International Journal of Women's Health

Dovepress
Taylor & Francis Group

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ORIGINAL RESEARCH

# Global and Regional Impact of Pelvic Inflammatory Disease in Females Across All Age Groups (1990–2021) with Projections to 2046: Findings from the 2021 Global Burden of Disease Study

Yun Cheng[1,2,*], Chen Yan[1,*], Jing Feng[2,*], Jie Chen[1], Ting Luan[1], Qianqian Lu[1], Xin Zeng[1]

[1]Department of Gynecology, Women's Hospital of Nanjing Medical University, Nanjing Women and Children's Healthcare Hospital, Nanjing Women and Children's Healthcare Institute, Nanjing, Jiangsu, People's Republic of China; [2]Department of Gynecology, Nanjing First Hospital, Nanjing Medical University, Nanjing, Jiangsu, People's Republic of China

*These authors contributed equally to this work

Correspondence: Xin Zeng, Email august555482@126.com



**Background:** Pelvic inflammatory disease (PID) is a common condition among women of childbearing age, referring to a group of infectious diseases of the upper female reproductive tract, tubo-ovarian abscess, and pelvic peritonitis, primarily caused by sexually transmitted infections (STIs). Delays in diagnosis and treatment can lead to sequelae associated with PID reproductive tract infections such as tubal factor infertility, ectopic pregnancy (EP), and chronic pelvic pain. This study assessed the global burden, trends, and cross-national disparities in PID among women, with projections extending to 2046.

**Methods:** Estimates and the corresponding 95% uncertainty intervals (UI) for the prevalence and years lived with disability (YLDs) of PID were extracted from the GBD (the Global Burden of Disease) 2021 Study. We described the epidemiology of PID at the global, regional, and national levels; analyzed trends in its burden from 1990 to 2021 on overall, local, and multidimensional scales; evaluated time trends using estimated annual percentage changes (EAPCs); and predicted changes in PID burden over the next 25 years by using Bayesian age-period-cohort (BAPC) analysis.

**Results:** From 1990 to 2021, an increase in the age-standardized prevalence rate (ASPR) (EAPC=−0.02, 95% confidence interval (CI): −0.07 to 0.02) was observed in PID. Although our findings show an EAPC of −0.02 and stable incidence rates (ASR), the global burden continues to grow because of several factors. In 2021, the estimated number of PID cases was 1,089,544 (95% UI: 815,164 to 1,405,520), with a corresponding ASPR of 13.38 (95% UI: 10.02 to 17.28) per 100,000 population. The burden of PID varied widely across countries, with the highest ASR for prevalence and YLDs recorded in Guinea. Our predictions indicate that the prevalence and YLDs of PID will continue to rise over the next 25 years.

**Conclusion:** PID remains a major global women's public health concern, with its burden rising from 1990 to 2021. This study highlights the persistent challenges in managing PID, and its unequal distribution, offering insights for more effective resource allocation and age-inclusive care strategies.

**Keywords:** Global Burden of Disease, pelvic inflammatory disease, inequality, sexually transmitted infections, women's reproductive health, Bayesian age-period-cohort, BAPC

## Background

Pelvic inflammatory disease (PID) is an inflammatory condition of the female upper genital tract, including endometritis, salpingitis, tubo-ovarian abscess, and pelvic peritonitis, primarily caused by sexually transmitted infections (STIs).[1] Among them, *Neisseria gonorrhoeae* and *Chlamydia trachomatis* are the primary pathogens involved in PID.[2] In the United States, over 1 million women are diagnosed with acute PID annually, accounting for approximately 8% of all

https://doi.org/10.2147/IJWH.S582360
Received: 18 November 2025
Accepted: 28 May 2026
Published: 16 June 2026

reproductive-aged women and 11% of African-American reproductive-aged women. Each year, around 150 women succumb to PID or its associated complications in the United States.[3]

As both a clinical and public health concern, PID-related sequelae impose a substantial global economic and social burden, posing a serious threat to women's reproductive health. According to the 2020 U.S. Preventive Services Task Force,[4] approximately 20 million STIs cases occur annually in the United States, with 94% involving PID.[5] In STI-related PID cases, further analysis of GBD data[6] revealed that Chlamydia infection accounted for the highest proportion (approximately 23%), followed by Neisseria gonorrhoeae (about 5%), while other multiple STI pathogens collectively contributed to the remaining 72%. This demonstrates the complexity and diversity of PID etiology. PID primarily affects sexually active young women. Between 1990 and 2021, the prevalence of STI-related PID in the 20–24 age group showed the greatest increase. However, another study[7] found that the non-HIV-related STI-PID burden is most concentrated in the female population aged 30–34. Additionally, the age-standardized prevalence of global STI-related PID is projected to continue rising between 2022 and 2040. Empirical and broad-spectrum antibiotics are the standard treatment for early-stage PID; however, prolonged or irregular use inevitably leads to the emergence of antibiotic resistance.[8,9] The incidence of PID has declined in recent years as a result of preventive STI screening and combination therapy for sexual partners,[10] leading to considerably reductions in both direct and indirect costs associated with PID and its sequelae-estimated at over $2,000 per person in prevention and management savings.[11–13]

Previous studies have reported the global burden and correlations between PID and ectopic pregnancy (EP) from 1990 to 2019.[14] However, with the evolving microbial diversity linked to the pathogenesis of PID and the rise of antimicrobial resistance, the epidemiological trend of PID has shifted to some extent. This study aimed to investigate the global prevalence and burden of PID across different age groups. A significant disease burden is frequently correlated with socioeconomic underdevelopment and limited access to healthcare.[15] Data on health inequalities are essential for integrating equity into evidence-based health planning and public health policies.[16]

This study describes the global burden and long-term trends of PID, highlighting the challenges in its control and management, particularly the increasing number of female cases and unequal distribution. It aims to inform the rational allocation of healthcare resources and enhance management strategies across all age groups.

# Methods

## Data Sources and Extraction

American scholars, utilizing the National Hospitalization Patient Sample Database, conducted retrospective cohort studies to analyze disease trends and characteristics in specific populations. Meanwhile, a cohort Markov model analysis based on data from the U.S. TECH-N clinical trial revealed the need for enhanced community healthcare for adolescent patients with PID. Additionally, multicenter observational studies across multiple hospitals in Pakistan demonstrated that coordinated antibiotic management policies are required in low- and middle-income countries to reduce the healthcare burden. Therefore, addressing PID issues urgently requires a dual approach. While variations in disease burden necessitate a global collaborative response, socioeconomic disparities and the uneven distribution of healthcare resources demand targeted strategies at the regional level. The primary data source was the Global Burden of Disease (GBD) 2021 database, which provides comprehensive estimates of health outcomes across a wide array of diseases and risk factors. It is the most extensive scientific assessment of the global epidemiological burden, offering data on 359 diseases and 84 risk factors across 204 countries and territories.[17–19] The GBD study systematically collects data from diverse sources, including population-based surveys, vital registration systems, hospital discharge records, and published literature.[20,21] Specifically, for PID (ICD-10 codes N70-N77), we retrieved GBD data on prevalence and extracted years lived with disability (YLDs), stratified by age, sex, and geographical location.

We employed the Nordpred age-period-cohort (APC) and Bayesian age-period-cohort (BAPC) models to project the disease burden from 2022 to 2046. The APC model serves as a statistical framework that assesses the combined effects of age, period, and cohort on the disease outcomes. By integrating these three dimensions, the APC model captures disease progression trends and supports predictive modeling, addressing the limitations of traditional approaches. However, estimating model parameters remains a significant challenge due to the linear relationships among these factors, which complicate the isolation of individual component effects. The BAPC model builds on the APC framework by incorporating a Bayesian approach, which combines observed data with information to estimate posterior parameters. This method improves the accuracy of parameter estimation and addresses the ambiguity inherent in traditional APC models. The BAPC model utilizes historical data to forecast disease trends.[22] Specifically, the age effect represents variations in health risks across different age groups, the period effect captures changes in public health levels during specific periods, and the cohort effect focuses on health changes across different generations. By integrating these factors, the model provides more precise long-term predictions.

During the initial phase of the study, we conducted an additional predictive analysis as a sensitivity analysis to verify data reliability. The BAPC model, based on the APC framework, employs a multi-model integration and a lifting method to nonlinearly capture time trends. It demonstrates strong fitting ability and adapts well to complex and variable patterns. Overall, the BAPC showed better prediction performance than the APC model. Consequently, we retained the superior predictions from the BAPC while excluding those from the APC to enhance the interpretability of our findings.

## Statistical Analysis

We analyzed the disease burden of PID using a structured approach. First, we reported the global prevalence and YLDs attributable to PID and their corresponding age-standardized rates (ASR) in 2021, stratified by age group, sociodemographic index (SDI) region, GBD region, and individual countries.

Second, we examined the temporal trend of the disease burden globally and across subtypes from 1990 to 2021. The EAPC value was calculated using a linear regression model. Based on the EAPC values, hierarchical cluster analysis was conducted to assess the changing pattern in disease burden across the GBD region, aiming to identify regions with similar trends. Consequently, all 54 GBD regions were grouped into four categories: significant increase, minor increase, remained stable or minor decrease, and significant decrease.

Finally, we projected the future disease burden from 2022 to 2046 using the BAPC model.

A *P*-value less than 0.05 was considered statistically significant. R software (version 4.0.2) was used for database construction, collation, and analysis.

# Results

## Global Trends

Globally, the number of prevalence cases attributable to PID has witnessed a notable rise from 664517 (95% uncertainty intervals (UI): 509093 to 847208) in 1990 to 1089544 (95% UI: 815164 to 1405520) cases in 2021. The corresponding ASPR demonstrated an upward trend, escalating from 12.73 (95% UI: 9.7 to 16.19) to 13.38 (95% UI: 10.02 to 17.28) per 100,000 population. Similarly, the number of YLDs has mirrored this trend, surging from 90430 (95% UI: 56654 to 137065) to 148407 (95% UI: 91512 to 226991), accompanied by an increase in the ASR of YLDs from 1.73 (95% UI: 1.08 to 2.63) to 1.82 (95% UI: 1.12 to 2.79) per 100,000 population (Figure 1, Tables 1 and S1).

## Age-Specific Patterns

An age-subtype analysis of prevalence and YLDs in 2021 is presented in Figure 2. The basic rule was that the disease burden increased with age, peaked in middle age, and then decreased, showing a trend of "N" shape. Notably, the highest number of cases was observed among adults aged 30–34 years, while the highest ASR, were seen in the 35–39 age group (Tables 1 and S1).

Further age-stratified analysis revealed intriguing insights into the shifting patterns of disease burden. Specifically, the trends in the number of cases mirrored those of the overall population across most age groups. For ASR, it suggest the same as the overall population in the burden at most ages, whereas the trend of burden at ages 50–54 was distinct (Figure 3, Tables 1 and S1).

## Regional Disparities

At the SDI regional level, the highest ASR of prevalence was found in the low SDI regions, while the highest number of cases was found in the middle SDI regions (Figure S4, Tables 1 and S1). All SDI regions exhibited an upward trend in

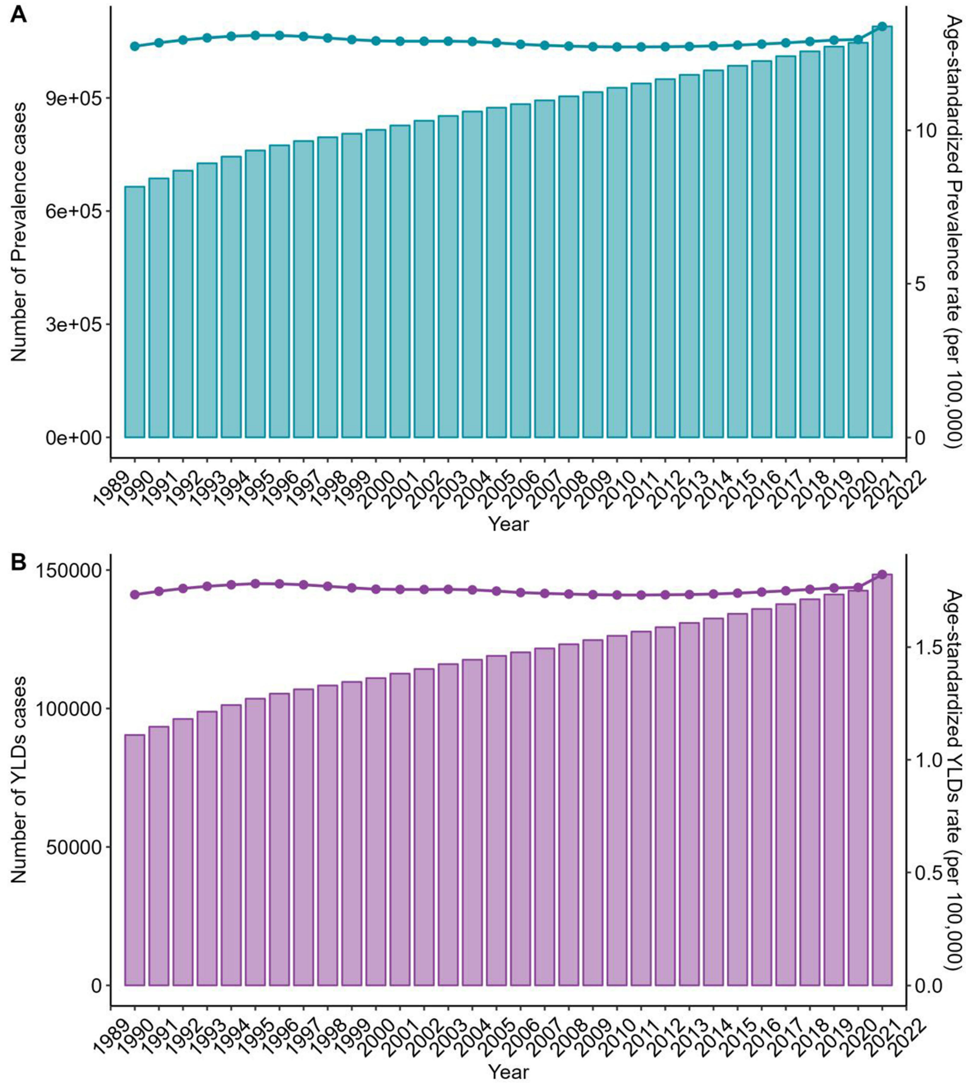


**Figure 1** Trends in the numbers and age-standardized rates of pelvic inflammatory disease-related prevalence and YLDs globally from 1990 to 2021. Abbreviations: YLDs, Years Lived with Disability. (**A**) Trends in the numbers of pelvic inflammatory disease-related prevalence and YLDs globally from 1990 to 2021. (**B**) Trends in the age-standardized rates of pelvic inflammatory disease-related prevalence and YLDs globally from 1990 to 2021.

the number of cases, consistent with the overall population. For ASR, the trend was similar globally except for Low-middle SDI regions and Low SDI regions (Figure S5, Tables 1 and S1).

Across the 54 GBD regions, Western Sub-Saharan Africa ranked the top one in pelvic inflammatory disease-related ASR of prevalence at 29.13 (95% UI: 20.91 to 40.45) and YLDs at 3.94 (95% UI: 2.43 to 6.14), followed by Western Africa and Australasia. Southeast Asia ranked the bottom one for ASR at 4.93 (95% UI: 3.69 to 6.38) for prevalence, and at 0.67 (95% UI: 0.41 to 1.04) for YLDs, followed by Western Europe and Middle East & North Africa - World Bank (WB). For the number of cases, Asia had the highest prevalence at 601118 (95% UI: 448411 to 788236) and YLDs at 81853 (95% UI: 49762 to 126517), followed by World Bank Lower Middle Income and Limited Health System. Oceania had the lowest prevalence at 1730 (95% UI: 1251 to 2337) and YLDs at 237 (95% UI: 137 to 374), followed by Caribbean and Australasia (Figure S6, Tables 1, S1, S3 and S4).

The burden of PID varied widely across countries, with the highest ASR for prevalence (32.62; 95% UI: 22.69 to 45.22) and YLDs (4.44; 95% UI: 2.5 to 7.08) recorded in Guinea, followed by Burkina Faso and Guinea-Bissau. Moreover, the bottom ASR observed in Iceland for prevalence (1.66; 95% UI: 1.03 to 2.43) and YLDs (0.23; 95% UI: 0.13 to 0.39), followed by Malta and Cyprus. As for the absolute number, India had the highest prevalence (241441; 95% UI: 176706 to 322824) and

**Table 1** The Number of Prevalence Cases and the Age-Standardized Prevalence Rate Attributable to Pelvic Inflammatory Disease in 1990 and 2021, and Its Trends from 1990 to 2021 Globally

| | **Number of Prevalence Cases (95% UI) in 1990** | **The Age-Standardized Prevalence rate/100000 (95% UI) in 1990** | **Number of Prevalence Cases (95% UI) in 2021** | **The Age-Standardized Prevalence Rate/100000 (95% UI) in 2021** | **EAPC (95% CI)** |
|---|---|---|---|---|---|
| Global | 664517 (509,093–847,208) | 12.73 (9.7–16.19) | 1,089,544 (815,164–1,405,520) | 13.38 (10.02–17.28) | −0.02 (−0.07–0.02) |
| Age | | | | | |
| 10–14 years | 5342 (2945–8596) | 1 (0.55–1.6) | 6775 (3753–10,846) | 1.02 (0.56–1.63) | −0.06 (−0.16–0.05) |
| 15–19 years | 23505 (13,426–38,715) | 4.53 (2.58–7.45) | 29,967 (16,952–49,139) | 4.8 (2.72–7.88) | −0.04 (−0.16–0.07) |
| 20–24 years | 64459 (44,483–90,370) | 13.1 (9.04–18.36) | 84,278 (56,725–122,180) | 14.11 (9.5–20.46) | −0.15 (−0.28–0.02) |
| 25–29 years | 126272 (78,924–185,817) | 28.53 (17.83–41.98) | 174,376 (102,017–270,261) | 29.64 (17.34–45.94) | −0.2 (−0.3--0.09) |
| 30–34 years | 143792 (95,461–206,474) | 37.31 (24.77–53.57) | 227,876 (146,086–338,711) | 37.7 (24.17–56.03) | −0.17 (−0.21–0.13) |
| 35–39 years | 131476 (88,992–184,337) | 37.33 (25.26–52.33) | 222,434 (145,867–317,845) | 39.66 (26.01–56.67) | 0.07 (0–0.14) |
| 40–44 years | 92397 (56,002–136,778) | 32.25 (19.55–47.74) | 174,247 (103,074–262,655) | 34.83 (20.6–52.5) | 0.18 (0.09–0.26) |
| 45–49 years | 44102 (29,945–61,462) | 18.99 (12.9–26.47) | 96,780 (64,030–135,858) | 20.44 (13.52–28.69) | 0.19 (0.11–0.28) |
| 50–54 years | 21110 (11,160–33,625) | 9.93 (5.25–15.82) | 47,155 (25,226–74,352) | 10.6 (5.67–16.71) | 0.2 (0.11–0.29) |
| 55–59 years | 12062 (7679–18,268) | 6.51 (4.15–9.86) | 25,656 (16,567–37,804) | 6.48 (4.19–9.55) | −0.1 (−0.16–0.05) |
| SDI region | | | | | |
| High-middle SDI | 110109 (81,791–144,442) | 9.85 (7.32–12.94) | 148,589 (111,653–192,675) | 10.24 (7.71–13.3) | 0.23 (0.16–0.29) |
| High SDI | 112221 (83,065–146,858) | 11.7 (8.66–15.29) | 133,621 (103,244–169,594) | 12.17 (9.42–15.25) | −0.15 (−0.25–0.04) |
| Low-middle SDI | 169598 (132,946–215,627) | 16.55 (13.04–20.81) | 305,163 (226,789–403,638) | 15.36 (11.45–20.3) | −0.5 (−0.59–0.41) |
| Low SDI | 105983 (84,361–132,406) | 25.56 (20.49–31.64) | 193,846 (142,377–258,662) | 19.45 (14.38–25.64) | −1.37 (−1.57–1.17) |
| Middle SDI | 166051 (123,532–214,947) | 9.94 (7.45–12.86) | 307,665 (231,412–396,219) | 11.53 (8.67–14.78) | 0.43 (0.4–0.47) |
| GBD region | | | | | |
| Andean Latin America | 6916 (5206–9110) | 19.81 (14.86–25.87) | 14,341 (11,220–18,194) | 20.36 (15.95–25.9) | 0.08 (0.03–0.12) |
| Australasia | 5060 (3764–6660) | 22.95 (17.31–30.18) | 7351 (5546–9590) | 23.95 (18.22–31.57) | 0.12 (0.1–0.14) |
| Caribbean | 4298 (3273–5591) | 12.64 (9.64–16.39) | 5785 (4335–7512) | 11.74 (8.74–15.25) | −0.2 (−0.38–0.03) |
| Central Asia | 10019 (7466–13,252) | 15.63 (11.68–20.63) | 16,649 (12,146–21,946) | 16.18 (11.89–21.18) | 0.05 (0–0.1) |
| Central Europe | 14708 (11,114–19,180) | 11.27 (8.56–14.73) | 13,482 (10,442–16,872) | 11.54 (9.1–14.48) | 0.18 (0.1–0.25) |
| Central Latin America | 17345 (13,003–22,320) | 11.86 (8.9–15.33) | 33,904 (25,841–43,456) | 12.58 (9.58–16.12) | 0.09 (0.01–0.17) |
| Central Sub-Saharan Africa | 9999 (7822–12,634) | 22.46 (17.76–28.21) | 22,947 (16,664–30,373) | 19.11 (13.91–24.96) | −0.87 (−0.98–0.75) |
| East Asia | 110947 (81,941–147,141) | 8.78 (6.44–11.6) | 157,642 (119,165–201,999) | 9.42 (7.13–12.25) | 0.35 (0.2–0.49) |
| Eastern Europe | 32915 (24,876–42,618) | 13.63 (10.33–17.66) | 27,518 (20,266–36,593) | 12.19 (9.05–15.97) | −0.41 (−0.59–0.23) |

(*Continued*)

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**Table 1** (Continued).

| | Number of Prevalence Cases (95% UI) in 1990 | The Age-Standardized Prevalence rate/100000 (95% UI) in 1990 | Number of Prevalence Cases (95% UI) in 2021 | The Age-Standardized Prevalence Rate/100000 (95% UI) in 2021 | EAPC (95% CI) |
|---|---|---|---|---|---|
| Eastern Sub-Saharan Africa | 32888 (25,881–41,677) | 21.9 (17.4–27.31) | 62,729 (45,688–82,773) | 16.52 (12.16–21.73) | −1.41 (−1.62–1.2) |
| High-income Asia Pacific | 37101 (27,794–47,970) | 19.61 (14.64–25.19) | 35,810 (27,440–46,149) | 21.15 (16.09–26.86) | 0.34 (0.29–0.39) |
| High-income North America | 41381 (30,397–54,902) | 13.2 (9.76–17.4) | 46,957 (36,949–58,408) | 13.11 (10.3–16.26) | −0.64 (−0.85–0.44) |
| North Africa and Middle East | 23887 (17,611–31,221) | 8.29 (6.17–10.8) | 55,755 (40,665–73,775) | 8.15 (6.03–10.71) | 0.14 (0–0.28) |
| Oceania | 1310 (1042–1621) | 23.71 (18.74–29.5) | 1730 (1251–2337) | 12.93 (9.33–17.56) | −1.21 (−1.55–0.88) |
| South Asia | 174291 (136,920–222,320) | 17.57 (13.82–22.24) | 322,393 (238,074–429,234) | 16.32 (12.14–21.81) | −0.49 (−0.63–0.35) |
| Southeast Asia | 22846 (16,605–29,962) | 5.2 (3.84–6.77) | 37,725 (28,243–48,759) | 4.93 (3.69–6.38) | −0.22 (−0.27–0.17) |
| Southern Latin America | 7971 (6006–10,308) | 16.42 (12.41–21.22) | 11,431 (8328–15,101) | 15.89 (11.52–20.91) | −0.2 (−0.24–0.15) |
| Southern Sub-Saharan Africa | 11906 (8984–15,630) | 24.37 (18.88–31.65) | 16,240 (11,664–21,809) | 18.36 (13.3–24.56) | −1.81 (−2.27–1.34) |
| Tropical Latin America | 7895 (6152–9910) | 5.43 (4.22–6.85) | 41,670 (32,385–53,477) | 16.7 (12.91–21.45) | 4.1 (2.85–5.37) |
| Western Europe | 20578 (14,952–27,074) | 5.1 (3.67–6.71) | 31,363 (23,829–40,075) | 7.59 (5.74–9.63) | 1.09 (0.79–1.39) |
| Western Sub-Saharan Africa* | 70255 (54,017–88,979) | 42.01 (32.83–53.15) | 126,120 (88,974–176,108) | 29.13 (20.91–40.45) | −1.87 (−2.17–1.58) |

**Notes**: *These regions/countries had wide UIs and low precision.


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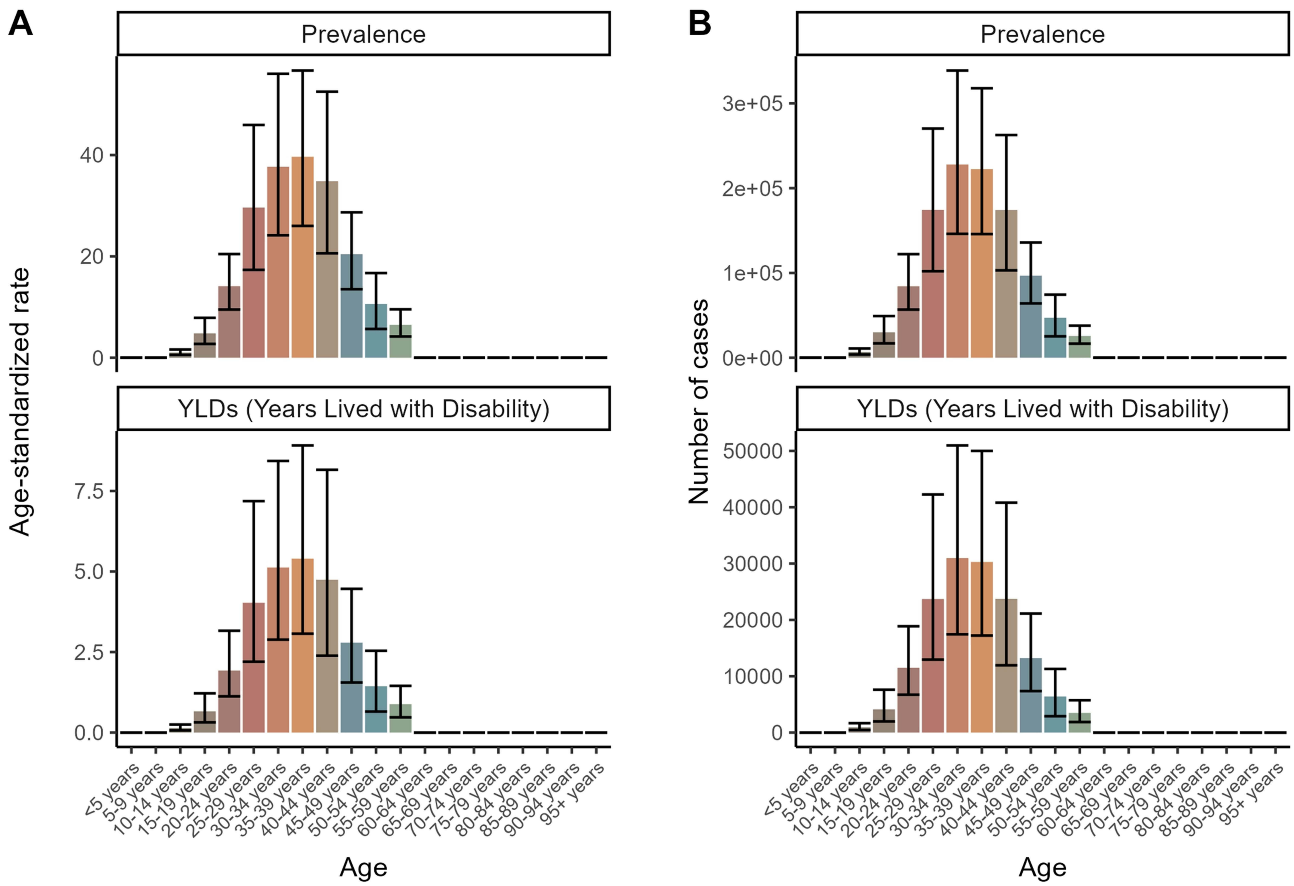


**Figure 2** Numbers and age-standardized rates of pelvic inflammatory disease-related prevalence and YLDs for different age groups in 2021. Abbreviations: YLDs, Years Lived with Disability. (**A**) Age-standardized rates of pelvic inflammatory disease-related prevalence and YLDs for different age groups in 2021. (**B**) Numbers of pelvic inflammatory disease-related prevalence and YLDs for different age groups in 2021.

YLDs (32796; 95% UI: 19600 to 50725), followed by China and Nigeria. The lowest prevalence and YLDs (0, 95% UI: 0 to 0) were observed in Tokelau in 2021, followed by Niue and San Marino (Figure S1, Tables S3 and S4).

Hierarchical clustering analysis[23–26] of GBD regions revealed distinct clusters with similar patterns of disease burden change (Figure S3). Applying this method to the GBD database not only refined the data stratification structure but also enriched research diversity and enhanced visualization effectiveness, thereby making the research report more innovative and persuasive. Notably, significant increases in ASR were observed in Tropical Latin America, while significant decreases were seen in 14 GBD regions including Sub-Saharan Africa-WB, African Region, World Bank Low Income, Southern Africa, Western Africa, Minimal Health System, Southern Sub-Saharan Africa, Western Sub-Saharan Africa, Oceania, Eastern Africa, Commonwealth Low Income, Central Africa, Eastern Sub-Saharan Africa, and Africa (Figure S3).

Across countries and territories, the most pronounced increase in ASR of prevalence [EAPC=4.20, 95% confidence interval (CI): 2.93 to 5.49] and YLDs (EAPC=4.19, 95% CI: 2.92 to 5.47) was observed in Federative Brazil. The most pronounced decrease was observed in Mali for ASR of prevalence (EAPC=−3.85, 95% CI: −4.30 to −3.39) and YLDs (EAPC=−3.85, 95% CI: −4.30 to −3.40) (Figure S2, Tables S3 and S4). In addition, the top/bottom 10 countries for ASR of prevalence and YLDs was showed (Tables S5 and S6).

## Predicted results

BAPC model predict an increasing trend in the global prevalence and YLDs of PID from 2022 to 2046, forecasting a greater rise. The BAPC model predicts that by 2046, the global prevalence of PID will reach 1,562,383.47 cases, a 43.40% increase from 2021, while YLDs will rise to 222,677.99, a 50.05% increase from 2021 (Figure 4 and Table S2).

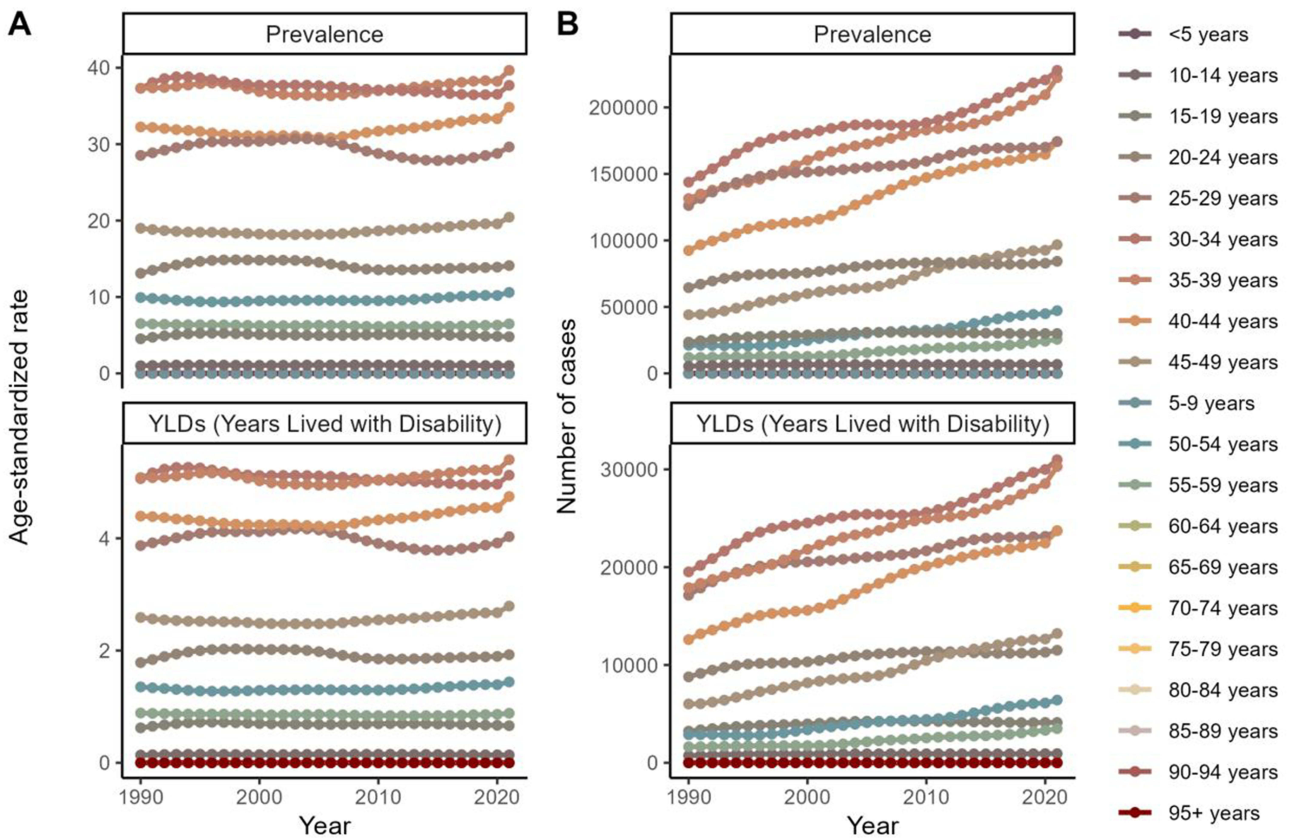


**Figure 3** Trends in the numbers and age-standardized rates of pelvic inflammatory disease-related prevalence and YLDs globally by age groups from 1990 to 2021. Abbreviations: YLDs, Years Lived with Disability. (**A**) Trends in age-standardized rates of pelvic inflammatory disease-related prevalence and YLDs globally by age groups from 1990 to 2021. (**B**) Trends in the numbers of pelvic inflammatory disease-related prevalence and YLDs globally by age groups from 1990 to 2021.

The age-standardized prevalence and YLDs predicted by BAPC models align with the trends observed for the number of prevalence cases and YLDs.

# Discussion

## Global Trends

This study presents the most recent data on the prevalence and YLDs of PID at the global, regional, and national levels from 1990 to 2021. It offers a comprehensive assessment through trend analysis, hierarchical clustering, and predictive modeling. Despite variations across all age groups, SDI and GBD regions, and countries, the global burden of PID increased overall from 1990 to 2021. Previous studies have examined the disease burden associated with PID over the past decades; however, most were limited to a single country or region.[27,28] Only a few studies have been conducted on a global scale, and those that exist are outdated.[14] Additionally, some studies excluded women, particularly adolescents and postmenopausal women. To address these gaps, we utilized comprehensive data from the GBD 2021 database to estimate the disease burden. In our manuscript, the term "increased burden" primarily refers to the sustained global rise in PID cases (Figure 1 and Table 1). Although our findings show an EAPC of −0.02 and stable incidence rates (ASR), the global burden continues to grow because of the following key factors. First, despite the stability in incidence rates, the increasing global population inevitably results in a higher number of cases.[29] Second, growing social burdens, including heightened concerns about women's safety, and increasing societal pressures have contributed to the rising number of PID cases. Thirdly, advancements in medical technology and diagnostic techniques have improved detection rates in recent years. Although projections suggest that both the ASR of prevalence and YLDs associated with PID may experience a slight decline annually from 2021 to 2046, it is anticipated that the absolute number of cases will continue to rise. This trend highlights a major challenge in the control and management of PID over the next decades. Therefore,

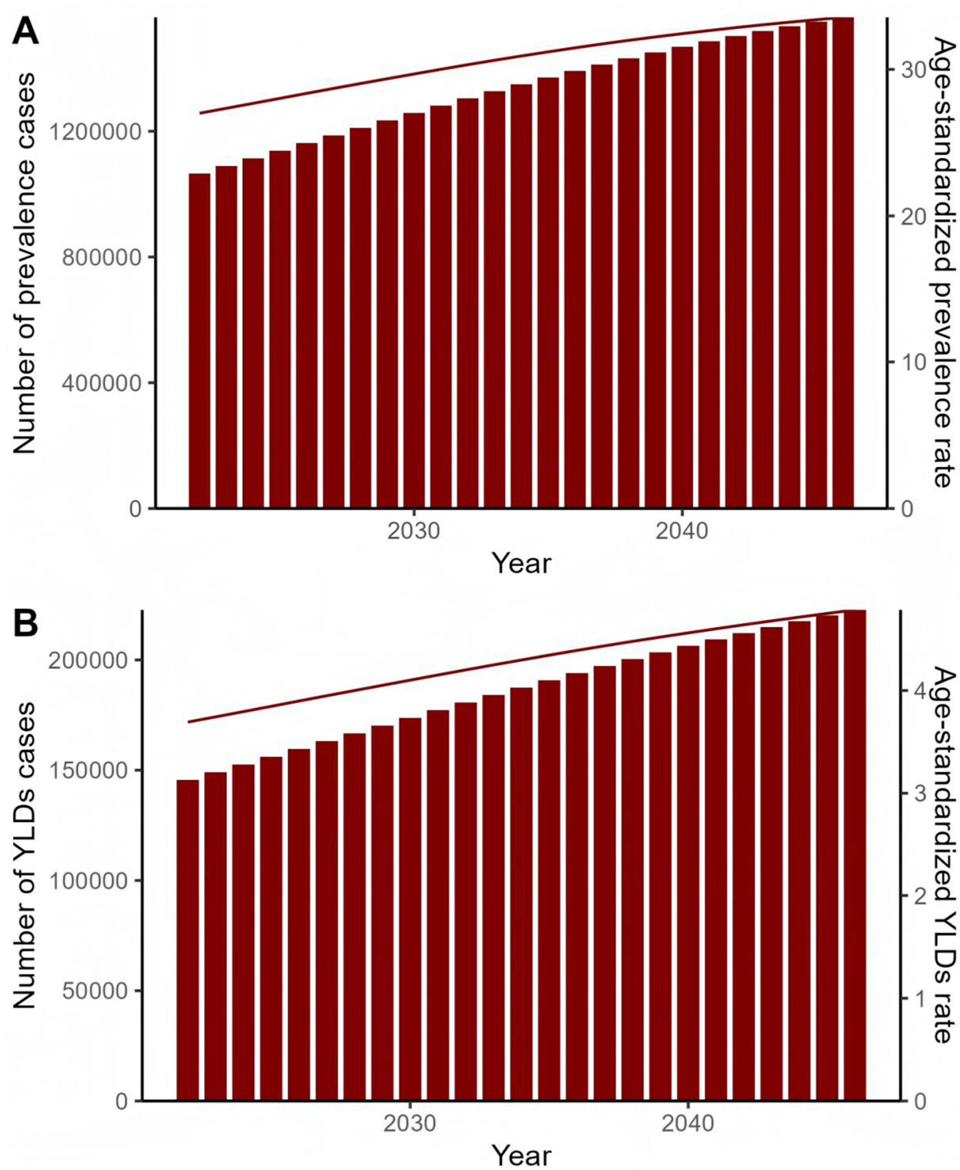


**Figure 4** The predicted results in the pelvic inflammatory disease-related numbers and age-standardized rates of prevalence and YLDs by sex globally from 2022 to 2046 of the BAPC model. Abbreviations: YLDs, Years Lived with Disability; BAPC, Bayesian age-period-cohort. (**A**) The predicted results in the pelvic inflammatory disease-related numbers and age-standardized rates of prevalence by sex globally from 2022 to 2046 of the BAPC mode. (**B**) The predicted results in the pelvic inflammatory disease-related numbers and age-standardized rates of YLDs by sex globally from 2022 to 2046 of the BAPC mode.

our research stratified different regions to address this disparity. The inequality of PID burden concentrating in different SDI countries may be mainly attributed to medical technology capability. As shown in Figures S4 and S5, indicators for low- and middle-SDI countries have increased rapid increases; this phenomenon is likely attributable to widespread internet usage alongside advancements in medical diagnostic capabilities. These findings suggest that our current understanding of the GBD may be underestimated.

## Age Patterns

Moreover, when segmented by age interval in Figure 2, the disease burden of PID showed an "N-shaped" trend, rising with age, peaking in middle age, and then declining. A previous study using the GBD 2019 data similarly found that the prevalence of PID was highest among individuals aged 25–45 years, corresponding to the reproductive period.[14] This particular age group is characterized by high sexual activity and a substantial population base, underscoring the necessity for implementing more targeted prevention, management, and treatment strategies. Compared to reproductive-age and older women, PID in adolescents has attracted more attention. Table 1 shows that the global prevalence of PID among adolescents (aged 10–19 years) in 2021 was 36,742 cases, which isexperiencing a slower growth rate with an increasing global awareness of sexual and reproductive health and improvement in social security. However, the consequences of PID within this age group are particularly severe, owing to its physical and psychological characteristics. Adolescents often encounter more barriers in accessing to timely medical services owing to limited income and low socioeconomic status. Simultaneously, sexual health education for adolescents is often neglected, as students and parents tend to focus on academics.[30] Awareness and appropriate use of contraceptives are crucial for preventing PID. Our findings highlight challenges that may inform the global guidance and implementation of sexual education and PID management for adolescents.

Although PID primarily affects women of childbearing age, demographic factors profoundly influence the absolute burden through two mechanisms. First, in developing countries, particularly in sub-Saharan Africa and South Asia, the population of women of childbearing age is experiencing explosive growth, even as the age-standardized incidence of PID may be slowly declining. Second, while PID itself is a disease of childbearing age, the YLDs estimated by the GBD study include its sequelae, such as chronic pelvic pain, ectopic pregnancy, and infertility. These sequelae may persist for decades, extending the burden even into old age.

## Socioeconomic Disparities

Quantifying the burden of PID across the SDI helps identify distribution patterns and highlights countries, mainly in sub-Saharan Africa, that need improved prevention and control efforts. In 2021, the total number of sexually transmitted disease (STD) cases reached 289.17 million, representing an increase of approximately 58.38% from 1990. These data are consistent with our research trends, especially concerning low-income countries and younger demographic groups. A study on the global, regional, and national burden of HIV/AIDS among 204 countries and regions from 1990 to 2021 indicates that there were 40 million people (95% UI 38.0–42.4) living with HIV worldwide in 2021, comprising about 18 million men and 22 million women. The majority of those infected with HIV are located in sub-Saharan Africa. This burden exhibits a notable consistency with our findings regarding the prevalence of PID. Poverty, inadequate healthcare and education, lack of sexuality education and promotion, insufficient attention to adolescents and older women, and the continued neglect of STDs,[31] have contributed to the rising annual prevalence of PID. To prevent PID and its long-term sequelae globally, the World Health Organization (WHO) has repeatedly conducted extensive screening and investigation on STDs.[32,33]

Traditional views hold that PID is primarily caused by STIs. However, approximately 50–60% of clinical PID cases cannot be explained by conventional STI pathogens.[34] Metagenomic studies have revealed that such cases are often associated with an enrichment of microbiota related to bacterial vaginosis. Additionally, research has shown that, unlike in healthy women, the cervical vaginal microbiota of PID patients exhibits a significant enrichment of bacterial vaginosis-associated bacteria. Furthermore, gut-derived microbes such as Enterococcus are frequently detected in the cervical canal of chronic PID patients, suggesting potential cross-infection by endogenous microbiota. In acute PID, Escherichia coli and Staphylococcus epidermidis are the most commonly isolated strains. The evolution of microbial environments is also accompanied by the development of antimicrobial resistance, posing significant challenges to empirical treatment. A 2023 study[35] demonstrated that the resistance rate to penicillin antibiotics has reached 56.3%, while that to cephalosporins has reached 23.8%. This implies that adhering to past empirical treatment regimens significantly increases the risk of treatment failure. The co-evolution of microbial populations and the exacerbation of resistance have profoundly impacted PID control strategies. In response to these challenges, PID disease control strategies are being compelled to shift from single antibiotic therapies toward more comprehensive and precise interventions.

## Impact of COVID-19 on PID Surveillance

Notably, the GBD 2021 study identified COVID-19 as the leading cause of the global disability-adjusted life year (DALY) rate.[34] While no direct evidence suggests that COVID-19 directly causes PID, the pandemic may have had an indirect impact on its diagnosis, treatment and prevention. For instance, during the pandemic, a significant allocation of medical resources was directed towards the prevention, control and treatment of COVID-19, thus limiting the diagnosis and treatment of other diseases, including PID. Consequently, delays in treatment during this period may have adversely affected patient prognosis.

In addition to the aforementioned GBD disease burden study, recent research on PID has yielded numerous findings in the areas of pathogenesis, treatment strategies, and exploration of novel therapies. For instance, a case-control study[34] published in *Microbial Genomics* in December 2025 delved into the association between cervical vaginal microbiota and PID. A meta-analysis[36] published in November 2025 systematically evaluated the efficacy and safety of fluoroquinolone antibiotics in treating PID. The results demonstrated that, compared to other treatment options, fluoroquinolones significantly reduced leukocyte counts and C-reactive protein levels in patients, with higher cure rates. A study[37] published in September 2025 innovatively combined Mendelian randomization, molecular docking of drugs, and animal experiments to identify novel therapeutic targets and compounds for repurposing existing drugs in PID. These findings provide a comprehensive panorama of PID research and clinical trials, highlighting the importance of epidemiological studies on PID, particularly for precision prevention and intervention tailored to different populations and regions, as a critical step in clinical diagnosis and treatment.

Of course, our research should take full account of its limitations. First, the data quality in many underdeveloped countries and primary hospitals is often poor or lacking, resulting in omissions, misdiagnoses and the loss of relevant medical documents. In many regions, GBD data for PID may be modeled because of underreporting or a lack of clinical diagnoses, particularly in low-and middle-income countries. The quality and quantity of input data in certain models may influence the GBD 2021 estimates. Moreover, the statistics only refer to hospital- or surgery-treated cases; thus, the burden may be underestimated, especially in low-SDI regions. Second, the raw data used in the GBD were from different countries, resulting in uneven data quality. Disease burden calculations were largely based on modeled rather than accurate data. Additionally, the GBD 2023 data, expected to replace the GBD 2021 estimates, were not yet available at the time of analysis. The timeline for releasing GBD 2023 remains uncertain and could potentially be postponed until the end of 2025 or later. Waiting for new data may lead to an extended research cycle. The GBD 2021 data has already been used in several high-quality studies, proving its continued research value. Therefore, the time lag of 1–2 years in GBD data reporting should be noted. While the 2021 data is slightly outdated, it can still provide a stable baseline reference. Although the time lag may lead to misjudgment of recent trends, such as rapid changes in certain diseases caused by policy interventions or environmental shifts, the GBD 2021 data still serves as historical comparison material. By focusing on specific diseases, regions, or populations, and combining the data for in-depth analysis, high-quality epidemiological insights can be obtained.

## Conclusions

The global burden of PID, a major public health concern, showed an overall increasing trend from 1990 to 2021. This study describes its global burden and long-term trends and highlights key challenges in its control and management in Figure 5. As described in our research, the number of PID-related cases worldwide has exhibited a significant growth pattern, with the disease burden increasing with age, peaking in middle age and then gradually declining. Countries with low SDI bear

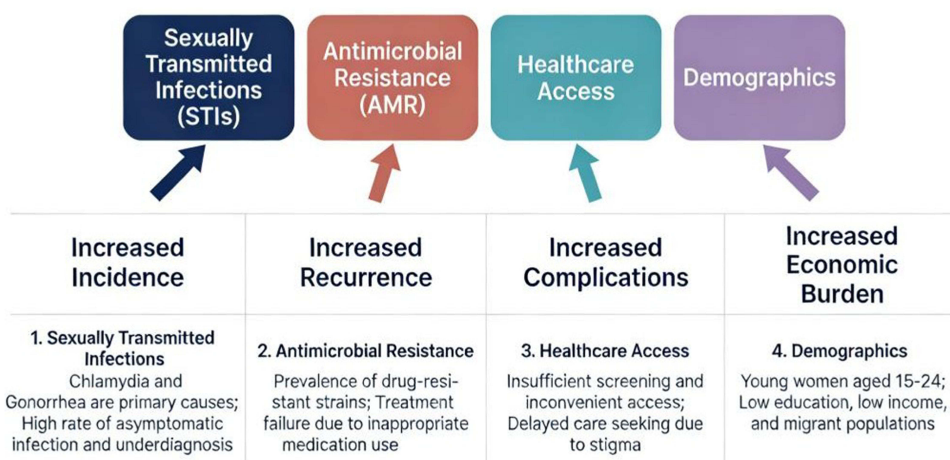


**Figure 5** Schematic summarizing drivers of PID burden.

a disproportionately high PID burden, which is closely linked to gender inequality and poverty. Our model projections indicate that by 2046, the global PID prevalence will increase by 43.40% compared to 2021, while YLDs will rise by 50.05%. These findings highlight the urgent need for equitable, context-specific prevention and management strategies for PID worldwide. Global health policy makers should adopt targeted interventions and flexible strategies to strengthen individualized healthcare systems and address the diverse medical needs in various countries. Only by integrating PID prevention into STI screening programs, expanding coverage in low-SDI regions through existing health platforms, implementing risk stratification screening, dynamically updating drug resistance treatment guidelines, and establishing privacy-friendly services for adolescents can the GBD projections be translated into concrete actions to reduce the global PID burden by 2046.

## Abbreviations

PID, Pelvic inflammatory disease; UI, Uncertainty interval; YLDs, Years lived with disability; GBD, Global Burden of Disease; EAPC, Estimated annual percentage change; BAPC, Bayesian Age-period-cohort; ASPR, Age-Standardized prevalence Rate; STIs, Sexually transmitted infections; EP, Ectopic pregnancy; SDI, Socio-Demographic Index; CI, Confidence interval; STDs, Sexually transmitted diseases.

## Data Sharing Statement

Data used in this study were derived from the Global Burden of Diseases,

Injuries, and Risk Factors Study 2021 (GBD 2021) (https://vizhub.healthdata.org/gbd-results/).

## Ethics Approval and Consent to Participate

This study used publicly available data from GBD 2021. All data in this database are anonymous aggregated data and do not contain any information that can be directly or indirectly identified (such as name, identity card number, medical record number, etc.). This study did not involve direct human intervention, no contact with subjects, and no new biological samples were collected.

According to China "Ethical Review Measures for Life Sciences and Medical Research Involving Humans" and related regulations, research using legally obtained, fully anonymized data falls within the scope of exemption from ethical review. Therefore, this study has applied for an exemption from ethical review and is exempt from the obligation to sign an informed consent form.

## 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.

## Funding

This study was supported by National Natural Science Foundation of China (82073392); National Natural Science Foundation of China (82204469); Jiangsu Provincial Key Research and Development Program (BE2021613).

## Disclosure

Yun Cheng, Chen Yan, and Jing Feng are co-first authors for this study. The authors declare no competing interests in this work.

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