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ORIGINAL RESEARCH

Global, Regional and National Burden of Pelvic Inflammatory Disease: Trend Projections and Health Inequality Analysis, 1990–2021

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Background: Pelvic inflammatory disease (PID), a global health challenge, poses a major challenge to women's health and economic development, but has received relatively little research investment and attention. We aimed to assess the global, regional, and national burdens and trends of PID in women from 1990 to 2021.

Methods: The Global Burden of Disease (GBD) 2021 standardized methodology was used to analyze the burden of PID at global, regional, and national levels, with attention to the age factor; Join-point regression was applied to identify turning points in the change in the burden of disease, and in addition, Spearman correlation analyses were used to assess the association between ASR and SDI; the study also involved a cross-countryinequality analysis with decomposition. Finally, Bayesian age-period-cohort modeling was used to predict the disease burden of pelvic inflammatory disease in 2035.

Results: PID prevalence and YLDs increased over 32 years, whereas ASPR and ASYR remained relatively stable; the PID burden of disease is concentrated in the 30–39 year age group; countries with lower SDI bear a greater burden of PID, and health inequalities have declined but persist, the Inequality Slope indices of ASPR and ASYR were −22.12 (95% CI: −27.15 to −17.08) and −0.16 (95% CI: −0.20 to −0.11), respectively; population growth and aging are driving the burden of PID, with epidemiological changes driving the increase in PID but slowing the rise in YLDs; projections based on the BAPC model suggest that the burden of PID will continue to rise through 2035.

Conclusion: The global burden of PID has risen and will continue to do so, with significant differences between regions and countries. Therefore, global investment in research on the epidemiology of PID should be strengthened, targeted health policies should be formulated to enhance disease management in low-income countries, female sexual health education should be strengthened, and safe and hygienic sexual lifestyles should be promoted.

Keywords: global burden of disease, pelvic inflammatory disease, socio-demographic index, inequality analysis, decomposition analysis

Introduction

In the field of reproductive epidemiology, research has focused primarily on gynecologic cancers and reproductive health outcomes, with relatively little research investment and attention paid to non-malignant gynecologic diseases, including pelvic inflammatory disease (PID).[1] PID is an inflammatory disease of the female pelvic internal reproductive organs (including the ovaries, uterus, and fallopian tubes) and their surrounding connective tissues, with sexually transmitted infections (chlamydia, streptococcus) as the main cause.[2,3] Patients with PID are more likely to have chronic pelvic pain and ectopic pregnancies than the non-PID population.[4,5] In addition, the diagnosis of PID is a comprehensive judgment process with some exclusionary features, and delays in the diagnosis and treatment of PID can lead to poorer long-term reproductive outcomes.[6] Although PID does not directly develop into cancer, it increases the risk of certain gynecologic

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cancers, particularly ovarian cancer.[7,8] PID has a significant negative impact on women's health and quality of life, and also adds to the economic burden of health care worldwide.[9,10]

PID affects a wide range of regions and populations globally, posing a major challenge to women's health and economic development. Economic progress and social change have triggered major demographic shifts around the globe, and the impact of population growth and ageing on the health sector,[11,12] as well as the interaction of lifestyle, genetic susceptibility and other factors, may have an impact on the development of disease.[13,14] However, the overall burden of sexually transmitted diseases, which are the main causes, remains high and continues to rise, and there are significant regional differences.[15,16] Therefore, in-depth understanding of the differences in the disease burden of PID among countries with different economic levels, exploring their epidemiological characteristics and predicting the future direction are of great importance for improving the efficiency and equity of global PID prevention and treatment.

Using the Global Burden of Disease (GBD) 2021 database, we assessed temporal trends and epidemiological characteristics of PID at the global, regional and national levels. This analysis will help to monitor trends in PID and identify health disparities and inequalities so that targeted health policies can be developed to improve women's health globally and regionally.

Method

Data Acquisition and Study Direction

The GBD study in 2021 updated the latest epidemiological data with optimized statistical models and computational methods and the inclusion of a wider range of health indicators and data sources than ever before, making it one of the most comprehensive global epidemiological studies to date. In the GBD study, the prevalence of pelvic inflammatory disease (ICD-10: N70-N77) was documented in detail. The diagnostic criteria for PID are: Combined with clinical symptoms such as lower abdominal pain and abnormal vaginal discharge, gynecological examination shows tenderness in the cervix and tenderness in the uterine or adnexal area, which may be accompanied by fever (≥38.3°C). Auxiliary examinations show elevated white blood cell count, CRP or erythrocyte sedimentation rate, or the detection of pathogens such as Neisseria gonorrhoeae and chlamydia in cervical/vaginal secretions. Ultrasound suggests thickening/effusion of the fallopian tubes or pelvic effusion. A comprehensive judgment should be made after excluding similar diseases such as ectopic pregnancy. We used the Global Health Data Exchange query tool to obtain the latest data on PID, standardized disease definitions and prevalence rates (http://ghdx.healthdata.org/gbd-results-tool).

Research Dimensions

This study analyzes the association between PID and the level of socio-economic development of countries or regions using the Socio-Demographic Index (SDI). The SDI integrates factors such as the average years of schooling of the population aged 15 and above, the total fertility rate of women under 25, and the lagged effect of income distribution, and classifies countries and regions into five levels of development, with a range of values from 0 to 1. The specific thresholds for the classification are: low SDI (<0–45), low-middle SDI (≥0–45 and <0–61), middle SDI (≥0–61 and <0–75), high-middle SDI (≥0–75 and <0–90), and high SDI (≥0–90). In addition, the study analyzed the burden of disease at the global, regional, and national levels, explored differences in disease among different age groups, and described trends over time.

Statistical Analysis and Prediction

This study evaluated prevalence and YLDs (Years Lived with Disability) rates using the Age-Standardized Rate (ASR) and its corresponding 95% Uncertainty Interval (UI), with the 95% UI being used to reflect the reliability of the data and the robustness of the model. The ASR denotes an estimate per 100,000 people, and the use of the ASR can facilitate scientific comparisons between populations, despite differences in age distribution and population size across populations, thereby improving the precision of population comparisons. These rates are derived from the following formula:

$$ASR = \frac{\sum_{i=1}^{A} a_i w_i}{\sum_{i=1}^{A} w_i} \times 100,000$$

Where A denotes the number of age groups, i denotes the ith age group, ai denotes the rate to be standardized, and wi denotes the number of standardized population of the same age.

Estimated Annual Percentage Change (EAPC) to analyze the trend over time was calculated from the regression model: Y is the natural logarithm of the ASR, α is the intercept, β is a variable that determines the positive or negative trend of the ASR, X denotes the calendar year, and ε is the error term. The EAPC and its 95% Confidence Interval (CI) are also derived from the model and calculated as $EAPC = 100 * (exp(\beta) - 1)$.

Join-point modeling was employed to identify the best-fit models and key turning points for disease trends, where annual percentage change (APC) reveals trends in disease burden over a specific period of time, and average annual percentage change (AAPC) describes the overall trend over the period 1990–2021 by identifying the best data linkage points. In addition, we used Spearman correlation analysis to assess the association between ASR and SDI, including R-index and p-value; to explore the distribution of socioeconomic disparities in PID across countries and regions globally, we used two standardized indicators, the slope index of inequality (SII) and the relative concentration index (CI); SII is an indicator that quantifies the absolute inequality in health indicators between the most dominant and least dominant subgroups in the population. Through a weighted regression model, it can visually reflect the degree of absolute differences in health indicators among different socio-economic classes. In contrast, CI is a relatively unequal indicator, mainly reflecting the concentration of health indicators among dominant or disadvantaged groups; and decomposition analyses were used to identify the association between demographic growth, aging, and epidemiological changeon trends in prevalence and YLDs; and finally, Bayesian age-period-cohort (BAPC) modeling was used to predict the disease burden of PID. All p-values were two-sided and $p<0.05$ was considered statistically significant. All statistical analyses and data visualizations were performed using R (version 4.5.1) and JD_GBDR (V2.37, JingdingMedical Technology Co., Ltd).

Results

The Burden of Disease Associated with PID

Global Trends

The global number of PID cases exhibited a substantial increase, rising from 664,517 cases (95% UI: 509,093–847,208) in 1990 to 1,089,544 cases (95% UI: 815,164–1,405,520) in 2021 (Table S1 and Figure 1). The age-standardized prevalence rate (ASPR) was 27.02 cases/100,000 (95% CI: 20.24–34.89). From 1990 to 2021, a decrease of 0.04 cases per 100,000 (95% CI: −0.09 to 0.01). In 2021, the number of YLDs for PID was 148,407 cases (95% UI: 91,512–-226,991), the age-standardized YLD rate (ASYR) was 3.68 cases/100,000 (95% CI: 2.27–5.63), and the EAPC was [−0.04 (95% CI: −0.09 to 0.01)].

SDI Regional Level

In 2021, the ASPR and ASYR for PID in low-SDI regions exhibited the highest values, with 38.23 cases per 100,000 (95% UI: 28.28–50.35) and 5.19 cases per 100,000 (95% UI: 3.13–7.90), but the decrease was the largest, EAPC was [−1.39 (95% CI: −1.59 to-1.18)] and [−1.37 (95% CI: −1.57 to-1.17)]. The Middle SDI region exhibited the most significant increase, with EAPC of [0.37 (95% CI: 0.34 to 0.41)] and [0.37 (95% CI: 0.34 to 0.41)]. The High-middle SDI region exhibited the lowest ASPR and ASYR rates for PID, with rates of [21.01 cases/100,000 (95% UI: 15.80–27.25)] and [2.87 cases/100,000 (95% UI: 1.74–4.43)], respectively (Table S1 and Figures 1, S1).

21 Geographical Areas Changed

Of the 21 regions, South Asia had the most PID cases and YLDs (Table S1 and Figures 1, S1). There were 322,393 cases (95% UI: 238,074–429,234) and 43,805 YLDs (95% UI: 26,086–67,685) in South Asia. Western Sub-Saharan Africa had the highest PID ASPR and ASYR, with rates of 55.25 cases/100,000 (95% UI: 39.73–76.69) and 7.48 cases/100,000 (95% UI: 4.62–11.65), respectively. However, it had the largest decline, with EAPC of −1.98 (95% CI: −2.28 to −1.68)

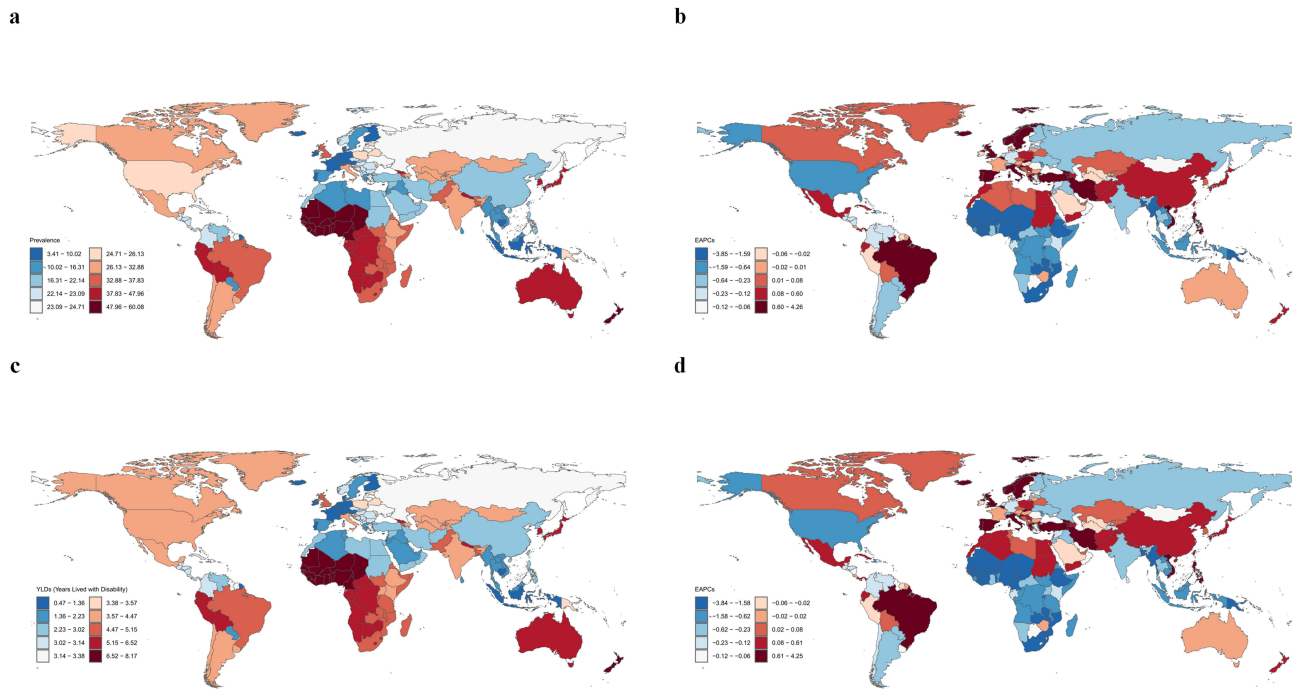

Figure 1 Global distribution of pelvic inflammatory disease burden in 2021. (**a**) The age-standardized prevalence rate of pelvic inflammatory disease; (**b**) Estimated annual percentage change in age-standardised prevalence rate for pelvic inflammatory disease; (**c**) The age-standardized YLDs rate of pelvic inflammatory disease; (**d**) Estimated annual percentage change in age-standardised YLDs rate for pelvic inflammatory disease.

and −1.97 (95% CI: −2.27 to −1.67), respectively. Tropical Latin America had the highest increase, with EAPC of 4.12 (95% CI: 2.81 to 5.45) and 4.11 (95% CI: 2.81 to 5.43), respectively.

National Level

India has the highest number of PID cases, with a total of 241,441 cases (95% UI: 176,706–322,824) (Table S1 and Figure 1). Guinea-Bissau has the highest ASPR [59.48 cases/100,000 (95% UI: 41.77–82.97)] among 204 countries, and its ASYR [8.09 cases/100,000 (95% UI: 4.62–13.05)] is also the highest. Iceland, on the other hand, has the lowest ASPR and ASYR, with 3.44 cases/100,000 (95% UI: 2.14–5.05) and 0.47 cases/100,000 (95% UI: 0.26–0.81), respectively. Among the 204 countries, Brazil exhibited the most significant increases in prevalence and YLD rates, with EAPC of [4.22 (95% CI: 2.89 to 5.57)] and [4.21 (95% CI: 2.88 to 5.55)] respectively. Conversely, Mali demonstrated the most substantial declines, with EAPC of [−3.81 (95% CI: −4.26 to −3.35)] and [−3.80 (95% CI: −4.25 to −3.35)].

Underlying Causes

Globally, the disease burden of pelvic inflammatory disease is mainly caused by Other sexually transmitted infections, followed by Chlamydia infection. In the 5SDI region, the causes of the prevalence of pelvic inflammatory disease are consistent with the global trend (Figure S2).

Age Distribution and Time Trends

In 2021, the number of people with PID worldwide peaked among those aged 30–39, then gradually declined with increasing age (Figure S3). The age-specific pattern of YLDs worldwide was consistent with the trend in prevalence.

Join-Point Regression Analysis

From 1990 to 2021, the ASPR and ASYR for PID worldwide exhibited a trend of first increasing, then decreasing, and finally increasing again. The trends in changes in disease burden across different years were consistent (Table S2 and Figure 2). From 1994 to 2011, both the prevalence rate and YLDs rate exhibited a downward trend, with APCs values of [−0.24 (95% CI:

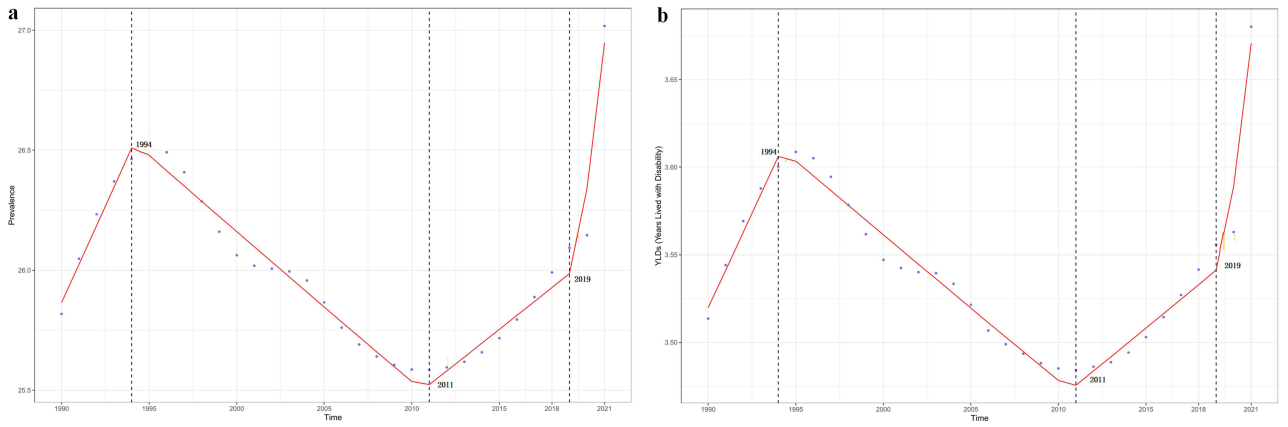

Figure 2 Join-point Regression Analysis of temporal trends in the burden of pelvic inflammatory disease from 1990 to 2021. (**a**) The age-standardized prevalence rate of pelvic inflammatory disease; (**b**) The age-standardized YLDs rate of pelvic inflammatory disease. The Y-axis represents the age-standardised rate, while the X-axis denotes the year.

−0.27 to −0.21; $p < 0.05$)] and [−0.24 (95% CI: −0.26 to −0.21; $p < 0.05$)]. As indicated by the data, the most significant increase was observed during the period from 2019 to 2021, with APCs values of 2.30 (95% CI: 1.56 to 3.05; $p < 0.05$) and 2.28 (95% CI: 1.54 to 3.02; $p < 0.05$), respectively.

Correlation Between SDI and Disease Burden

In 2021, we further explored the association between SDI and PID in different countries and regions worldwide (Figure 3). The results showed that SDI was negatively correlated with ASPR in 21 regions ($R = -0.2277$, $p < 0.05$) and 204 countries ($R = -0.5102$, $p < 0.05$). This trend was also reflected in the YLDs rate, with a correlation of $R = -0.2211$ ($p < 0.05$) in 21 regions and $R = -0.5046$ ($p < 0.05$) in countries.

Inequality Analysis

The present study examined the association between SDI and health inequalities, revealing both absolute and relative health inequalities at the SDI level (Table S3 and Figure 4). A correlation has been demonstrated between a country's SDI and its disease burden, with lower SDI levels correlating with a higher disease burden. From the perspective of inequality reflected by the slope index, the ASPR exhibited an improvement from −30.63 (95% CI: −36.33 to −24.94) in 1990 to −22.12 (95% CI: −27.15 to −17.08) in 2021. The relative concentration index demonstrated a shift in the ASPR from −0.23 (95% CI: −0.27 to −0.17) in 1990 to −0.16 (95% CI: −0.20 to −0.11) in 2021. A similar trend was observed in the ASYR.

Decomposition Analysis

From 1990 to 2021, the proliferation of global PID cases was predominantly influenced by population growth (79.76%), aging (10.96%), and epidemiological shifts (9.28%) (Table S4 and Figure 5). In the five SDI regions, the aging process was found to be associated with a deceleration in the growth of PID cases, particularly in the high-SDI and high-middle-SDI regions. Concurrently, in the low-SDI and lower-middle-SDI regions, epidemiological shifts exhibited a favorable influence on the reduction of PID cases. The observed rise in global PID YLDs can be attributed to two primary factors: population growth (78.46%) and aging (29.4%). However, this growth is partially offset by epidemiological changes (−7.86%). Furthermore, the increase in YLDs rates across the five SDI regions is consistent with the patterns observed in prevalence rates.

Predicted Trends in the Burden of PID Disease

Future projections and trend analyses of the prevalence and YLDs rates of PID were conducted (Figure S4). By the year 2035, it is estimated that the global number of prevalent cases and YLDs will reach 1,142,649 cases (95% UI: 1,071,980–1,213,317) and 154,996 cases (95% UI: 145,055–164,937), respectively. The disease burden of PID is projected to continue rising.

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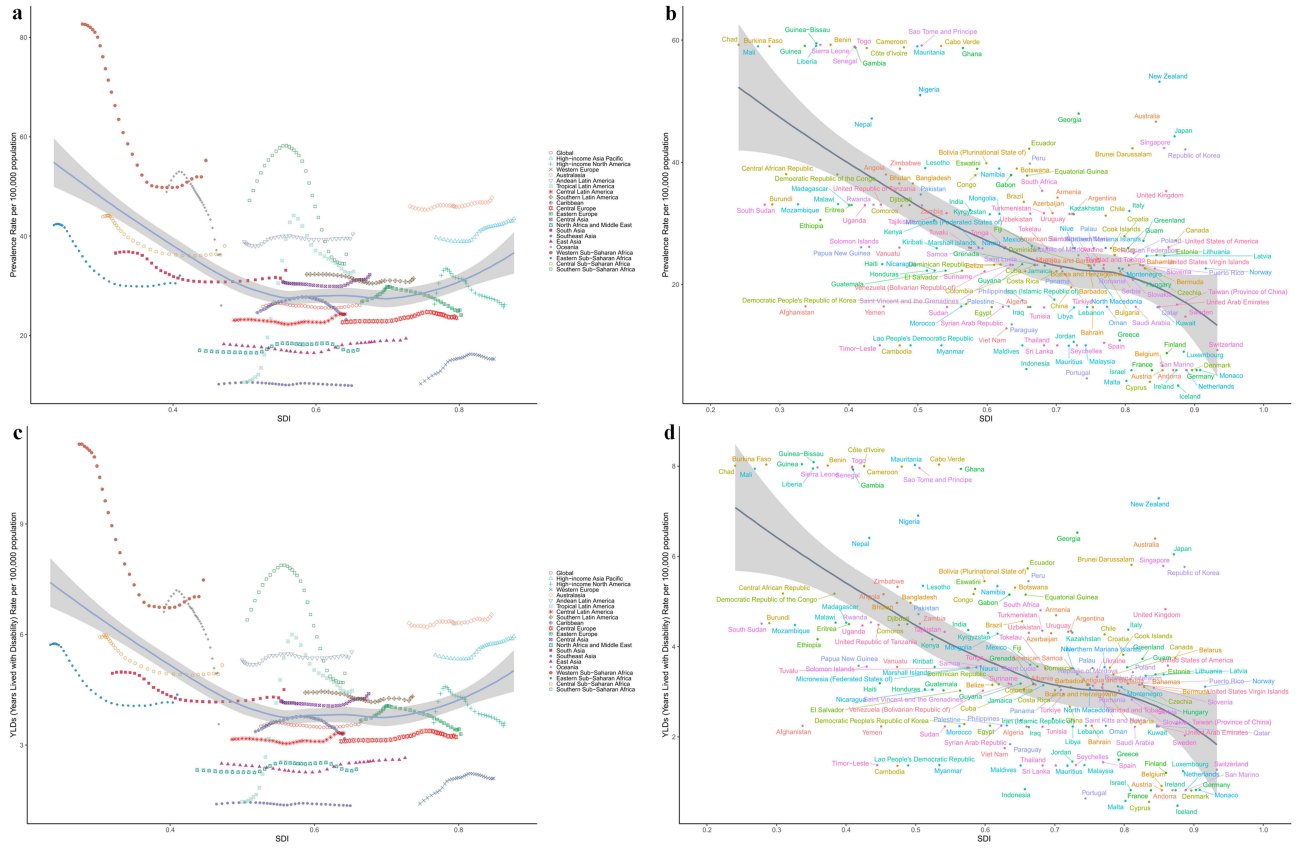

Figure 3 Correlation between ASR of pelvic inflammatory disease and SDI at the national and regional levels in 2021. (**a**) The age-standardized prevalence rate of pelvic inflammatory disease in 21 regions; (**b**) The age-standardized prevalence rate of pelvic inflammatory disease in 204 countries; (**c**) The age-standardized YLDs rate of pelvic inflammatory disease in 21 regions; (**d**) The age-standardized YLDs rate of pelvic inflammatory disease in 204 countries. The Y-axis represents the age-standardised rate, while the X-axis denotes the year. Different curves represent distinct Sociodemographic Index regions.

Discussion

Our research indicates that the number of pelvic inflammatory disease cases and YLDs are on the rise, while ASPR and ASYR remain relatively stable The disease burden of PID is primarily concentrated in the 30–39 age group. Countries with low SDI experience a disproportionate PID burden, and although health inequalities have decreased, they remain persistent. Population growth and aging have contributed to the increased burden of PID, and epidemiological changes have contributed to the increase in the number of PID cases, but have slowed the increase in YLDs; Projections derived from the BAPC model suggest that the PID disease burden will continue to escalate by the year 2035.

Since 1990, health inequalities in PID have declined but remain. Low SDI regions, particularly Western Sub-Saharan Africa, have seen significant improvements in the burden of PID, consistent with public health initiatives to control sexually transmitted infections (STIs), which have also declined since 1990;[17,18] In addition, promoting condom use has also played a positive role in reducing PID.[19] However, the burden in low SDI regions remains high, which is attributed to socio-political and economic instability and issues with access to healthcare services.[20,21] In addition, gender inequality makes it more difficult for women to access basic health services.[22] These challenges highlight the necessity of international aid and local governance, and indicate the need for further targeted investment in the health systems, community care, and gender equality issues of low-income countries in order to effectively narrow the gap in global health inequality. Among regions with increasing PID burdens, Tropical Latin America has seen the most significant increase, with Brazil standing out in particular. Brazil has obvious shortcomings in sex education and sexually transmitted infection prevention, especially among adolescents and young people.[23] Women who engage in sexual activity at an early age, use fewer contraceptive measures, and do not place enough importance on sexual health are more susceptible to STIs, increasing their risk of developing PID.[5,13,24] SDI is negatively correlated with the burden of

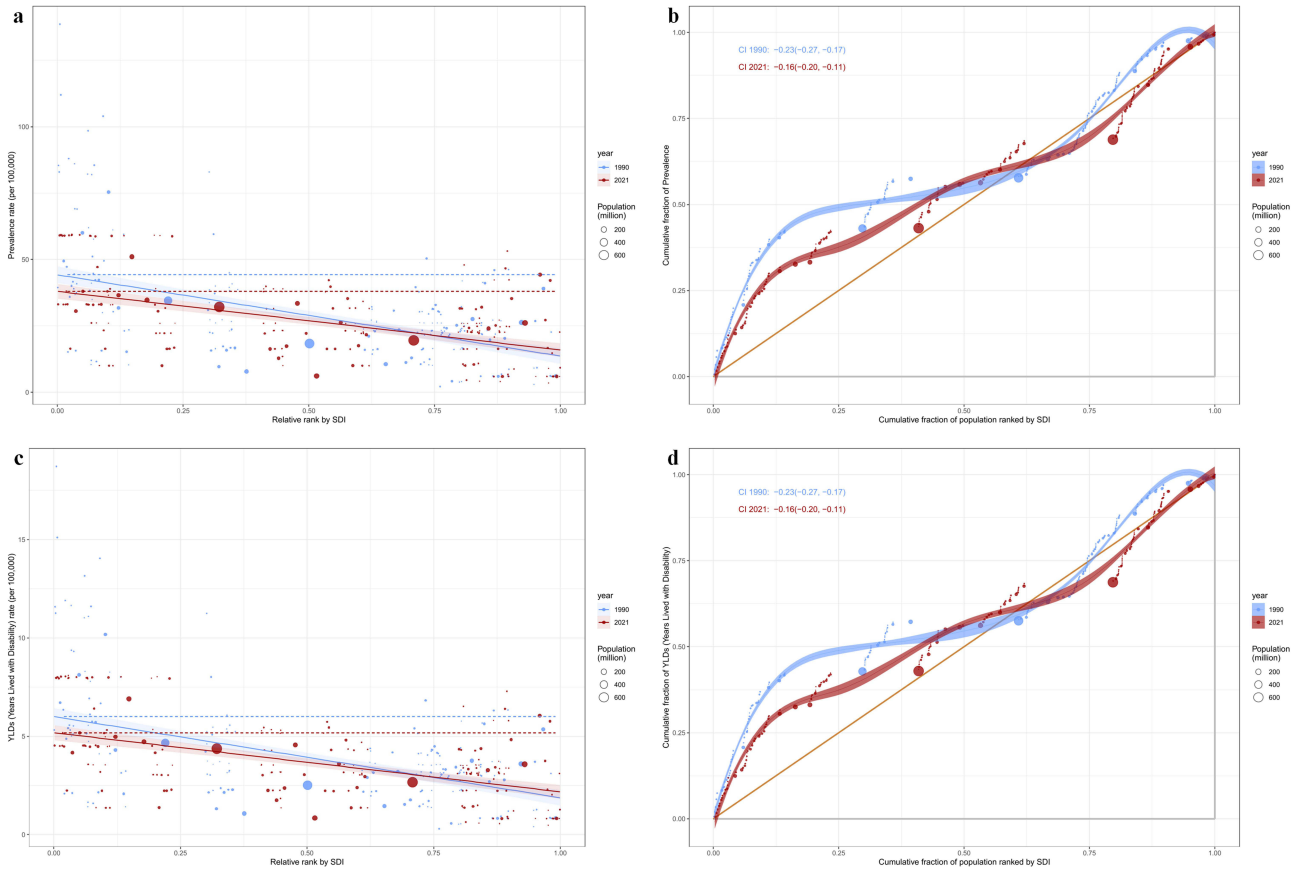

Figure 4 SDI-related health inequality regression curves and concentration curves for the global burden of pelvic inflammatory disease, 1990 and 2021. (**a** and **b**) The age-standardized prevalence rate of pelvic inflammatory disease; (**c** and **d**) The age-standardized YLDs rate of pelvic inflammatory disease. The health inequality regression curve on the left and the concentration curve on the right; In the absolute inequality analysis, the Y-axis represents age-standardised rates, while the X-axis denotes sociodemographic index values. In the relative inequality analysis, the Y-axis represents the cumulative fraction for age-standardised rates, while the X-axis represents the sociodemographic index values.

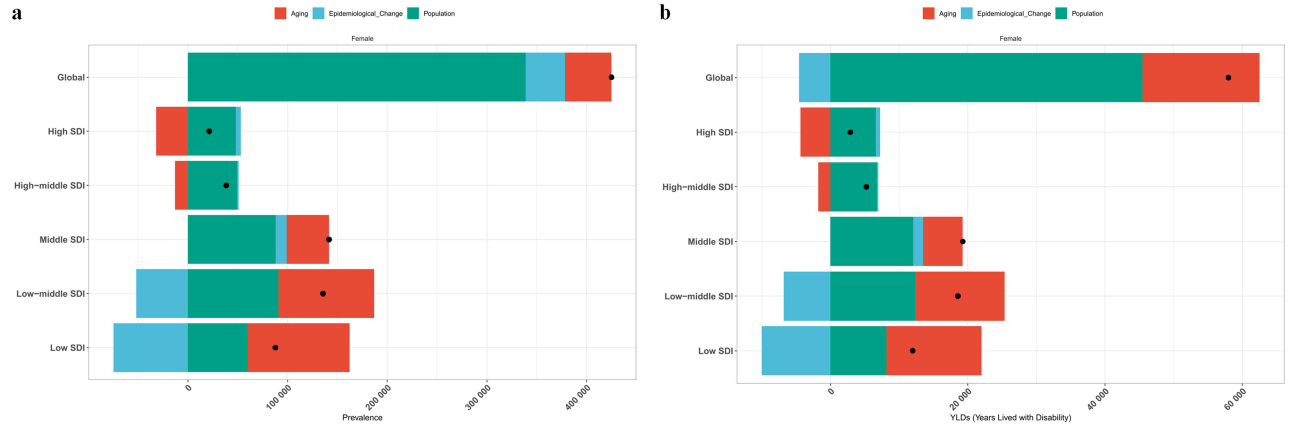

Figure 5 Key drivers of pelvic inflammatory disease burden at global and SDI levels from 1990 to 2021: population growth, ageing, and epidemiological changes. (**a**) The prevalent cases of pelvic inflammatory disease; (**b**) The YLDs of pelvic inflammatory disease. The black dots represent the sum of contributions to changes in all three factors. The Y-axis represents different sociodemographic index regions, while the X-axis denotes the percentage share of each driving factor.

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pelvic inflammatory disease. Uneven economic development has a significant impact on the allocation of health resources and access to medical services. High-income countries such as Iceland, with their advanced healthcare systems and high health awareness, have maintained the burden of PID at a low level.[25] Therefore, promoting the equitable distribution of global medical resources, strengthening support for low-income countries and regions, and improving basic health facilities and medical services are particularly critical. This also highlights the importance of making the improvement of SDI a core objective of health policy.

The disease burden of pelvic inflammatory disease is mainly caused by Other sexually transmitted infections, followed by Chlamydia infection and gonococcal infection. Although Chlamydia infection and gonococcal infection show regional differences[26–30] and changes in age trends[31–34] due to differences in sexual behavior patterns, regional cultures, public health policies and medical accessibility. However, its high incidence age is usually concentrated between 15 and 24 years old,[17] while the PID burden is most concentrated in the 30–39 age group. This may be related to the delayed visit of patients and the delayed development of chronic tissue damage, resulting in many infections not being diagnosed and treated, and ultimately leading to the concentrated manifestation of the inflammatory burden in the older stage. In addition, women in this age group are sexually active and engage in sexual activity frequently, which increases their risk of STIs.[35,36] In addition, women in this age group are frequently engaged in reproductive activities, such as pregnancy, childbirth, abortion, and insertion and removal of intrauterine devices, which may damage the natural defense mechanisms of the reproductive tract[37,38] and further increase the risk of infection. At the same time, family and work pressures may cause them to neglect their own health issues, leading to an increased burden of PID. Therefore, women should pay attention to their reproductive health, undergo regular gynecological examinations, and promptly identify and manage sexually transmitted infections. In terms of sexual activity, it is important to maintain good hygiene and use appropriate contraceptive measures to reduce the risk of sexually transmitted infections.

The Join-point results showed that the prevalence and YLDs rate of PID increased significantly during 2019–2021, which may have been influenced by the COVID-19 pandemic.[39,40] Global public health resources were reallocated, leading to a relaxation of PID prevention and control measures and making it difficult for some populations to obtain timely and effective medical services. In addition, the problem of antibiotic resistance is becoming increasingly serious, making the treatment of PID more difficult.[41,42] During the period from 1994 to 2011, the downward trend in PID burden was closely associated with public health interventions, including the global promotion of condom use, enhanced sexual health education, which strengthened measures for the prevention and control of sexually transmitted infections. At the same time, advances in medical technology have made the diagnosis and treatment of PID more accurate and effective.

Population growth and aging have increased the global burden of pelvic inflammatory disease (PID). A larger population has raised the absolute number of cases, while expanded reproductive activity elevates infection risk.[43,44] Older adults, often with chronic conditions and weakened immunity, are more susceptible to PID. Epidemiological shifts and greater focus on non-communicable diseases have diverted healthcare resources, reducing attention to PID and hindering timely diagnosis.[45,46] However, in low and lower-middle SDI regions, strengthened public health measures and improved healthcare access have successfully reduced PID prevalence. Tailored prevention strategies are therefore essential to address region-specific patterns.

This study has several limitations. First, data quality in the GBD database varies, especially in underdeveloped regions where healthcare gaps may cause underreporting or misclassification. Although statistical models were used to correct errors, data comparability may still be affected. Second, although projections for 2035 are based on robust models, they rely on specific assumptions and remain vulnerable to external factors. Thus, while these findings provide valuable insights into global PID trends, they should be interpreted with caution considering potential biases and methodological complexities.

Conclusion

The global burden of pelvic inflammatory disease has generally increased between 1990 and 2021, and this trend is expected to continue. A considerable disparity exists between regions and countries, with low-SDI countries

experiencing a disproportionately higher PID burden. While there has been a decrease in the prevalence of health inequalities, they continue to be a pervasive issue. Therefore, it is essential to increase global investment in epidemiological research on PID, develop targeted health policies to strengthen disease management in low-income countries, enhance sexual health education for women, and promote safe and hygienic sexual practices to mitigate the adverse effects of PID on women's health.

Abbreviations

PID, Pelvic Inflammatory Disease; GBD, Global Burden of Disease; ASR, Age-standardized rates; YLDs, Years Lived with Disability; ASPR, Age-standardized prevalence rate; ASYR, Age-standardized Years Lived with Disability rate; EAPC, Estimated annual percentage changes; SDI, Socio-demographic Index; UI, Uncertainty Interval; CI, Confidence Interval; SII, Inequality Slope Index; BAPC, Bayesian Age-Period-Cohort; STIs, Sexually Transmitted Infections.

Data Sharing Statement

The relevant data can be accessed using the Global Health Data Exchange tool (https://ghdx.healthdata.org/gbd-2021/sources). The prevalence and YLDs measurements for pelvic inflammatory disease at global, regional, and national levels from 1990 to 2021 were retrieved using the GBD Results Tool (https://vizhub.healthdata.org/gbd-results/).

Ethics Statement

This study utilized de-identified data that was publicly available from the Global Burden of Disease Study 2021. According to Article 32.1 and 32.2 of the "Ethical Review Measures for Life Sciences and Medical Research Involving Human Subjects" (China, February 18, 2023), studies based on public databases and without personal identifiers are exempt from institutional ethical review. Therefore, this analysis does not require separate ethical approval.

Consent for Publication

All authors gave consent for the publication of this study.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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