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Global, Regional, and National Impact of Pelvic Inflammatory Disease: Changing Landscape from 1990 to 2021

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Background: Pelvic inflammatory disease (PID) is a polymicrobial infection of the upper female genital tract affecting women globally. The study aimed to assess the global prevalence and years lived with disability (YLDs) of PID from 1990 to 2021 and analyze influencing factors.

Methods: The 2021 Global Burden of Disease (GBD) dataset provided data on the PID statistics of women of childbearing age (15–49 years), including case counts and age-standardized rates (ASRs). Trends were assessed using estimated annual percentage changes (EAPCs), while the relation of regions, nations and Socio-demographic Index (SDI) was examined using local weighted regression (Lowess). To predict the burden, the Bayesian age-period-cohort (BAPC) model was devised.

Results: The GBD data show PID burden negatively correlated with SDI: the age-standardized prevalence rate (ASPR) and the age-standardized years lived with disability rate (ASYR) were higher in low-SDI regions (eg, sub-Saharan Africa) and lower in high-SDI regions (eg, Western Europe). In 2021, rates were 27.02 and 3.68 per 100,000, respectively. Country disparities are marked (Guinea-Bissau highest). Burden peaks at ages 30–39. Projections show persistent increases in both rates across childbearing ages through 2050.

Conclusion: Through severity-stratified estimations, detailed cause-specific burden analysis, and BAPC projection modeling, this study provides a comprehensive and detailed description of the global burden and epidemiological trends of PID. Despite overall progress, persistent disparities remain notably the disproportionately high burden in low-SDI regions such as sub-Saharan Africa and Eastern Europe. These projections underscore an urgent need for context-specific prevention strategies, including strengthened STI screening and treatment, improved antibiotic access, and community-based sexual health education tailored to local health system capacity.

Keywords: pelvic inflammatory disease, global burden of disease, socio-demographic index, age-standardized prevalence rate, age-standardized YLDs rate

Introduction

Female reproductive health is a cornerstone of global public health, with profound implications not only for individual well-being but also for societal and economic stability. Among the various concerns, the public health system is confronted with a significant challenge from pelvic inflammatory disease (PID), an infectious inflammatory disease that harms the lower reproductive tract of women, causing discomfort in organs such as the uterus and ovaries.[1] PID primarily results from ascending infection of the lower genital tract, most commonly by Chlamydia trachomatis or Neisseria gonorrhoeae.[2] However, emerging evidence indicates other infections, like *Mycoplasma genitalium,* are also significant in PID.[3,4] In the long run, PID can lead to a series of consequences that affect fertility, causing infertility, ectopic pregnancies, chronic pelvic pain, and the formation of ovarian and fallopian tube cysts.[5,6] Significant emotional discomfort, a decline in quality of life, and high direct and indirect financial expenditures for both

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patients and healthcare services are all consequences of these issues. Consequently, understanding the full scope of their burden is of great significance for the development of effective public health strategies and the allocation of resources.

Historically, the epidemiological assessment of PID has mainly relied on data from single-center studies or regional surveys.[7] Although these data provide a large amount of information, they are usually limited in scope, lack standardized diagnostic criteria, and are not suitable for cross-national or time comparisons. The measurement of the worldwide illness burden and the tracking of long-term preventative and management procedures are hampered by the fragmented understanding of the epidemiological features of PID caused by the high variety of diseases. Therefore, a comprehensive and standardized analysis must be conducted to clarify the global distribution pattern of PID.

The Global Burden of Disease (GBD) study establishes a powerful framework for bridging this knowledge gap.[8,9] The GBD study offers standardized and comparable estimates for disease prevalence and incidence, in addition to mortality and indicators of health impairment like years lived with disability (YLD) in 21 regions and 204 countries over the period between 1990 and 2021, aiming to conduct a comprehensive analysis of the factors influencing diseases. Its rigorous methodology ensures consistency, allowing for reliable comparisons of disease burden over time and between different geographical and demographic populations.

While previous GBD-based analyses have offered valuable epidemiological estimates for PID, critical gaps remain.[10] Prior studies lacked cross-national comparability, did not stratify by severity despite higher risks of sequelae, and left global trends for non-chlamydial, non-gonococcal STIs unquantified. Furthermore, variations in age-specific burden by socioeconomic development have not been examined, and future burden projections are absent. This study addresses these gaps by ensuring global comparability through the standardized GBD 2021 dataset, providing the first severity-stratified analysis, comprehensively examining etiology-specific trends, analyzing age-SDI interactions, and projecting PID burden to 2050 using Bayesian age-period-cohort modeling. These novel contributions offer actionable insights for targeted prevention and resource allocation.

Leveraging the data and methodology of the GBD study, this analysis aimed to provide the most comprehensive and up-to-date assessment of the global burden of PID. We sought to quantify its age-standardized prevalence rate (ASPR) and age-standardized years lived with disability rate (ASYR) at global, regional, and national levels from 1990 to 2021. Furthermore, we analyzed trends by age and Socio-demographic Index (SDI) to identify disparities and at-risk populations. Our results were meant to drive focused intervention initiatives, support evidence-based health policy, and set a baseline for tracking future advancements in the fight against this harmful disorder.

Methods

Study Data Source

With standardized and comparable epidemiological data spanning health challenges, harm, and contributory elements, the GBD Study represents the most extensive attempt to measure global health trends. This iteration of the GBD study utilized sophisticated statistical models, used DisMod-MR 2.1, a Bayesian meta-regression tool and integrated data from national censuses, hospital records of disease registration, etc, to conduct a systematic assessment of the disease burden attributable to 369 causes of morbidity and mortality across 204 countries and territories between 1990 and 2021. This ensured the comparability of the results.[9]

We examined the prevalence of PID in women between the ages of 15 and 49 in all 204 nations and territories, subdivided by 21 geographical areas. About 95% uncertainty intervals (UIs) were included with estimates to explain for statistical heterogeneity in modeling and data inputs.

Data Definition

According to GBD 2021, the International Classification of Diseases 10th (ICD-10) code for PID includes: A54.24, A56.1–56.11 and so on, and the detailed disease categories are shown in Table S1. According to the severity of the patient's symptoms, GBD classifies PID as moderate PID (described as severe belly pain, feels nauseated, difficulties in daily activities) and severe PID (described as belly pain, feels anxious and even unable to lead a normal life).[9] In GBD 2021, the causes of PID include chlamydia infections, gonorrhea infections, and other sexually transmitted infections, and their disease definitions and ICD-10 codes are provided in Tables S2. The definitions of PID causes and the measurement of long-term sequelae within the GBD framework are

detailed below. GBD 2021 disaggregates PID burden by three main infectious causes: chlamydial infection, gonococcal infection, and other sexually transmitted infections (see Table S2 for ICD-10 codes). YLDs, which quantify non-fatal health loss, capture both acute PID episodes and long-term sequelae based on natural history parameters and established etiological fractions derived from systematic reviews.

Trend Analysis

To contextualize the burden of PID across different development settings, we incorporated the SDI, a composite measure of income per capita, educational attainment, and total fertility rate. The SDI ranges from 0 (lowest development) to 1.0 (highest development) and categorizes regions into five quintiles: low SDI (<0.455); low-middle SDI (0.455–0.608); middle SDI (0.608–0.690); high-middle SDI (0.690–0.805); high SDI (0.805–1.0). Following GBD standard methodology, countries with populations under 1 million were excluded from the analysis to improve the stability of estimates, as small populations are prone to greater data sparsity and random fluctuations. By integrating SDI stratification, our analysis explores how socioeconomic development influences the epidemiology of PID.

Statistical Analysis

We compared the differences between heterogeneous age distributions or within a longitudinal assessment of the population by using the age-standardized rate (ASR) (for 15–49-year-old females). The ASR does not represent the actual case count but allows for standardized comparisons of disease burden across countries, regions, or periods.

The ASR, including ASPR and ASYR for PID, was computed as:

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

Where: a_i= age-specific rate (prevalence or YLDs) in the i^{th} age stratum; w_i= the weight derived from the standard population's distribution within the corresponding stratum; A = the total number of strata.

Covering the years 1990 through 2021, calculate the expected annual percentage changes (EAPC) from the global down to the regional and national level and assess the time patterns. The following is the computation method:

$$y = \alpha + \beta x + \varepsilon$$

Where $y = \ln(ASR)$; x = year; β = regression coefficient. The EAPC and its 95% confidence interval (CI) were derived as:

$$EAPC_{with\,95\%\,CI} = 100 \times \left(e^{\beta} - 1\right)$$

A positive EAPC and 95% CI reflect an increasing trend, whereas a negative value reflects a decreasing trend, the zero denotes a stable trend.

Correlation Analysis

The association between ASPR and YLDs of PID and SDI was evaluated using (Lowess).[11] Lowess is a non-parametric regression method used for smoothing data and trend prediction. It estimates the value of the dependent variable by fitting a low-order polynomial around each data point and combining it with the weighted least squares method.

Projection Analysis

Projections of the ASPR and ASYR of PID were generated through 2050 by employing a Bayesian age-period-cohort (BAPC) model. Briefly, this approach employs a log-linear Poisson model that accounts for the multiplicative effects of three factors, assuming Poisson-distributed outcomes and using a model-specific link function. Projections were derived based on the 1990–2021 dataset. The number and ASR of PID prevalence and YLDs in 2021 served as the baseline. To validate the BAPC model, we compared projections with actual GBD 2021 data.

R (version 4.3.0) was used for all statistical analyses and visualizations in this study. All raw data sourced from the publicly available GBD 2021 dataset, which has been de-identified without the need for additional ethical approvals, in

accordance with the data use protocol and the Guidelines for Accuracy and Transparency in Reporting Health Estimates (GATHER).

Results

Trends in ASPR and ASYR of PID Across SDI Regions

Significant trends in the prevalence and YLDs of PID (Table 1), including moderate and severe cases, were seen throughout several SDI regions between 1990 and 2021, according to an analysis of the GBD data (Figure 1). At the global level, the EAPC of ASPR (−0.04, 95% UI: −0.09–0.00) and ASYR (−0.04, 95% UI: −0.09–0.01) indicated a very slight non-significant decrease over the period. PID exhibited varying temporal patterns, with distinct differences observed across the five SDI quintiles. The most socioeconomically advanced regions consistently exhibited the lowest prevalence rates. Conversely, the highest rates were observed in low and low-middle SDI regions. (Figure 1A). Although they shared a similar trend, the prevalence of moderate PID (mPID) was significantly higher than that of severe PID (sPID) (Figure 1B and C). The disease burden of PID and its subtypes (moderate and severe) exhibited a consistent reduction across regions possessing high SDI over the study period, particularly after 2000. However, in low SDI regions, the ASYR remained elevated. Notably, sPID displayed a disproportionate burden in regions with low SDI (Figure 1D–F).

Regional Variations in ASPR and ASYR: Trends of PID

Among the 21 regions, the EAPC showed an overall decline in both ASPR and ASYR from 1990 to 2021, although there is heterogeneity in some regions (Figure 2A and B). The most rapid decline was observed in Western Sub-Saharan Africa, where the ASPR decreased at an EAPC of −1.98 (95% UI: −2.27 to −1.69) and the ASYR declined with an EAPC of −1.97 (95% UI: −2.25 to −1.68). Conversely, Tropical Latin America exhibited rising trends, with the ASPR increasing at an EAPC of 4.12 (95% UI: 2.87 to 5.40) and the ASYR rising at an EAPC of 4.11 (95% UI: 2.86 to 5.38).

In 2021, ASPR varied markedly across regions. The highest prevalence rates occurred in Central (85.07 per 100,000) and Western Sub-Saharan Africa (103.03/100,000), whereas the lowest rates were observed in Western Europe (30.70 per 100,000) and Southeast Asia (32.77/100,000) (Figure 2C). ASYR also varied substantially by severity and region in 2021 (Figure 2D). Sub-Saharan Africa had the highest ASYR for overall PID (13.94/100,000) and moderate PID. In contrast, sPID rates were low across all regions, including in Western Sub-Saharan Africa.

Country-Specific Patterns in PID Epidemiology

Our country-level analysis revealed that high-burden countries, notably Guinea-Bissau (ASPR: 59.48/100,000; ASYR: 8.08/100,000) and Sierra Leone (ASPR: 59.25/100,000; ASYR: 7.97/100,000) exhibited both exceptionally high prevalence rates and severe disability impacts. In contrast, high-income nations like the United States have high reported PID prevalence rates (ASPR: 26.13/100,00) yet maintained remarkably low YLDs (ASYR: 3.58/100,000) (Figure 3A and B).

Similarly, mPID distribution closely paralleled that of global PID. Countries like Ethiopia and Sudan in East Africa, along with those in the West and Central African nations, showed ASPR peaks approaching 60 per 100,000 and ASYR peaks approaching 6 per 100,000. Countries like Australia and New Zealand had moderately higher ASPR than many Asian and European countries, but still much lower than African hotspots (Figure 3C and D). Overall, the ASPR and ASYR range of sPID was far lower than for moderate PID; the same African countries (eg, Nigeria, Côte d'Ivoire, with ASPR 5.62 and 6.47 per 100,000 and ASYR 1.80 and 2.08 per 100,000) remained the most affected, whereas most other countries had values below 2 per 100,000 (Figure 3E and F).

Age-Specific Temporal Trends in PID Burden

The longitudinal analysis of PID epidemiology from 1990 to 2021 revealed distinct age-stratified patterns in disease burden and temporal trends (Figure 4). Temporal patterns showed significant epidemiological transitions, including a notable decline in mPID prevalence among adolescents (aged 15–19 years) following 2000, a stabilization of sPID disability rates in reproductive-age women after 2010, and an unexpected rate rise period across most age groups during 2020–2021. While

Table 1 The Prevalence and YLDs of Pelvic Inflammatory Disease and Their EAPCs from 1990 to 2021 at the Global and Regional Levels

Characteristics	Prevalence					YLDs				
	Number of Cases, Thousand, 1990 (95% UI)	ASR per 100,000 Population, 1990 (95% UI)	Number of Cases, Thousand, 2021 (95% UI)	ASR per 100,000 Population, 2021 (95% UI)	EAPC, 1990–2021 (95% UI)	Number of Cases, Thousand, 1990 (95% UI)	ASR per 100,000 Population, 1990 (95% UI)	Number of Cases, Thousand, 2021 (95% UI)	ASR per 100,000 Population, 2021 (95% UI)	EAPC, 1990–2021 (95% UI)
Global	626.00(473.63–805.67)	25.82(19.66–32.82)	85.18(52.44–129.61)	27.02(20.24–34.89)	−0.04 (−0.09–0.00)	1009.96 (743.84–1330.47)	3.51(2.20–5.33)	177.20(108.36–260.12)	3.68(2.27–5.63)	−0.04 (−0.09–0.01)
Cause										
Chlamydial infection	143.26(106.14–194.78)	5.80(4.43–7.70)	232.25(169.27–318.93)	6.22(4.61–8.40)	0.04 (−0.02–0.09)	19.55(11.52–30.46)	0.79(0.49–1.21)	31.72(18.51–49.90)	0.85(0.51–1.31)	0.04 (−0.02–0.10)
Gonococcal infection	39.21(28.41–51.80)	1.53(1.12–2.01)	50.27(36.00–69.16)	1.31(0.94–1.78)	−0.8 (−0.91–−0.69)	5.39(3.12–8.58)	0.21(0.12–0.33)	6.92(3.90–11.29)	0.18(0.10–0.29)	−0.79 (−0.90–−0.68)
Other sexually transmitted infections	443.54(329.45–577.01)	18.49(13.92–23.85)	727.44(535.82–966.40)	19.49(14.54–25.56)	−0.01 (−0.05–0.03)	60.24(36.71–92.53)	2.51(1.57–3.84)	98.93(58.71–152.88)	2.65(1.63–4.09)	−0.01 (−0.05–0.03)
Socio-demographic index										
High SDI	104.74(75.80–139.51)	23.70(17.53–30.99)	121.96(91.92–157.31)	25.12(19.43–31.49)	−0.08 (−0.18–0.02)	14.36(8.41–21.94)	3.25(1.91–4.96)	16.70(10.25–25.15)	3.44(2.17–5.14)	−0.08 (−0.18–0.02)
High-middle SDI	99.93(72.20–134.93)	19.95(14.81–26.22)	130.23(94.57–172.97)	21.01(15.80–27.25)	0.25 (0.20–0.31)	13.66(8.15–21.21)	2.73(1.64–4.18)	17.79(10.68–28.09)	2.87(1.74–4.43)	0.25 (0.20–0.31)
Middle SDI	155.63(114.15–203.38)	20.35(15.26–26.33)	279.88(206.08–370.45)	23.29(17.49–29.84)	0.37 (0.34–0.40)	21.22(12.81–32.36)	2.77(1.71–4.21)	38.15(22.48–58.87)	3.17(1.93–4.84)	0.37 (0.34–0.40)
Low-middle SDI	162.04(125.51–207.96)	33.52(26.41–42.10)	289.72(211.80–388.59)	30.72(22.90–40.60)	−0.55 (−0.65–−0.45)	21.92(13.81–33.40)	4.53(2.89–6.84)	39.41(23.46–60.82)	4.18(2.52–6.42)	−0.53 (−0.63–−0.44)
Low SDI	103.16(81.54–129.07)	50.35(40.43–62.22)	187.57(135.62–252.57)	38.23(28.28–50.35)	−1.39 (−1.58–−1.19)	13.94(9.05–21.16)	6.80(4.42–10.22)	25.44(15.22–39.15)	5.19(3.13–7.90)	−1.37 (−1.56–−1.17)
GBD regions										
Andean Latin America	6.57(4.84–8.78)	38.88(29.16–50.75)	13.49(10.36–17.32)	40.47(31.73–51.36)	0.11 (0.07–0.16)	0.90(0.53–1.37)	5.30(3.26–8.04)	1.84(1.10–2.82)	5.53(3.35–8.44)	0.12 (0.07–0.17)
Australasia	4.83(3.52–6.45)	46.01(34.71–60.41)	6.88(5.02–9.16)	47.74(36.38–63.01)	0.11 (0.08–0.13)	0.66(0.38–1.06)	6.31(3.77–9.97)	0.94(0.55–1.47)	6.54(3.87–10.20)	0.11 (0.08–0.13)
Caribbean	4.05(3.05–5.31)	24.66(18.80–31.97)	5.26(3.80–6.99)	23.24(17.29–30.17)	−0.15 (−0.32–0.03)	0.55(0.34–0.86)	3.36(2.08–5.22)	0.72(0.42–1.12)	3.17(1.89–4.87)	−0.14 (−0.32–0.03)
Central Asia	9.30(6.77–12.51)	30.81(23.04–40.68)	15.36(10.98–20.71)	32.25(23.68–42.23)	0.1 (0.04–0.16)	1.27(0.74–2.00)	4.20(2.52–6.44)	2.09(1.25–3.34)	4.40(2.65–6.91)	0.1 (0.04–0.17)
Central Europe	12.90(9.29–17.16)	22.67(17.20–29.62)	11.62(8.79–15.03)	23.57(18.57–29.59)	0.24 (0.16–0.31)	1.77(1.03–2.73)	3.10(1.81–4.80)	1.59(0.97–2.41)	3.22(1.97–4.84)	0.23 (0.16–0.31)
Central Latin America	16.10(11.84–21.02)	23.10(17.34–29.86)	30.44(22.79–39.85)	24.32(18.51–31.15)	0.08 (−0.01–0.16)	2.20(1.29–3.33)	3.16(1.89–4.76)	4.17(2.43–6.40)	3.33(2.01–5.05)	0.08 (−0.01–0.17)
Central Sub-Saharan Africa	9.72(7.57–12.36)	43.94(34.71–55.22)	22.26(15.92–29.73)	38.02(27.68–49.67)	−0.82 (−0.92–−0.71)	1.31(0.80–1.96)	5.94(3.69–8.86)	3.03(1.74–4.74)	5.17(3.08–7.95)	−0.79 (−0.89–−0.68)
East Asia	101.50(71.83–137.82)	18.30(13.40–24.14)	132.88(96.85–177.02)	19.43(14.71–25.28)	0.28 (0.13–0.44)	13.88(8.44–21.45)	2.50(1.52–3.90)	18.15(10.81–28.46)	2.65(1.62–4.09)	0.28 (0.13–0.44)
Eastern Europe	29.00(21.34–38.96)	26.85(20.37–34.81)	23.92(16.76–32.78)	24.13(17.88–31.62)	−0.4 (−0.58–−0.23)	3.95(2.37–6.10)	3.66(2.20–5.54)	3.27(1.91–5.20)	3.30(1.95–5.05)	−0.4 (−0.57–−0.23)
Eastern Sub-Saharan Africa	31.98(24.93–40.73)	42.25(33.62–52.63)	60.81(43.83–81.05)	32.09(23.63–42.17)	−1.38 (−1.59–−1.18)	4.33(2.78–6.57)	5.72(3.70–8.57)	8.28(4.91–13.00)	4.37(2.58–6.68)	−1.37 (−1.57–−1.16)
High-income Asia Pacific	34.28(25.27–45.22)	39.70(29.62–50.95)	32.36(24.27–42.39)	43.51(33.07–55.26)	0.39 (0.34–0.44)	4.70(2.78–7.14)	5.44(3.21–8.21)	4.42(2.65–6.76)	5.95(3.62–9.05)	0.38 (0.33–0.43)

(*Continued*)

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Table 1 (Continued).

Characteristics	Prevalence					YLDs				
	Number of Cases, Thousand, 1990 (95% UI)	ASR per 100,000 Population, 1990 (95% UI)	Number of Cases, Thousand, 2021 (95% UI)	ASR per 100,000 Population, 2021 (95% UI)	EAPC, 1990–2021 (95% UI)	Number of Cases, Thousand, 1990 (95% UI)	ASR per 100,000 Population, 1990 (95% UI)	Number of Cases, Thousand, 2021 (95% UI)	ASR per 100,000 Population, 2021 (95% UI)	EAPC, 1990–2021 (95% UI)
High-income North America	39.29(27.96–52.40)	26.31(19.42–34.69)	43.44(33.61–54.78)	26.23(20.62–32.52)	−0.65 (−0.86–−0.43)	5.39(3.10–8.45)	3.61(2.08–5.57)	5.96(3.74–8.87)	3.60(2.29–5.37)	−0.64 (−0.85–−0.43)
North Africa and Middle East	22.49(16.19–29.87)	17.05(12.68–22.24)	52.22(36.63–70.37)	17.18(12.68–22.59)	0.24 (0.10–0.38)	3.07(1.83–4.77)	2.33(1.41–3.54)	7.14(4.17–11.27)	2.35(1.39–3.66)	0.25 (0.10–0.39)
Oceania	1.28(1.01–1.58)	48.91(38.66–60.85)	1.65(1.17–2.26)	26.07(18.84–35.35)	−1.29 (−1.62–−0.96)	0.17(0.10–0.26)	6.61(4.00–9.81)	0.23(0.13–0.36)	3.57(2.09–5.66)	−1.26 (−1.59–−0.93)
South Asia	166.28(128.52–214.24)	36.60(28.80–46.33)	305.09(220.84–411.95)	33.13(24.62–44.24)	−0.59 (−0.74–−0.44)	22.48(13.97–34.55)	4.95(3.15–7.48)	41.46(24.68–64.58)	4.50(2.68–6.97)	−0.58 (−0.73–−0.42)
Southeast Asia	21.56(15.42–28.65)	10.23(7.54–13.32)	34.79(25.76–45.73)	9.95(7.44–12.87)	−0.14 (−0.19–−0.09)	2.95(1.73–4.56)	1.40(0.83–2.15)	4.75(2.86–7.39)	1.36(0.83–2.10)	−0.14 (−0.19–−0.09)
Southern Latin America	7.54(5.63–9.84)	32.33(24.42–41.78)	10.75(7.69–14.35)	31.48(22.82–41.42)	−0.18 (−0.23–−0.14)	1.03(0.59–1.61)	4.42(2.59–6.77)	1.48(0.85–2.30)	4.32(2.59–6.65)	−0.18 (−0.23–−0.13)
Southern Sub-Saharan Africa	11.63(8.73–15.35)	47.17(36.52–61.24)	15.71(11.14–21.25)	36.35(26.28–48.62)	−1.69 (−2.13–−1.24)	1.58(0.98–2.47)	6.40(3.99–10.02)	2.14(1.25–3.40)	4.95(2.89–7.76)	−1.67 (−2.11–−1.23)
Tropical Latin America	7.26(5.54–9.29)	10.66(8.28–13.44)	38.91(29.68–50.75)	32.89(25.40–42.26)	4.12 (2.87–5.40)	0.99(0.62–1.52)	1.46(0.92–2.21)	5.30(3.29–8.18)	4.48(2.84–6.88)	4.11 (2.86–5.38)
Western Europe	19.21(13.49–25.72)	10.29(7.41–13.55)	28.61(21.04–36.97)	15.31(11.56–19.41)	1.08 (0.78–1.38)	2.63(1.54–4.18)	1.41(0.83–2.23)	3.92(2.38–6.07)	2.10(1.33–3.20)	1.07 (0.77–1.37)
Western Sub-Saharan Africa	69.24(53.04–87.94)	82.67(64.54–104.29)	123.52(86.51–173.70)	55.25(39.73–76.69)	−1.98 (−2.27–−1.69)	9.35(6.04–13.82)	11.16(7.14–16.74)	16.71(10.05–25.82)	7.48(4.62–11.65)	−1.97 (−2.25–−1.68)

Abbreviations: ASR, Age-standardized rate; YLD, years lived with disability; EAPC, estimated annual percentage change; UI, uncertainty interval.

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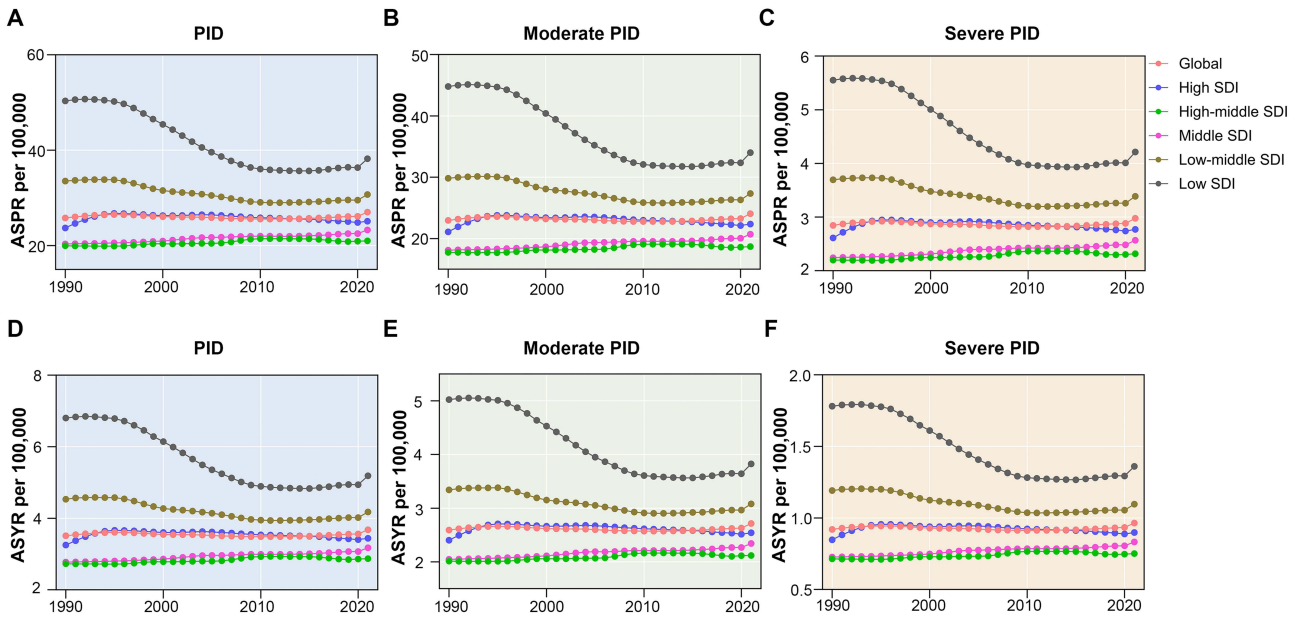

Figure 1 Trends in ASPR and ASYR of PID from 1990 to 2021, stratified by severity (moderate, severe) and SDI levels (global, high, high-middle, middle, low-middle, low). (**A**–**C**) ASPR for PID (**A**), moderate PID (**B**), and severe PID (**C**), respectively. (**D**–**F**) ASYR for PID (**D**), moderate PID (**E**), and severe PID (**F**), respectively.
Abbreviations: ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate; PID, pelvic inflammatory disease; SDI, Socio-Demographic Index.

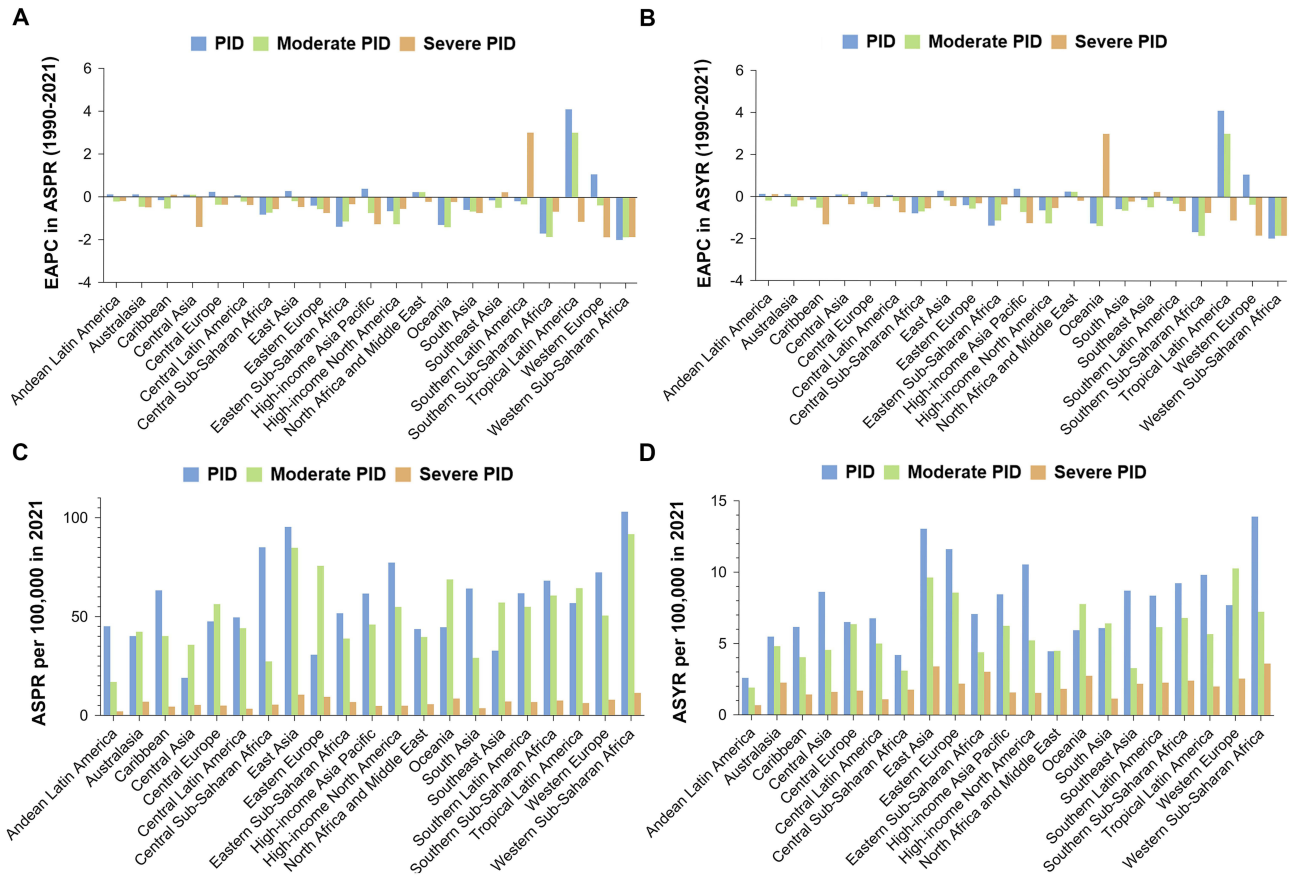

Figure 2 Regional Variations in Age-Standardized Prevalence and Age-Standardized years lived with disability Trends of PID. (**A**) EAPC in ASPR of PID, moderate PID, and severe PID. (**B**) EAPC in ASYR of PID, moderate PID, and severe PID. (**C**) ASPR of PID, moderate PID, and severe PID by region in 2021. (**D**) ASYR of PID, moderate PID, and severe PID by region in 2021.
Abbreviations: PID, pelvic inflammatory disease; EAPC, estimated annual percentage change; ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate.

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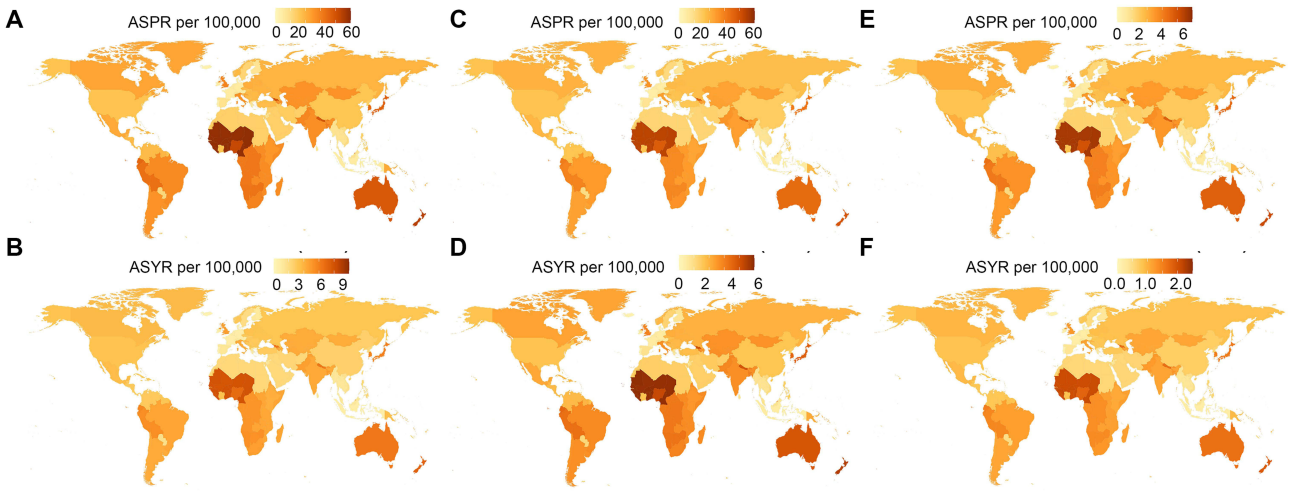

Figure 3 Global burden of PID in 204 countries and territories in 2021, presented as age-standardized rates. (**A** and **B**) Global distribution of ASPR (**A**) and ASYR (**B**) of PID. (**C** and **D**) Global distribution of ASPR (**C**) and ASYR (**D**) of moderate PID. (**E** and **F**) Global distribution of ASPR (**E**) and ASYR (**F**) of severe PID.
Abbreviations: PID, pelvic inflammatory disease; EAPC, estimated annual percentage change; ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate.

overall PID prevalence gradually declined, PID cases showed a concerning increase between 2010 and 2021 among women aged 35–44 years (Figure 4A–F). Young women aged 30–39 years consistently bore the highest burden, exhibiting peak prevalence rates across all PID categories, with mPID cases reaching their zenith in this demographic by 2021 (Figure 4A–C). The disability burden displayed age-specific characteristics, with mPID-related YLDs predominantly affecting women in their late twenties, while sPID disproportionately impacted older age groups 45–49 years, showing markedly elevated disability rates compared to younger cohorts (Figure 4D–F).

The 2021 ASPR data revealed that the disease burden among women aged 20–39 years showed a rising trend, peaking in the 30–39 age subgroup (ASPR 80.069/100,000) before gradually declining with increasing age. The number of mPID cases and its prevalence trend were similar to those of overall PID. The number and prevalence of sPID were relatively lower, with peak values in the 30–39 age group followed by a decline (Figure 4G). The trend of YLDs in 2021 followed a similar pattern (Figure 4H).

Etiology-Specific Trends in PID Burden

From 1990 to 2021, the burden of PID caused by its three main infectious etiologies, gonococcal infection, chlamydial infection, and other STIs was examined (Figure 5). The etiological factor had a relatively small impact on both moderate and severe PID, and the overall trend remained stable with no significant fluctuations. The ASPR of other STIs was consistently at a relatively high level. Although the overall trend was stable, it remained much higher than those of chlamydial infection and gonococcal infection (Figure 5A–C). A similar pattern was observed for ASYR, although the values were substantially lower than those for ASPR (Figure 5D–F).

Association Between Burdens and SDI Index

The SDI and the burden of PID were found to be negatively correlated after a thorough analysis. Figure 6A and B display the observed worldwide and regional ASPR, ASYR, regarding the region SDI, in comparison to the projected level for each site based on SDI. Western sub-Saharan Africa and Western Europe displayed unique trends in their ASPR and ASYR, whereas consistency was noted among most other regions. National SDI levels showed a strong negative correlation with the ASPR and ASYR from 1990 to 2021 (Figure 6C and D). This relationship was non-linear, with the most dramatic gradient observed between low and middle SDI quintiles. Countries with the lowest SDI values consistently exhibited the highest PID prevalence, while nations with high SDI values sustained the lowest burdens throughout the study period.

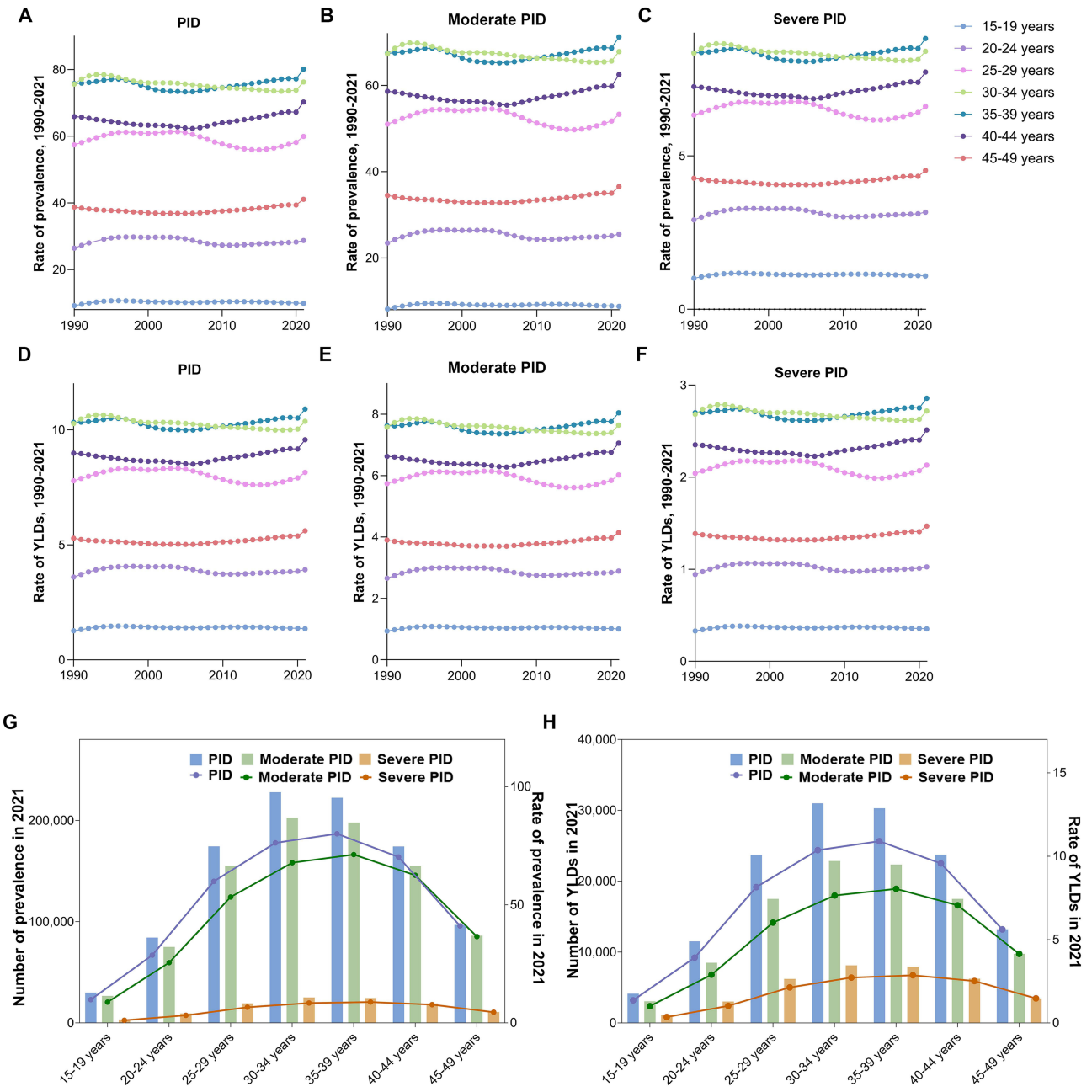

Figure 4 Temporal trends and age-related distributions of PID from 1990 to 2021. (**A**–**C**) ASPR of PID (**A**), moderate PID (**B**), and severe PID (**C**), respectively. (**D**–**F**) ASYR for PID (**D**), moderate PID (**E**), and severe PID (**F**), respectively. (**G**) Number of prevalence cases and ASPR of PID, moderate PID, and severe PID by age group in 2021. (**H**) Number of YLDs cases and ASYR of PID, moderate PID, and severe PID by age group in 2021.

Abbreviations: PID, pelvic inflammatory disease; EAPC, estimated annual percentage change; ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate; YLDs, Years lived with disability.

Prediction of PID-Related Burden of Age-Specific in the Next 29 Years

The accuracy of the prediction model was verified by comparing it with the actual data of GBD2021 (Figure S1). The ASPR and ASYR of PID were projected to continue increasing until 2050 (Figure 7). The ASPR and ASYR showed a significant upward trend from around 2030 onwards. Notably, the prevalence rates were higher in older age groups (45–49 years) in comparison to younger ones (15–19 years) throughout the observed period. Similar to ASPR, the ASYR also exhibited a marked increase starting around 2030 for all age groups. Older age groups consistently had higher ASYR values than younger age groups (Figure S2).

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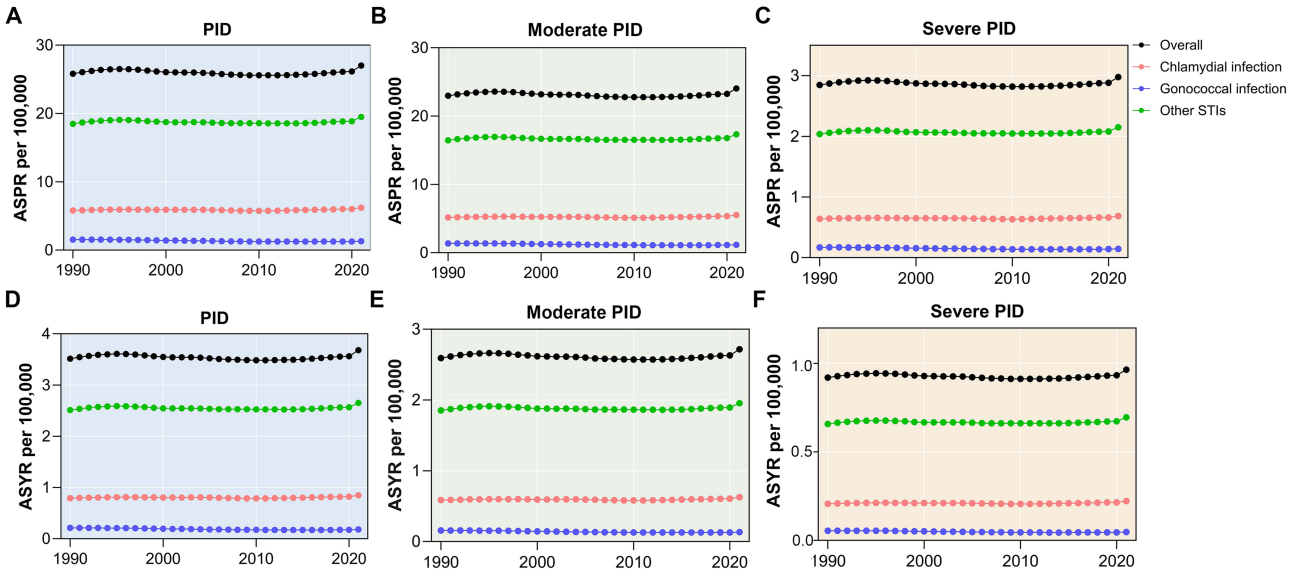

Figure 5 Temporal trends in ASPR and ASYR of PID etiology from 1990 to 2021. (**A**–**C**) ASPR about chlamydial infection, gonococcal infection, and other STIs of PID (**A**), moderate PID (**B**), and severe PID (**C**). (**D**–**F**) ASYR about chlamydial infection, gonococcal infection, and other STIs of PID (**D**), moderate PID (**E**), and severe PID (**F**).
Abbreviations: ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate; PID, pelvic inflammatory disease.

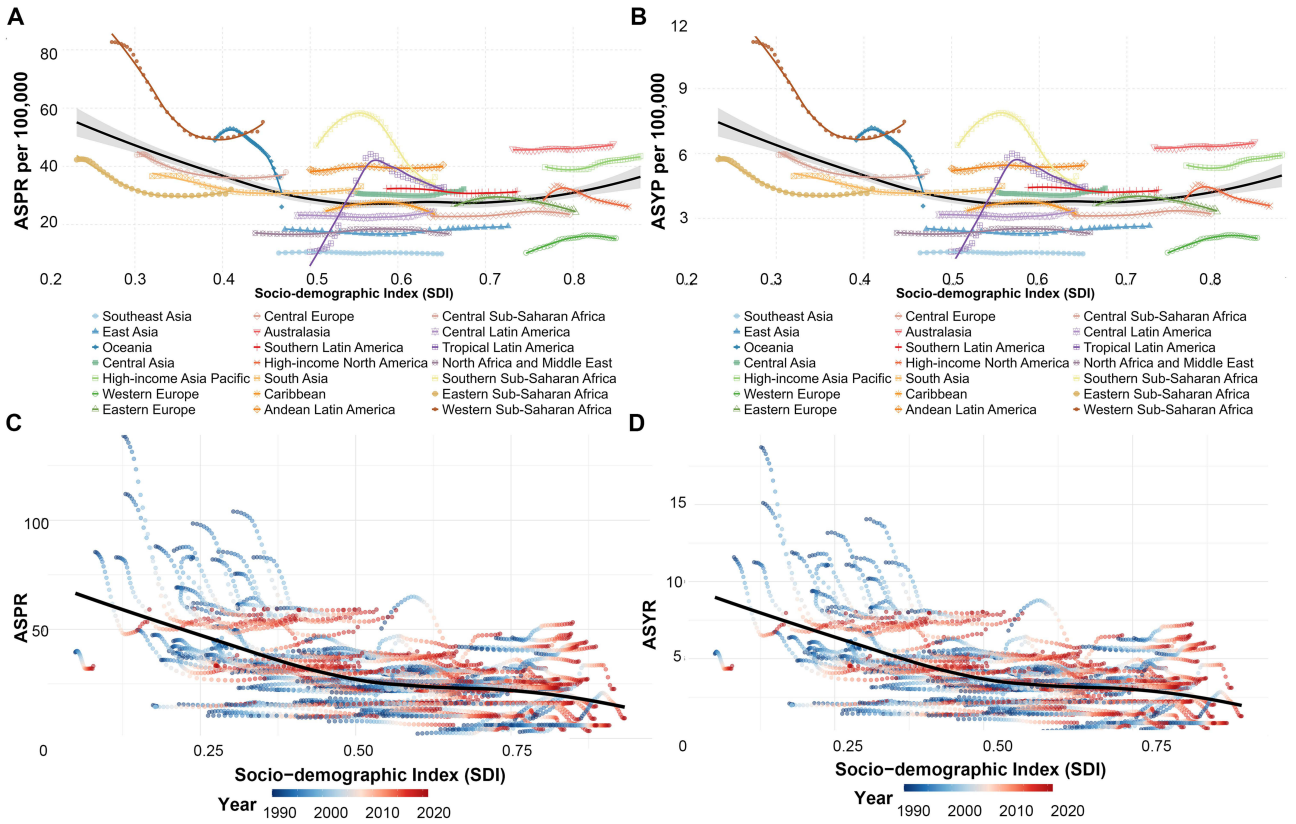

Figure 6 Coevolution of age-standardized burden estimates with SDI globally and for countries and regions for PID, 1990–2021. (**A**) ASPR of PID in regions by SDI, with lines representing different regions. (**B**) ASYR of PID in regions by SDI, with lines representing different regions. (**C**) ASPR of PID in countries by SDI, with color representing year of countries. (**D**) ASYR of in countries by SDI, with color representing year of countries.
Abbreviations: SDI, Socio-Demographic Index; PID, pelvic inflammatory disease; ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate.

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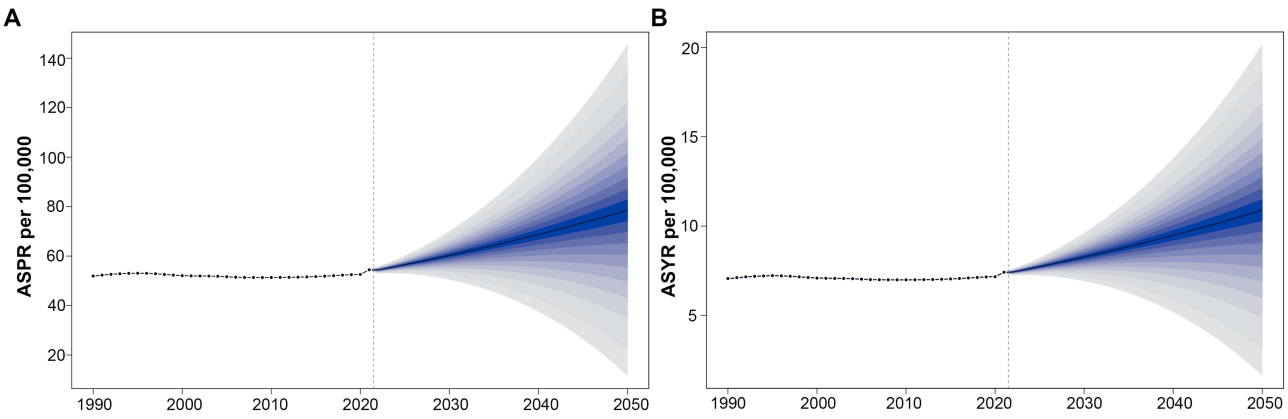

Figure 7 The Prediction of PID in ASPR and ASYR (**A**) The Prediction in ASPR. (**B**) The Prediction in ASYR.
Abbreviations: PID, pelvic inflammatory disease; ASPR, age-standardized prevalence rate; ASYR, age-standardized years lived with disability rate.

Discussion

PID remains a critical women's health issue with evolving epidemiological patterns. This study advances existing GBD-based analyses through several novel contributions. First, we provide the most granular severity-stratified analysis to date, demonstrating that while moderate PID accounts for the majority of cases, severe PID disproportionately affects low-SDI regions and older reproductive-aged women, a finding with important implications for resource allocation. Second, through detailed cause-specific burden analysis, we examined the etiological composition of PID, revealing that the predominance of "other STIs" is consistent across all severity levels. Third, this study presents the first projections of PID burden to 2050 using Bayesian age-period-cohort modeling, revealing a concerning upward trend from approximately 2030 onward, particularly among women aged 45–49 years, challenging the assumption that PID burden will continue to decline.

GBD estimates document the persistent disparities in PID burden across SDI regions and between countries, highlighting the profound impact of socioeconomic determinants on sexual and reproductive health outcomes. External literature provides important context for interpreting these patterns, particularly by elucidating how region-specific diagnostic practices and healthcare-seeking behaviors can influence the reported burden, potentially leading to underestimation in some settings.[12,13] Studies suggested that in low-SDI settings, reliance on syndromic management may lead to both underdiagnosis of asymptomatic PID and overdiagnosis of non-STI conditions. It has been reported that in these settings, women with mild or atypical symptoms may not seek care, and even when they do, the lack of sensitive diagnostic tools (eg, ultrasound, laparoscopy) means that many cases are missed.[2,14] This creates a paradoxical situation: the high rates we observe in low-SDI regions likely represent only the "tip of the iceberg" of symptomatic, moderate-to-severe cases, while the true burden, including mild and asymptomatic infections, may be substantially higher. Conversely, high-SDI countries with comprehensive diagnostic capacity may capture more mild cases, contributing to the "diagnostic paradox" where higher reported prevalence coexists with lower disability burden.[12,15] The severe burden seen in places with poor health systems and high STI incidence, such as South Africa and Ukraine, highlights the urgent need for focused intervention.[16] For low-SDI regions, priority strategies should include: (1) strengthening STI screening and treatment programs through point-of-care diagnostics and antibiotic access; (2) implementing community-based interventions such as school-based sexual health education and community health worker programs; and (3) enhancing surveillance systems to better capture true burden and guide resource allocation. Addressing these challenges will require sustained investment in sexual health services, antimicrobial stewardship, and targeted interventions tailored to local health system capacity.

The age-specific trends revealed by GBD data showed an evolving epidemiological pattern that challenges traditional notions of PID as primarily affecting young women. Our estimates indicated that increasing sPID burden among women aged 35–44 is particularly concerning. Underdiagnosis may also distort observed age patterns. As for older reproductive-aged women (35–49 years) may be particularly susceptible to underdiagnosis for several reasons, like clinicians may have lower suspicion for PID in older women, traditionally considered a disease of younger populations,[17] symptoms in older women may be atypical or attributed to other common conditions such as endometriosis or fibroids and cultural backwardness and gender

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discrimination were existed, which leads to delayed medical treatment.[18,19] These findings supported calls for expanded PID prevention efforts beyond traditional adolescent and young adult populations.

Our etiology-specific analysis provided important insights into the changing microbial landscape of PID. GBD estimates showed that "other STIs" is the leading etiological category, accounting for the majority of PID burden across all severity levels. While chlamydial and gonococcal infections are prioritized in most STI control programs, emerging evidence suggests that pathogens such as *Mycoplasma genitalium* and bacterial vaginosis-associated organisms contribute substantially to PID burden, particularly in low-SDI settings.[20,21] While the GBD framework does not directly measure antimicrobial resistance patterns, evidence from external literature indicates that AMR, particularly in *Neisseria gonorrhoeae*, represents an emerging threat to PID management.[22,23] Rising resistance to cephalosporins and azithromycin compromises first-line treatment regimens and may increase the risk of treatment failure, disease progression, and long-term sequelae.[24] Although our GBD-derived estimates do not incorporate resistance data, this contextual consideration is essential for understanding the evolving challenges in PID control and underscores the urgent need for antimicrobial stewardship and resistance surveillance, especially in regions with high gonococcal burden.

Additionally, the substantial YLD burden documented in our GBD analysis reflects the long-term reproductive consequences of PID, which perpetuate cycles of morbidity and health system costs. These findings underscore the need for expanded diagnostic capacity, research into non-traditional pathogens, and integrated care models that address both acute infections and their chronic sequelae.

GBD estimates show an increase in PID burden during 2020–2021, but this observation should be interpreted with caution, as it likely reflects a combination of factors rather than a simple epidemiological shift. External literature suggests several possible explanations. Healthcare disruptions due to the COVID-19 pandemic, including reduced screening, delayed care-seeking, and service interruptions, may have led to both underdiagnosis in 2020 and a backlog of more severe cases presenting in 2021.[25–27] Data artifacts, such as reporting lags and changes in health information system operations, may also contribute.[28] Furthermore, GBD modeling assumptions, while robust for long-term trends,[9] may not fully capture the unique disruptions of the pandemic period. Future studies with more complete post-pandemic data will be essential to disentangle these complex influences and determine the true trajectory of PID burden.

The discrepancy between the modestly declining global EAPCs (ASPR: −0.04; ASYR: −0.04) observed in GBD data and the projected increase in ASPR and ASYR after 2030 from our BAPC model warrants explanation. First, at the global level, our result showed that the EAPCs of ASPR (−0.04, 95% UI: −0.09 to 0.00) and ASYR (−0.04, 95% UI: −0.09 to 0.01) indicated overall stability from 1990 to 2021 rather than a confirmed decline. Second, from the methodological perspective, EAPC and BAPC projection describe different aspects of the data. EAPC summarizes the average historical annual change over the observed period (1990–2021), whereas the BAPC model projects future burden based on age-, period-, and cohort-specific patterns and does not assume a linear continuation of the historical average trend. While data from most countries or regions have declined or remained stable, a small number of regions have shown an upward trend, and high burdens remain concentrated in specific areas, particularly sub-Saharan Africa. Therefore, the projected increase in ASPR and ASYR after 2030 should not be interpreted as a contradiction of the global EAPCs, but rather as a possible future inflection identified by the projection model.

The study's findings and the external literature highlight several critical priorities for PID prevention and control. Targeted interventions in high-burden countries must prioritize strengthening STI screening[29] and treatment programs[30] while addressing systemic healthcare barriers.[31] Prevention strategies should expand beyond traditional young adult populations to address the growing burden among older women, who are increasingly affected by sPID and its complications. Antimicrobial stewardship programs are urgently needed to combat rising gonococcal PID rates, particularly in regions where resistance patterns threaten the efficacy of first-line treatments. In addition, international cooperation is necessary to tackle the transboundary problem of antimicrobial-resistant STIs, which calls for resource sharing between high- and low-income nations, standardized treatment protocols, and coordinated surveillance. Future studies should concentrate on clarifying the behavioral, biological, and health-care-access aspects that may contribute to delayed identification and treatment of PID in older women of reproductive age.[32,33]

Finally, cost-effectiveness analyses of expanded screening programs in LMICs are crucial to guide policy decisions and optimize resource allocation in settings where PID burden remains disproportionately high.[34] Addressing these research gaps will be essential for refining global PID control strategies and mitigating the long-term consequences of untreated infections.[35]

Limitations

The limitations of the data are also a part that we cannot ignore. Several limitations related to the accuracy of GBD estimates warrant discussion. First, estimates for countries with limited primary data carry greater uncertainty; asymptomatic PID remains difficult to model accurately; and regional heterogeneity in diagnostic practices introduces residual confounding that covariate adjustment cannot fully eliminate.[36] Second, regional variability in diagnostic practices, ranging from syndromic management in low-income countries to laparoscopy-confirmed diagnosis in high-income settings, introduces heterogeneity in case detection.[37] GBD's use of standardized case definitions and healthcare access covariates partially mitigates this, but residual confounding remains. Third, the severity classification (moderate vs. severe) is based on symptom descriptions from administrative data, which may not fully capture clinical nuances such as tubo-ovarian abscess or peritonitis. These factors should be considered when interpreting regional and temporal trends. Additionally, this study did not include data on treatment access, antibiotic regimens, patient management outcomes, or antimicrobial resistance patterns, factors that are critical for understanding the full clinical picture of PID and for informing evidence-based treatment guidelines. Future studies should integrate clinical treatment data with epidemiological burden estimates to provide a more comprehensive understanding of PID control strategies.

Conclusion

This comprehensive analysis reveals persistent global disparities, a shifting age distribution toward older reproductive-aged women, and the predominance of "other STIs" as the leading etiological category. For policy and resource allocation, low-SDI regions, particularly sub-Saharan Africa, must be prioritized through investments in surveillance, point-of-care diagnostics, and antibiotic access. For clinical practice, clinicians should maintain suspicion for PID in older women (35–44 years) and consider non-traditional pathogens in treatment decisions. For future research, cost-effectiveness analyses of expanded screening programs in low-SDI settings and studies on care barriers among older women are urgently needed to guide targeted interventions.

Abbreviations

ASR, Age-standardized rate; ASPR, Age-standardized prevalence rate; ASYR, Age-standardized YLDs rate; BAPC, Bayesian age-period-cohort; CI, Confidence interval; EAPC, Estimated Annual Percentage Change; GBD, Global Burden of Disease; GHDx, Global Health Data Exchange; ICD-10, International Classification of Diseases 10th; LMICs, Low- and middle-income countries; Lowess, Local weighted regression; mPID, Moderate PID; PID, Pelvic inflammatory disease; SDI, Socio-demographic Index; sPID, Severe PID; STIs, Sexually transmitted infections; UIs, Uncertainty intervals; YLDs, Years lived with disability.

Data Sharing Statement

The data supporting the findings of this study were sourced from the Global Burden of Disease (GBD) 2021 study. Publicly accessible data can be retrieved directly from the GBD Results Tool at http://ghdx.healthdata.org/gbd-results-tool.[9]

Ethics Statement

This study utilized publicly available, anonymized, and aggregated data from the GBD 2021 database. According to Article 3 of the Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects (issued by the National Health Commission of the People's Republic of China on February 18, 2023), this study does not involve activities that require ethical review as it uses only publicly available anonymized data and fully complies with the principle of protecting privacy and personal information as stipulated in Article 17 of the same Measures. Therefore, this study was granted an exemption by the Ethics Committee of First Affiliated Hospital of Guangzhou Medical University.

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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 no competing interests in this work.

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