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RESEARCH

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Global, regional and national burden of HIV/AIDS among individuals aged 15-79 from 1990 to 2021

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Abstract

Background HIV/AIDS persists as a global health challenge despite significant advancements in antiretroviral therapy (ART). The transformation of HIV into a chronic condition, coupled with regional disparities and evolving epidemiological trends, necessitates an updated analysis of the disease burden.

Methods We conducted a comprehensive analysis of HIV/AIDS burden among individuals aged 15–79 years from 1990 to 2021 using the latest data from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021 database. Multiple statistical approaches were employed to investigate temporal trends, geographic variations, and health inequalities.

Results From 1990 to 2021, global HIV/AIDS age-standardized incidence rates (ASIR) decreased by 41%, while age-standardized prevalence rates (ASPR), mortality rates (ASMR), and disability-adjusted life year rates increased by 222%, 57%, and 59%, respectively. Sub-Saharan Africa demonstrated the highest HIV/AIDS ASPR in 2021, with High-middle and Middle SDI regions, particularly Oceania, South Asia, and Eastern Europe, experiencing the most significant ASPR growth over three decades. Joinpoint analysis identified 1997 and 2015 as critical years for ASIR declines, and 2004 for ASMR reductions. Decomposition analysis revealed population growth as the primary driver of increasing incidence in lower SDI regions, while epidemiological changes were more influential in higher SDI areas. The age-period-cohort model showed peak HIV/AIDS incidence among individuals aged 25–34, with diminishing incidence risk across successive birth cohorts and periods. Health inequality analysis from 1990 to 2021 revealed a substantial widening of disparities across countries, with the slope index of inequality rising from 265 to 1006.

Conclusion While global efforts have reduced HIV/AIDS incidence, increasing prevalence due to extended survival with antiretroviral therapy presents ongoing challenges. Regional disparities and rising incidence among specific demographics underscore the need for sustained, targeted interventions.

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Keywords HIV/AIDS, Global Burden of Disease (GBD), Socio-Demographic Index (SDI), Age-period-cohort analysis, Health inequalities

Introduction

Since the identification of AIDS and its causative HIV infection by the U.S. Centers for Disease Control and Prevention in the 1980s [1], HIV/AIDS has emerged as a significant global health challenge. In 2023, 39.9 million people were living with HIV globally [2], with 630,000 deaths from HIV-related causes, over 60% of which occurred in Africa [3]. In response, the United Nations initiated the Millennium Development Goals (MDGs), investing more than US$500 billion in HIV/AIDS prevention and management from 2000 to 2015 [4]. While the initial goals of universal treatment access by 2010 and halting HIV/AIDS spread by 2015 were not fully achieved, significant progress has been made [5, 6]. The MDGs were subsequently revised, targeting a 90% reduction in annual new HIV/AIDS infections and deaths by 2030 compared to 2010 levels [7].

It has demonstrated that HIV/AIDS epidemiology is intricately linked to population aging, growth, and epidemic patterns [8]. With the advent of effective treatments, particularly antiretroviral therapy, HIV/AIDS has evolved from an acute fatal condition to a manageable chronic disease in many regions [9]. For newly infected adults, timely treatment can reduce mortality rates by 80% and extend life expectancy by 20–50 years [9–11], while delayed intervention significantly worsens outcomes [12]. To achieve the 2030 MDG targets, systematic data-driven approaches have become essential for evidence-based policy-making and resource allocation in AIDS prevention [13].

The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD), initiated by the World Bank in 1990 [14], provides comprehensive data for assessing the global HIV/AIDS burden. The latest GBD version quantified health effects across hundreds of diseases and injuries in over 200 countries and territories [15]. However, existing analyses have notable gaps, particularly regarding gender-specific burden changes [16, 17]. Therefore, examining the newly released GBD database offers an opportunity for a more updated and comprehensive understanding of the HIV/AIDS epidemic. This study conducted a thorough analysis using the latest data to assess the HIV/AIDS burden from 1990 to 2021, examining incidence, prevalence, mortality, disability-adjusted life years (DALYs), and the factors driving these changes.

Methods and materials

Data source and acquisition

This research utilized data from the GBD database (https://vizhub.healthdata.org/gbd-results/), a publicly accessible resource last updated in May 2024. The GBD database is widely recognized as a comprehensive repository of global health data, integrating surveys, vital statistics, censuses, and other relevant sources. It provides comprehensive data on the burden of 459 health outcomes and risk factors across 204 countries and territories and 811 subnational locations from 1990 to 2021 (https://www.healthdata.org/research-analysis/gbd). All analyses were performed using R version 4.3.3.

Age selection

Mother-to-child transmission is the primary mode of HIV/AIDS infection in children under the age of five. Notably, according to the GBD 2021 database, there were no reported cases of HIV/AIDS among individuals aged 10–14 or those over 80 years old in 2021 (Figure S1). Consequently, this study focused on analyzing the disease burden of HIV/AIDS among individuals aged 15–79, covering the period from 1990 to 2021.

Overall disease burden

Data on HIV/AIDS cases among the 15–79 age group, as well as the age-standardized incidence rate (ASIR), age-standardized prevalence rate (ASPR), age-standardized mortality rate (ASMR), and age-standardized DALY rate (ASDR), including their 95% uncertainty intervals (UIs), were extracted from the GBD database for the years 1990 to 2021. The analysis also incorporated the Socio-Demographic Index (SDI), which reflects education, income, and fertility levels. SDI values are classified into five levels: Low SDI ($0 \le SDI < 0.45$), Low-middle SDI ($0.45 \le SDI < 0.61$), Middle SDI ($0.61 \le SDI < 0.69$), High-middle SDI ($0.69 \le SDI < 0.81$), and High SDI ($0.81 \le SDI \le 1.00$).

The trend and prediction of global HIV/AIDS burden

To assess the direction and speed of overall and period-specific trends in ASIR and ASMR globally and across different countries or regions, we employed the Joinpoint regression program. The observations for a given set of points $\{(x_1, y_1), \cdots, (x_n, y_n) | x_1 \le \cdots \le x_n\}$ could be described with a few linear phases on the logarithmic scale as:

$$E[y|x] = \exp\begin{pmatrix} \beta_0 + \beta_1\chi + \delta_1(x-\tau_1)^+ \\ + \ldots + \delta_k(x-\tau_k)^+ \end{pmatrix}$$

where τ_k denotes the inflection point, β, δ are the coefficients and $(x-\tau_k)^+ = x-\tau_k$ for $x-\tau_k > 0$ and 0 otherwise. This approach calculated the annual percent change (APC) and average annual percent change (AAPC) with 95% confidence intervals (CI), utilizing a logarithmic linear regression model that accommodated up to four inflection points (k value) [18]. The optimal model was selected based on the Modified Bayesian Information Criterion (MBIC) and subjected to hypothesis testing to derive the APC and AAPC values.

Furthermore, we applied the Bayesian age-period-cohort (BAPC) model to project global ASIR and ASMR for HIV/AIDS through the year 2040. The BAPC model analyzes age, period, and cohort effects using Bayesian inference, providing robust estimates and overcoming traditional APC model limitations [19]. It effectively predicts future trends by accounting for historical data and uncertainty. A classic APC model is often described as:

$$\log Y_{ijk} = \mu + \alpha_i + \pi_j + \gamma_k + \varepsilon_{ijk}$$

where Y_{ijk} is the prediction, μ is the general intercept, $\alpha_{\ i}$, $\pi_{\ j}$, and $\gamma_{\ k}$ denotes the ith age effect, jth period effect and kth cohort effect respectively. The $?_{ijk}$ is the error term that assumed to be normally distributed as $\varepsilon_{ijk} \sim N\left(0, \sigma^2\right)$. The formula could be simplified with matrix notation as $\mathbf{y} = \mathbf{X}\beta + \varepsilon$, where $\mathbf{y}$ denotes the response vector, $\mathbf{X}$ denotes the design matrix of the observation, $\boldsymbol{\beta}$ denotes parameter vector and $\mathbf{?}$ is the error vector. From the Bayesian perspective, the goal is to figure out the posterior distribution:

$$p\left(\boldsymbol{\beta}\ , \sigma^{\ 2} \middle| \mathbf{y}\right) \propto\ p\left(\mathbf{y} \middle| \boldsymbol{\beta}\ , \sigma^{\ 2}\right) p\left(\boldsymbol{\beta}\ , \sigma^{\ 2}\right)$$

where in practice, sampling methods are used to approximate this posterior.

Decomposition of factors driving the changes in disease burden

To dissect the factors driving the fluctuations in disease burden over the past thirty years, we conducted a comprehensive decomposition analysis. This approach allowed us to identify and quantify the distinct components contributing to changes in incidence cases, including demographic shifts such as aging and population growth, as well as epidemiological changes [20]. By decomposing these factors, we were able to assess the relative impact of each component on the overall trend, providing valuable insights into the underlying drivers of disease burden.

Age-period-cohort analysis

The influence of age, period, and birth cohort on HIV/AIDS incidence and mortality rates among individuals aged 15–79 years from 1990 to 2021 was examined using the age-period-cohort (APC) web tool [21]. APC analysis is a statistical method designed to disentangle the independent effects of age, period, and cohort on health outcomes. Age effects refer to variations linked to biological and social processes of aging, such as physiological changes and accumulation of social experiences specific to individuals' age groups. Period effects result from external factors that equally affect all age groups at a particular calendar time, including environmental, social, and economic factors like wars, economic crises, or changes in data collection methods. Cohort effects arise from the unique experiences or exposures of a group of individuals born in the same time period, which can influence disease patterns differently across age groups.

This analysis involved both cross-sectional and longitudinal age-specific rates, as well as period and cohort rate ratios. The APC model estimated the overall trend (net drift) and age-specific trends (local drifts), providing a comprehensive understanding of how these factors influence disease patterns over time. Statistical significance was assessed using the Wald chi-square test, with a *P*-value less than 0.05 indicating that the observed effects were statistically significant.

Healthy inequality evaluation

Health inequalities, defined as unfair, avoidable, and systematic differences in health outcomes between social groups, stem from unequal distributions of social, economic, and environmental health determinants [22]. To evaluate these disparities comprehensively, this study analyzed ASR-DALYs across 204 countries. The methodology employed two key measures recommended by the World Health Organization: The Concentration Index (CIX) for assessing relative inequalities, and the Slope Index of Inequality (SII) for measuring absolute inequalities [23]. These indices quantify health disparities across socioeconomic gradients, with CIX capturing the degree of health outcome concentration among socioeconomic groups and SII estimating the absolute difference between the most and least advantaged groups. Countries were categorized based on their SDI to enable comparisons across different development levels. This approach provides a nuanced understanding of both the magnitude and proportional differences in health outcomes, accounting for population-weighted measures to reflect real-world distributions. By combining these methods, the study offers a robust framework for monitoring global health inequalities, informing equity-oriented policies, and identifying areas for targeted interventions to reduce health disparities.

Results

Global HIV/AIDS epidemiological transition (1990–2021): declining incidence coupled with escalating disease burden

Globally, the incidence of HIV/AIDS among individuals aged 15–79 decreased by 11.9% from 1990 to 2021, dropping from approximately 1.8 million (95% UI: 1.6–1.9 million) to 1.5 million (95% UI: 1.3–1.8 million). In 2021, males slightly outnumbered females, with a male-to-female ratio of 1:0.93 (Table S1). ASIR also decreased significantly by 41.1%, from 46.9 per 100,000 to 27.6 per 100,000. However, the prevalence of HIV/AIDS cases surged substantially, increasing by 407.9% from approximately 7.6 million (95% UI: 7.0-8.3 million) in 1990 to 38.6 million (95% UI: 36.0–41.5 million) in 2021. This growth was reflected in the ASPR, which rose by 222.2% from 207.2 per 100,000 to 667.7 per 100,000.

Over the past three decades, HIV/AIDS-related deaths among individuals aged 15–79 increased by 160.5%, from approximately 0.26 million (95% UI: 0.18–0.37 million) in 1990 to 0.68 million (95% UI: 0.56–0.83 million) in 2021 (Table S1). The ASMR also increased by 57.4% during this period, from 7.4 per 100,000 to 11.7 per 100,000. In 2021, the global HIV/AIDS burden resulted in a total of approximately 36.7 million (95% UI: 31.1–44.4 million) DALYs, representing a significant increase of 152.5% compared to 1990. Between 1990 and 2021, the ASR-DALYs escalated by 59.0%, from 404.1 per 100,000 to 642.5 per 100,000.

Global HIV/AIDS epidemiological patterns and future trajectories 1990–2040

The Joinpoint regression model revealed a substantial decline in the global HIV/AIDS ASIR among individuals aged 15–79 years (AAPC: -1.6%). Initially, between 1990 and 1997, there was a notable increase, followed by a rapid decline. From 2005 to 2015, the ASIR remained stable before undergoing a notable and swift decline post-2015 (Fig. 1). Conversely, the worldwide HIV ASPR among those people has consistently risen by an average annual rate of 3.8%, although it remained stable from 2001 to 2009. Furthermore, the global HIV/AIDS ASMR exhibited an initial increase followed by a subsequent decrease over the past three decades, reaching a turning point in 2004.

The BAPC forecasting model predicted a continued decline in global HIV/AIDS ASIR, alongside a projected increase in ASPR (Fig. 2A). Additionally, the model forecasted a continuous decrease in ASMR until 2030, followed by an anticipated rebound. By 2040, the global HIV/AIDS ASIR, ASPR, and ASMR are projected to reach 14.8, 1.1×10^3, and 16.9 per 100,000, respectively. Figure 2B illustrates the anticipated HIV incidence rate curves for various age groups. Notably, the analysis reveals a substantial forecasted increase in incidence rates among males aged 15–39 compared to females, while a converse pattern is evident for individuals aged 60–79.

Sub-Saharan Africa exhibited the highest prevalence of HIV/AIDS globally, with emerging epidemic growth observed in Oceania, South Asia, and Eastern Europe

In 2021, a stark disparity in HIV/AIDS ASPR was observed globally. The ten countries with the highest ASPR (ranging from 9.9 to 31.0 thousand per 100,000) were all located in Sub-Saharan Africa: Lesotho, Eswatini, Botswana, South Africa, Zimbabwe, Zambia, Namibia, Mozambique, Malawi, and Equatorial Guinea (Fig. 3A). Within Sub-Saharan Africa, significant regional variations were evident in 2021 (Table S1), where Southern, Eastern, Western, and Central Sub-Saharan Africa reported HIV/AIDS ASPR of 2.0×10^4, 5.1×10^3, 1.9×10^3, and 1.6×10^3 per 100,000, respectively. Each of these rates is substantially higher compared to other global regions. Notably, the ASPR of HIV/AIDS in Sub-Saharan Africa was higher among women than men. This

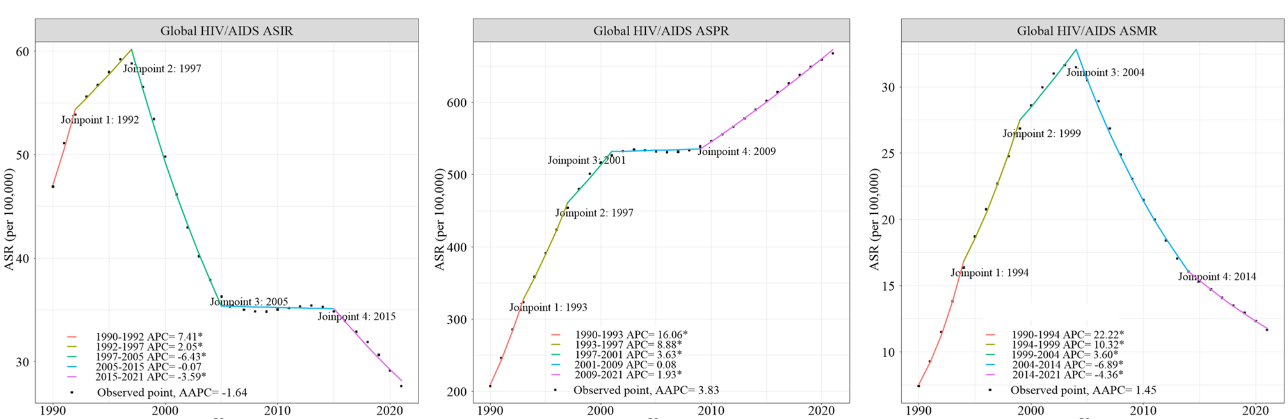

Fig. 1 Global trends in ASIR and ASMR for HIV/AIDS among individuals aged 15–79 years (1990–2021), analyzed using the Joinpoint regression model

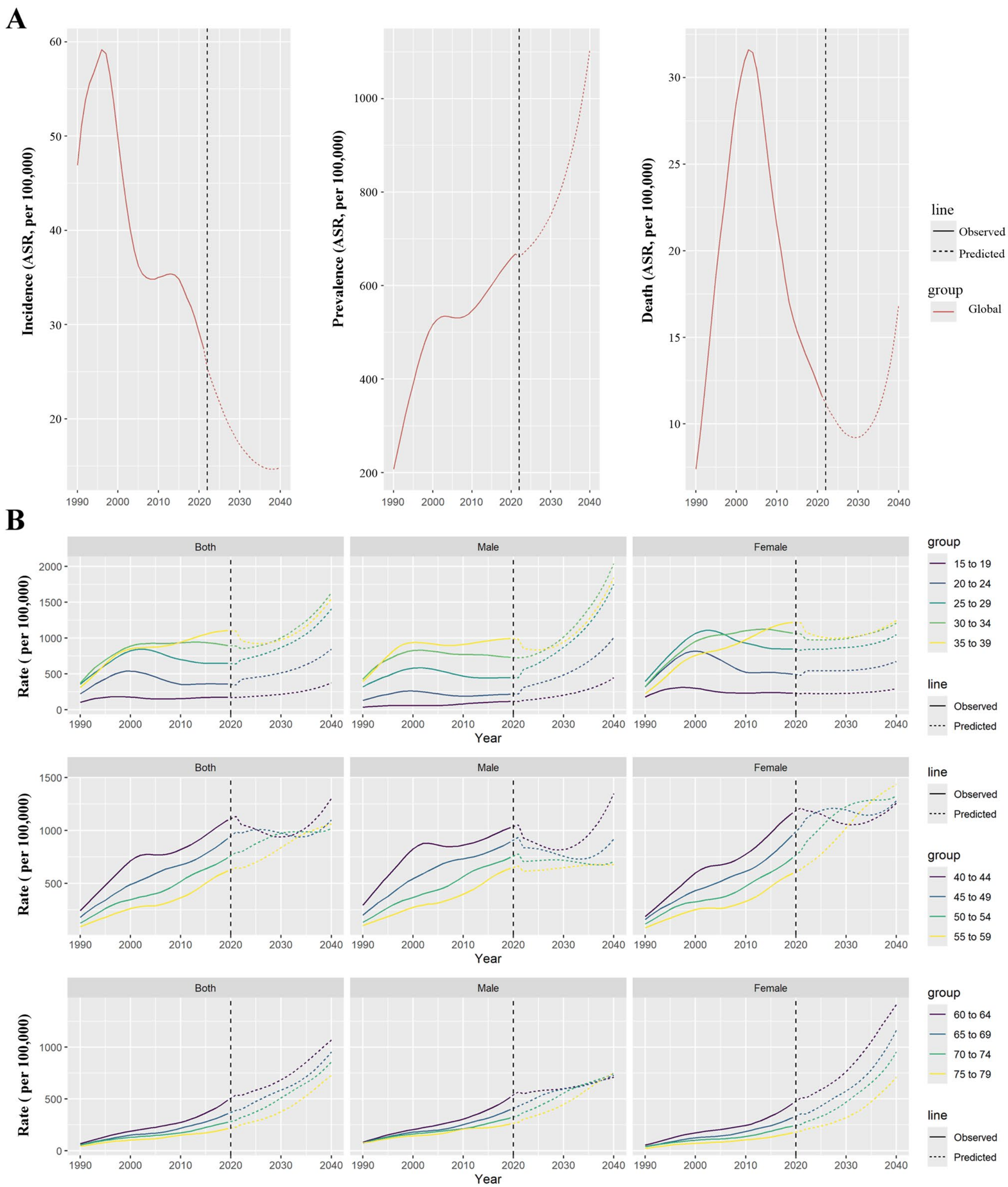

Fig. 2 Projected trends and age-specific patterns of HIV/AIDS epidemiological indicators through 2040, based on BAPC model. (**A**) BAPC model forecasts of ASIR, ASPR, and ASMR for HIV/AIDS, 2021–2040; (**B**) The projected age-specific incidence rate of HIV/AIDS by 2040

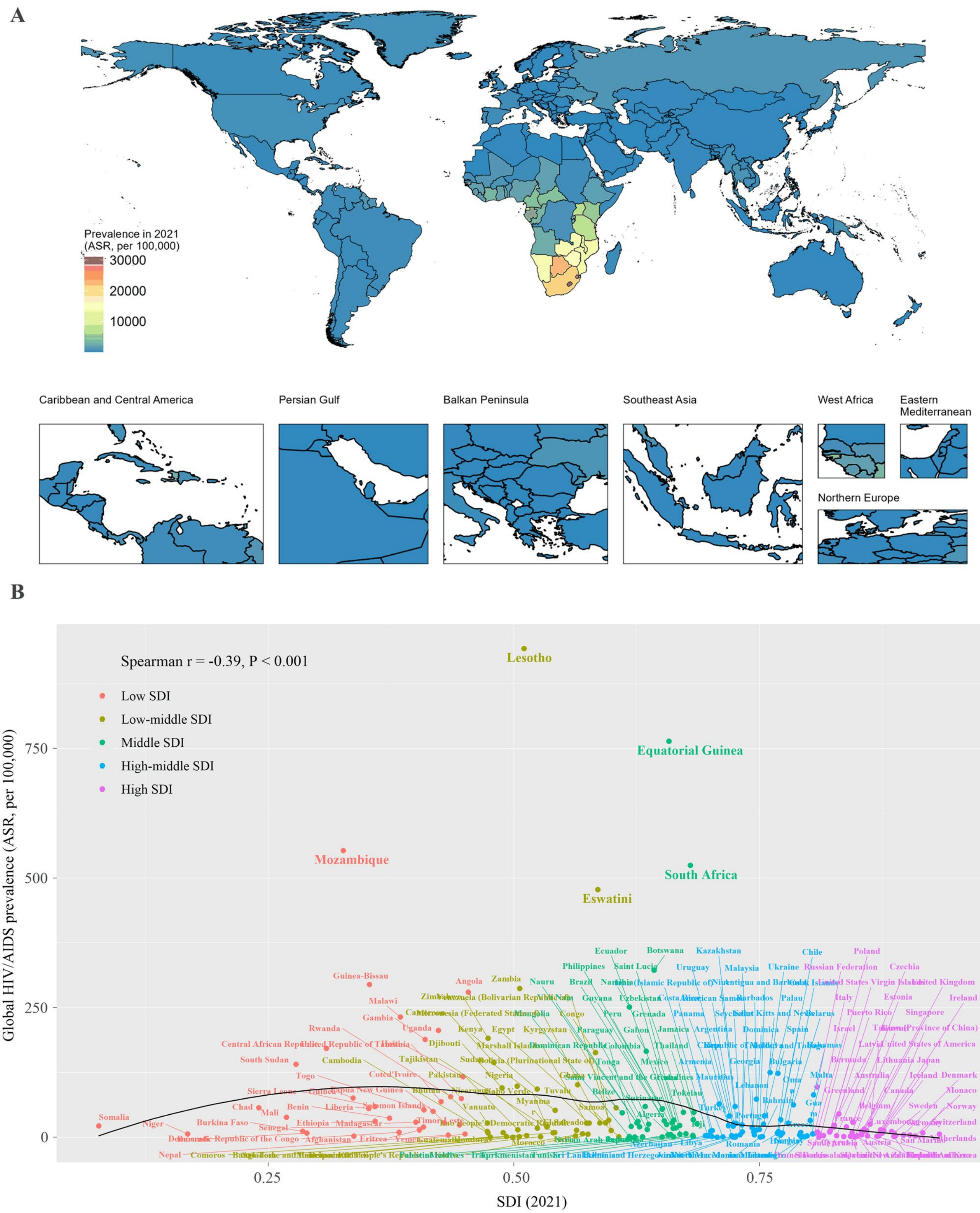

Fig. 3 Global HIV/AIDS distribution among individuals aged 15–79 in 2021. (**A**) Map of ASPR; (**B**) Relationship Between SDI and ASPR

contrasts with other regions, particularly High-SDI and High-middle SDI areas, where HIV/AIDS prevalence was higher among men. Furthermore, Oceania, South Asia, and Eastern Europe experienced the most rapid increases in HIV/AIDS ASPR over the past three decades, with AAPC values exceeding 10%. In 2021, A modestly negative correlation was observed between the SDI and the HIV/AIDS's ASIR (Spearman r=-0.39, $P<0.001$) (Fig. 3B). The highest HIV/AIDS prevalence rates were observed in regions with Low SDI, Low-middle SDI, and Middle SDI classifications (Table S1). Notably, the Middle SDI and High-middle SDI regions experienced the most rapid average annual growth rates in HIV/AIDS prevalence from 1990 to 2021, with AAPC values of 9.3% and 5.3%, respectively.

Population growth drives global HIV/AIDS incidence increases while epidemiological shifts shape High-Income regions

A decomposition analysis was employed to elucidate the factors driving changes in global HIV/AIDS incidence from 1990 to 2021. Results indicated that population growth was the predominant driver of increasing global incidence across all regions and both sexes (Fig. 4). This effect was most pronounced in Low, Low-Middle, and Middle SDI regions, where population growth accounted for the preponderance of the increase in HIV/AIDS cases. Conversely, epidemiological changes constituted a significant contributing factor in higher SDI regions. For instance, Eastern Europe exhibited a substantial incidence increase driven by epidemiological factors, reflecting the region's distinct HIV/AIDS epidemic dynamics. The influence of aging on incidence changes was minimal across most regions. Gender-disaggregated analyses revealed consistent trends across both sexes.

HIV/AIDS incidence and mortality risks decline with gender disparities and shifting Age-specific peaks across successive cohorts

An age-period-cohort analysis was conducted to examine trends in ASIR and ASMR for HIV/AIDS among individuals aged 15–79 years between 1990 and 2021 (Fig. 5). The model revealed statistically significant declines in both ASIR and ASMR, with net drifts of -2.7% and – 1.5%

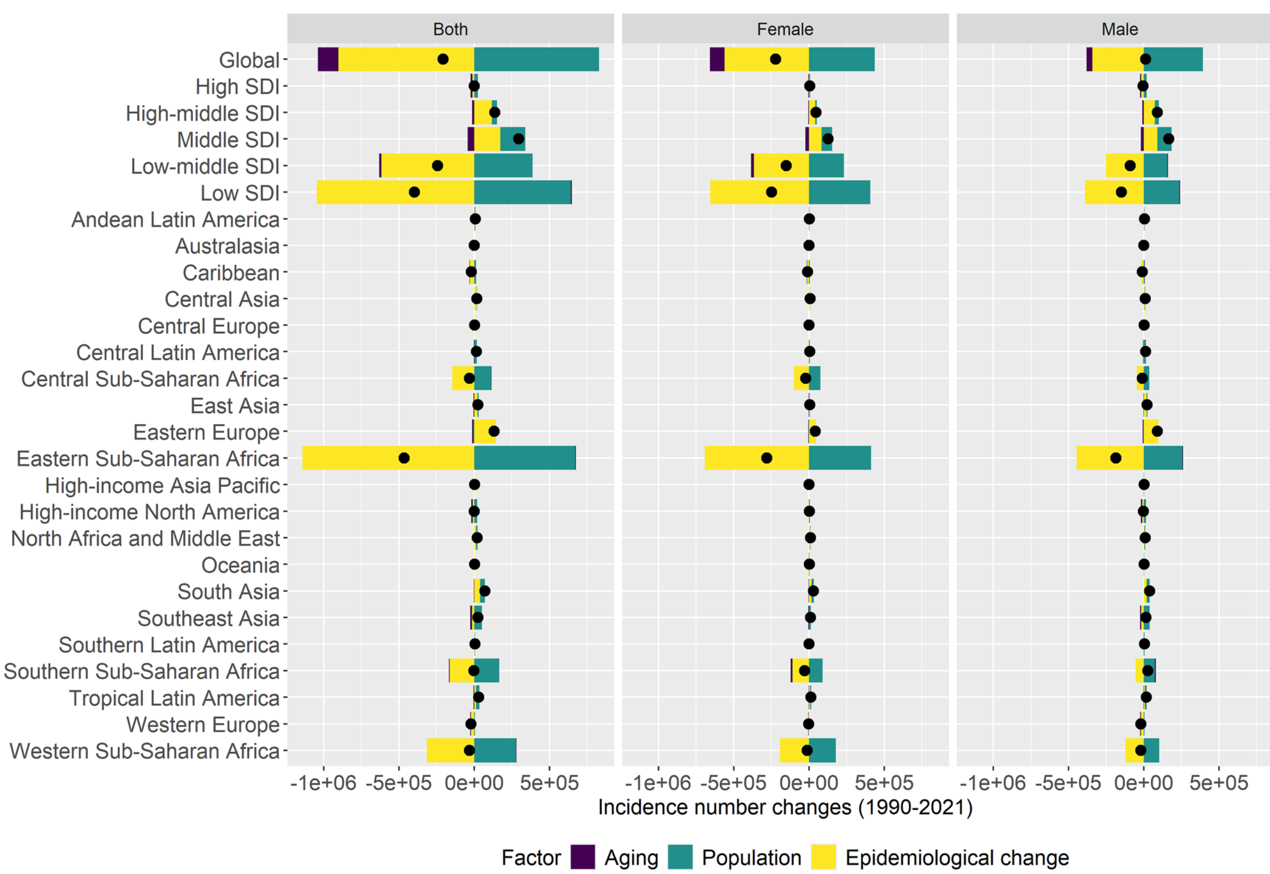

Fig. 4 Population growth drives increases in HIV/AIDS incidence, while epidemiological improvements alleviate the burden in most regions (1990–2021). Note: The bars illustrate changes in HIV/AIDS incidence attributed to three factors: demographic aging (purple), population growth (green, indicating increases in total population size), and epidemiological changes (yellow, representing shifts in disease transmission patterns, prevention efforts, and treatment access)

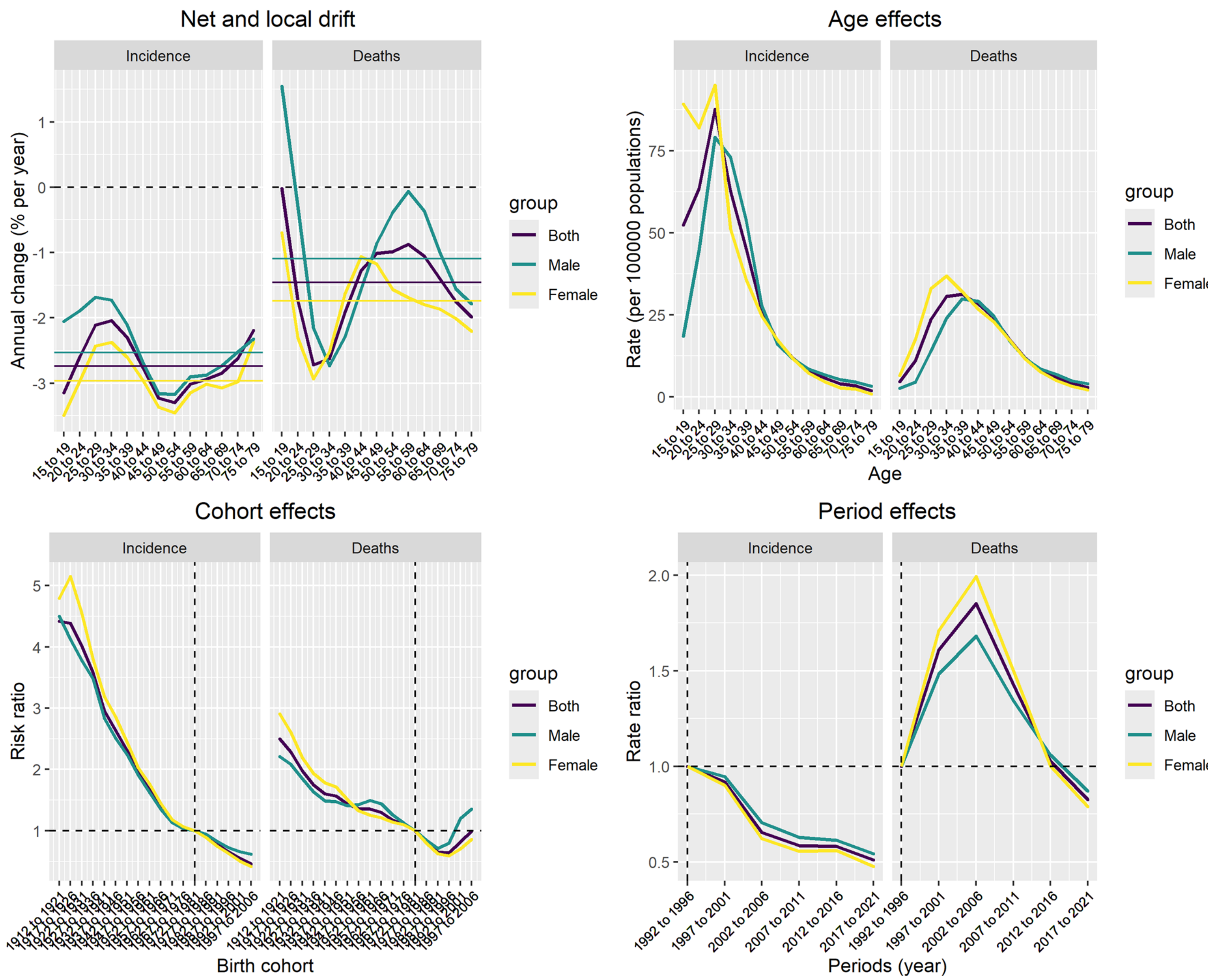

Fig. 5 Age-period-cohort analysis reveals declining HIV/AIDS incidence and mortality rates with distinct gender differences from 1990 to 2021. Note: Annual percentage changes in rates (top-left); age-specific incidence and mortality patterns (top-right); birth cohort risk ratios (bottom-left); and period-specific rate ratios (bottom-right) are displayed for males, females, and both sexes combined

respectively ($P<0.05$). Notably, females exhibited more pronounced reductions in HIV/AIDS incidence risk compared to males. The analysis of age-specific effects indicates that the incidence rate of HIV/AIDS reached its zenith prominently among individuals aged 25 to 34, approximating 65 per 100,000 individuals, before experiencing a gradual decline in older age cohorts. Conversely, mortality rates attained their peak at a later stage among individuals aged 35 to 44. Cohort effects demonstrated a pronounced and systematic decline in incidence risk ratios across consecutive birth cohorts, with individuals born between 1912 and 1941 experiencing substantially elevated risks (3 to 5 times higher) compared to reference groups(1977–1981). Despite the overall downward trend in mortality risk across birth cohorts, individuals born after 1987 exhibited a notable resurgence in HIV/AIDS death risk, particularly among males. Period effects showed a consistent decline in incidence rates over time, while mortality rates peaked between 2002 and 2006, with females exhibiting higher rate ratios compared to males.

Escalating HIV/AIDS health inequality SII surge reveals widening disparities with persistent Low-Income burden

Between 1990 and 2021, the absolute inequality in DALYs across 204 countries, as measured by the SII, underwent a dramatic escalation. The SII surged from 265 in 1990 to 1006 in 2021 (Fig. 6), indicating a pronounced widening of health disparities over time. The Lorenz curve consistently remained above the line of equality, visually illustrating the unequal distribution of the HIV/AIDS burden. Furthermore, the CIX corroborated this inequity, with negative values denoting that lower-income nations shouldered a disproportionate share of the health burden. Notably, the CIX remained relatively stable, with a value of -0.44 in 2021 compared to -0.45 in 1990, underscoring

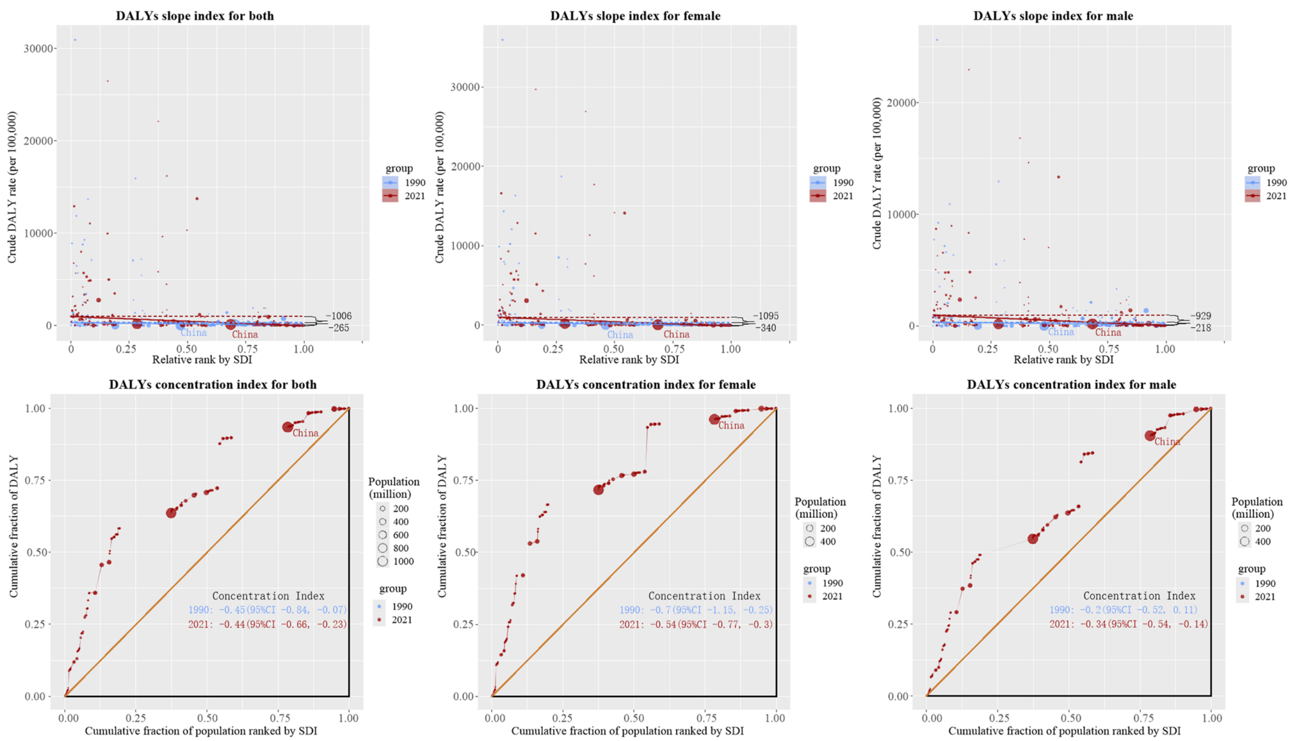

Fig. 6 Absolute inequality in HIV/AIDS burden quadrupled from 1990 to 2021 while relative inequality persisted among lower-income countries. Note: The top panels display the slope index of inequality (SII), which measures absolute differences in DALYs across countries ranked by SDI, with steeper slopes indicating greater absolute inequality. The bottom panels present the concentration index (negative values indicate the concentration of disease burden in disadvantaged populations) and Lorenz curves that illustrate the distribution of DALYs relative to the population distribution by socioeconomic status

the persistence of severe disparities in HIV/AIDS. These findings highlight a growing concentration of health burdens among impoverished populations, emphasizing the need for targeted policy interventions to address these inequities effectively.

Discussion

HIV/AIDS is considered a significant public health problem that requires considerable attention. Rather than responding to an acute and potentially life-threatening complication, clinicians are now faced with managing a chronic disease that will persist for decades [24]. This comprehensive analysis of HIV/AIDS epidemiological trends reveals a complex interplay between therapeutic advancements and persistent public health challenges. The observed 41.10% reduction in ASIR among individuals aged 15–79 from 1990 to 2021 contrasts with substantial increases in ASPR (222.2%), ASMR (57.4%), and ASR-DALYs (59.0%). The transformation of HIV into chronic condition through antiretroviral therapy (ART) has paradoxically amplified disease prevalence by extending survival. According to the data released by the World Health Organization (WHO) in 2023, WHO reported that 77% of people living with HIV (PLWH) are receiving treatment and 72% are achieving viral suppression globally [25]. This suggests that approximately half of PLWH maintain high viral loads, posing a substantial risk of transmission. Even with effective ART, low-level HIV replication persists in a subset of PLWH [26, 27]. Consequently, lymph nodes in ART-treated PLWH can harbor the virus, acting as a "sanctuary" [28] and contributing to new HIV infections, which threatens public health. Although treating all new infections with ART, reducing the HIV reservoir to negligible levels would take several decades [29]. Therefore, despite the significant decrease in the ASIR, sustained governmental efforts in HIV/AIDS prevention and treatment remain crucial.

Joinpoint regression analysis identified 1997 and 2015 as pivotal years for ASIR declines, while 2004 marked a turning point for ASMR reductions. At the beginning of the 21st century, the Red Cross and Red Crescent Pan-African Conference (2000), through the Ouagadougou Declaration, underscored the interconnectedness of prevention, treatment, care, support, and the fight against stigma and discrimination as essential elements of effective HIV/AIDS responses. Our research also reveals that HIV prevalence peaked among individuals aged 25–34 globally, primarily attributed to heightened sexual activity within this demographic [30]. Additionally, the HIV epidemic exhibits notable regional variations in its characteristics. For instance, in some SDI regions, males aged 60 and above have demonstrated elevated AIDS-related mortality rates in recent years [31]. These age- and sex-specific patterns underscore the complexity of HIV/AIDS epidemiology, which is influenced by sexual behaviors and regional cultural factors. Consequently, effective HIV/AIDS prevention strategies necessitate tailored control measures that address the unique dynamics of each demographic and geographic context.

Currently, the HIV/AIDS infections predominantly stem from unsafe sex, while effective responses to HIV/AIDS transmission remain underdeveloped. Consequently, anticipated outcomes in health education, medical therapies, and control measures have not yet been realized [32]. In some regions, young women with HIV/AIDS are more vulnerable to sexual violence or transactional sex, thereby elevating the risk of HIV transmission [33]. In the low-SDI regions, the HIV/AIDS burden was primarily attributable to economic underdevelopment, inadequate healthcare systems, and limited therapeutic access. In these areas, domestic resource constraints, exacerbated by fiscal limitations in low-income governments resulting from restricted revenue streams, hinder sustainable HIV/AIDS prevention efforts. Prevention of HIV/AIDS in these countries mainly relies on Overseas Development Assistance (ODA), though international aid often falls short of meeting local needs [34]. The President's Emergency Plan for AIDS Relief (PEPFAR) has emerged as a transformative ODA initiative in the 21st century [35], providing antiretroviral therapy to over 20 million individuals and significantly reducing global HIV infections and AIDS-related deaths [36]. However, PEPFAR's funding is primarily concentrated in a limited number of countries, leaving other regions with severe HIV/AIDS epidemics underfunded. Additionally, the program's long-term sustainability remains a challenge, highlighting the need for more equitable resource allocation and strategies to ensure continued progress in combating HIV/AIDS globally.

While global ASIR of HIV/AIDS showed significant decline, persistent increases were observed in high-middle (3.4% annually) and middle SDI countries (1.5% annually) over recent decades. Notably, regions with accelerated ASIR growth– including South Asia and Eastern Europe– demonstrate disproportionate HIV burden among males compared to females, likely attributable to rising transmission among men who have sex with men (MSM) [32]. Additionally, despite a global decrease in ASIR across the majority of populations, young MSM constitute one of the few demographic groups exhibiting a concerning upward trend in incidence [37]. Consequently, governments in these aforementioned countries should prioritize and implement targeted interventions to mitigate HIV/AIDS transmission among MSM.

Conclusion

In conclusion, while global efforts have yielded a significant decline in HIV/AIDS incidence, the evolving epidemiology of the disease presents ongoing challenges. The increasing prevalence, driven by extended survival with ART and persistent transmission risks, coupled with regional disparities and concerning trends among specific demographics like young MSM, underscores the need for sustained and targeted interventions. Governments and global health organizations must prioritize comprehensive strategies that encompass prevention, treatment access, and culturally appropriate approaches to effectively address the complex and evolving HIV/AIDS landscape.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12981-025-00745-5.

Supplementary Material 1

Supplementary Material 2

Author contributions

YC, AL, and YY performed the methodology, developed the R code, and contributed to writing the manuscript. JL, YX, XJ, LW, LH, and BZ contributed to the study's design and edited the manuscript. MX conceived the project's overall scope, analyzed data, and wrote the manuscript. MX provided funding support. All authors contributed to the article and approved the submitted version.

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Data availability

For GBD studies, the Institutional Review Board at the University of Washington evaluated and granted a waiver for informed consent (https://www.healthdata.org/research-analysis/gbd).

Declarations

Competing interests

The authors declare no competing interests.

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