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From west to east: dissecting the global shift in inflammatory bowel disease burden and projecting future scenarios

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Abstract

Background The epidemiology of inflammatory bowel disease (IBD) has changed dramatically worldwide. This survey analyzed patterns and trends in the burden of IBD to aid future decision making.

Methods The incidence, prevalence, mortality, and disability-adjusted life year data for IBD were derived from the GBD (Global Burden of Disease) study.

Results In 2021, there were 3,830,119 cases of IBD worldwide, including 375,140 new cases, 42,423 IBD-related deaths, and 1,510,784-year healthy life loss due to IBD. The burden of IBD is usually concentrated in regions and countries with high sociodemographic indices(SDI). In 2021, the number of cases (2,000,478) and deaths (22,968) in women were higher than those in men, but the number of new cases in men was higher (188,005 cases). At the global, regional, and national levels, the number of IBD-related illnesses and deaths is still slowly increasing, but the age-standardized rate(ASR) is on a downward trend. The decomposition analysis showed that the change in the burden of IBD was mainly due to the growth of the global population. Frontier analysis showed that age-standardized incidence rate(ASIR) were positively correlated with sociodemographic indexes. As SDI declines, IBD ASIR's effective difference (EF) for a particular SDI is smaller.

Conclusion As a major global public health issue, there are significant regional differences in the burden of IBD. There data are crucial for healthcare professionals, policymakers, and researchers to refine and enhance management strategies, aiming to further mitigate IBD 's global impact.

Keywords Inflammatory bowel disease, Global burden of disease, Incidence, Disability-adjusted life years, Epidemiology

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Introduction

Inflammatory bowel disease (IBD) is a chronic and recurrent inflammatory disease of the intestine and primarily includes ulcerative colitis and Crohn's disease [1, 2]. IBD is characterized by a relapsing-remitting course and various clinical presentations that include intermittent abdominal pain, chronic diarrhea, and hematochezia. This disease manifests in the gut tract, but it also affects extraintestinal organs, such as IBD-assocciated arthropathy(peripheral arthritis and spinal arthritis), skin and mucosal manifestations (oral ulcers, nodular erythema, and gangrenous pyoderma), eye lesions (iritis and scleritis), liver and gallbladder diseases, and thromboembolic diseases, which leads to substantial healthcare costs and places great stress on healthcare systems [3]. In the last few decades, IBD has emerged as a global disease with a conspicuous burden on public health and healthcare costs [4]. Although the cause of IBD remains unknown, the pathogenesis of IBD is suggested to be associated with environmental factors, genetic susceptibility of the host, gut microbiome, and host immune response [5].

IBD has emerged as a significant clinical and public health concern on a global scale. In the past century, IBD has been predominantly associated with Western populations [4]. With the implementation of relevant medical measures, the incidence of IBD in Western countries seems to be leveling off in the 21 st century [6]. In contrast, with increasing urbanization and Westernization, the number of IBD cases in populous nations such as India and China is expected to rise over the next decade. It may surpass the number of cases in Western countries [7]. The shifts in disease patterns in certain areas will increase and alter the global disease burden. These significant changes emphasize the necessity for a consistent and systematic analysis of disease burden and trends related to IBD across various regions and countries.

The Global Burden of Disease (GBD) study is a multinational collaborative effort that assesses health indicators, including the incidence and mortality of 371 diseases, across 204 countries and regions worldwide [8]. This study provides a comprehensive summary of the evolving trends in the incidence, prevalence, mortality, and disability-adjusted life years (DALYs) associated with IBD from 1990 to 2021. We conducted subgroup analyses based on age and gender, as well as correlation analyses. Moreover, we utilized various models to forecast the disease burden related to IBD for the next 29 years (2022–2050). Lastly, through frontier and decomposition analyses, we sought to understand the factors contributing to the increase in IBD-related burden across different regions and determine the potential for reducing this burden. Our aim with this study is to comprehensively investigate and analyze epidemiological data related to IBD, offering a theoretical foundation for policy development to alleviate the burden of IBD.

Materials and methods

Data source

This study is based on GBD 2021 [8]. To the best of our knowledge, this is the most comprehensive and systematic study to date that assesses the burden of disease, injury, and risk factors at global, regional, and national levels. GBD 2021 estimates 371 diseases and injuries, 288 causes of death, and 88 behavioral, environmental, occupational, and metabolic risk factors [9]. The age-standardized rate (ASR) used in the GBD study met the criteria for the global population. Considering uncertainties in parameter prediction, model selection, and data compilation, the projected burden of disease for GBD is expressed as a 95% UI, indicating a 95% probability of true parameter values [8]. Additionally, the study employed the sociodemographic index (SDI), a measure that quantifies a region's sociodemographic progression based on income, education, and fertility circumstances [10].

Statistical analysis

ASR estimates and counts per 100,000 people are consistent with the GBD Population Standard Framework, and the final projections are calculated as the average of 1000 iterations, with 95% of the UI at the upper and lower bounds being the values ranked 97.5 and 2.5 in the iterations [8]. The relevant formula is as follows:

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

The study calculated the ASR and estimated annual percentage change (EAPC). To achieve this, we employed a linear regression model, assuming a linear relationship: $y = \alpha + \beta x + \varepsilon$ between the natural logarithm of the ASR y and the calendar year x, where ε accounts for the random deviation, and β denotes the positive or negative trend in the ASR. The EAPC was calculated using the formula: $EAPC = 100 \times (\exp(\beta) - 1)$. The 95% confidence interval (CI) was obtained from the linear model. An increasing trend in the age standardized rate was indicated when both the lower bound of the EAPC and its CI were above zero. Conversely, a decreasing trend was observed when the upper bounds of the EAPC and CI fell below zero.

In our analysis, we employed Hierarchical Clustering to categorize and dissect the variations in the burden of IBD across distinct geographical regions. The SDI serves as a metric that encapsulates the developmental status of a nation or territory by integrating indicators such as fertility rates, educational attainment, and income per capita.

This index spans from 0 to 1, with higher values signifying a more advanced state of socio-economic development. For the purposes of this research, we stratified countries and regions into quintiles based on their SDI scores (low, low-middle, middle, middle-high, and high) to scrutinize the interplay between the IBD burden and socio-economic progress. Furthermore, we engaged in frontier analysis to ascertain the minimum feasible rates for IBD-associated incidence, prevalence, mortality, and DALYs across nations with varying developmental profiles. The frontier analysis delineates the optimal control of IBD burden within a specific SDI context, with the 'effective frontier distance' (EF) quantifying the divergence between the actual disease burden observed and the potential burden that could be achieved. This divergence, or 'effective frontier distance,' indicates the room for improvement in disease management relative to a country or region's socio-demographic resources, potentially narrowing or closing the gap. For instance, a substantial discrepancy between a country or region's SDI and the frontier threshold suggests that, contingent upon its developmental status, a window of opportunity exists to mitigate (or enhance) the IBD burden [11].

To explore the potential correlations between EAPC, ASR, and the Human Development Index (HDI), we conducted a thorough correlation analysis. The HDI data were sourced from the authoritative Human Development Report [12]. In addition to this, we performed a decomposition analysis that took into account the age structure, demographic size, and epidemiological shifts to gain a more nuanced understanding of the factors that have influenced the prevalence of IBD from 1990 to 2021 [13]. Concluding our analytical approach, we utilized Auto-Regressive Integrated Moving Average (ARIMA) and Ensemble Smoothing (ES) models to forecast the projected prevalence, incidence, and corresponding ASR for IBD between 2022 and 2050 [14, 15]. The ARIMA model is a popular technique used in epidemiology for forecasting time-series data [15]. We also employed the ES model, initially extracting the relevant data and converting it into a time series object, followed by using the Holt's Exponential Smoothing method to forecast the IBD burden for the next 29 years [16].

All statistical analysis and data visualization were performed using R programming software (R4.2.3), including the "dplyr" R package (Version 1.1.3), the "data.table" R package (Version 1.14.8) and the "forecast" R package (Version 8.22.0). Use the "ggplot2" R package (version 3.5.1) to generate plots.

Results

IBD worldwide

Globally, IBD incidence cases nearly doubled from 199,236 in 1990 to 375,140 in 2021, with corresponding deaths increasing from 21,418 to 42,423 during the same period (see Additional file 1, eTable 1–2). By 2021, IBD affected 3,830,119 individuals and resulted in 1,510,784 DALYs (see Additional file 1, eTable 3–4). Over these three decades, a significant rise was observed in incidence cases (88.29%), deaths (98.07%), and DALYs (59.22%) (Fig. 1). The ASIR has been rising worldwide, yet the ASDR and age-standardized DALY rate have declined (EAPCs and 95% CIs provided).

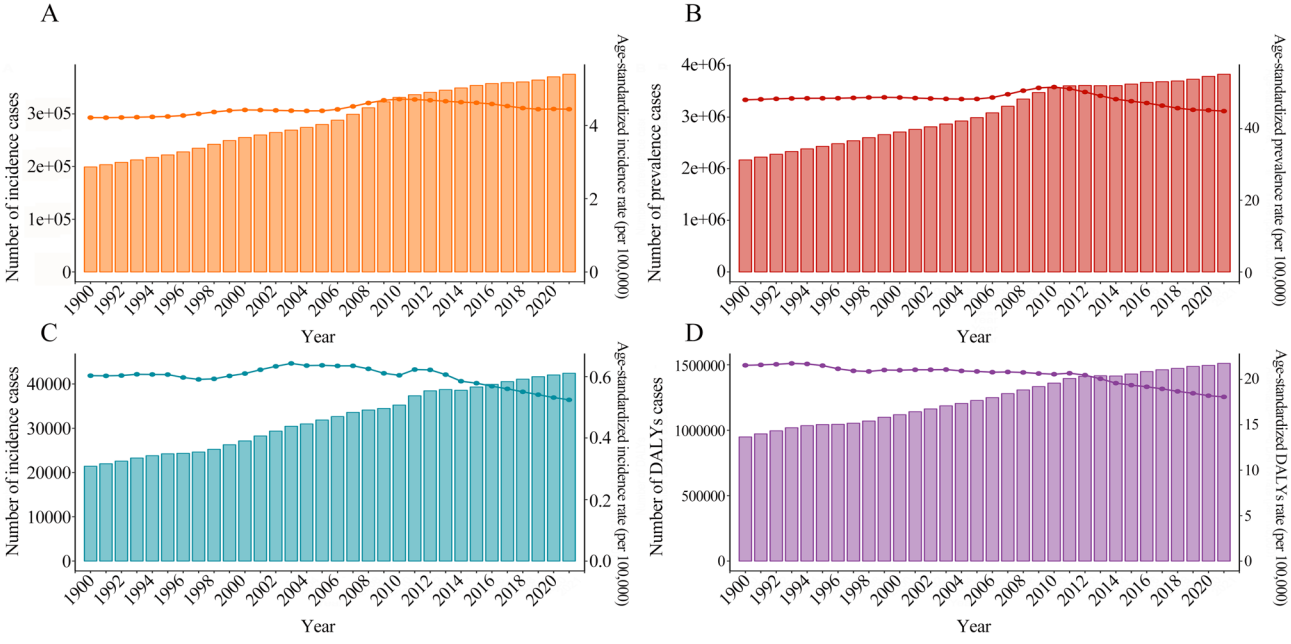

Fig. 1 The changing trend of global IBD burden from 1990 to 2021

Gender-wise, the IBD burden was slightly more in males than females, with an increasing trend in ASIR for both, but a decrease in ASDR and age-standardized DALY rate (see Additional file 1, eFigure 1). The impact of IBD varied significantly across age groups (see Additional file 1, eFigure 3–4).

Geographically, the US, India, and Germany reported the highest IBD incidence in 1990, while India, the US, and China did so in 2021. China had the highest IBD deaths in 1990, but by 2021, the US took the lead. Similarly, China led in IBD DALYs in 1990, but was surpassed by the US in 2021. Regionally, East Asia showed a significant increase in IBD burden (Figs. 2 and 3) (Additional file 1, eFigs. 5, 6, 7, 8 and 9, eFigure 7).

The cluster analysis divided the trend of IBD burden in different regions into four categories (Minor increase, Remained stable or minor decrease, Significant decrease, Significant increase), and only East Asia is classified as a significant increase (see Additional file 1, eFigure 7).

IBD incidence

Globally, the age-standardized incidence rate (ASIR) of IBD climbed from 1990 to 2021, with males showing slightly more incident cases than females. However, females exhibited a higher annual percentage change (EAPC) in ASIR than males (see Additional file 1, eTable 1, eFigure 1). The age groups with the highest incident cases shifted slightly older over the years, with the fastest growth observed in the 60–64 years age group (EAPC, 0.62) (see Additional file 1, eTable 1, eFigure 3–4).

Geographically, Canada reported the highest IBD ASIR, while the Netherlands saw the most significant increase. In contrast, Denmark experienced the largest decrease. The World Bank High Income region had the

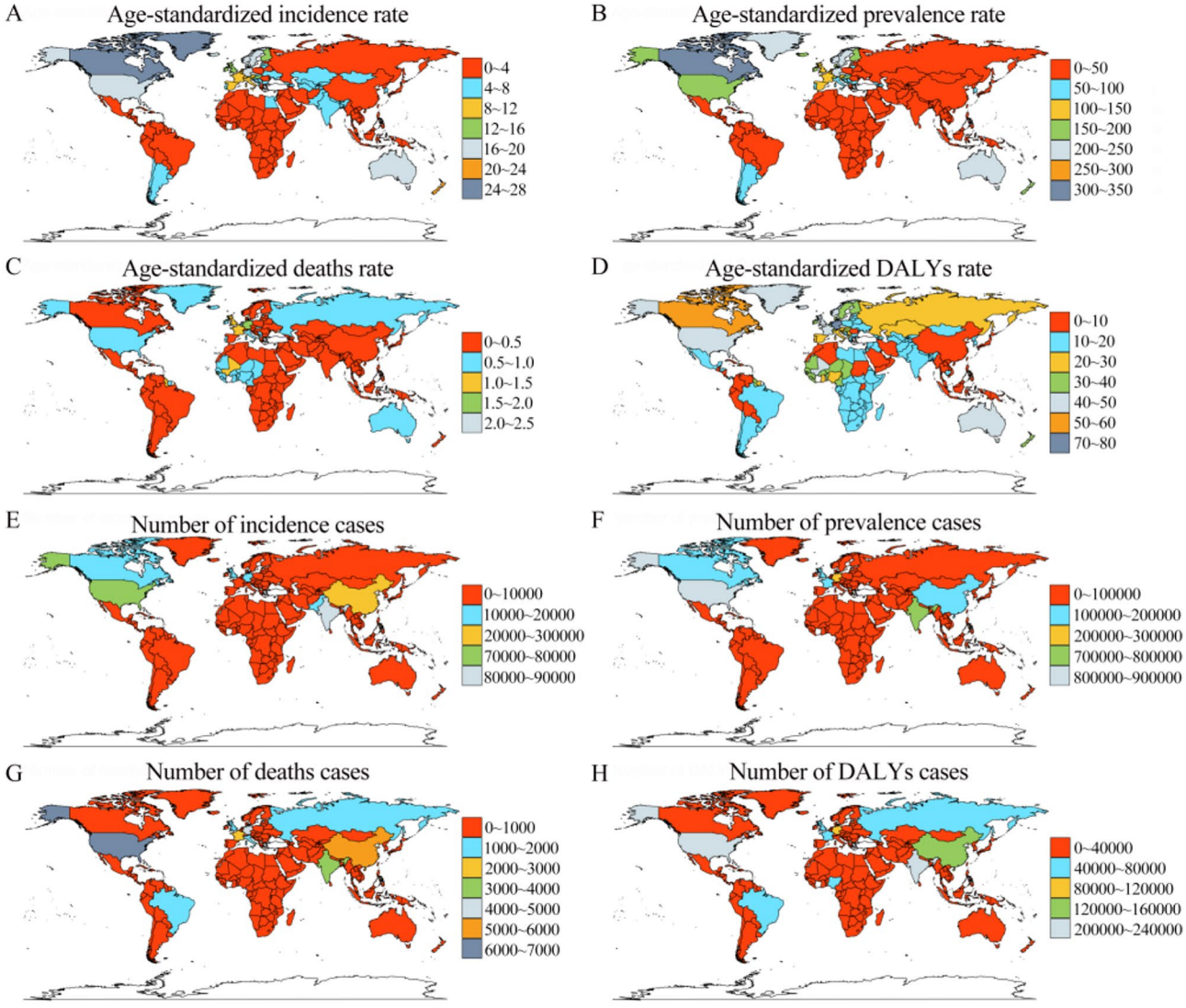

Fig. 2 The IBD burden map for each country or region in 2021

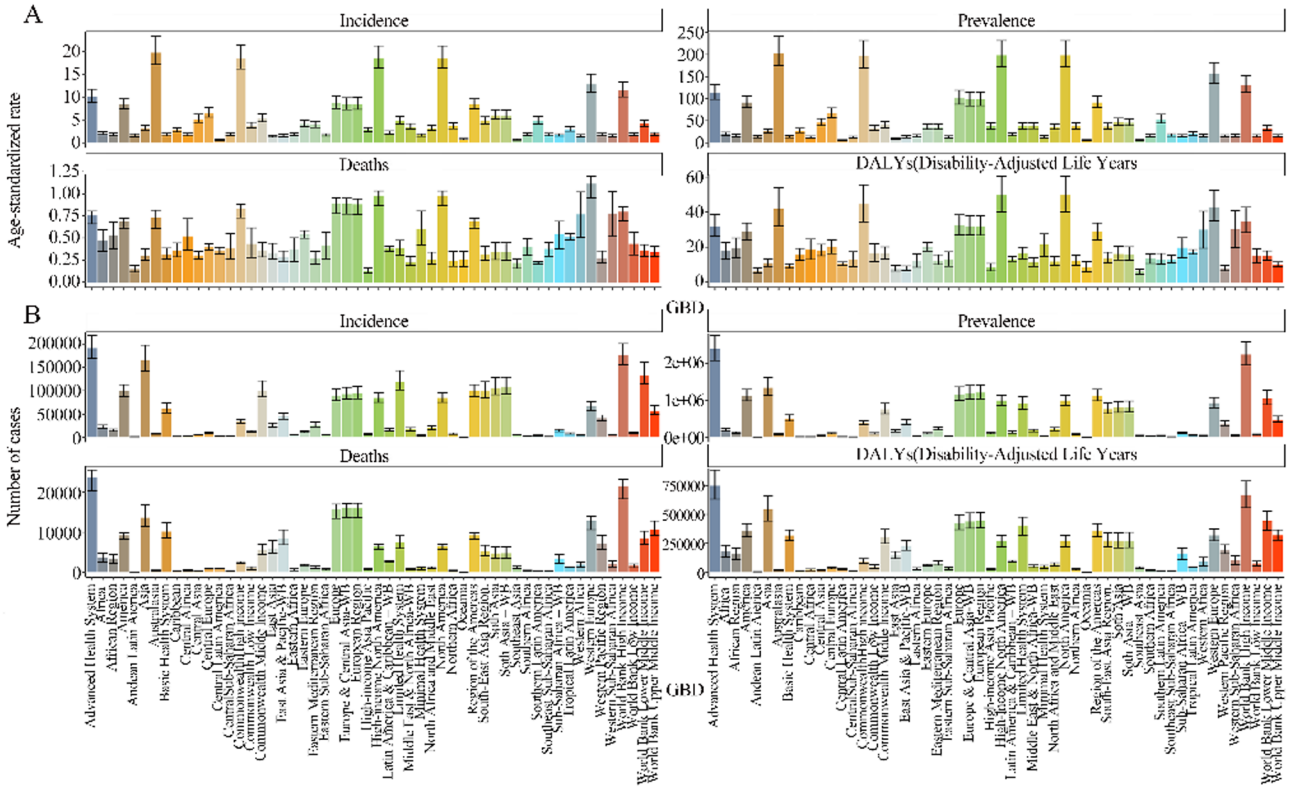

Fig. 3 The IBD burden of each GBD region

highest number of incident cases, whereas Oceania had the fewest. North America showed the greatest increase in ASIR, whereas South America showed the most significant decrease. There was a negative correlation between EAPC and ASR (ρ = −0.18, $P = 0.01$) (see Additional file 1, eFigure 12).

A positive correlation exists between IBD ASIR and the Socio-demographic Index (SDI), with the high SDI quintile showing the fastest growth in ASIR. Notably, as SDI decreases, the expected fraction (EF) of IBD ASIR diminishes, stabilizing when SDI is below 0.6. New Zealand, the Netherlands, Sweden, Australia, and the United Kingdom had the highest EF, while Niger had the lowest, suggesting effective control measures (Fig. 5) (see Additional file 1, eTable 5).

Decomposition analysis indicated that global population growth and aging accounted for 60.35% and 30.75% of the increased IBD burden, respectively. Epidemiological changes added 8.9% to the global IBD burden between 1990 and 2021. The low SDI quintile was most affected by population growth, contributing significantly to the rise in IBD ASIR (78.05%), whereas the high SDI region had a relatively smaller contribution (58.78%) (Fig. 4, Table 1).

IBD death

From 1990 to 2021, the IBD-related death toll rose by 67.0%, yet the global age-standardized death rate (ASDR) fell by 16.4%, suggesting improved survival rates. Women experienced a higher number of IBD-related deaths compared to men, albeit at a lower ASDR. The age distribution of these deaths varied, with the oldest age group showing the most significant increase in ASDR (see Additional file 1, eFigure 1–2).

Cyprus and the Netherlands had the highest ASDRs in 1990 and 2021, respectively. Germany saw the greatest increase in ASDR, while the United States had the highest raw number of IBD deaths. Deaths rose across all SDI quintiles, but the ASDR increased only in high SDI areas, highlighting a disparity in outcomes (see Additional file 1, eFigure 9, eTable 6).

Decomposition analysis indicated that high-SDI regions were most affected by the increase in IBD deaths, with aging contributing significantly to this rise. Interestingly, epidemiological changes contributed negatively to the growth of IBD-related deaths in middle SDI regions, suggesting that improvements in healthcare may be playing a role in reducing mortality (Table 1; Fig. 4).

IBD Prevalence.

Between 1990 and 2021, the global prevalence of IBD rose by 85.1%, growing from 2.17 million to over 3.83 million individuals affected (see Additional file 1, eTable 3). Despite this increase, the age-standardized prevalence rate (ASPR) for IBD declined, dropping from 48.02 per 100,000 individuals in 1990 to 44.88 per 100,000 in

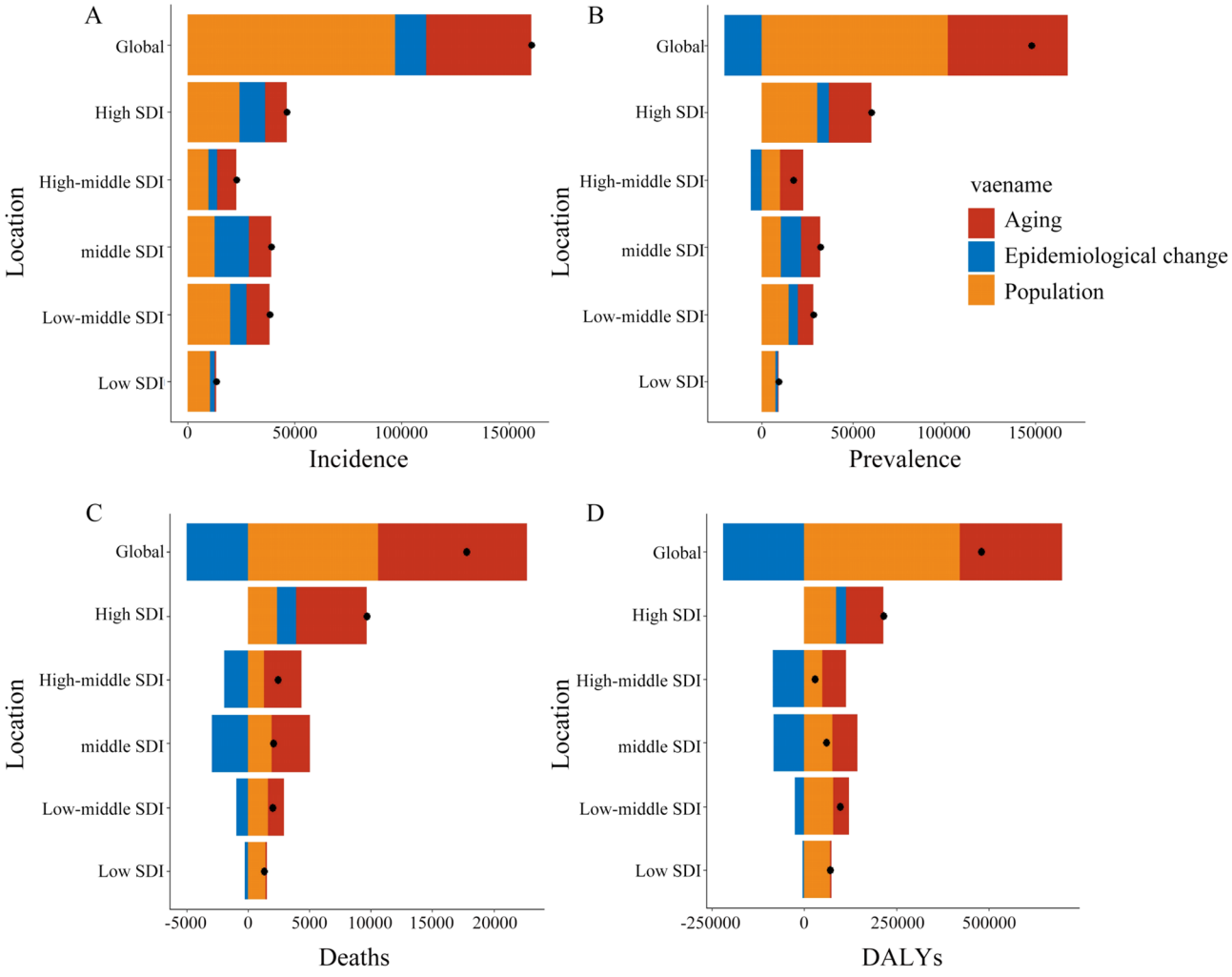

Fig. 4 Alterations in IBD burden based on the population-level determinants of population growth, aging, and epidemiological alteration between 1990 and 2021 at the global level and by SDI quintile

2021 (Fig. 1B). Throughout this period, females exhibited higher prevalence rates than males, with 2.0 million females (52%) and 1.83 million males (48%) affected in 2021. The ASPR peaked in the 70–74 age group with 120.13 per 100,000 individuals (95% CI, 96.76–144.36) (see Additional file 1, eFigure 3).

At the country level, Canada reported the highest ASPR for IBD in both 1990 and 2021, though the EAPC showed a negative correlation with HDI (ρ = −0.19, $P = 0.02$) (see Additional file 1, eFigure 12). The ASPR was found to climb with rising SDI, with the highest SDI countries, such as San Marino, Germany, Sweden, Greenland, and Czech Republic, enjoying the greatest excess fraction (EF) of the ASPR (Fig. 5) (see Additional file 1, eFigure 10B, eFigure 11B, eTable 7).

From 1990 to 2021, the increase in IBD prevalence was fueled by population growth (69.02%) and aging (44.61%), while epidemiological changes had a slight negative impact (−13.63%) on prevalence rates worldwide (Table 1; Fig. 4). High SDI regions experienced the most significant rise in prevalence burden due to population growth (50.89%), whereas aging had a minimal impact in low SDI regions (5.72%).

IBD DALYs

From 1990 to 2021, the age-standardized DALY rate for IBD generally declined, with significant decreases for both males (EAPC, −0.48) and females (EAPC, −0.54) (see Additional file 1, eTable 4, eFigure 1–2). The age group with the highest DALYs shifted from 40 to 44 to 60–64 years, and the lowest shifted from 95 + to 5–9 years. Notably, the 95 + age group saw the largest increase in DALY rates, while the 80–84 age group experienced the steepest decline (see Additional file 1, eFigure 3–4).

Leadership in the highest age-standardized DALY rates transitioned from Canada in 1990 to the Netherlands in 2021. American Samoa showed the most significant decrease, while Germany had the largest increase. The

Table 1 Changes in IBD burden based on the population-level determinants between 1990 and 2021

Location	Overll difference	Aging		Population		Epidemiological change	
		Number	Percent	Number	Percent	Number	Percent
Incidence							
Global	175,903.90	54,090.45	30.75%	106,158.00	60.35%	15,655.45	8.90%
Low SDI	14,691.33	834.47	5.68%	11,466.58	78.05%	2,390.28	16.27%
Low-middle SDI	44,603.18	12,301.56	27.58%	23,425.59	52.52%	8,876.03	19.90%
Middle SDI	42,041.17	11,494.06	27.34%	13,617.13	32.39%	16,929.98	40.27%
High-middle SDI	21,152.49	8,399.65	39.71%	8,930.58	42.22%	3,822.25	18.07%
High SDI	53,335.08	11,893.72	22.30%	27,990.25	52.48%	13,445.77	25.21%
Prevalence							
Global	3630,883.4	1619,737.08	44.61%	2506,035.72	69.02%	−494,889.41	−13.63%
Low SDI	158,419.9	9,061.62	5.72%	131,995.46	83.32%	17,362.82	10.96%
Low-middle SDI	530,659.4	159,887.68	30.13%	276,898.07	52.18%	93,926.71	17.70%
Middle SDI	521,672.2	172,464.83	33.06%	172,151.83	33.00%	177,055.54	33.94%
High-middle SDI	509,432.3	371,325.20	72.89%	305,506.55	59.97%	−167,399.45	−32.86%
High SDI	1907,767.3	733,536.53	38.45%	970,862.78	50.89%	203,177.22	10.65%
Death							
Global	21,004.936	14,365.28	68.39%	12,529.44	59.65%	−5,889.78	−28.04%
Low SDI	1,440.104	123.56	8.58%	1,562.94	108.53%	−246.40	−17.11%
Low-middle SDI	2,326.797	1,525.22	65.55%	1,880.05	80.80%	−1,078.47	−46.35%
Middle SDI	3,008.728	4,403.27	146.35%	2,837.83	94.32%	−4,232.38	−140.67%
High-middle SDI	2,752.771	3,391.14	123.19%	1,511.82	54.92%	−2,150.19	−78.11%
High SDI	11,463.201	6,818.31	59.48%	2,802.75	24.45%	1,842.14	16.07%
DALYs							
Global	561,923.02	325,016.27	57.84%	493,705.57	87.86%	−256,855.01	−45.71%
Low SDI	76,372.88	4,849.68	6.35%	77,014.41	100.84%	−5,491.21	−7.19%
Low-middle SDI	115,959.74	50,894.73	43.89%	95,585.61	82.43%	−30,520.60	−26.32%
Middle SDI	79,629.74	88,954.38	111.71%	101,496.07	127.46%	−110,820.71	−139.17%
High-middle SDI	34,539.99	76,993.09	222.91%	58,144.62	168.34%	−100,597.72	−291.25%
High SDI	255,154.9	120,866.88	47.37%	101,679.23	39.85%	32,608.80	12.78%

Advanced Health System region had the highest DALYs, whereas Oceania had the lowest. Australasia experienced the greatest increase, and East Asia saw the most significant decrease in age-standardized DALY rates (Fig. 2DH) (Additional file 1, eFigure 5D, eFigure 6D). There was a positive correlation between EAPC and DALY rates ($\rho = 0.28$, $P < 0.01$) (see Additional file 1, eFigure 12).

High SDI quintiles consistently had the highest DALYs, whereas low SDI quintiles had the lowest. Except for high SDI groups, which showed a positive EAPC, other groups displayed negative EAPCs. The age-standardized DALY rate increased with SDI, with significant growth in EF values beyond an SDI of 0.75. Germany, the USA, Iceland, France, and Gambia had the largest EF in 2021 (Fig. 5) (see Additional file 1, eTable 8).

Decomposition analysis revealed that population growth and aging positively contributed to the DALYs burden increase, while epidemiological changes had a negative impact worldwide. Aging had the most significant contribution to DALYs in high-middle SDI regions, and epidemiological changes positively contributed only in high SDI regions (Table 1; Fig. 4).

Prediction of global IBD incidence and prevalence

To further understand the future incidence and prevalence of IBD globally, we used the ES and ARIMA models to predict them. As shown in eFigure 13 (see Additional file 1) and Table 2, the total number of cases is expected to increase from 375,140 in 2021 to 416,641 in 2050 based on the ES analysis, while the ASIR is expected to decrease from 4.45 per 100,000 in 2021 to 4.408 per 100,000 in 2050. The total number of IBD patients will increase from 3,830,119 in 2021 to 4,181,631 in 2050, while the analysis based on the ARIMA model yielded a similar conclusion, predicting that the number of cases will increase from 375,140 in 2021 to 513,778 in 2050, while the ASIR is expected to decrease from 4.45 cases per 100,000 population in 2021 to 4.335 cases per 100,000 population in 2050. In summary, we expect the incidence and prevalence of IBD to continue to rise, posing a continuing burden on global public health.

Discussion

In this study, we used a standardized approach to describe the burden due to IBD at the global, super-region, regional, and national levels. GBD reported

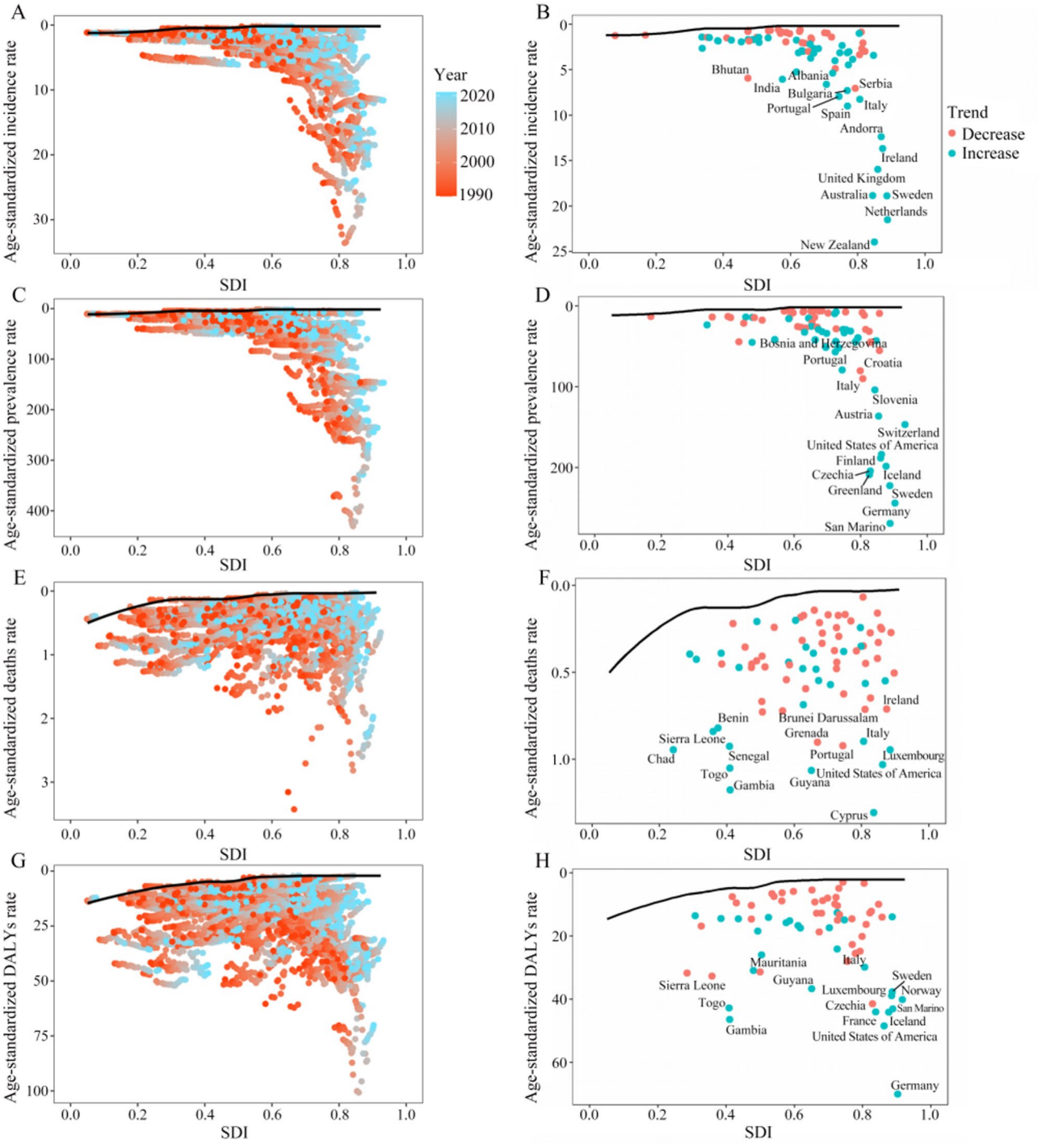

Fig. 5 Frontier analysis involving SDI and IBD burden in 2021. The leading 15 countries with the most EF (the highest burden of IBD gap from the frontier) are marked in black

3.83 million global IBD cases in 2021, compared to 4.9 million global IBD cases reported in 2019 [17] in GBD in 2019 and 6.85 million cases reported in 2017 [18]. The GBD 2021 study provides the most recent estimate of the global burden of IBD, incorporating new data sources and updated methods for improved reliability [9].

According to our results, there were about 3,830,119 cases of IBD in the world in 2021, accounting for about 0.49‰ of the total number of people in the world. Among them, the prevalence, mortality, DALYs, and ASPR rates of females were slightly higher than those of males. In contrast, the rates of ASIR, ASDR, and age-standardized

Table 2 The prediction results of the ES model and ARIMA model for the incidence and prevalence of IBD from 2022 to 2050

Year	ES model				ARIMA model			
	Age-standardized incidence rate	Numer of incidence cases	Age-standardized prevalence rate	Numer of prevalence cases	Age-standardized incidence rate	Numer of incidence cases	Age-standardized prevalence rate	Numer of prevalence cases
2022	4.44	379,495.08	44.67	3867,008.76	4.41	376,815.62	44.40	3840,853.39
2023	4.44	383,414.82	44.48	3900,208.50	4.37	378,436.56	44.01	3845,699.49
2024	4.44	386,942.59	44.30	3930,088.26	4.34	381,587.05	43.84	3860,083.31
2025	4.43	390,117.58	44.15	3956,980.04	4.32	385,611.36	43.92	3889,968.26
2026	4.43	392,975.08	44.01	3981,182.65	4.32	390,134.88	44.19	3934,272.06
2027	4.43	395,546.82	43.88	4002,964.99	4.32	394,943.59	44.59	3988,249.76
2028	4.43	397,861.39	43.77	4022,569.10	4.33	399,915.23	45.03	4046,451.70
2029	4.42	399,944.50	43.67	4040,212.80	4.33	404,979.94	45.46	4104,593.58
2030	4.42	401,819.30	43.58	4056,092.13	4.34	410,097.83	45.85	4160,276.75
2031	4.42	403,506.62	43.49	4070,383.53	4.34	415,246.10	46.18	4212,853.66
2032	4.42	405,025.21	43.42	4083,245.78	4.34	420,411.73	46.44	4262,849.92
2033	4.42	406,391.94	43.35	4094,821.81	4.34	425,587.27	46.65	4311,301.91
2034	4.42	407,622.00	43.29	4105,240.24	4.34	430,768.48	46.80	4359,236.86
2035	4.42	408,729.05	43.24	4114,616.83	4.34	435,952.92	46.91	4407,382.29
2036	4.41	409,725.39	43.19	4123,055.75	4.34	441,139.21	47.00	4456,088.06
2037	4.41	410,622.10	43.15	4130,650.79	4.34	446,326.55	47.06	4505,390.80
2038	4.41	411,429.14	43.11	4137,486.32	4.34	451,514.50	47.12	4555,139.97
2039	4.41	412,155.48	43.07	4143,638.30	4.34	456,702.80	47.16	4605,122.66
2040	4.41	412,809.18	43.04	4149,175.08	4.34	461,891.29	47.20	4655,151.86
2041	4.41	413,397.52	43.01	4154,158.18	4.34	467,079.89	47.23	4705,108.77
2042	4.41	413,927.01	42.98	4158,642.97	4.34	472,268.56	47.25	4754,947.14
2043	4.41	414,403.56	42.96	4162,679.28	4.34	477,457.26	47.28	4804,674.88
2044	4.41	414,832.46	42.94	4166,311.96	4.34	482,645.99	47.30	4854,328.17
2045	4.41	415,218.46	42.92	4169,581.38	4.34	487,834.72	47.32	4903,948.76
2046	4.41	415,565.87	42.90	4172,523.85	4.34	493,023.47	47.33	4953,569.57
2047	4.41	415,878.53	42.89	4175,172.07	4.34	498,212.22	47.35	5003,209.10
2048	4.41	416,159.93	42.88	4177,555.47	4.34	503,400.97	47.36	5052,872.42
2049	4.41	416,413.19	42.86	4179,700.54	4.34	508,589.72	47.37	5102,555.56
2050	4.41	416,641.12	42.85	4181,631.09	4.34	513,778.47	47.37	5152,250.60

DALY rate were lower than those of males, suggesting that the disease has certain gender differences, which is consistent with the results of previous studies [18]. Regarding gender differences, we have learned that appendectomy and smoking are associated with an increased risk of IBD in women [19, 20]. Smoking is a recognized and widely accepted risk factor for the occurrence and progression of IBD. Although smoking has traditionally been more common among men of all age groups, this situation has undergone significant changes in recent years. The number of smoking women, especially young women, has been increasing steadily, which will increase the incidence rate of IBD [21]. It is worth noting that hormone exposure during childhood, adolescence, and menopause/male menopause may play a role in the pathogenesis and course of IBD [22]. There is a clear gender specific correlation between antibiotics and IBD, and men may be more likely to develop IBD after taking antibiotics [23]. Compared to sporadic IBD cases, the advantage of females in familial IBD cases seems to be higher [24].

From 1990 to 2021, IBD's burden exhibited temporal and spatial variations, with the ASIR initially rising before declining, and expected to continue this downward trend towards stabilization. Meanwhile, ASPR for IBD has risen in regions previously characterized by low incidence, attributed to factors such as environmental shifts, dietary and lifestyle modifications, enhanced hygiene, and microbial lineage evolution [25]. Improvements in medical infrastructure, surveillance, and patient education have boosted diagnostic rates. Between 1990 and 2021, IBD mortality rates fell due to better disease management, heightened colonoscopy awareness, surgical advancements, and the adoption of innovative therapies [26, 27].

Historically, IBD has been considered a condition in high-income countries [18]. We found that in the past, high-income regions in North America, particularly the United States, have contributed significantly to the

number of IBD patients worldwide [28]. Today, Asia, especially India, has the highest number of new IBD cases [29], surpassing the United States to rank first globally. However, the United States is still the country with the highest total number of IBD patients in the world, with 21.8% of the total number of IBD patients living in the United States in 2021. India is a close second, accounting for 16.8% of the total number of IBD patients worldwide. In the North African region, Libya experiences the most rapid increase in its ASIR. In Eastern Europe, Romania's annual growth rate of ASIR is significantly higher than that of other countries. Among European countries, the Netherlands has the highest age-standardized prevalence [30]. Globally, Canada has the highest ASPR globally, consistent with previous studies [31]. The reasons for the increasing burden of IBD in newly industrialized countries can be attributed to several key factors [1, 2, 32, 33]. Firstly, these countries are undergoing rapid social transformations, not only reflected in the migration of populations from rural to urban areas and the shift in economic structures from agriculture to manufacturing, but also accompanied by significant changes in lifestyle, including an increase in smoking, changes in dietary habits (such as reduced fiber intake and decreased breastfeeding), increased environmental pollution, and longer periods of sedentary work. These changes have led to economic growth and urbanization, resulting in densely populated urban environments that have not only altered people's lifestyles but may also have increased exposure to environmental risk factors associated with IBD. Furthermore, with improvements in healthcare services and the application of medical technologies, such as colonoscopies, the detection and diagnosis of IBD have been enhanced. Technological advancements and the implementation of electronic health records have also improved the surveillance and reporting of IBD cases. Concurrently, natural population growth and the pace of urbanization have contributed to an increase in the number of IBD cases. These temporal and spatial trends in the burden associated with IBD have prompted managers in newly industrialized countries to develop more effective disease control measures. Lastly, genetic factors also play a role in the differences in IBD burden among different regions. For instance, genetic loci that show significant association with IBD in European populations do not exhibit the same differences in East Asian populations [34–36]. A genetic meta-analysis across different racial groups found that while most IBD risk loci are shared among people of African American, Caucasian, and Asian descents, there are a few specific risk loci with heterogeneous effect sizes [34]. These findings emphasize the complex role of genetic factors in the pathogenesis of IBD and their potentially varying impacts across different populations.

It is noteworthy that the incidence of IBD is increasing in all SDI quintile regions [37]. In this study, we observed a continuous increase in ASIR in the high quartile of SDI until 2010, when it began to decline. The remaining four regions showed a slight upward trend in ASIR. We also noted a higher prevalence of IBD in countries with high SDI quintiles [38]. Over time, this pattern has been preserved. This suggests that IBD has long caused a significant health burden in countries with high development indices, such as the United States, Canada, and the Netherlands. Many studies suggest that this correlation may indicate a common environmental stress in these regions, which may include urbanization, high-fat, low-fiber, high-sugar diets, or consumption of processed foods [39–41]. Researchers found that metabolites of animal fat have pro-inflammatory properties, and excessive intake can increase the incidence of IBD [40]. At the same time, we found that low SDI regions have lower morbidity and deaths, which means a lower burden of IBD. Nevertheless, the impact of poorer medical services and diagnostic measures cannot be ruled out. Because IBD is not an easy disease to diagnose, it requires colonoscopy, which is difficult to achieve for most people living in low SDI countries [42]. The variation in the burden of IBD across regions with different SDI levels can be partially attributed to environmental factors. According to models of immune disease development, the higher incidence of IBD in populations with higher socioeconomic status may be due to reduced or delayed exposure to common pathogens during childhood. This discrepancy leads to corresponding changes in immune responses among individuals with genetic predispositions [43]. In Western countries, the use of antibiotics is considered a risk factor for IBD, while it may have a protective effect among Asian and Middle Eastern immigrants. This could be because, in developing countries, widespread exposure to diverse microbial communities during childhood makes dysbiosis caused by antibiotics less likely, as these microbial communities can rapidly repopulate the gut [44].

Our study, by analyzing GBD data, revealed that there were approximately 3.83 million IBD cases worldwide in 2021, including over 375,000 new cases and over 42,000 IBD-related deaths, resulting in the loss of about 1.51 million years of healthy life. This data highlights the significant impact of IBD in the global health sector, particularly in regions and countries with higher Sociodemographic Index (SDI), where the burden of IBD is more concentrated. Although the number of IBD cases and deaths continues to increase gradually at the global, regional, and national levels, it is encouraging to see a downward trend in the Age-Standardized Incidence Rates (ASR), which may reflect improvements in the management and prevention of IBD worldwide. When projecting the trend of IBD disease burden over the next

29 years (2022–2050), our research uncovers a significant increase in the IBD burden in emerging industrialized countries, a trend that calls for increased investment to curb the rise in IBD burden. To more effectively address this challenge, we recommend establishing international cooperative organizations between different countries to share the latest research findings and address the issue of IBD from a global perspective. In this context, the roles of two important international platforms—IOIBD and UR-CARE—cannot be overlooked.

IOIBD [45], as an international cooperative organization, provides a platform for collaboration and communication in global IBD research, fostering information sharing and research cooperation, which is crucial for understanding the global epidemiological trends of IBD and developing targeted health strategies. UR-CARE [46], as an online international registry, offers a comprehensive tool for capturing IBD patient records in daily clinical practice and research, making data collection more convenient and comprehensive, beneficial for both routine clinical practice and research. The combined use of these two platforms not only strengthens research cooperation globally but also enhances the quality and accessibility of IBD case data, thereby better monitoring disease trends and evaluating the effectiveness of intervention measures. Therefore, we suggest that when discussing the global challenges of IBD, full advantage should be taken of the resources and networks provided by platforms like IOIBD and UR-CARE to improve our understanding and response to IBD. Through these platforms, we can more comprehensively understand the global epidemiological trends of IBD, identify the needs of different regions, and develop targeted health strategies, making a significant contribution to global IBD research and patient care.

Our study, while employing rigorous research methods, also has some limitations, particularly in terms of the availability and quality of data. Reliance on secondary data from the GBD may introduce inherent biases or inaccuracies from the original data collection methods, which limits our comprehensive capture of micro-level trends. Furthermore, although GBD 2021 covers more countries and regions, data gaps still exist, making our analysis prone to ecological fallacies, as correlation does not directly imply causation. As a secondary analysis of GBD data, our study cannot fully account for demographic biases such as race, education, or occupation, which may play a significant role in the distribution and impact of IBD. Nevertheless, we strive to reduce these errors and enhance the accuracy and reliability of our results by applying strict statistical methods and modeling.

In terms of the limitations of predictive models, our study used ARIMA and ES models to forecast future scenarios. However, these models may not capture nonlinear or structural changes caused by new technologies, policy changes, or socioeconomic factors, which could affect the accuracy of the forecast results. For instance, ARIMA models are limited in dealing with nonlinear relationships and external influencing factors, while ES models rely on historical data and may not accurately reflect future risks. Additionally, the accuracy of predictive models is also constrained by the quality and completeness of the data. Therefore, to enhance the accuracy and robustness of forecasts, future research needs to explore and develop models capable of handling nonlinear relationships and external influencing factors, such as machine learning models, and integrate multi-source data, employ advanced data preprocessing techniques, conduct cross-validation and model adjustments, and perform multi-scenario analyses to consider the potential impacts of different policy changes and technological advancements, thereby providing more comprehensive forecast results.

GBD data inevitably contains heterogeneity and bias because they come from various databases of varying quality. Although SDI is a useful tool for classifying regions, it does not capture all development dimensions that may affect health, such as the quality of medical care or health infrastructure. This could lead to a partial understanding of the underlying conditions contributing to the IBD burden. Therefore, it is necessary to conduct more high-quality population-based studies in these countries to obtain more accurate estimates of the IBD burden. In summary, our study provides insights into the global burden of IBD but also highlights the challenges that need to be addressed in data collection, processing, and analysis. Future research needs to focus on improving data quality, reducing bias, and considering more comprehensive demographic factors to better understand and address the global burden of IBD.

Conclusion

The study provides insights into monitoring the burden and trends of IBD globally. Despite reductions in ASPR and ASDR, IBD remains a major public health burden due to increasing cases worldwide. The incidence of IBD has increased rapidly in newly industrialized and developing countries but has stabilized in Western countries. More systematic surveillance strategies and inclusion of risk factors in estimation models will facilitate IBD management.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-24009-z.

Additional file 1: eTable 1. IBD-Related Incidence Between 1990 and 2021 for Both Sexes, Each Age Groups and All Locations, With EAPC Between 1990 and 2021. eTable 2. IBD-Related Death Between 1990 and 2021

for Both Sexes, Each Age Groups and All Locations, With EAPC Between 1990 and 2021. eTable 3. IBD-Related Prevalence Between 1990 and 2021 for Both Sexes, Each Age Groups and All Locations, With EAPC Between 1990 and 2021. eTable 4. IBD-Related Disability-adjusted Life Years(DALYs) Between 1990 and 2021 for Both Sexes, Each Age Groups and All Locations, With EAPC Between 1990 and 2021. eTable 5. Frontier IBD-related Incidence Rate and Effective Difference(EF) by Country or Territory in 2021. eTable 6. Frontier IBD-related Death Rate and Effective Difference(EF) by Country or Territory in 2021. eTable 7. Frontier IBD-related Prevalence Rate and Effective Difference(EF) by Country or Territory in 2021. eTable 8. Frontier IBD-related DALYs Rate and Effective Difference(EF) by Country or Territory in 2021. eFigure 1. Comparison of IBD burden between males and females in 2021. eFigure 2. The changing trend of IBD burden in males and females from 1990 to 2021. eFigure 3. The IBD burden by age group in 2021. eFigure 4. The changing trend of IBD burden among different age groups from 1990 to 2021. eFigure 5. Geographical map of the global IBD burden change rate in 2021 compared to 1990. eFigure 6. Geographical map of estimated annual percentage change (EAPC) for IBD burden. eFigure 7. Cluster analysis results of the overall burden of IBD in the GBD regions. eFigure 8. Comparison chart of IBD burden in various SDI regions in 2021. eFigure 9. Trends in IBD burden in SDI regions from 1990 to 2021. eFigure 10. Scatter Plot Analysis of Health Metrics across Different GBD Regions: The Impact of Socio-Demographic Index (SDI) on Incidence, Prevalence, Mortality, and Disability-Adjusted Life Years (DALYs). eFigure 11. Scatter Plot Analysis of 2021 Inflammatory Bowel Disease (IBD) Health Metrics across Countries: The Relationship between Socio-Demographic Index (SDI) and Incidence, Prevalence, Mortality, and Disability-Adjusted Life Years (DALYs). eFigure 12. Analysis results of the correlation between EAPC and ASR or HDI. eFigure 13. The prediction results of the ES model (A, B) and ARIMA model (C, D) for the future incidence and prevalence of IBD.

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Authors' contributions
Kaiqi Yang, Changhao Zhang and Rui Gong had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: Kaiqi Yang, Wei Jiang, Min Zhu. Acquisition or interpretation of data: Yuchen Ding, Yang Yu, Jinlong Chen. Statistical analysis: Rui Gong, Jiaxuan Zuo, Xueping Huang. Drafting of the manuscript: Changhao Zhang, Lumei Wang. Obtained funding: Min Zhu, Xiujing Sun. Supervision: Peng Li, Xiujing Sun.

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Data availability
To download the data used in these analyses, please visit the Global Health Data Exchange GBD 2021 website.

Declarations

Ethics approval and consent to participate
Not Applicable.

Consent for publication
All authors have contributed to the conception and design of the study, to the acquisition of data, or to the analysis and interpretation of data; have drafted or revised the article critically for important intellectual content; and have given final approval of the version to be published.

Competing interests
The authors declare no competing interests.

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