1	17.7	1.7	64.7	0.2	2.2
Hungary	154.1	51.9	−10.6	−92.9	33.7	−1.8	−0.2
Iceland	1.4	0.5	0.4	−1.2	38.8	−2.4	0.8
India	3,689.0	2,092.5	2,707.6	−1,041.9	56.7	−0.5	1.3
Indonesia	904.0	618.5	571.2	−62.7	68.4	−0.1	0.9
Iran	242.5	212.6	129.4	−211.7	87.6	−1.0	0.6
Iraq	104.6	39.5	126.6	−54.4	37.8	−1.4	3.2
Ireland	26.9	8.8	7.5	−28.7	32.8	−3.3	0.9
Israel	23.9	8.4	16.7	−29.7	35.0	−3.5	2.0
Italy	395.7	214.2	19.8	−312.6	54.1	−1.5	0.1
Jamaica	9.7	4.2	1.9	−3.0	42.9	−0.7	0.5
Japan	562.6	573.0	9.8	−545.7	101.8	−1.0	0.0
Jordan	13.2	11.0	27.3	−21.1	83.2	−1.9	2.5
Kazakhstan	129.6	26.1	20.1	−29.9	20.1	−1.1	0.8
Kenya	38.1	14.5	50.2	2.1	38.1	0.1	3.5
Kiribati	0.5	0.1	0.3	−0.1	23.4	−1.0	3.0
Kuwait	4.9	4.5	8.3	−5.8	92.3	−1.3	1.8
Kyrgyzstan	30.7	1.7	14.8	−10.3	5.7	−6.1	8.7
Laos	33.5	9.3	22.6	−22.7	27.8	−2.4	2.4
Latvia	39.4	16.1	−11.7	−18.1	40.8	−1.1	−0.7
Lebanon	20.1	10.2	14.2	−23.8	50.9	−2.3	1.4
Lesotho	5.0	0.2	1.4	3.0	3.9	15.0	7.0
Liberia	11.0	−2.2	11.3	−3.2	−19.5	−	−
Libya	16.5	8.5	12.4	0.7	51.2	0.1	1.5
Lithuania	41.9	22.5	−11.7	−19.5	53.6	−0.9	−0.5
Luxembourg	3.1	0.4	1.3	−2.7	14.2	−6.4	2.7
Madagascar	63.7	−3.4	80.0	−18.9	−5.3	−	−
Malawi	30.0	−0.5	27.9	−3.7	−1.6	−	−
Malaysia	78.5	59.2	70.7	−40.7	75.5	−0.7	1.2
Maldives	1.0	0.7	1.2	−1.6	72.1	−2.3	1.7
Mali	31.0	−7.1	44.7	−14.2	−22.9	−	−
Malta	2.5	1.9	0.5	−2.8	74.7	−1.5	0.3
Marshall Islands	0.3	0.2	0.1	0.0	71.4	0.0	0.5

Continued

Characteristics	DALYs in 1990 No.×10⁴	Population aging No. ×10⁴	Population growth No. ×10⁴	DALY rate change No. ×10⁴	Proportion of DALYs attributed to population aging (%)	R_1	R_2
Mauritania	9.9	0.3	9.4	−5.4	2.7	−18.0	31.3
Mauritius	7.8	6.5	1.3	−7.3	82.7	−1.1	0.2
Mexico	177.0	175.9	118.9	−52.2	99.3	−0.3	0.7
Micronesia	0.8	0.4	0.0	−0.2	45.6	−0.5	0.0
Monaco	0.3	0.0	0.1	−0.2	10.9	–	–
Mongolia	12.9	5.6	6.9	−7.3	43.0	−1.3	1.2
Montenegro	4.9	2.7	−0.1	0.2	54.4	0.1	0.0
Morocco	174.7	102.5	89.6	−65.5	58.7	−0.6	0.9
Mozambique	47.0	−13.7	59.5	6.0	−29.0	–	–
Myanmar	329.6	137.9	122.6	−211.2	41.8	−1.5	0.9
Namibia	5.4	1.6	4.0	−1.4	29.4	−0.9	2.5
Nauru	0.1	0.0	0.0	0.0	14.0	–	–
Nepal	81.6	42.4	51.1	−36.1	52.0	−0.9	1.2
Netherlands	96.9	38.6	12.6	−82.0	39.8	−2.1	0.3
New Zealand	22.5	8.4	9.4	−21.6	37.2	−2.6	1.1
Nicaragua	6.8	5.2	5.4	−3.8	76.0	−0.7	1.0
Niger	24.7	−1.1	43.9	−14.9	−4.3	–	–
Nigeria	369.6	−85.5	447.3	−199.8	−23.1	–	–
Niue	0.0	0.0	0.0	0.0	–	–	–
North Macedonia	19.6	10.9	2.0	−7.6	55.3	−0.7	0.2
Northern Mariana Islands	0.2	0.2	0.0	0.0	113.1	0.0	0.0
Norway	37.8	4.3	7.3	−31.4	11.3	−7.3	1.7
Oman	9.2	2.6	10.4	−9.0	28.3	−3.5	4.0
Pakistan	448.9	29.6	527.5	42.5	6.6	1.4	17.8
Palau	0.1	0.1	0.0	0.0	78.2	0.0	0.0
Palestine	10.0	1.4	12.3	−8.2	13.7	−5.9	8.8
Panama	6.4	4.4	5.4	−4.3	68.7	−1.0	1.2
Papua New Guinea	21.7	3.9	32.8	−6.4	18.1	−1.6	8.4
Paraguay	12.7	6.7	10.3	−5.5	52.9	−0.8	1.5
Peru	51.0	27.3	33.4	−37.9	53.5	−1.4	1.2
Philippines	242.1	152.6	233.8	−9.8	63.0	−0.1	1.5
Poland	424.2	196.0	0.7	−325.4	46.2	−1.7	0.0
Portugal	85.3	52.1	3.6	−89.2	61.1	−1.7	0.1
Puerto Rico	17.0	14.8	−1.7	−15.0	87.2	−1.0	−0.1
Qatar	1.3	0.9	5.5	−3.8	67.5	−4.2	6.1
Republic of Korea	177.2	217.3	31.9	−275.4	122.6	−1.3	0.1
Moldova	44.3	27.3	−9.9	−18.3	61.5	−0.7	−0.4
Romania	284.5	167.5	−59.7	−139.8	58.9	−0.8	−0.4
Russian Federation	1,901.1	673.9	−80.5	−600.6	35.4	−0.9	−0.1
Rwanda	37.9	7.5	24.5	−35.6	19.8	−4.7	3.3
Saint Kitts and Nevis	0.4	0.1	0.1	−0.3	22.6	−3.0	1.0

Continued

Characteristics	DALYs in 1990 No.×10[4]	Population aging No. ×10[4]	Population growth No. ×10[4]	DALY rate change No. ×10[4]	Proportion of DALYs attributed to population aging (%)	R_1	R_2
Saint Lucia	0.7	0.7	0.2	−0.7	96.2	−1.0	0.3
Saint Vincent and the Grenadines	0.6	0.4	0.0	−0.3	71.4	−0.8	0.0
Samoa	0.9	0.3	0.3	−0.1	34.3	−0.3	1.0
San Marino	0.1	0.1	0.0	−0.1	57.4	−1.0	0.0
Sao Tome and Principe	0.4	0.0	0.3	0.0	−2.8	−	−
Saudi Arabia	67.1	42.9	98.5	−27.2	64.0	−0.6	2.3
Senegal	31.6	5.6	31.8	−12.0	17.6	−2.1	5.7
Serbia	115.4	78.1	−9.4	−70.0	67.7	−0.9	−0.1
Seychelles	0.5	0.2	0.2	−0.3	38.0	−1.5	1.0
Sierra Leone	21.0	−3.5	20.4	−5.4	−16.6	−	−
Singapore	13.8	12.1	10.9	−22.4	87.9	−1.9	0.9
Slovakia	60.4	25.5	1.6	−38.1	42.2	−1.5	0.1
Slovenia	15.5	8.6	0.7	−13.7	55.6	−1.6	0.1
Solomon Islands	2.1	0.8	2.3	−0.3	38.9	−0.4	2.9
Somalia	26.5	−1.4	38.3	−14.1	−5.1	−	−
South Africa	124.6	58.6	76.0	−15.1	47.0	−0.3	1.3
South Sudan	21.7	−1.6	12.3	−5.2	−7.6	−	−
Spain	227.4	119.3	36.5	−192.9	52.5	−1.6	0.3
Sri Lanka	78.1	63.6	26.6	−50.7	81.4	−0.8	0.4
Sudan	164.0	−3.2	150.1	−106.7	−1.9	−	−
Suriname	2.1	1.2	1.1	−1.2	59.6	−1.0	0.9
Sweden	81.0	13.5	12.9	−59.1	16.7	−4.4	1.0
Switzerland	44.9	13.7	10.6	−39.4	30.6	−2.9	0.8
Syrian Arab Republic	85.8	67.5	10.5	−38.9	78.7	−0.6	0.2
Taiwan (Province of China)	77.3	81.6	13.9	−87.0	105.5	−1.1	0.2
Tajikistan	29.4	3.2	23.3	−13.9	10.7	−4.3	−7.3
Thailand	180.6	223.3	42.8	−128.0	123.6	−0.6	0.2
Timor−Leste	2.7	2.0	2.6	−0.4	71.8	−0.2	1.3
Togo	12.0	5.1	16.4	−2.9	42.8	−0.6	3.2
Tokelau	0.0	0.0	0.0	0.0	−	−	−
Tonga	0.4	0.1	0.0	0.0	32.9	0.0	0.0
Trinidad and Tobago	7.4	5.8	1.3	−5.5	79.0	−0.9	0.2
Tunisia	38.8	33.5	19.2	−19.7	86.5	−0.6	0.6
Turkey	315.7	219.4	143.6	−267.8	69.5	−1.2	0.7
Turkmenistan	24.3	13.6	11.4	−2.9	55.8	−0.2	0.8
Tuvalu	0.1	0.0	0.0	0.0	18.1	−	−
Uganda	48.6	−4.6	60.7	−23.4	−9.4	−	−
Ukraine	714.6	237.2	−150.3	−46.0	33.2	−0.2	−0.6
United Arab Emirates	5.5	8.2	21.7	−16.3	148.9	−2.0	2.6
United Kingdom	552.3	91.3	74.7	−440.4	16.5	−4.8	0.8

Continued

Characteristics	DALYs in 1990 No.×10[4]	Population aging No. ×10[4]	Population growth No. ×10[4]	DALY rate change No. ×10[4]	Proportion of DALYs attributed to population aging (%)	R_1	R_2
Tanzania	76.8	5.8	91.8	−18.7	7.5	−3.2	15.8
USA	1,700.1	576.0	486.8	−986.9	33.9	−1.7	0.8
United States Virgin Islands	0.6	0.6	−0.1	−0.5	105.3	−0.8	−0.2
Uruguay	24.4	6.4	1.8	−14.9	26.3	−2.3	0.3
Uzbekistan	117.4	49.5	82.9	−19.0	42.2	−0.4	1.7
Vanuatu	1.1	0.5	1.2	−0.2	43.7	−0.4	2.4
Venezuela	64.8	73.5	36.1	−28.2	113.5	−0.4	0.5
Viet Nam	285.5	209.8	162.8	−71.9	73.5	−0.3	0.8
Yemen	83.1	17.3	108.4	−50.2	20.8	−2.9	6.3
Zambia	24.6	0.6	34.4	−4.0	2.5	−6.7	57.3
Zimbabwe	23.2	3.8	15.8	16.9	16.3	4.4	4.2

Note: For countries where population aging was associated with increases in DALYs between 1990 and 2021, we calculated the R_1 and R_2. R_1 was calculated as “DALYs attributed to DALY rate change / DALYs attributed to population aging”; R_2 was calculated as “DALYs attributed to population growth / DALYs attributed to population aging”.

Abbreviation: DALYs=disability-adjusted life years.

Preplanned Studies

Limited Social Support, but Comparable Health Literacy and Service Utilization, Among Elderly People Living Alone — Six PLADs, China, May–September 2020

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Summary

What is already known about this topic?

The proportion of elderly living alone in China is approximately 10%. Living away from family poses enormous challenges for older adults.

What is added by this report?

Compared to those living with family, elderly individuals living alone exhibit a lower registration rate with general practitioners and have less social support.

What are the implications for public health practice?

While the current health service system for elderly people living alone is working relatively well, there is a need for additional programs to enhance social support and improve their social well-being.

As the world experiences an aging population, elderly individuals living alone have become a particularly vulnerable subgroup. Living alone is associated with feelings of loneliness and insecurity, as well as difficulties in daily living. It has been shown to be a risk factor for a range of adverse health outcomes, including physical and mental health (*1*). In this study, a nationally representative sample of 2,959 elderly people in China was selected using a stratified multi-stage random sampling method from May to September 2020. Each participant completed a cross-sectional questionnaire with the support of a local research assistant. The questionnaire consisted of validated scales measuring health literacy, service utilization, and social support. Descriptive statistics and chi-square tests were performed, adjusting for potential confounding factors. This study found that elderly individuals living alone in China have a lower registration rate with a general practitioner (GP), limited social support, but comparable health literacy and service utilization compared to elderly individuals living with family. Targeted and effective community care interventions should be developed to improve the quality of life of elderly individuals living alone.

The 2015 China Family Development Report found that around 10% of the elderly population in China lived alone, and these individuals often experienced loneliness, which limited their access to social support (*2*). However, current research on this topic has some limitations. First, existing data mostly focus on specific provincial-level administrative divisions (PLADs) or cities and lack national-level representation. Second, previous research has primarily examined the health and mental well-being of elderly people living alone. These assessments often focus on individual levels, while overlooking important factors such as health literacy, social support, and service utilization, especially community health education and public health services. These factors can be comprehensively evaluated from 3 aspects: individual capabilities, interpersonal skills, and service utilization, which can be modified through intervention programs. The aim of this study was to compare the differences in health status, service utilization, and social support between elderly people living alone and those living with family in China to inform medical resource allocation and policy decision-making.

A stratified, multistage, cluster sampling method was used to randomly select six PLADs in China from May to September 2020. First, two PLADs were randomly selected from the eastern, western, and central regions of Chinese mainland. Second, the provincial capital and another randomly selected cities/districts (below the median GDP) were selected from each PLAD. Overall, a total of 3,009 participants were selected from Zhejiang, Jiangxi, Chongqing, Gansu, Liaoning, and Beijing. The sampled cities were further stratified by urban and rural areas, and participants were randomly selected from household registration lists. According to the guidelines of the National Human Rights Action Plan (2016–2020), more than 90% of adults aged ≥60 years are registered at their local community health centers. The inclusion criteria were as follows: 1) aged ≥60 years; and 2) agreement to participate. Participants with dementia or mental disorders were excluded. Participants were recruited from community health centers with support from GPs. The methodology of this study has been described previously (*3*). This study was approved by the ethics committee of Peking University Health Science Center (ethical approval number: IRB00001052-19143). Informed consent was obtained from all participants.

The questionnaire was developed by a multidisciplinary research team and pilot tested before use. The measurements included socio-demographic information, health status (whether participants had chronic diseases, hospitalizations in the past year, and outpatient visit within two weeks), GP registration status, service utilization (regular physical examination, oral examination, regular blood pressure monitoring, and blood sugar measurement), health literacy, social support, and self-reported anxiety/depression status. Health literacy, with a full score of 26, was measured with reference to the Core Information on Elderly Health released by the National Health Commission of China (*4*). A health literacy questionnaire score of 80% or above was judged as high health literacy (*5*). The Social Support Rate Scale (SSRS) developed by Xiao (*6*) was used to measure social support. The SSRS has 10 items and a score range of 12–83. Descriptive statistics were calculated for all participant characteristics. Categorical variables are presented as frequency (*n*) and percentage (%). Differences between groups were examined using an independent-samples t-test. The comparison of categorical variables was examined using a chi-square test. Additional adjustments for potential confounders (gender, age, marital status, education level, and income) were made using covariate analysis or stratification analysis. The statistical significance level was $P<0.05$. All tests were two-tailed. Statistical analyses were conducted with SPSS (version 27, IBM Corp., Armonk, New York, United States).

In this cross-sectional study, a total of 3,009 participants over the age of 60 were approached for the survey, of which 50 (1.7%) were excluded due to incomplete or ambiguous answers. Among the 2,959 elderly people included in the analysis, 260 (8.8%) lived alone. Of the participants, 56.0% (1,657/2,959) were women, and 75.4% (2,230/2,959) were aged 65 and above. Nearly half of the participants (48.8%, 1,445/2,959) had attained primary school education or below, and 51.2% (1,515/2,959) were registered urban residents. Of all participants, 46.4% (1,374/2,959) were of low- and middle-income [600–3,500 Chinese Yuan (CNY) per month] (Table 1). Overall, 10.4% (309/2,959) had high health literacy. Furthermore, 59.7% (1,766/2,959) reported having a diagnosis of at least one chronic disease, 13.5% (399/2,959) had a hospitalization experience in the past year, and 72.9% (159/218) had an outpatient experience in the past two weeks (Table 2). Females accounted for 65.0% (169/260) among elderly living alone, while 55.1% (1,488/2,699) of the elderly living with family were female; the difference was statistically significant ($P=0.002$). Of the elderly living alone, 58.0% (151/260) were in the senior age group (70 and above), while 40.3% (1,088/2,699) of those living with family were over 70 years old. Overall, the elderly living alone were more likely to be in higher age groups ($P<0.001$) (Table 1).

After adjusting for confounding factors, there was no significant difference in the outpatient rate between older adults living alone (76.9%, 20/26) and those living with family (72.4%, 139/192) in the past 2 weeks. Furthermore, the GP coverage rate for older adults living with family was 47.8% (1,289/2,699), which was higher than the rate of 42.7% (111/260) for those living alone ($P=0.024$). The total social support score for older adults living alone was 33.1±8.1, compared to 39.3±7.5 for those living with family. The mean subjective social support (20.5±4.9 *vs*. 23.6±4.8) and objective social support (5.7±3.1 *vs*. 8.7±2.7) scores of older adults living alone were lower than those of older adults living with family ($P<0.001$). There was no significant difference in the utilization of social support between the two groups (6.8±2.4 *vs*. 7.1±2.3). The health literacy score of older adults living alone (12.1±5.6) was significantly lower than that of older adults living with family (13.1±5.6) ($P<0.001$). Only 6.2% (16/260) of older adults living alone had high health literacy, compared to 10.9% (293/2,699) of those living with family. However, the difference was non-significant in the adjusted analysis. In total, 85.8% (223/260) of older adults living alone and 89.3% (2,409/2,699) of older adults living with family reported no anxiety or depression. The differences were not statistically significant (Table 2).

DISCUSSION

This study found that elderly people living alone tended to be female, older, have lower education and

TABLE 1. Comparison of demographic characteristics of elderly living alone and living with family in six PLADs of China, May–September 2020.

Items, *n* (%)*	Total (*n*=2,959)	Elderly living alone (*n*=260)	Elderly living with family (*n*=2,699)	*P*†
Gender				
Male	1,302 (44.0)	91 (35.0)	1,211 (44.9)	0.002
Female	1,657 (56.0)	169 (65.0)	1,488 (55.1)	
Age, years				
60–64	729 (24.6)	47 (18.1)	682 (25.3)	<0.001
65–69	991 (33.5)	62 (23.8)	929 (34.4)	
70–79	1,001 (33.8)	108 (41.5)	893 (33.1)	
≥80	238 (8.0)	43 (16.5)	195 (7.2)	
Marital status				
Married	2,414 (81.6)	50 (19.2)	2,364 (87.6)	<0.001
Widowed/divorced/unmarried	545 (18.4)	210 (80.8)	335 (12.4)	
Highest education obtained				
Primary school or below	1,445 (48.8)	164 (63.1)	1,281 (47.5)	<0.001
Middle school	876 (29.6)	70 (26.9)	806 (29.9)	
High school or above	638 (21.6)	26 (10.0)	612 (22.7)	
Type of registered permanent residence				
Urban	1,515 (51.2)	129 (49.6)	1,386 (51.4)	0.604
Rural	1,444 (48.8)	131 (50.4)	1,313 (48.6)	
Scale of incomes§				
Low-income	798 (27.0)	100 (38.5)	698 (25.9)	<0.001
Low- and middle-income	1,374 (46.4)	106 (40.8)	1,268 (47.0)	
Middle- and high-income	650 (22.0)	51 (19.6)	599 (22.2)	
High-income	137 (4.6)	3 (1.2)	134 (5.0)	
Source of personal income (multichoice)				
Endowment insurance system/savings	1,372 (46.4)	114 (43.8)	1,258 (46.6)	0.398
Retirement pension	959 (32.4)	77 (29.6)	882 (32.7)	0.332
Household income/family support	950 (32.1)	80 (30.8)	870 (32.2)	0.677
Government aid	87 (2.9)	20 (7.7)	67 (2.5)	<0.001

Abbreviation: PLADs=provincial-level administrative divisions; SD=standard deviation; CNY=Chinese Yuan.

* Data are *n* (%) or mean±SD.

† Chi test was performed and the corresponding *P* value was listed.

§ Urban elderly income standards (personal monthly income): Low-income < 600 CNY; Low- and middle-income 600–3,500 CNY; Middle- and high-income 3,500–6,500 CNY; High-income ≥ 6,500 CNY. Rural elderly income standards (annual household income): Low-income <17,000 CNY; Low- and middle-income 17,000–65,000 CNY; Middle- and high-income 65,000–100,000 CNY; High-income ≥100,000 CNY.

income levels, lower GP registration rates, and lower social support compared with elderly people living with family. However, the level of service utilization and health status of elderly people living alone was similar to that of elderly people living with family. Elderly people living alone need extra attention in terms of health literacy and social support.

Social support for older adults is complicated by the different needs of those living alone versus those living with family, placing significant pressure on individuals living alone. Dong et al. (*7*) demonstrated that older adults living alone reported higher levels of loneliness. Lower social support is associated with a 29% increased risk of heart disease and a 32% higher risk of stroke. Social support can significantly reduce feelings of loneliness in older adults. Moreover, better social support can promote disease recovery and treatment, improve quality of life, and enhance mental well-being (*8*). These findings suggest that policymakers should prioritize initiatives that foster social support for older

TABLE 2. Comparison of characteristics related to health status and social support of elderly living alone and living with family in six PLADs of China, May-September 2020.

Items, *n* (%)*	Total (*n*=2,959)	Elderly living alone (*n*=260)	Elderly living with family (*n*=2,699)	*P*†
High health literacy§				
No	2,650 (89.6)	244 (93.8)	2,406 (89.1)	0.217
Yes	309 (10.4)	16 (6.2)	293 (10.9)	
Any diagnosis of chronic disease				
No	1,193 (40.3)	106 (40.8)	1,087 (40.3)	0.974
Yes	1,766 (59.7)	154 (59.2)	1,612 (59.7)	
Hospitalization experience in the past year				
No	2,560 (86.5)	223 (85.8)	2,337 (86.6)	0.602
Yes	399 (13.5)	37 (14.2)	362 (13.4)	
Outpatient experience in the last two weeks¶				
No	59 (27.1)	6 (23.1)	53 (27.6)	0.443
Yes	159 (72.9)	20 (76.9)	139 (72.4)	
Regular blood pressure measurement				
No	1,039 (35.1)	89 (34.2)	950 (35.2)	0.386
Yes	1,920 (64.9)	171 (65.8)	1,749 (64.8)	
Regular blood sugar measurement				
No	1,645 (55.6)	144 (55.4)	1,501 (55.6)	0.956
Yes	1,314 (44.4)	116 (44.6)	1,198 (44.4)	
Regular physical examination				
No	563 (19.0)	56 (21.5)	507 (18.8)	0.141
Yes	2,396 (81.0)	204 (78.5)	2,192 (81.2)	
Oral examination within six months				
No	659 (22.3)	47 (18.1)	612 (22.7)	0.720
Yes	2,300 (77.7)	213 (81.9)	2,087 (77.3)	
Contracted with a general practitioner				
No	1,559 (52.7)	149 (57.3)	1,410 (52.2)	0.024
Yes	1,400 (47.3)	111 (42.7)	1,289 (47.8)	
Self-reported anxiety/depression status				
No anxiety/depression	2,632 (88.9)	223 (85.8)	2,409 (89.3)	0.753
Mild anxiety/depression	313 (10.6)	35 (13.5)	278 (10.3)	
Moderate anxiety/depression	14 (0.5)	2 (0.8)	12 (0.4)	
Social support** (mean±SD)				
Total score	38.76±7.74	33.07±8.09	39.31±7.48	<0.001
Subjective support score	23.32±4.89	20.51±4.92	23.59±4.80	<0.001
Objective support score	8.39±2.88	5.74±3.06	8.65±2.73	<0.001
Utilization of support	7.05±2.30	6.82±2.39	7.07±2.28	0.609

Abbreviation: PLADs=provincial-level administrative divisions; SD=standard deviation.

* Data are *n* (%) or mean±SD.

† Adjusted for gender, age, marital status, education level and scale of incomes.

§ The full score of health literacy is 26. A score of 80% or more (≥21) on the health literacy questionnaire is considered high health literacy.

¶ Outpatient rate of elderly who have fallen ill in the past two weeks. A total of 218 people falling ill in the past two weeks, including 26 elderly living alone.

** The social support revalued scale (SSRS) contains 10 items in total. Subjective support score: the sum of 1, 3, 4 and 5; Objective support score: the sum of 2, 6 and 7; The utilization of support: the sum of 8, 9 and 10.

adults. Ensuring GP registration for older adults living alone is crucial, as this population is vulnerable due to their distance from family and potential lack of healthcare access. Community-based GP health services are particularly important for older adults living alone to ensure appropriate health management (*9*). Juan Zheng et al. found that 29.3% of older adults in China intended to register for GP services, with influencing factors including self-reported health status, medical treatment history, chronic disease status, and understanding of the GP registration system (*10*). Promoting accessible and comprehensive healthcare services for older adults living alone is essential to address their unique needs and foster a sense of community and well-being. The present study found similar levels of chronic disease management and physical examination participation between older adults living alone and those living with family. This might be explained by the Essential Public Health Services program in China, which offers highly accessible and affordable care to all older adults.

This study is subject to several limitations. First, data were collected from May to September 2020. Although China's COVID-19 lockdown had been lifted and the government had implemented routine epidemic prevention and control measures, some older adults still chose to stay home or did not actively participate in this study. Additionally, only those willing to participate were included, potentially introducing selection bias. Therefore, the findings may not represent the entire target population, reflecting only the views and characteristics of individuals who actively volunteered. Second, because this study used cross-sectional data from a single year, the results can only demonstrate differences in the distribution of social characteristics, health literacy, and social support among older adults living alone, without verifying causality. Despite these limitations, this study included representative provinces and cities, enabling the generalizability of the conclusions. Additionally, this survey was based on officially published standards and guidelines in China, using a reliable scale suitable for measuring health literacy and service utilization among older adults from the perspective of national basic public health services.

This study examined elderly individuals aged 60 years and above living alone in China. The comprehensive measurements provide a potential reference for Chinese health service policymakers to promote comprehensive healthcare for this population. Targeted public health actions for elderly individuals living alone should prioritize health literacy and social support. Strengthening health literacy programs, establishing social support networks, and improving healthcare accessibility will enhance the health status and quality of life for this demographic.

Conflicts of interest: No conflicts of interest.

Acknowledgements: The support from community health service centers in Xicheng and Daxing Districts, Beijing. We also appreciate the kind help and support from Provincial Center for Disease Control and Prevention in Zhejiang; Provincial Patriotic Health and Health Promotion Center in Jiangxi; Provincial Health Education Center in Chongqing, Liaoning and Gansu.

doi: 10.46234/ccdcw2024.210

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Submitted: April 18, 2024; Accepted: July 18, 2024

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Indexed by Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), PubMed Central (PMC), Scopus, Chinese Scientific and Technical Papers and Citations, and Chinese Science Citation Database (CSCD)

The inauguration of *China CDC Weekly* is in part supported by Project for Enhancing International Impact of China STM Journals Category D (PIIJ2-D-04-(2018)) of China Association for Science and Technology (CAST).

CCDC weekly

Vol. 6 No. 39 Sept. 27, 2024

Responsible Authority

National Disease Control and Prevention Administration

Sponsor

Chinese Center for Disease Control and Prevention

Editing and Publishing

China CDC Weekly Editorial Office
No.155 Changbai Road, Changping District, Beijing, China
Tel: 86-10-63150501, 63150701
Email: weekly@chinacdc.cn

CSSN

ISSN 2096-7071 (Print)
ISSN 2096-3101 (Online)
CN 10-1629/R1