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Global, regional, and national burden of infective endocarditis from 2010 to 2021 and predictions for the next five years: results from the Global Burden of Disease Study 2021

Liyu Lin[1,2†], Jiongbo Xu[1,2†], Yuanru Chai[1,2] and Wei Wu[1,2,3*]

Abstract

Objective To comprehensively evaluate the global, regional, and national burden of infective endocarditis (IE) from 2010 to 2021, and to project future trends.

Methods This study utilized data from the Global Burden of Disease (GBD) Study 2021. Statistical methods, including joinpoint regression and the auto-regressive integrated moving average (ARIMA) model, were employed to analyze the prevalence, mortality, and disability-adjusted life years (DALYs) of IE, stratified by gender, age, and socio-demographic index (SDI).

Result From 2010 to 2021, the global prevalence of IE increased by 40.1%, with a total of 421,667 cases reported in 2021. The age-standardized prevalence rate (ASPR) rose from 4.7 per 100,000 to 5.3 per 100,000. Although the number of deaths increased by 23.01% and DALYs rose by 13.26%, both the age-standardized death rate (ASDR) and the age-standardized DALYs rate exhibited slight declines. Significant regional disparities in ASPR were observed, with an overall increase correlated with higher SDI levels. Joinpoint regression analysis revealed that the average annual percentage change (AAPC) in ASPR, ASDR, and age-standardized DALYs rate during this period was 0.8 (0.6, 1.0), -1.1 (-1.7, -0.5), and -1.3 (-1.9, -0.7), respectively. Notably, predictions from the ARIMA model indicate that the ASPR for men is expected to continue rising over the next five years, while a decline is anticipated for women; however, both genders are projected to experience a decrease in ASDR.

Conclusion Over the past decade, the ASPR of IE has been on a gradual increase, while the ASDR and the age-standardized DALY rate have slightly decreased. It is indicated that some progress has been achieved in the global disease management and treatment effectiveness of IE. Based on the increasing prevalence rate and the relatively high mortality rate, the burden of IE globally will still remain a major public health challenge in the future.

Keywords Infective endocarditis, Global Burden of Disease Study, Epidemiology, Socio-demographic Index, Joinpoint regression

†Liyu Lin and Jiongbo Xu shared first authorship and contributed equally to this work.

*Correspondence:
Wei Wu
zywuwei@163.com
Full list of author information is available at the end of the article

Introduction

Infective endocarditis (IE), characterized by the direct invasion of cardiac tissue by fungi, bacteria, or other microorganisms circulating in the bloodstream, imposes a significant global health burden [1]. Due to its complexity, IE demands immediate therapeutic intervention to mitigate mortality risk and prevent further damage to surrounding tissues and organs [2]. Despite aggressive antibiotic regimens and surgical interventions, IE persists as a severe and life-threatening condition [3]. Mortality rates associated with IE exhibit considerable variation depending on the availability of healthcare resources across countries and regions. The estimated in-hospital mortality rate is approximately 20%, with a one-year mortality rate escalating to nearly 30% [4]. Notably, IE mortality rates surpass those of certain cancers by up to 40% [5].

In the United States, the prevalence of IE has shown a consistent increase. Between 2000 and 2011, the annual prevalence rose from 11 to 15 cases per 100,000 individuals [6], despite updated prophylactic guidelines for IE. From 1970 to 2000, the annual prevalence remained statistically stable, ranging between 30 and 100 cases per 100,000 people. However, by 2019, this rate had gradually risen to 13.8 cases per 100,000 individuals [1].

Despite substantial progress in the prevention, diagnosis, and treatment of IE, the global burden of this disease remains significant, with marked disparities evident across regions and socioeconomic groups. Previous research has investigated the worldwide epidemiology of IE using data from the Global Burden of Disease (GBD) study. The GBD 2019 analysis demonstrated an increase in both the age-standardized prevalence rate (ASIR) and the age-standardized death rate (ASDR) for IE between 1990 and 2019 [7]. Specifically, the prevalence of IE escalated from 9.9 per 100,000 individuals in 1990 to 13.8 per 100,000 in 2019. This trend was mirrored in the mortality rate, which rose from 0.7 per 100,000 in 1990 to 0.9 per 100,000 in 2019. Additionally, disability-adjusted life years (DALYs) associated with IE exhibited a steady annual increase, reaching 1.72 million DALYs by 2019, with the annual death toll from IE reaching 66,300 in the same year.

To date, no comprehensive analysis utilizing the latest GBD 2021 data has been conducted to thoroughly assess the global burden of IE. To address this gap, the present study aims to provide an updated evaluation of the trends in IE prevalence, mortality, and DALYs from 2000 to 2021 at global, regional, and national levels. The analysis is stratified by sex, age, and socio-demographic index (SDI) to identify the populations most affected by IE, thus facilitating targeted prevention and treatment strategies.

Materials and methods

Data sources

In the GBD 2021 study, the latest epidemiological data and refined standardized methodologies were employed to conduct a comprehensive assessment of health losses associated with 369 diseases, injuries, and impairments, as well as 88 risk factors, across 204 countries and territories [8]. The GBD database utilizes sophisticated methods to address the issue of missing data and make adjustments for confounding factors, which have been elaborately recorded in the previously published literature [8, 9]. This study adheres to the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) [10]. The Institutional Review Board of the First Affiliated Hospital of Guangzhou University of Chinese Medicine determined that approval was not required for this study, as it utilized publicly available data.

Socio-demographic index

The SDI utilizes data on fertility rates, educational attainment, and per capita income to quantify the level of development in a country or region. Within a range of 0 to 1, a higher SDI indicates better socio-economic development [11]. In this study, countries and regions were categorized into five SDI groups: low, lower-middle, middle, high-middle, and high, this stratification was employed to investigate the relationship between the burden of IE and socio-economic development. Furthermore, a smooth spline model was utilized to assess the association between the burden of IE and SDI across 21 regions and 204 countries and territories.

Statistical analyses

Prevalence, mortality, DALYs, and their respective ratios per 100,000 individuals, serve as the primary indicators for quantifying the burden of endocarditis in the affected populations. Each ratio is accompanied by a 95% uncertainty interval (UI), determined using the GBD methodology [12–14], specifically, the uncertainty level is calculated by performing 1,000 random samplings at each computational step, integrating uncertainties from multiple sources, including input data variability, measurement error corrections, and residual non-sampling error estimates, the UI is defined as the range between the 25th and 975th percentiles of the ordered sampled values.

The joinpoint regression model is a linear statistical model designed to assess trends in disease burden over time [15]. This model estimates the changes in prevalence rates using the least squares method, thereby addressing the subjectivity inherent in traditional trend analyses based on linear models. By calculating the sum of squared residuals between the estimated and observed values, the inflection points of the moving trends can be determined. The model was constructed using Joinpoint software (version 4.9.1.0; National Cancer Institute) [15]. Furthermore, the average annual percent change (AAPC) was calculated and compared to zero to evaluate the statistical significance of fluctuations in different regions [16].

Based on the ASR from 2010 to 2021, an ARIMA model [17, 18] was constructed using the "forecast" package to predict the changes in prevalence and mortality of endocarditis by gender over the next five years. Data analysis and visualization were performed using R 4.3.2. Statistical significance was denoted by a two-tailed *p*-value of less than 0.05.

Results

Global level

In 2021, the global burden of IE remained substantial, with an estimated 421,667.2 cases (95% UI: 362,727.6, 482,472.1), reflecting a 40.09% increase compared to 2010. Similarly, the age-standardized prevalence rate (ASPR) rose from 4.7 (95% UI: 4.1, 5.2) in 2010 to 5.3 (95% UI: 4.6, 6.1) in 2021. The AAPC (95% CI) for age-standardized prevalence was 0.8 (95% CI: 0.6, 1.0), indicating a significant upward trend in the global prevalence of IE over the past decade (Table 1).

Mortality-related data revealed that the number of deaths in 2021 was 77,843.9 (95% UI: 69,010, 86,337.8), representing a 23.01% increase from 2010. Although the absolute number of cases increased significantly, the ASDR slightly declined from 1.1 per 100,000 population (95% UI: 0.9, 1.2) in 2010 to 1.0 per 100,000 population (95% UI: 0.9, 1.1) in 2021, the AAPC for ASDR was −1.1 (95% CI: −1.7, −0.5) (Table 1).

Additionally, the global burden of DALYs in 2021 was estimated at 2,076,412.9 (95% UI: 1,827,083.8, 2,308,504.2), representing a 13.26% increase compared to 2010. In 2021, the age-standardized DALYs rate was 25.6 per 100,000 population (95% UI: 22.3, 28.4), indicating a decrease from 2010, the AAPC for the age-standardized DALYs rate was −1.3 (95% CI: −1.9, −0.7) (Table 1).

Regional level

The global burden of IE exhibits significant regional disparities and is closely correlated with the SDI levels. Overall, the ASPR of IE increases with higher SDI levels (Table 1; Fig. 1). In low SDI regions, the ASR is reported as 4.2 (3.2, 5.4) per 100,000, whereas in high SDI regions, it rises to 9.8 (8.5, 11.2) per 100,000. However, this trend is not absolute; it is noteworthy that the ASR in low-middle SDI regions (3.3, 95% UI: 2.8–3.9) has decreased compared to low SDI regions.

On the other hand, an approximately U-shaped relationship was observed between different levels of SDI and ASDR (Table 1; Fig. 1). Compared to the medium SDI category, both low and high SDI regions exhibited higher ASDRs, with the lowest ASDR recorded in the medium SDI category at 0.6 (95% UI: 0.5, 0.7).

At the level of the 21 regions defined in the GBD framework, Western Europe, High-income North America, and Australasia ranked as the top three regions with the highest ASPR. In contrast, the three regions with the lowest ASPR were all located in Asia, specifically Central Asia, East Asia, and South Asia (Table 1; Fig. 1). Over time, compared to 2010, the ASDR for most regions showed an increase by 2021. The most significant increases were observed in Eastern Europe, Central Europe, and Western Europe, with rises of 66.7%, 33.3%, and 21.4%, respectively, indicating a notable rise in the burden of endocarditis in Europe over the past decade. However, not all regions experienced an upward trend. Central Latin America and Central Asia saw slight decreases in ASPR.

Country level

Figure 2 illustrates the distribution of the ASPR, ASDR, and age-standardized DALYs rates across 204 countries. The ASPR of endocarditis across 204 countries exhibits significant variation, ranging from 0.5 to 29.5, with most countries clustering between 4 and 10. For instance, the ASPR in the United States is 9.6, while in Sweden it is 8.8. In developing countries, such as Brazil, the prevalence is 6.6, and in India, it is 2.7.

Similarly, substantial differences are observed in ASDR due to IE, ranging from 0.1 to 3.7. Hungary reports a relatively high ASDR of 3.7, while the United States shows a significantly lower ASDR of 0.5. Uruguay records an ASDR of 1.2. In developing countries, such as Brazil and India, the ASDRs are 1.3 and 1.7, respectively.

While developed countries generally show higher average prevalence and mortality rates, exceptions exist. For example, France has an extraordinarily high prevalence rate of 29.5 (95% UI: 24.8, 35.0), but a remarkably low mortality rate of 0.1 (95% UI: 0.1, 0.1). The specific data for each country are provided in Table S1.

Age and sex differences and time trends

To investigate the effects of gender and age on the prevalence of endocarditis, the data on prevalence, mortality, and DALYs in 2021 were extracted and analyzed across different population subgroups (Fig. 3). The age groups with the highest number of patients are primarily concentrated in the ranges of 15–39 years and 65–90 years, which is consistent with current understanding, as individuals in the former group are more

Table 1 The prevalence, death and DALYs of endocarditis in 2010 and 2021 and its changing trends

Location	2010		2021		AAPC (95% CI)
	Number (95%UI)	ASR (per 100,000, 95% UI)	Number (95%UI)	ASR (per 100,000, 95% UI)	
Prevalence					
Global	301,000.2 (265,441.2,339,855.1)	4.7 (4.1,5.2)	421,667.2 (362,727.6,482,472.1)	5.3 (4.6,6.1)	0.8 (0.6, 1.0)
Low SDI	30,431.2 (22,815.5,40,262.2)	3.6 (2.8,4.6)	47,420.5 (34,796.5,63,412.8)	4.2 (3.2,5.4)	2.0 (1.8, 2.2)
Low-middle SDI	41,653.4 (35,424.4,49,622)	2.7 (2.3,3.2)	60,687.1 (50,741.4,73,193.5)	3.3 (2.8,3.9)	0.2 (0.1, 0.2)
Middle SDI	69,221.5 (60,421.8,79,305.7)	3.4 (3,3.9)	90,484.3 (79,395.9,103,371.6)	3.8 (3.3,4.3)	−0.9 (−1.1, −0.7)
High-middle SDI	45,919.3 (41,157.5,51,101.3)	3.7 (3.3,4.1)	63,095.1 (56,229.4,70,028.3)	4.4 (3.9,4.9)	2.7 (2.3, 3.2)
High SDI	113,489.4 (99,894.8,126,920.8)	8.4 (7.5,9.3)	159,612.4 (133,414,186,949.5)	9.8 (8.5,11.2)	−0.3 (−0.4, −0.2)
Andean Latin America	2271.8 (1917,2683.7)	4.3 (3.7,5)	3009.8 (2557.8,3556.5)	4.6 (4,5.5)	2.1 (1.9, 2.2)
Australasia	2530.7 (2188,2906.1)	7.6 (6.6,8.6)	4227.6 (3631.4,4907.2)	9.4 (8.1,10.7)	1.3 (1.2, 1.3)
Caribbean	2006.4 (1717.5,2324.7)	4.6 (4,5.4)	2267 (1949,2585)	4.7 (4.1,5.4)	4.4 (4.0, 4.8)
Central Asia	815.8 (698.6,953.9)	1 (0.9,1.2)	848.3 (737,987.1)	0.9 (0.8,1.1)	1.0 (1.0, 1.1)
Central Europe	5436 (4835,6129.7)	4.5 (3.9,5.1)	7059.7 (6231.1,8051.3)	6 (5.2,7)	1.2 (1.0, 1.4)
Central Latin America	10,815.5 (9253.9,12,697.9)	4.9 (4.2,5.6)	11,700.7 (10,072.7,13,553.6)	4.7 (4.1,5.5)	0.4 (0.3, 0.5)
Central Sub-Saharan Africa	3545.1 (2463.3,5011.9)	3.4 (2.5,4.6)	6111.6 (4148.9,8570.2)	4.2 (3,5.8)	1.5 (1.3, 1.6)
East Asia	24,707.3 (21,739.2,28,233.5)	1.9 (1.7,2.1)	36,462.3 (31,764.6,41,150.5)	2.2 (1.9,2.4)	1.5 (1.2, 1.7)
Eastern Europe	6291.8 (5484.7,7266.8)	3 (2.6,3.6)	9635.9 (8187.1,11,357.3)	5 (4.1,6)	1.4 (1.1, 1.6)
Eastern Sub-Saharan Africa	20,524.3 (14,653.4,28,066.7)	5.7 (4.2,7.6)	30,133.7 (20,831,41,884.4)	6.4 (4.6,8.5)	1.8 (1.7, 2.0)
High-income Asia Pacific	18,003.7 (15,053.8,21,148.7)	6.5 (5.7,7.4)	24,445.5 (19,365.1,30,706.7)	6.8 (5.8,7.8)	1.4 (1.3, 1.5)
High-income North America	36,087 (31,113.3,40,849.7)	8.5 (7.4,9.6)	48,667.3 (40,229.4,58,468.5)	9.9 (8.3,11.9)	0.9 (0.8, 1.0)
North Africa and Middle East	13,148.3 (11,435.6,15,201.1)	2.8 (2.5,3.1)	16,885.1 (14,548.3,19,343.1)	2.9 (2.6,3.3)	0.5 (0.3, 0.6)
Oceania	271 (224.9,317.8)	3.4 (3,3.9)	391.5 (327.6,463)	3.8 (3.2,4.3)	0.8 (0.8, 0.9)
South Asia	28,697.8 (24,948.2,32,889.1)	2.1 (1.8,2.3)	45,564.4 (39,258.9,52,440.3)	2.7 (2.3,3.1)	2.4 (2.2, 2.6)
Southeast Asia	26,601.9 (23,186.7,30,057.8)	5.1 (4.5,5.7)	34,227.4 (30,147.7,38,383)	5.5 (4.8,6.2)	0.7 (0.7, 0.8)
Southern Latin America	3709.2 (3168.8,4270.3)	5.8 (5,6.6)	4524.4 (3884.4,5299.5)	6 (5.2,6.9)	0.3 (0.3, 0.4)
Southern Sub-Saharan Africa	4480.3 (3308.9,6014.9)	5.7 (4.4,7.5)	5503.7 (4060.2,7401)	6.6 (5,8.8)	1.3 (0.8, 1.8)
Tropical Latin America	12,808.4 (11,035.9,15,007.5)	6.6 (5.8,7.7)	14,946.6 (12,820.1,17,749.8)	6.7 (5.7,8)	0.1 (−0.0, 0.2)
Western Europe	63,217.7 (56,005.3,70,715.9)	10.3 (9.3,11.3)	90,490.9 (75,587.7,108,637.8)	12.5 (10.8,14.2)	1.8 (1.4, 2.2)
Western Sub-Saharan Africa	15,030.4 (11,058.7,20,024.2)	4.3 (3.2,5.6)	24,563.7 (17,959.8,32,786.9)	5 (3.7,6.5)	1.4 (1.4, 1.5)
Death					
Global	63,285.8 (56,776.5,69,180.2)	1.1 (0.9,1.2)	77,843.9 (69,010,86,337.8)	1 (0.9,1.1)	−1.1 (−1.7, −0.5)
Low SDI	6105.5 (4094.1,7754.4)	1.4 (0.9,1.8)	7782.1 (5220.3,10,127.2)	1.3 (0.9,1.7)	1.2 (0.0, 2.3)
Low-middle SDI	10,120.4 (8190.7,12,069.3)	0.9 (0.7,1.1)	12,137.6 (9925.6,14,664.2)	0.8 (0.7,1)	0.3 (0.1, 0.5)
Middle SDI	11,590.5 (10,356,14,546.2)	0.6 (0.6,0.8)	13,864.9 (12,121.5,17,626.1)	0.6 (0.5,0.7)	−1.4 (−1.8, −0.9)
High-middle SDI	10,270.5 (9415.3,10,944.1)	0.8 (0.7,0.8)	12,498 (11,240,13,378.6)	0.7 (0.6,0.7)	0.8 (−0.3, 1.9)
High SDI	25,136.7 (21,784,26,911.5)	1.4 (1.2,1.5)	31,485.1 (26,951.9,34,018.3)	1.3 (1.2,1.4)	−1.2 (−1.6, −0.8)
Andean Latin America	218.4 (182.1,251.3)	0.5 (0.4,0.5)	247.2 (196.8,300.4)	0.4 (0.3,0.5)	−0.5 (−0.6, −0.4)
Australasia	382.1 (337,412.2)	0.9 (0.8,1)	623 (536.5,682.3)	1.1 (1,1.2)	−1.9 (−2.3, −1.6)
Caribbean	409.4 (355.4,469.7)	0.9 (0.8,1.1)	500.5 (413,601.9)	1 (0.8,1.2)	1.2 (−0.4, 2.8)
Central Asia	149.3 (136.4,161.1)	0.2 (0.2,0.2)	149.1 (130.3,167.5)	0.2 (0.2,0.2)	−1.1 (−1.1, −1.0)
Central Europe	1036 (976.2,1079)	0.6 (0.6,0.6)	1274.2 (1163.1,1389.2)	0.6 (0.6,0.7)	−0.8 (−1.0, −0.6)
Central Latin America	1169.3 (1122.6,1208.3)	0.6 (0.6,0.6)	1337.1 (1178.4,1505.5)	0.5 (0.5,0.6)	−2.3 (−2.6, −2.0)
Central Sub-Saharan Africa	780 (436.7,1113.9)	1.8 (1,2.6)	1018.3 (557.9,1506.8)	1.7 (0.9,2.5)	−0.3 (−0.5, −0.1)
East Asia	2366.6 (2061.9,3041.2)	0.2 (0.2,0.3)	2813.3 (2367.6,3539.1)	0.2 (0.1,0.2)	−0.6 (−1.0, −0.3)
Eastern Europe	2168.4 (2116.4,2230.7)	0.8 (0.8,0.8)	2563.9 (2381.5,2739.7)	0.9 (0.8,1)	−0.5 (−0.9, −0.2)
Eastern Sub-Saharan Africa	2479.5 (1587.2,3372.7)	1.6 (1,2.1)	3049.4 (1987.3,4273.1)	1.4 (0.9,1.9)	−0.7 (−0.8, −0.5)
High-income Asia Pacific	4529.5 (3613.6,5096.9)	1.1 (0.9,1.2)	5583.7 (4267.6,6416.1)	0.8 (0.7,1)	−0.4 (−0.6, −0.2)
High-income North America	8893.6 (7776.7,9507)	1.7 (1.5,1.8)	10,589.4 (9280.7,11,349.3)	1.6 (1.4,1.7)	−1.1 (−1.1, −1.0)
North Africa and Middle East	2351.5 (1900.5,2888)	0.7 (0.6,0.9)	2589.3 (2130.7,3420.2)	0.6 (0.5,0.8)	−1.4 (−1.7, −1.2)
Oceania	139.8 (105.8,187.8)	2.1 (1.6,3)	195.1 (141.9,271.5)	2.1 (1.6,3)	0.1 (−0.1, 0.3)
South Asia	9408.3 (7206.1,11,235.8)	0.9 (0.7,1)	11,823.1 (9270,14,110.1)	0.8 (0.6,1)	−0.5 (−1.0, −0.1)
Southeast Asia	6373.4 (5163.6,9135)	1.4 (1.1,2)	7494 (5824.8,10,960.6)	1.2 (1,1.8)	−1.0 (−1.2, −0.8)

Table 1 (continued)

Location	2010		2021		AAPC (95% CI)
	Number (95%UI)	ASR (per 100,000, 95% UI)	Number (95%UI)	ASR (per 100,000, 95% UI)	
Southern Latin America	1422.7 (1330.6,1495.6)	2 (1.9,2.1)	1421.1 (1298.8,1522.4)	1.6 (1.5,1.7)	−1.8 (−2.1, −1.4)
Southern Sub-Saharan Africa	564.2 (440.1,680.5)	1.1 (0.8,1.3)	633.4 (530.9,811.9)	1 (0.8,1.2)	−0.9 (−1.1, −0.6)
Tropical Latin America	2181.5 (2078.2,2263.9)	1.2 (1.1,1.2)	2685.7 (2511.6,2815.4)	1.1 (1,1.1)	−1.1 (−1.4, −0.9)
Western Europe	13,930.5 (12,169.9,14,921.5)	1.6 (1.4,1.7)	18,319.7 (15,574.2,19,954)	1.6 (1.4,1.7)	0.3 (0.1, 0.4)
Western Sub-Saharan Africa	2331.7 (1350.8,3164)	1.4 (0.8,1.9)	2933.4 (1638.2,4134.8)	1.2 (0.7,1.7)	−0.8 (−1.0, −0.7)
DALYs					
Global	1,833,361 (1,600,511.6,2,020,599.4)	27.8 (24.3,30.6)	2,076,412.9 (1,827,083.8,2,308,504.2)	25.6 (22.3,28.4)	−1.3 (−1.9, −0.7)
Low SDI	273,251.2 (177,512.1,341,460.8)	43.3 (29.1,55.1)	339,524.2 (220,719.2,443,733.2)	40.7 (27.4,53)	1.2 (0.1, 2.3)
Low-middle SDI	403,360.6 (319,925.7,469,988.9)	28.9 (23.2,34.1)	443,018.1 (360,737.4,525,611.7)	26 (21.2,30.9)	0.4 (−0.1, 0.9)
Middle SDI	432,834.2 (392,459.1,528,787.4)	20.6 (18.7,25.2)	456,988.4 (405,398,570,414.4)	17.9 (15.9,22.4)	−2.6 (−3.2, −2.1)
High-middle SDI	276,206.6 (262,364.6,296,374.6)	20.3 (19.2,22)	297,630.2 (279,572.7,319,558.7)	18.3 (17.1,19.8)	0.5 (−0.7, 1.6)
High SDI	445,645 (408,059.9,466,331.3)	29 (27.1,30.2)	536,898.5 (489,608,567,759.2)	28.6 (26.6,30)	−1.8 (−2.1, −1.5)
Andean Latin America	9726.6 (8100.5,11,387.5)	18.8 (15.6,21.9)	9992.3 (7992.1,12,380.4)	15.5 (12.5,19.2)	−0.6 (−0.7, −0.6)
Australasia	7236.5 (6653.7,7674.9)	20 (18.6,21.2)	11,314.8 (10,254.1,12,180.4)	23.5 (21.7,25.3)	−2.1 (−2.2, −1.9)
Caribbean	16,075.8 (13,109.9,18,824.8)	36.9 (30,43.5)	19,027.4 (14,887.6,23,517.6)	39.2 (30.2,49)	0.8 (−0.9, 2.6)
Central Asia	6941.6 (6274.4,7605.7)	8.7 (7.8,9.4)	6000.4 (5209,6882.8)	6.4 (5.6,7.3)	−1.1 (−1.1, −1.0)
Central Europe	29,223.6 (27,858.9,30,320.4)	18.3 (17.5,19)	33,123.2 (30,400.3,36,042.3)	19.3 (17.7,20.9)	−0.8 (−0.9, −0.6)
Central Latin America	47,493.6 (45,455.1,49,756.5)	22.5 (21.6,23.5)	46,052.8 (40,241,52,614)	18.4 (16.1,21.2)	−2.1 (−2.4, −1.9)
Central Sub-Saharan Africa	33,622.6 (17,987.7,47,433.1)	51.4 (29.3,73.4)	41,708.1 (22,801,61,469.5)	47.9 (26.5,70.8)	0.7 (0.3, 1.2)
East Asia	72,655.4 (62,411,96,206.2)	5.8 (5,7.8)	70,985.4 (59,079.7,92,253.6)	4.6 (3.7,6.2)	−0.8 (−1.4, −0.3)
Eastern Europe	89,480.4 (87,330.6,92,148.1)	35.9 (35,37.1)	96,914.7 (89,999.2,103,916.2)	38.6 (35.8,41.5)	−0.1 (−0.4, 0.1)
Eastern Sub-Saharan Africa	119,337.3 (76,403.3,160,088.7)	50.6 (32.3,69)	142,679 (93,701.3,199,451.9)	45 (29.5,62.9)	−0.9 (−1.1, −0.8)
High-income Asia Pacific	66,816.2 (56,903.9,73,873.2)	19.3 (17.1,21.3)	73,249.8 (59,719.2,83,213.5)	15.3 (13.4,17.4)	−0.5 (−0.6, −0.4)
High-income North America	169,430.9 (156,314.9,177,334)	35.6 (33.3,37)	211,635.1 (195,398,223,604.7)	38.5 (36,40.5)	−1.3 (−1.3, −1.2)
North Africa and Middle East	101,265.9 (77,422.4,119,714.8)	22.3 (17.4,26.4)	96,363.2 (77,215,121,351.6)	17.8 (14.5,22.7)	−2.0 (−2.0, −1.9)
Oceania	6684.9 (5027.6,8840)	73.5 (55.7,98.3)	9093.3 (6503.6,12,389.9)	75.4 (54.5,104.3)	0.2 (0.0, 0.4)
South Asia	348,461.4 (266,914,414,200.5)	26.5 (20.3,31.3)	401,831.7 (315,555.3,481,638.1)	24.2 (18.9,28.9)	−0.8 (−1.0, −0.6)
Southeast Asia	240,200.7 (199,371,334,363.8)	42.4 (34.9,59.7)	254,838.6 (202,734.3,361,941.3)	37 (29.3,52.8)	−1.2 (−1.3, −1.2)
Southern Latin America	32,484.4 (31,086.6,33,754.4)	48.4 (46.4,50.2)	31,625.1 (29,434.4,33,645)	38.3 (35.7,40.7)	−1.8 (−2.1, −1.4)
Southern Sub-Saharan Africa	25,036.4 (19,782.6,29,995.8)	39.3 (30.7,47.2)	27,175.8 (23,055.6,34,834.1)	35.8 (30.3,45.9)	−0.8 (−1.1, −0.6)
Tropical Latin America	78,056.7 (75,274.5,80,747.8)	39.8 (38.2,41.3)	84,372.3 (80,580.2,87,805.9)	33.9 (32.4,35.3)	−1.8 (−2.0, −1.5)
Western Europe	228,577.5 (208,295,240,342.9)	30.9 (28.7,32.2)	275,986.8 (246,485.4,295,826.5)	30.6 (28.2,32.4)	−0.1 (−0.5, 0.3)
Western Sub-Saharan Africa	104,552.4 (58,842.4,139,650.4)	40.5 (23.6,55.2)	132,443.2 (72,027.4,184,106.1)	37.2 (21,52.3)	−0.8 (−0.9, −0.6)
Western Sub-Saharan Africa	1,833,361 (1,600,511.6,2,020,599.4)	27.8 (24.3,30.6)	2,076,412.9 (1,827,083.8,2,308,504.2)	25.6 (22.3,28.4)	−1.3 (−1.9, −0.7)

ASR Age-standardized rate, *AAPC* Average annual percentage change, *SDI* Socio-demographic index

likely to experience heart and organ damage due to heightened immune responses, while those in the latter group are more susceptible to infections as a result of the decline in physiological function. Among different age groups, it was observed that the ASPR, ASDR, and age-standardized DALYs rate of endocarditis exhibited a gradual increase with advancing age. Notably, a significant inflection point for both ASPR and ASDR dwas identified in the age group of 60 to 64 years. Prior to this age, the influence of increasing age on ASPR and ASDR was not significant; however, following the onset of the 60–64 age group, a rapid escalation in both prevalence and mortality associated with endocarditis was evident.

When comparing different genders, it was found that the ASPR and ASDR for endocarditis were remarkably similar across the majority of age groups. However, in the age bracket of 90 to 94 years, the ASPR and ASDR for males exhibited a marked increase that surpassed those of females.

The trends of ASPR, ASDR, and age—standardized DALYs rates regarding global endocarditis during 2010—2021 are depicted in Fig. 4. During this period, a significant increase in the global ASPR of endocarditis, along with significant decreases in both ASDR and DALYs, are witnessed.

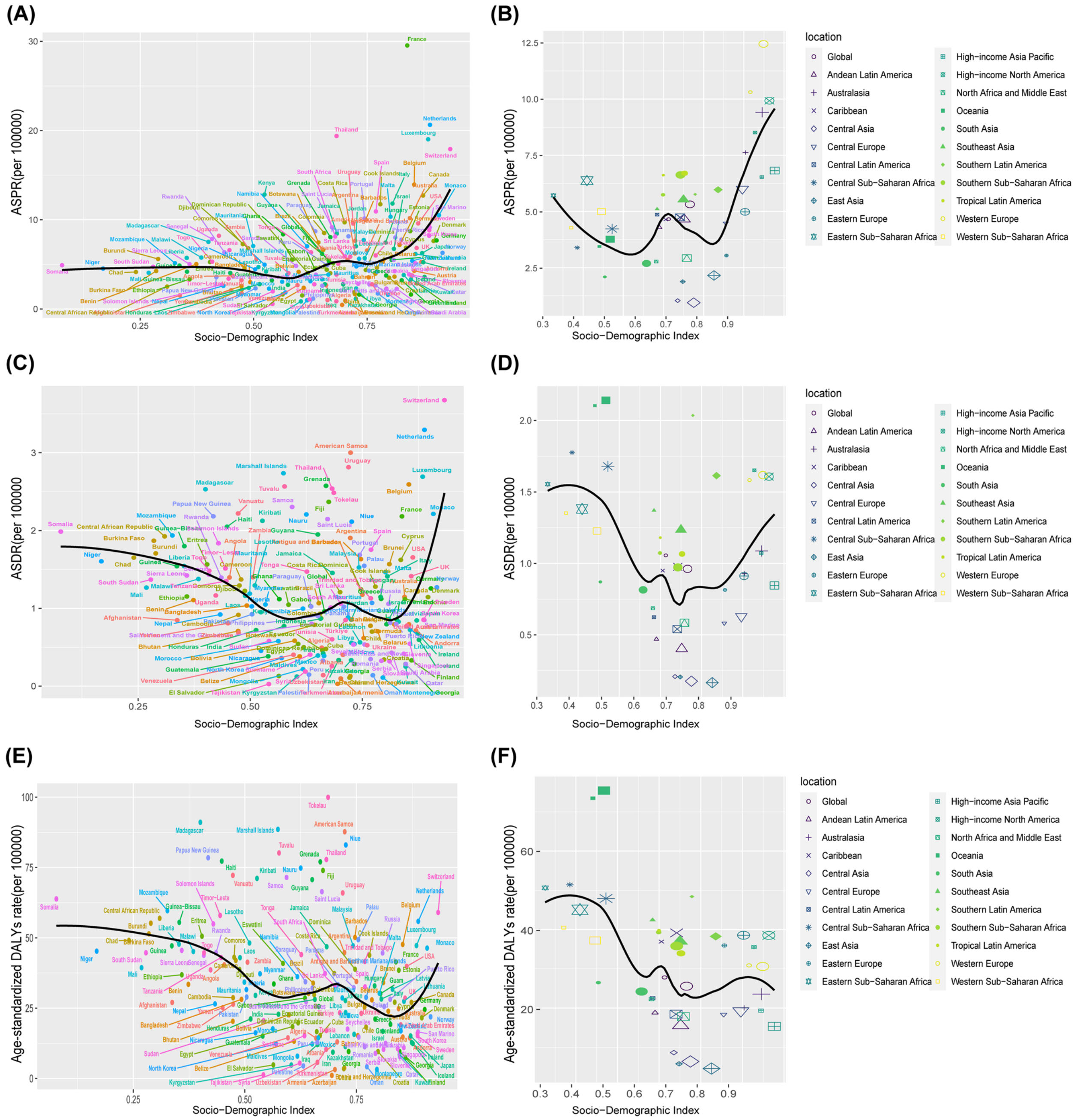

Fig. 1 Relationship between socio-demographic index levels and age-standardized prevalence, mortality, and disability-adjusted life years rates in 204 countries and 22 regions in 2021, with nonlinear fit trends indicated by black lines

Joinpoint regression analysis

The trends of ASPR, ASDR, and age-standardized DALYs rate for IE from 2010 to 2021 were evaluated globally and across quintile regions classified by the SDI using joinpoint regression analysis, as illustrated in Fig. 5.

In terms of ASPR, a general upward trend was observed globally. Specifically, the average annual percent change (APC) from 2010 to 2014 was 1.76, 1.32 from 2014 to 2018, and 0.33 from 2018 to 2021. In high SDI regions, an upward trend was noted with an APC of 2.33 from 2010 to 2014, 1.40 from 2014 to 2018, and 0.09 from 2018 to 2021. High-middle SDI regions also experienced an upward trajectory with an APC of 2.24 from 2010 to 2014, 1.38 from 2014 to 2018, and 0.59 from 2018 to 2021. In low-middle SDI regions, a continuous rise occurred, marked by an APC of 2.12 from 2010 to 2019

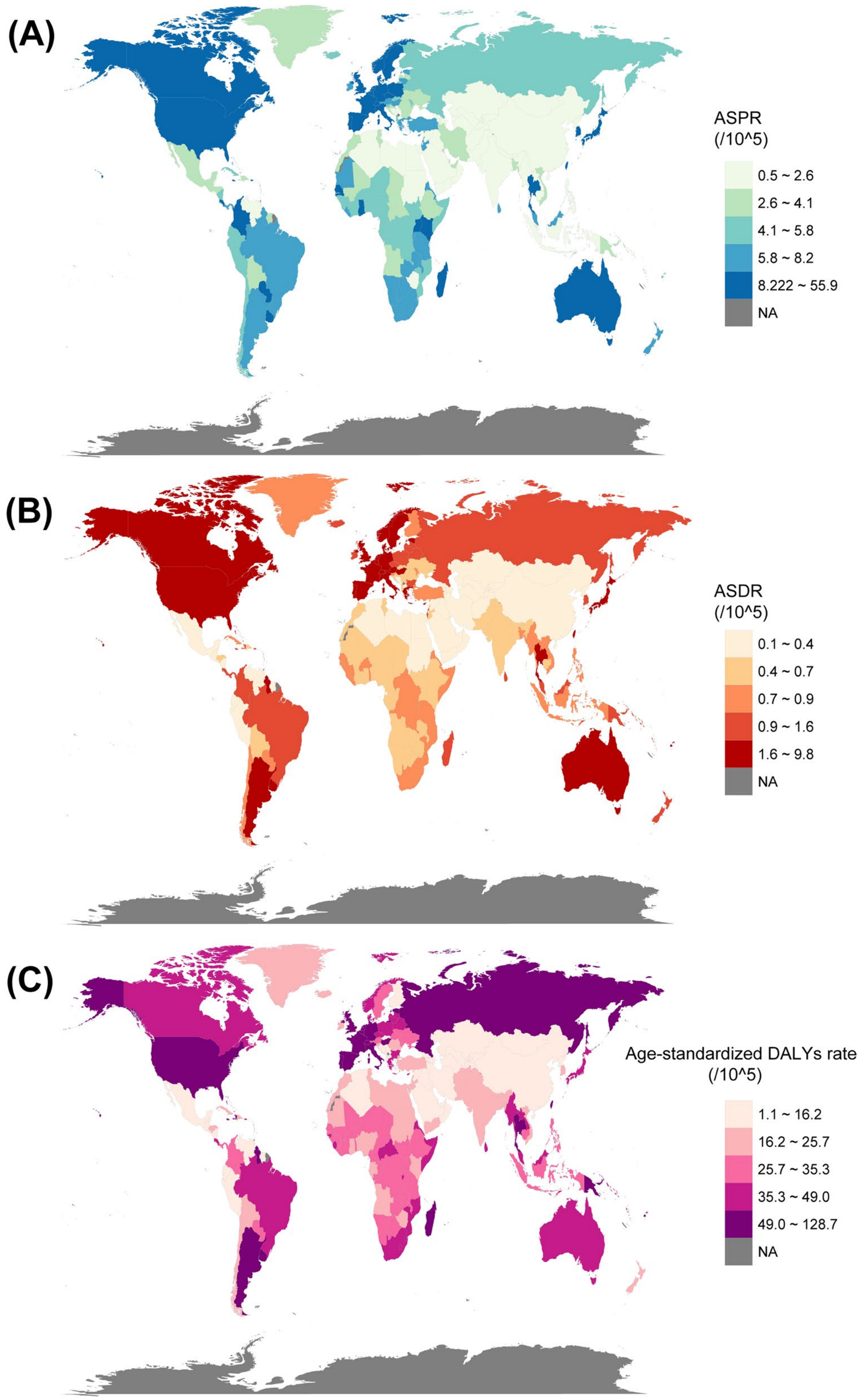

Fig. 2 Age-standardized prevalence rates, age-standardized death rates and age-standardized DALYs rates of infective endocarditis by location for both sexes, 2021

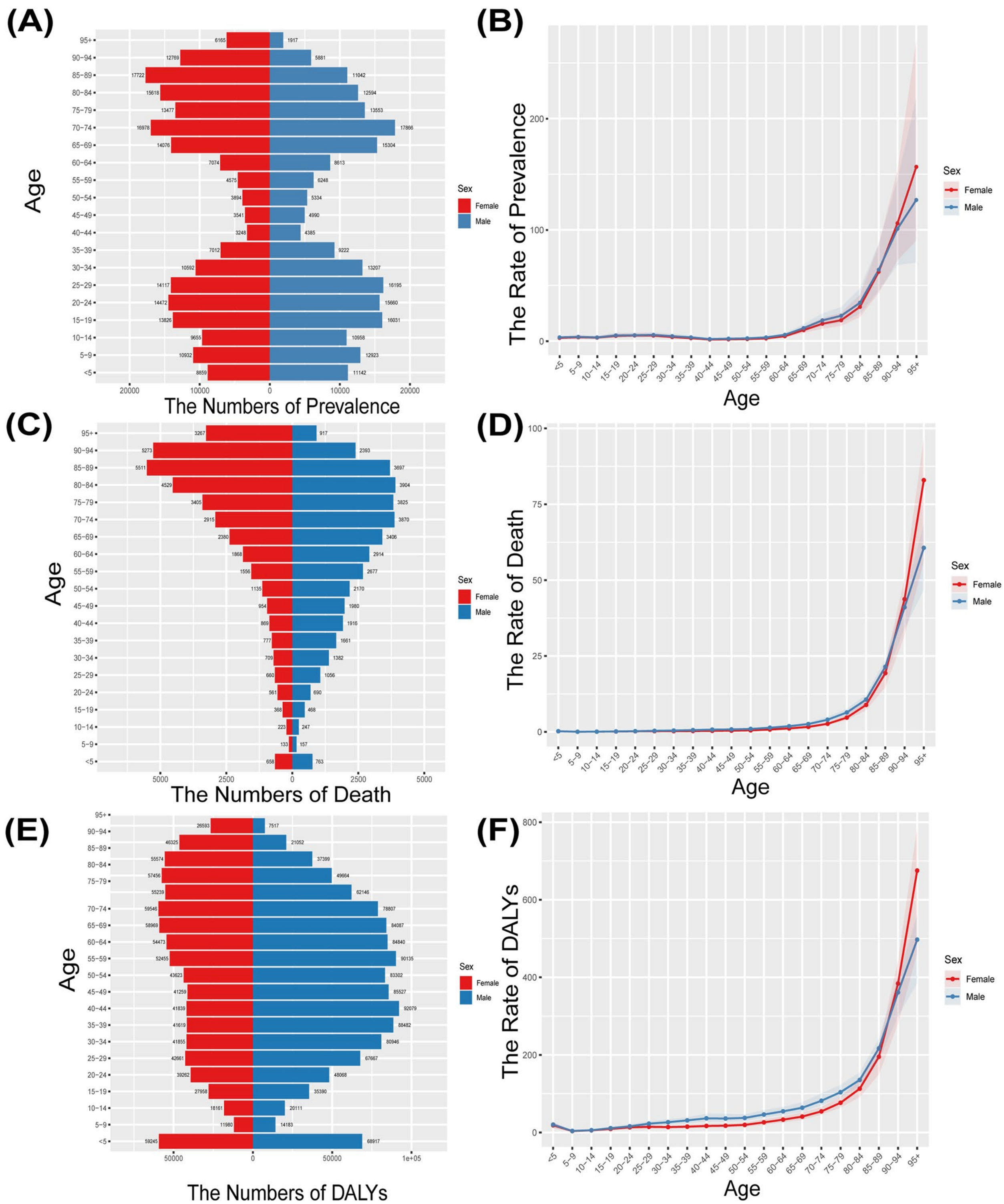

Fig. 3 Global prevalence, mortality, and DALYs of endocarditis in 2021: age-standardized rates and age-specific numbers. **A** Prevalence numbers by age group and gender. **B** Age-standardized prevalence rates by age group and gender. **C** Death numbers by age group and gender. **D** Age-standardized death rates by age group and gender. **E** DALYs numbers by age group and gender. **F** Age-standardized DALYs rates by age group and gender

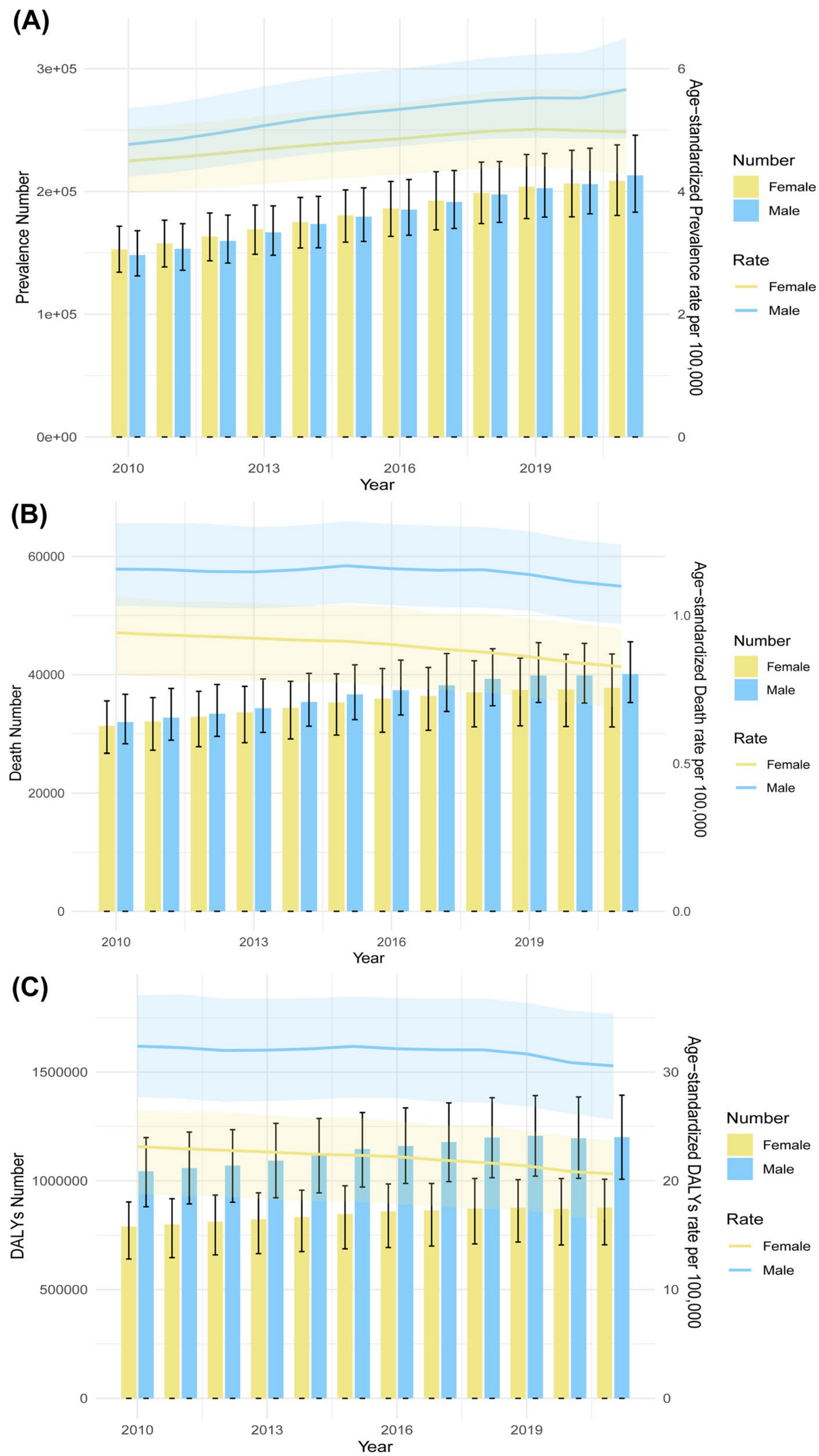

Fig. 4 Trends in endocarditis cases, age-standardized prevalence, mortality, and DALYs rates by gender across all age groups from 2010 to 2021. **A** Prevalence numbers and rates. **B** Mortality numbers and rates. **C** Numbers and rates of DALYs

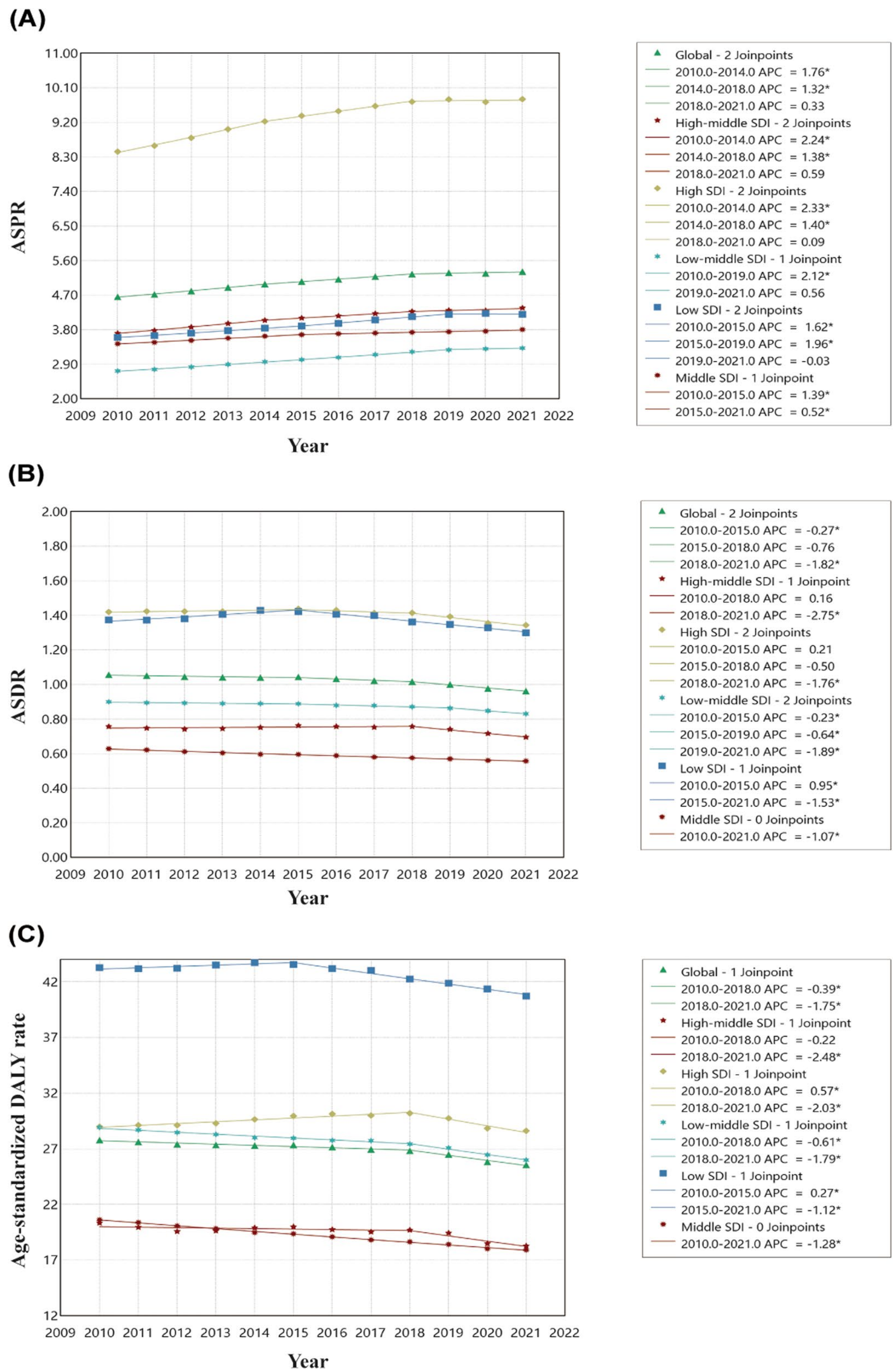

Fig. 5 Joint point regression analysis of age-standardized rates for global infective endocarditis from 2010 to 2021. **A** Joint point regression analysis of age-standardized prevalence rate. **B** Joint point regression analysis of age-standardized death rate. **C** Joint point regression analysis of age-standardized disability-adjusted life years rate

and 0.56 from 2019 to 2021. Conversely, low SDI regions exhibited an initial increase followed by a slight decline, with an APC of 1.62 from 2010 to 2015, 1.96 from 2015 to 2019, and −0.03 from 2019 to 2021. Moderate SDI regions demonstrated a gradually decelerating increase, characterized by an APC of 1.39 from 2010 to 2015 and 0.52 from 2015 to 2021.

For ASDR, a global decline was evident. The APC from 2010 to 2015 was −0.27, −0.76 from 2015 to 2018, and −1.82 from 2018 to 2021. High SDI regions experienced an overall decline with an APC of 0.21 from 2010 to 2015, −0.50 from 2015 to 2018, and −1.76 from 2018 to 2021. In high-middle SDI regions, a stable period was followed by a significant decrease, with an APC of 0.16 from 2010 to 2018 and −2.75 from 2018 to 2021. Low-middle SDI regions showed a sustained decline with an increasing rate, marked by an APC of −0.23 from 2010 to 2015, −0.64 from 2015 to 2019, and −1.89 from 2019 to 2021. Low SDI regions initially rose but later declined, with an APC of 0.95 from 2010 to 2015 and −1.53 from 2015 to 2021. Moderate SDI regions consistently decreased, with an APC of −1.07 from 2010 to 2021.

Regarding DALYs, a global declining trend was observed. The APC was −0.39 from 2010 to 2018 and −1.75 from 2018 to 2021. In high-middle SDI regions, a gradual decline in the earlier period accelerated over time, with an APC of −0.22 from 2010 to 2018 and −2.46 from 2018 to 2021.

These trend analyses enhance the understanding of the changing burden of IE globally and across various SDI regions.

Five-year forecast of the global burden of IE

Results from the ARIMA models indicate a diverging trend in the ASPR between genders over the next five years. Specifically, the ASPR for males is projected to increase, reaching 6.1 per 100,000 by the year 2026, whereas the ASPR for females is expected to decrease to 4.9 per 100,000 within the same timeframe. Concurrently, mortality rates for both genders are forecasted to decline, with the rates dropping to 1.0 per 100,000 for males and 0.8 per 100,000 for females by 2026 (Fig. 6). All models demonstrated robust predictive performance, with detailed information provided in Table S2.

Discussion

This study offers a comprehensive and up-to-date assessment of the global burden of IE from 2010 to 2021. During this period, a substantial 40.09% increase in the prevalence of IE was observed worldwide, with the age-standardized prevalence rate rising from 4.7 cases per 100,000 individuals to 5.3 cases per 100,000. Additionally, the number of deaths attributed to IE rose by 23.01%, and the associated DALYs increased by 13.3%. Notably, both the ASDR and the age—standardized DALYs rate showed slight declines. At the regional level, significant variations

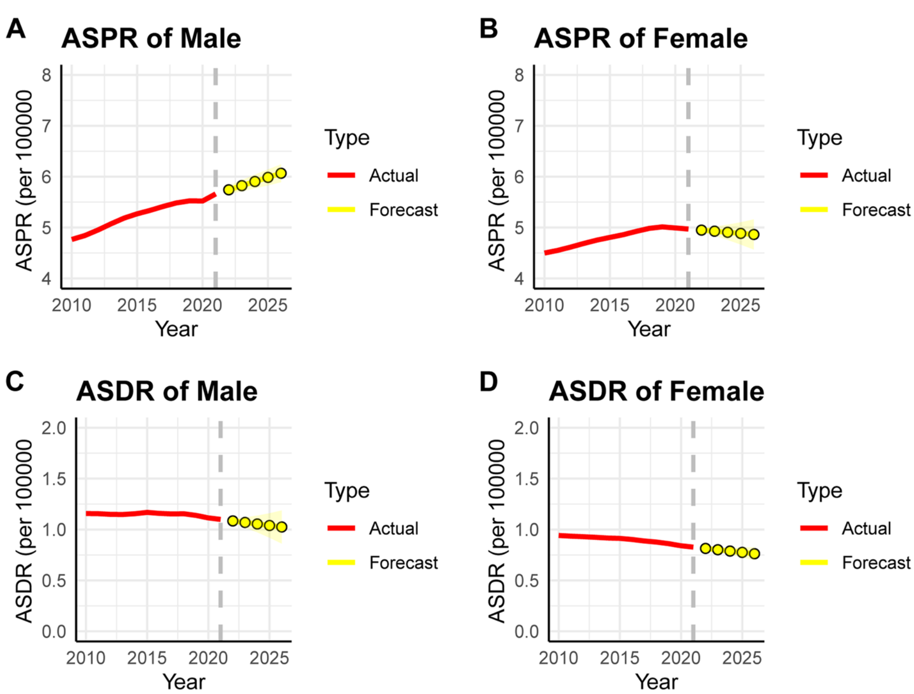

Fig. 6 Prediction of age-standardized prevalence rate and age-standardized death rate in the next five years. ASPR, age-standardized prevalence rate. ASDR, age-standardized death rate

in the ASPR were observed, with an overall trend of increasing rates that correlates positively with the SDI. At the national level, notable differences in IE—related metrics were also evident, developed countries generally exhibit higher ASPR. Furthermore, according to projections from the ARIMA model, the ASPR in males is expected to continue rising over the next five years, while a decline in this rate is anticipated among females. Nevertheless, the ASDR for both sexes is expected to decrease. These findings provide essential insights to guide further research and the optimization of global strategies for the prevention and control of IE.

These trends seem to suggest that advancements in medical practices have brought about an overall improvement in the global diagnosis and treatment of IE. The increase in prevalence is likely associated with population aging, enhancements in diagnostic techniques, and improved disease identification rates. Over the study period, significant advancements in diagnostic technologies, particularly in echocardiography, have likely contributed to the observed increase in IE prevalence. Improved imaging techniques, such as high-resolution transesophageal echocardiography, may have enhanced the detection of smaller vegetations and early-stage IE, leading to higher reporting rates [19, 20]. However, these advancements also raise questions about the potential overdiagnosis of 'possible' IE cases, which should be carefully considered in future studies. Furthermore, It is believed that the decline in mortality rates related to IE is primarily attributed to the implementation of more effective treatment protocols, refined antibiotic usage, and timely medical interventions. The reduction in DALYs highlights an improvement in the quality of recovery among treated patients and a decrease in the incidence of complications. A greater number of previously undiagnosed cases of IE have been identified and managed through more systematic treatment approaches, thereby reducing the mortality risk for affected individuals. These trends reflect significant advancements in disease management and treatment. Overall, the data underscore the successes of global health systems in managing cardiovascular diseases over the past decade. Additionally, they illustrate that the growth of the population, along with aging demographics, constitutes critical factors contributing to the observed increases in prevalence and mortality rates [21].

Historically, IE has been regarded as a subacute disease primarily caused by streptococci and enterococci, frequently affecting younger populations. People in low SDI regions may get infected due to inadequate health conditions. Recent data, however, reveal shifting epidemiological patterns, particularly in regions with varying socioeconomic development. The ASPR has shown a notable increase in medium and high SDI regions, while remaining elevated in low SDI areas. This divergence may reflect distinct underlying drivers: ①The overall aging population in high SDI regions contributes significantly to this phenomenon. ②Improvements in medical conditions have led to an increase in the number of individuals with IE, particularly among those with cardiac devices (such as permanent pacemakers and implantable cardioverter-defibrillators), increased vascular interventions (including the rising number of chronic kidney disease patients undergoing hemodialysis [22]), and enhanced availability of venous catheters [23], which has resulted in a growing elderly patient population [10]. ③Several studies have reported that the development of invasive dental procedures [24], immunosuppression, cancer, diabetes, and intravenous drug [25] use also contributes to the rising prevalence of IE. ④Additionally, Staphylococcus and enterococci, both common causes of nosocomial infections and not targeted by current antibiotic prophylaxis strategies, may further drive this increase. Although less common, the occurrence of IE caused by Campylobacter, known for its high pathogenicity, should also be seriously considered. ⑤Moreover, it is important to note that high SDI regions possess advanced medical technologies capable of facilitating early detection and diagnosis, and have more widespread access to social health insurance, leading to increased reporting rates of IE. Among various regions, Western Europe exhibits the highest ASPR, with France standing out as the leading country. While France has a notably high prevalence, it also demonstrates a relatively low mortality rate. Therefore, targeted studies of France's healthcare policies, geographic factors, and climate may provide valuable insights for alleviating the global burden of IE.

An approximate U-shaped relationship has been observed between different SDI levels and both ASDR and age-standardized DALYs rate. In low SDI regions, the increase in mortality is primarily attributed to insufficient medical facilities, a lack of pharmaceutical resources, limited access to primary healthcare services, and high disease prevalence. These regions also face significant challenges related to infectious diseases and malnutrition, and the limited healthcare infrastructure exacerbates diagnostic delays and poor medical care, creating a vicious cycle that further heightens mortality rates. Conversely, in high SDI regions, the increase in mortality is typically associated with non-communicable diseases related to lifestyle, such as cardiovascular diseases, cancer, and diabetes. Patients with IE in high SDI areas are often older, physically frail, and suffer from multiple comorbidities; while streptococci and enterococci are primarily community-acquired, the increased accessibility to healthcare services has led to a higher incidence of these infections. Currently, enterococci have emerged as the most frequently isolated pathogens in transcatheter aortic valve implantation (TAVI) [26].

Interestingly, medium SDI regions exhibit lower ASDR and age-standardized DALYs rates. This may be due to better healthcare infrastructure compared to low SDI regions, and these areas have not yet fully confronted the lifestyle-related challenges faced by high SDI regions, resulting in a beneficial equilibrium.

This phenomenon underscores the complex interplay between socioeconomic development and disease prevalence, influenced by factors such as population aging, healthcare accessibility, lifestyle changes, and variations in antibiotic resistance patterns. Therefore, the correlation between SDI levels and disease burden should be interpreted cautiously and regarded as a partial reference.

Prior studies indicated a consistent rise in the prevalence and m ˎ ortality rates among females before 2019 [27]. However, data from the 2021 GBD study show a decline in age-standardized prevalence and mortality rates for females from 2019 to 2021. Additionally, predictions from the ARIMA model suggest a downward trend in female ASPR, which contrasts with the trend observed in males. The observed gender differences in ASPR trends are believed to result from a variety of factors, including lifestyle differences, healthcare accessibility, and social pressure. Males are generally more prone to engage in high-risk behaviors such as smoking and alcohol consumption [28, 29]. Moreover, they may face greater physical labor and occupational injury risks [30]. In some regions, traditional gender norms may contribute to males suppressing emotional expressions and underestimating health concerns, leading to a lower likelihood of seeking medical help [31, 32]. The combined effect of these factors may explain the increase in ASPR observed in males. Nonetheless, caution should be exercised in interpreting these results, as previous research [33, 34] has highlighted discrepancies between GBD data and actual conditions. This study is based on secondary analysis of existing data and should be considered as a reference point. Given the dynamic nature of GBD data, regular updates and evaluations will be essential for verifying the accuracy of these findings.

The primary strength of this study is found in its systematic assessment of the global burden of IE from 2010 to 2021, encompassing various age groups, gender categories, countries, regions, and socioeconomic levels. Several limitations are acknowledged within this research. First, the estimation of the burden of IE is largely dependent on the availability and quality of data from the GBD 2021. A lack of access to original data in some countries, particularly those with low and middle incomes, may hinder the ability of GBD researchers to produce accurate estimates. Second, while this study primarily focuses on describing the global burden of IE, it does not encompass other related cardiovascular diseases or complications, which could result in a limited understanding of the overall impact of IE. Third, variations in diagnostic and detection standards for IE across different countries may affect the comparability of results, especially when considering changes over time. Given the uncertainties associated with the raw data, caution is warranted in interpreting the trends in IE burden identified in this study. Fourth, GBD data may be affected by differences in diagnostic accuracy and coding practices across regions. The validity of IE diagnoses in claims data can be influenced by differences in healthcare systems, diagnostic criteria, and reporting standards. This could potentially lead to over- or under-estimation of the true burden of IE. Finally, an excessive emphasis on statistical significance may overlook the clinical relevance of the findings. While the GBD Study provides a comprehensive assessment of IE burden, the analysis is based on aggregated data, which may lack granularity in capturing regional and temporal variations in disease patterns. Future studies incorporating more detailed, individual-level data could provide additional insights into the epidemiology of IE. Despite these limitations, our findings remain relevant for understanding the global burden of IE and identifying regions and populations at higher risk. The results can inform public health strategies and resource allocation to address the growing burden of IE, particularly in aging populations and regions with limited healthcare resources.

Conclusion

In conclusion, based on data analysis from the 2021 GBD Study covering the period from 2010 to 2021, IE has emerged as a significant global health burden. Globally, the ASPR of IE demonstrated an upward trend, while the ASDR and age-standardized DALYs rate displayed a declining trend. However, in absolute terms, the total number of deaths attributed to IE increased by 23.01%, and the DALYs rose by 13.26% over this period, underscoring the growing absolute impact of IE on public health.

Given the ongoing demographic shift toward an aging population and advancements in healthcare, IE is anticipated to pose even greater challenges in the future. This study provides a comprehensive assessment of the global, regional, and national burdens of IE and projects its future impact on the disease burden. These insights may serve as a critical resource for policymakers in designing targeted control measures and optimizing healthcare services to address the increasing healthcare demands associated with IE and its comorbidities.

Abbreviations

IE	Infective endocarditis
GBD	Global Burden of Disease
DALYs	Disability-adjusted life years
SDI	Socio-demographic index
ASPR	Age-standardized prevalence rate
ASDR	Age-standardized death rate
AAPC	Average annual percentage change
ARIMA	Auto-regressive integrated moving average
UI	Uncertainty interval
GATHER	Guidelines for Accurate and Transparent Health Estimates Reporting
IHME	Institute for Health Metrics and Evaluation
TAVI	Transcatheter aortic valve implantation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22100-z.

Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

L.L. (Liyu Lin) was responsible for research design, data analysis, figure creation, and writing. J.X. (Jiongbo Xu) conducted data analysis, figure creation, and writing. Y.C. (Yuanru Chai) was involved in writing and modification. W.W. (Wei Wu) was engaged in writing, review and editing. All authors have reviewed, revised, read, and approved the final manuscript.

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Data availability

Data can be accessed through the online query tool available on the Institute for Health Metrics and Evaluation (IHME) website (http://ghdx.healthdata.org/), with no permission required for retrieval.

Declarations

Ethics approval and consent to participate

This study utilized publicly available data from the Global Burden of Disease (GBD) Study 2021. The Institutional Review Board of the First Affiliated Hospital of Guangzhou University of Chinese Medicine determined that approval was not required for this study, as it utilized publicly available data.

Consent for publication

Not applicable. This study does not contain any individual person's data in any form.

Competing interests

The authors declare no competing interests.

Author details

[1]The First Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, China. [2]Guangzhou University of Chinese Medicine, Guangzhou, China. [3]Guangdong Clinical Research, Academy of Chinese Medicine, Guangzhou, China.

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