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Trends in and Projections of Breast Cancer Incidence, Mortality, and Disability-Adjusted Life Years (DALY) at Global and Regional Levels, 1990-2030: A Bayesian Age-Period-Cohort Modeling Study

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ABSTRACT

Background: Breast cancer (BC) remains the most common malignancy among women and the second leading cause of cancer-related death worldwide in 2022. Monitoring long-term morbidity and mortality trends and forecasting future patterns can inform effective prevention and control strategies.

Methods: Data on BC incidence, mortality, disability-adjusted life years (DALYs), years of life lost (YLLs), and years lived with disability (YLDs) from 1990 to 2021 were obtained from the Global Burden of Disease database. Temporal trends were assessed using average annual percentage change (AAPC), and a Bayesian age-period-cohort model projected trends for the next 9 years.

Results: From 1990 to 2021, the global absolute burden of BC increased markedly: the number of cases rose from 0.87 million to 2.08 million, and that of deaths from 0.35 million to 0.66 million. This rise is projected to continue through 2030, largely due to population growth and aging. Age-standardized rates showed mixed patterns. Incidence increased from 40.28 to 46.23 per 100 000, and YLDs from 28.55 to 32.26. In contrast, age-standardized mortality, DALYs, and YLLs declined from 16.74, 507.43, and 478.89 to 14.58, 455.56, and 476.13 per 100 000, respectively. By 2030, incidence and YLD rates are projected to rise to 47.97 and 33.04, while mortality, DALY, and YLL rates are expected to decline to 14.45, 459.32, and 429.18 per 100 000.

Conclusion: Although mortality and disability may continue to decline due to advances in screening and treatment, aging populations and improved detection may increase incidence and management complexity, underscoring the need for sustained investment in research, education, and equitable care.

INTRODUCTION

According to the World Health Organization (WHO), the global prevalence of cancer is increasing rapidly.[1] Breast cancer (BC) is the most common cancer among women, and the incidence rate of BC has increased by 0.5% per year over the past 40 years.[2]

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The pathophysiology of BC is multidimensional and not yet well understood; however, certain risk factors for this disease are known and can be divided into 2 categories: genetic and environmental. Genetic causes, such as mutations in *BRCA1* and *BRCA2* (tumor suppressor genes), cause approximately 10% of BC cases.[3] Other known risk factors include a history of in situ ductal carcinoma, high body mass index (BMI), first birth over age 30 years, early menarche (before age 13 years), family history of breast or ovarian cancer, late menopause, alcohol consumption, and use of postmenopausal hormone therapy.[4,5]

The increase in the number of cases in recent years is due to the decline in fertility among women owing to the increased use of oral contraceptives[6] and increasing BMI and obesity.[7] Another important risk factor for BC is alcohol consumption. In 1990, 5.6 L of alcohol was consumed per adult per year, which increased to 6.5 L in 2019 and is expected to reach 7.6 L by 2030. This increase in alcohol consumption may increase BC incidence and mortality.[8]

Exposure to high levels of endogenous or exogenous estrogen is generally accepted as the most important risk factor for the development of BC. Epidemiologic studies have shown that an increase in serum E1 and E2 levels after menopause significantly increases the risk of BC.[9]

Breast cancer mortality rates have decreased by 43% since 1989, with an average of 460 000 BC deaths; however, the rate is disproportionately high among women in resource-limited settings. The reason for this decline is early diagnosis through mammography and screening. Despite having a 22% lower incidence than White women, Black women experience 19% more deaths owing to screening and treatment in unreliable centers.[2]

In summary, changes in BC risk factors can lead to large changes in the number of cases, prevalence, and mortality, and predicting the extent of this disease in the future will better prepare health system planners to deal with its complications. This will give them a general outline to know what resources and how much are needed to better control this disease in the future (e.g., how much chemotherapy, surgery, oncology specialists, and radiotherapy are needed).[10,11]

Despite extensive knowledge of BC risk factors, less attention has been paid to how the future burden of the disease will evolve across regions with different levels of sociodemographic development. Understanding projected trends and inequalities in incidence, mortality, and disease burden is essential for anticipating health system needs and guiding equitable resource allocation. Therefore, this study aimed to examine trends in BC incidence, mortality, and burden from 1990 to 2021 by age and geographic region, to project these indicators through 2030, and to assess the contribution of demographic and epidemiological factors to observed changes.

METHODS

Study design and data sources

In this ecological study, data on incidence, mortality, disability-adjusted life years (DALYs), years of life lost due to premature mortality (YLLs), and years lived with disability (YLDs) associated with BC in women worldwide were obtained from the Global Burden of Disease (GBD) database, publicly available at https://ghdx.healthdata.org/gbd-2021. The GBD data provide comprehensive estimates of the impact of 369 diseases and injuries, along with 87 attributable risk factors, categorized by sex, age, region, and country.

Our analysis focused exclusively on females and stratified them into 4 age subgroups: 19 years or younger, 20 to 39 years, 40 to 59 years, and 60 years or older. Countries were categorized according to the Sociodemographic Index (SDI), a composite measure developed by the GBD study that summarizes a country's development status based on 3 key components: average income per capita, average years of schooling for individuals aged 15 years or older, and total fertility rate under age 25 years. Based on the SDI, 204 countries and territories were classified into 5 categories: low, low-middle, middle, high-middle, and high SDI. The GBD allocates countries to these 5 SDI groups using predefined thresholds for the composite index, allowing for consistent comparisons across regions.

Statistical analysis and projection framework

A Bayesian age-period-cohort (BAPC) modeling framework was used to project global BC incidence, mortality, DALYs, YLDs, and YLLs. Model estimation was performed using the integrated nested Laplace approximation (INLA), which provides accurate and computationally efficient Bayesian inference for latent Gaussian models and has been widely applied in population-based cancer projection studies.

We employed a BAPC framework to disentangle the intertwined temporal effects of age at diagnosis, calendar period, which captures secular shifts in diagnostic practices and therapeutic interventions, and birth cohort, reflecting early-life exposures, on cancer incidence trends. To facilitate biologically plausible and smoothly varying estimates, second-order random walk (RW2) priors were imposed on age, period, and cohort components. Model performance and predictive validity were evaluated by fitting the APC model to data from 1990 to 2010

and forecasting the period 2011 to 2021. Observed incidence during this validation interval consistently fell within the model's 95% credible intervals (CrIs), affirming its suitability for projecting cancer trends through 2030.

Within the APC framework, the number of BC cases or deaths is modeled using a log-linear Poisson regression structure. Specifically, for age group i and calendar period j, the observed count $Y_{i,j}$, is assumed to follow a Poisson distribution:

$$Y_{i,j} \approx Poisson(\mu_{i,j}),$$

Where $\mu_{i,j}$ denotes the expected number of events. The expected value is defined as $\mu_{i,j} = \lambda_{i,j}N_{i,j}$, with $N_{i,j}$ representing the population at risk and $\lambda_{i,j}$ denoting the underlying incidence or mortality rate. The logarithm of the underlying rate was modeled using a standard age-period-cohort (APC) formulation:

$$\log(\lambda_{ij}) = \alpha + A_i + P_j + C_k,$$

Where α is the intercept, A_i denotes the age effect for age group i, P_j represents the period effect for calendar year j, and C_k corresponds to the cohort effect for birth cohort k, defined as $k = j - i$.

To ensure smoothness and temporal coherence of age, period, and cohort effects, RW2 priors were assigned to A_i, P_j, and C_k. Under the RW2 prior, the second difference of consecutive effects is assumed to follow a Gaussian distribution with mean zero, which penalizes abrupt changes while allowing flexible nonlinear trends over time. Precision parameters for these priors were assigned inverse gamma distributions. Posterior marginal distributions of all model parameters were estimated using INLA.

Temporal trends in age-standardized incidence, mortality, DALY, YLD, and YLL rates were quantified using the average annual percentage change (AAPC) for 2 time periods: 1990 to 2021 (observed) and 2022 to 2030 (projected). The AAPC was calculated using a simple average annual change approach based on the first and last years of each period, rather than joinpoint regression. Specifically, the AAPC was calculated by averaging the yearly percent change in the age-standardized rates over the specified interval:

$$AAPC = \frac{Rate_{end} - Rate_{start}}{Rate_{start}}$$

This approach provided an interpretable summary measure of overall temporal change across the specified periods and was applied consistently to both observed and projected estimates.

All projected estimates for incidence, mortality, DALYs, YLDs, and YLLs were summarized using posterior distributions and are reported with corresponding 95% CrIs to quantify uncertainty. All statistical analyses were performed using R software version 4.2.1. This study was approved by the Medical Ethics Committee of Hamadan University of Medical Sciences (IR.UMSHA.REC.1403.245).

Model validation

To assess the predictive accuracy of the BAPC model, a temporal validation analysis was conducted. The model was fitted using data from 1990 to 2015, and projections were generated for the period 2016 to 2021. Predicted values were then compared with observed estimates for the same period. Predictive performance was quantified using the mean absolute percentage error (MAPE), which was 6.82%, indicating good agreement between predicted and observed values and supporting the reliability of the forecasting approach.

Data validation and uncertainty analysis

Validation of cancer data in the GBD study is a multifaceted process that involves multiple methodological steps to ensure accuracy, reliability, and comparability of estimates. This process includes the systematic evaluation of data sources such as cancer registries, medical records, health surveys, and vital statistics, with careful consideration of data quality, credibility, and geographic and temporal coverage. Standardized case definitions based on the *International Classification of Diseases* are applied to ensure consistency in cancer classification across populations. In addition, advanced statistical methods, including Bayesian modeling approaches, are used by the GBD framework to integrate data from multiple sources and to account for variability and potential bias, while age standardization is applied to enhance comparability across demographic groups.

In the present study, projected estimates were further examined in relation to published global and regional BC statistics from the WHO and peer-reviewed literature to ensure consistency in the magnitude and direction of observed and projected trends. Finally, uncertainty in all projected estimates was explicitly quantified using posterior 95% CrIs, allowing assessment of the precision and reliability of model-based projections across age groups and SDI strata.

RESULTS

Number of new cases, deaths, DALYs, YLDs, and YLLs due to BC between 1990 and 2030

Between 1990 and 2021, the global absolute burden of BC increased markedly across all measured indicators, a trend that is projected to persist through 2030 (Table 1; Figure 1).

The number of new BC cases more than doubled, rising from 0.87 million in 1990 to 2.08 million in

2021, and is projected to reach 2.54 million by 2030 (95% CrI, 2.38–2.70). This sustained growth reflects the combined effects of population expansion, demographic aging, and evolving exposure to risk factors, despite improvements in age-specific outcomes in many regions.

Table 1. Global Number of Incident Cases, Deaths, Disability-Adjusted Life Years, Years Lived with Disability, and Years of Life Lost Due to Breast Cancer From 1990 to 2021, With Bayesian Projections for 2022 and 2030 by Age Group and Sociodemographic Index

Category	1990, No. (×1000)	2021, No. (×1000)	AAPC, 1990–2021	2022, No. (×1000) (95% CrI)	2030, No. (×1000) (95% CrI)	AAPC, 2022–2030
Incidence	NA	NA	NA	NA	NA	NA
Total	867.05	2084.36	1.40	2133.57 (2133.12–2134.02)	2541.85 (2382.52–2701.17)	0.19
Age group, y	NA	NA	NA	NA	NA	NA
0–19	0.93	2.23	1.39	2.29 (2.28–2.30)	2.70 (2.58–2.83)	0.18
20–39	86.91	177.16	1.04	181.56 (181.51–181.61)	217.89 (199.50–236.28)	0.20
40–59	366.00	904.13	1.47	921.50 (921.36–921.64)	1067.39 (1042.48–1092.31)	0.16
≥60	413.21	1000.84	1.42	1028.20 (1027.99–1028.42)	1248.10 (1161.36–1334.84)	0.21
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	20.03	74.54	2.72	78.00 (77.99–78.01)	105.70 (99.08–112.33)	0.36
Low-middle	51.50	235.58	3.57	245.42 (245.39–245.39)	324.97 (307.27–342.66)	0.32
Middle	122.51	536.51	3.38	558.70 (558.63–558.76)	740.87 (699.40–782.34)	0.33
High-middle	214.53	506.39	1.36	517.20 (517.08–517.31)	607.65 (575.30–640.00)	0.17
High	457.36	729.16	0.59	732.04 (731.80–732.28)	757.95 (682.90–833.00)	0.04
Mortality	NA	NA	NA	NA	NA	NA
Total	352.55	662.53	0.88	677.23 (677.04–677.58)	795.55 (729.64–738.24)	0.17
Age group, y	NA	NA	NA	NA	NA	NA
0–19	0.33	0.62	0.88	0.63 (0.62–0.64)	0.70 (0.69–0.71)	0.11
20–39	26.53	40.94	0.54	41.76 (41.75–41.78)	48.45 (43.04–53.85)	0.16
40–59	129.15	235.74	0.83	239.94 (239.88–240.01)	275.46 (259.60–291.32)	0.15
≥60	196.54	385.24	0.96	394.90 (394.79–395.00)	472.30 (433.12–511.47)	0.20
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	14.71	45.36	2.08	47.15 (47.14–47.16)	62.27 (57.48–67.06)	0.32
Low-middle	33.33	116.91	2.51	120.97 (120.95–120.98)	154.50 (145.96–163.03)	0.28
Middle	64.50	181.28	1.81	187.10 (187.07–187.14)	235.24 (213.82–256.66)	0.26
High-middle	94.00	145.46	0.55	147.25 (147.20–147.30)	161.66 (150.97–172.36)	0.10
High	145.50	172.70	0.19	173.93 (173.85–174.01)	184.18 (162.53–205.83)	0.06
Disability-Adjusted Life Years	NA	NA	NA	NA	NA	NA
Total	11 084.80	20 275.50	0.83	20 699.70 (20 693.90–20 705.60)	24 097.50 (22 048.10–26 105.90)	0.16

Age group, y	NA	NA	NA	NA	NA	NA
0–19	24.26	46.33	0.91	47.04 (46.87–47.20)	52.73 (52.33–53.23)	0.12
20–39	1536.14	2409.51	0.57	2458.52 (2457.70–2459.35)	2855.02 (2543.46–3166.59)	0.16
40–59	5349.20	9835.64	0.84	10 006.10 (10 003.30–10 008.90)	11 437.70 (10 802.40–12 073.00)	0.14
≥60	4175.16	7983.99	0.91	8188.07 (8185.84–8190.30)	9799.79 (8959.20–10 640.40)	0.20
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	522.68	1609.19	2.08	1673.98 (1673.70–1674.26)	2192.60 (2067.05–2318.15)	0.31
Low-middle	1221.53	4091.12	2.35	4228.35 (4227.71–4228.98)	5323.23 (5017.92–5628.54)	0.26
Middle	2301.35	6036.42	1.62	6214.61 (6213.42–6215.81)	7662.26 (7206.13–8118.40)	0.23
High-middle	2950.77	4170.78	0.41	4211.46 (4209.82–4213.11)	4544.24 (4147.44–4941.04)	0.08
High	4072.80	4345.25	0.07	4348.50 (4346.29–4350.71)	4386.11 (3886.74–4885.47)	0.01
Years lived with disability	NA	NA	NA	NA	NA	NA
Total	614.89	1449.27	1.36	1482.33 (1482.01–1482.65)	1753.83 (1644.87–1868.78)	0.18
Age group, y	NA	NA	NA	NA	NA	NA
0–19	0.63	1.49	1.37	1.53 (1.52–1.54)	1.86 (1.83–1.89)	0.22
20–39	61.19	123.87	1.02	126.83 (126.80–126.87)	151.73 (139.46–163.99)	0.20
40–59	246.98	607.94	1.46	618.98 (618.89–619.07)	717.18 (699.69–734.67)	0.16
≥60	306.09	715.98	1.34	734.99 (734.83–735.16)	887.61 (826.34–948.88)	0.21
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	11.90	44.61	2.75	46.70 (46.68–46.72)	63.70 (62.43–64.97)	0.36
Low-middle	31.88	144.99	3.55	151.09 (151.07–151.11)	200.12 (192.02–208.21)	0.32
Middle	78.46	348.84	3.45	363.34 (363.30–363.38)	486.85 (469.01–504.69)	0.34
High-middle	151.16	357.24	1.36	365.00 (364.92–365.08)	430.69 (405.82–455.56)	0.18
High	340.76	552.16	0.62	554.75 (554.57–554.93)	578.94 (522.95–634.93)	0.04
Years of life lost	NA	NA	NA	NA	NA	NA
Total	10 469.87	18 826.19	0.80	19 217.41 (19 211.90–19 222.90)	22 344.34 (20 429.30–24 259.40)	0.16
Age group, y	NA	NA	NA	NA	NA	NA
0–19	23.64	44.84	0.90	45.52 (45.36–45.68)	50.99 (50.51–51.47)	0.12
20–39	1474.95	2285.64	0.55	2331.70 (2330.91–2332.49)	2704.13 (2404.38–3003.87)	0.16
40–59	5102.22	9227.70	0.81	9387.11 (9384.36–9389.85)	10 707.53 (9938.90–11 476.10)	0.14
≥60	3869.07	7268.02	0.88	7453.08 (7451.01–7455.15)	8913.81 (8129.26–9698.37)	0.20
Sociodemographic Index	NA	NA	NA	NA	NA	NA

Low	510.79	1564.58	2.06	1627.28 (1627.01–1627.56)	2136.17 (1981.79–2290.59)	0.31
Low-middle	1189.65	3946.12	2.32	4077.25 (4076.63–4078.88)	5122.63 (4825.87–5419.39)	0.26
Middle	2222.89	5687.59	1.56	5851.27 (5850.11–5852.42)	7179.29 (6746.67–7611.90)	0.23
High-middle	2799.61	3813.54	0.36	3846.48 (3844.92–3748.04)	4116.52 (3729.19–4503.85)	0.07
High	3732.05	3793.09	0.02	3792.42 (3780.84–3804.00)	3787.63 (3756.08–3819.18)	0.00

AAPC, average annual percentage change; CrI, credible interval.

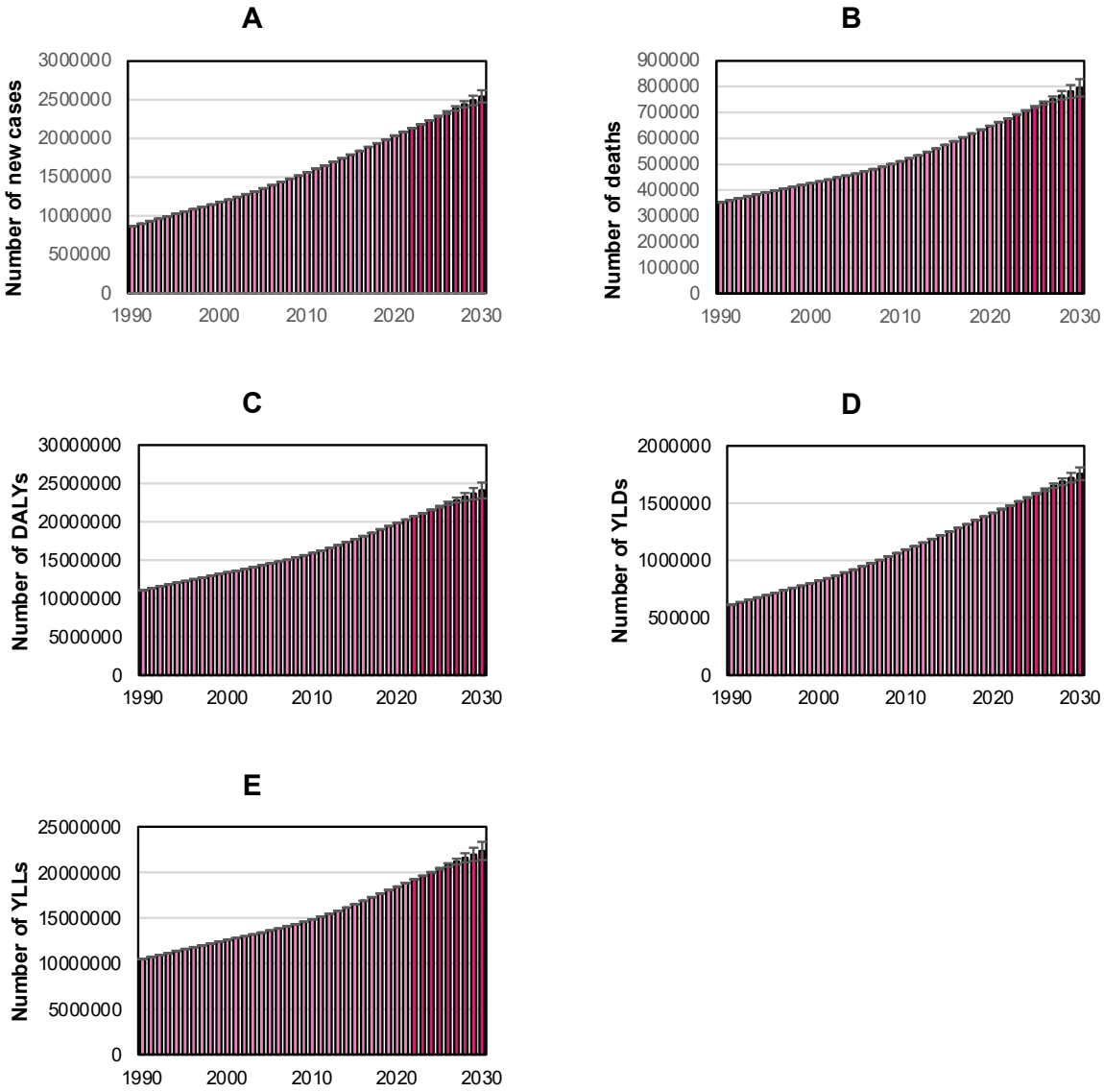

Figure 1. Temporal Trends in the Breast Cancer Burden Worldwide, 1990-2021, with Projections to 2030. A, Absolute counts of incident cases. B, Absolute counts of deaths. C, Absolute counts of disability-adjusted life years (DALYs). D, Absolute counts of years lived with disability (YLDs). E, Absolute counts of years of life lost (YLLs).

Breast cancer–related deaths followed a similar trajectory in absolute terms, increasing from 0.35 million in 1990 to 0.66 million in 2021, with projections indicating a further rise to 0.80 million deaths by 2030 (95% CrI, 0.73–0.85). Although mortality counts continue to increase globally, the associated uncertainty intervals highlight substantial heterogeneity across age groups and

sociodemographic settings, suggesting uneven progress in cancer control.

Age-stratified analyses demonstrated that the burden of BC is increasingly concentrated among older populations. Individuals aged 40 to 59 years and 60 years or older accounted for the majority of the cases and deaths throughout the study period, and these age groups are expected to experience the largest absolute increases by 2030. In particular, deaths among women aged 60 years or older are projected to exceed 470 000 annually by 2030, underscoring the growing impact of population aging on BC mortality.

Pronounced disparities were observed across SDI categories. While high-SDI regions continued to contribute a substantial proportion of global cases, the most rapid increases in incidence and mortality occurred in middle- and low-middle-SDI countries. Notably, all burden indicators—including incidence, deaths, DALYs, YLDs, and YLLs—are projected to rise steeply in middle-SDI settings, signaling a future shift of the global BC burden toward regions undergoing rapid epidemiological transition.

Globally, total DALYs attributable to BC nearly doubled from 11.1 million in 1990 to 20.3 million in 2021 and are projected to reach 24.1 million by 2030 (95% CrI, 22.0–26.1). This increase was driven predominantly by YLLs, which are expected to exceed 22.3 million by 2030, reflecting the persistent contribution of premature mortality. Concurrently, YLDs are projected to rise to 1.75 million (95% CrI, 1.64–1.87), indicating a growing population of survivors living with long-term morbidity.

Temporal analysis using AAPC revealed sustained increases in absolute counts across most burden indicators between 1990 and 2021, particularly in low- and low-middle-SDI regions. Although the AAPC of deaths is projected to slow or slightly decline after 2022 at the global level, continued growth in absolute numbers—especially in resource-limited settings—highlights the ongoing challenge of addressing BC burden in the context of demographic change and persistent health system inequalities.

Age-standardized incidence, mortality, DALYs, YLDs, and YLLs rates due to BC between 1990 and 2030.

From 1990 to 2021, global age-standardized rates (ASRs) of BC demonstrated divergent temporal patterns across burden indicators, reflecting improvements in survival and disease management alongside rising incidence (Table 2; Figure 2).

Table 2. Age-Standardized Incidence, Mortality, Disability-Adjusted Life Years, Years Lived with Disability, and Years of Life Lost Rates (per 100 000 Population) Due to Breast Cancer From 1990 to 2021, With Bayesian Projections for 2022 and 2030 by Age Group and Sociodemographic Index

Category	1990	2021	AAPC, 1990–2021	2022 (95% CrI)	2030 (95% CrI)	AAPC, 2022–2030
Age-Standardized Incidence Rate	NA	NA	NA	NA	NA	NA
Total	40.28	46.23	0.15	46.57 (46.55–46.59)	47.97 (41.60–54.35)	0.03
Age group, y	NA	NA	NA	NA	NA	NA
0–19	0.04	0.09	1.25	0.09 (0.08–0.10)	0.11 (0.10–0.12)	0.22
20–39	5.88	7.80	0.33	7.91 (7.90–7.92)	8.82 (7.72–9.92)	0.12
40–59	42.29	51.61	0.22	51.78 (51.76–51.80)	53.57 (46.84–60.30)	0.03
≥60	77.30	87.22	0.13	87.29 (87.24–87.33)	88.02 (77.13–98.92)	0.01
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	15.65	24.20	0.55	24.69 (24.68–24.70)	28.78 (25.55–32.01)	0.17
Low-middle	14.71	28.55	0.94	29.12 (29.11–29.13)	33.89 (31.15–36.63)	0.16
Middle	20.62	37.13	0.80	37.94 (37.92–37.95)	44.57 (40.65–48.50)	0.17
High-middle	39.37	50.97	0.29	51.27 (51.25–51.29)	53.86 (49.50–58.22)	0.05
High	79.76	77.41	−0.03	76.54 (76.50–76.58)	69.54 (57.10–81.99)	−0.09
Age-Standardized Mortality Rate	NA	NA	NA	NA	NA	NA
Total	16.74	14.58	−0.13	14.57 (14.57–14.58)	14.45 (11.81–17.09)	−0.01
Age group, y	NA	NA	NA	NA	NA	NA
0–19	0.03	0.05	0.67	0.05 (0.04–0.06)	0.06 (0.05–0.07)	0.20
20–39	3.62	3.60	−0.01	3.63 (3.62–3.64)	3.91 (3.28–4.55)	0.08
40–59	30.35	26.66	−0.12	26.68 (26.67–26.69)	26.97 (22.51–31.43)	0.01
≥60	65.79	59.14	−0.10	59.03 (59.00–59.05)	58.21 (50.49–65.93)	−0.01
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	12.27	16.18	0.32	16.39 (16.38–16.40)	18.41 (13.73–23.09)	0.12

Low-middle	10.09	14.82	0.47	14.98 (14.97–14.99)	16.13 (15.69–16.56)	0.08
Middle	11.52	12.69	0.10	12.78 (12.76–12.80)	13.45 (13.16–13.74)	0.05
High-middle	17.27	13.77	−0.20	13.65 (13.64–13.66)	12.64 (10.26–15.01)	−0.07
High	23.88	15.47	−0.35	15.27 (15.26–15.29)	13.70 (10.18–17.21)	−0.10
Age-Standardized DALY Rate	NA	NA	NA	NA	NA	NA
Total	507.43	455.56	−0.10	456.18 (455.90–456.46)	459.32 (377.71–540.94)	0.01
Age group, y	NA	NA	NA	NA	NA	NA
0–19	2.20	3.62	0.65	3.67 (3.66–3.68)	4.01 (3.82–4.21)	0.09
20–39	208.43	211.37	0.01	213.36 (213.25–213.47)	230.46 (192.42–268.49)	0.08
40–59	1234.45	1100.75	−0.11	1102.06 (1101.57–1102.55)	1117.50 (938.70–1296.30)	0.01
≥60	1553.47	1376.29	−0.11	1374.06 (1374.05–1374.07)	1354.80 (1137.89–1571.71)	−0.01
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	381.85	491.75	0.29	498.39 (498.19–498.60)	555.47 (480.84–630.09)	0.11
Low-middle	332.15	484.58	0.46	489.94 (489.69–490.19)	530.02 (515.35–544.70)	0.08
Middle	373.35	415.61	0.11	419.21 (419.00–419.41)	446.39 (384.81–507.96)	0.06
High-middle	541.27	421.07	−0.22	418.12 (417.82–418.42)	393.82 (319.14–468.51)	−0.06
High	725.27	467.67	−0.36	460.98 (460.57–461.39)	410.71 (310.74–510.69)	−0.11
Age-Standardized YLD Rate	NA	NA	NA	NA	NA	NA
Total	28.55	32.26	0.13	32.32 (32.31–32.34)	33.04 (29.70–36.37)	0.02
Age group, y	NA	NA	NA	NA	NA	NA
0–19	0.06	0.12	1.00	0.12 (0.11–0.13)	0.14 (0.13–0.15)	0.17
20–39	8.34	10.88	0.30	11.02 (11.01–11.03)	12.28 (10.66–13.89)	0.11
40–59	57.39	68.21	0.19	68.34 (68.30–68.37)	69.94 (60.33–79.55)	0.02
≥60	104.06	114.37	0.10	114.32 (114.26–114.38)	114.20 (100.74–127.65)	0.00
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	9.09	14.01	0.54	14.30 (14.29–14.31)	16.78 (15.22–18.34)	0.17
Low-middle	9.02	17.40	0.93	17.76 (17.75–17.78)	20.73 (19.09–22.37)	0.17
Middle	13.09	24.13	0.84	24.66 (24.65–24.67)	29.23 (26.93–31.53)	0.19
High-middle	27.60	35.91	0.30	36.14 (36.12–36.15)	38.10 (35.11–45.08)	0.05
High	58.98	58.27	−0.01	58.30 (57.49–59.11)	58.45 (56.20–60.71)	0.00
Age-Standardized YLL Rate	NA	NA	NA	NA	NA	NA
Total	478.89	476.13	−0.01	423.86 (423.60–424.13)	429.18 (353.68–504.68)	0.01
Age group, y	NA	NA	NA	NA	NA	NA
0–19	2.15	3.50	0.63	3.55 (3.54–3.56)	3.88 (3.69–4.06)	0.09
20–39	200.09	200.50	0.00	202.34 (202.23–202.45)	218.17 (181.37–254.96)	0.08
40–59	1177.06	1032.54	−0.12	1033.73 (1033.25–1034.21)	1048.33 (849.60–1247.05)	0.01
≥60	1449.41	1261.93	−0.13	1259.74 (1258.95–1260.53)	1240.13 (1033.94–1446.31)	−0.02
Sociodemographic Index	NA	NA	NA	NA	NA	NA
Low	372.76	477.74	0.28	484.09 (483.89–484.29)	538.71 (465.96–611.46)	0.11

Low-middle	323.13	467.17	0.45	472.17 (471.93–472.41)	509.46 (495.15–423.77)	0.08
Middle	360.27	391.49	0.09	394.55 (394.35–394.74)	417.38 (358.52–476.23)	0.06
High-middle	513.66	385.16	−0.25	381.98 (381.70–382.27)	355.67 (283.27–428.06)	−0.07
High	666.29	409.39	−0.39	403.33 (402.96–403.70)	355.43 (259.64–451.22)	−0.12

AAPC, average annual percentage change; CrI, credible interval; DALY, disability-adjusted life year; YLD, year lived with disability; YLL, year of life lost.

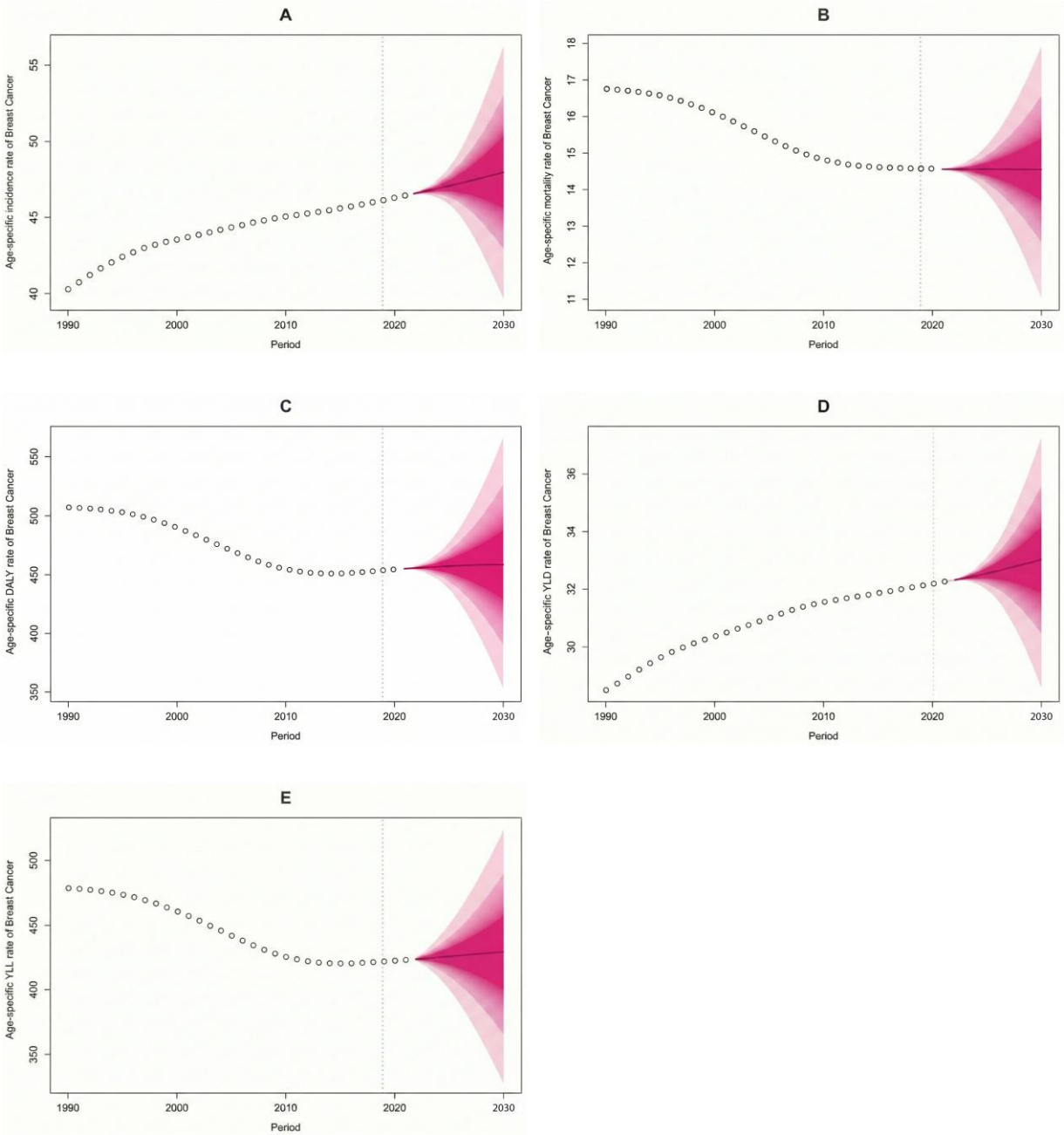

Figure 2. Temporal Trends in the Breast Cancer Burden Worldwide, 1990–2021, With Projections to 2030. A, Age-standardized incidence rate per 100 000 population. B, Age-standardized mortality rate per 100 000 population. C, Age-standardized disability-adjusted life years (DALYs) rate per 100 000 population. D, Age-standardized years lived with disability (YLDs) rate per 100 000 population. E, Age-standardized years of life lost (YLLs) rate per 100 000 population.

The global age-standardized incidence rate increased steadily from 40.28 per 100 000 population in 1990 to 46.23 in 2021 and is projected to reach 47.97 by 2030 (95% CrI, 45.12–50.83), indicating a sustained increase in diagnosed cases independent of population aging.

In contrast, age-standardized mortality rates declined over the study period, decreasing from 17.12

per 100 000 in 1990 to 14.01 in 2021, with projections suggesting a further reduction to 13.06 per 100 000 by 2030 (95% CrI, 12.01–14.15). This downward trend in mortality risk highlights substantial progress in early detection, treatment, and clinical management of BC at the global level, despite the continued rise in absolute numbers of deaths.

Similar patterns were observed for composite burden measures. The global age-standardized DALY rate declined from 471.5 per 100 000 in 1990 to 388.9 in 2021 and is projected to decrease further to 360.7 by 2030 (95% CrI, 330.4–391.2). This reduction was primarily driven by sustained declines in age-standardized YLL rates, reflecting decreasing premature mortality risk across most regions.

Conversely, age-standardized YLD rates exhibited a modest but consistent increase, rising from 32.6 per 100 000 in 1990 to 36.8 in 2021 and projected to reach 38.4 by 2030 (95% CrI, 36.2–40.7). This pattern suggests a growing population of BC survivors living with long-term health consequences, underscoring the increasing importance of survivorship care and rehabilitation services.

Marked heterogeneity in ASR trends was evident across SDI regions. High-SDI regions experienced stable or declining age-standardized mortality and DALY rates throughout the study period, whereas low- and middle-SDI regions showed slower declines and, in some cases, plateauing trends. Notably, uncertainty around projections was substantially greater in low- and low-middle-SDI settings, as reflected by wider CrIs, highlighting persistent data gaps and variability in future burden estimates.

Overall, these findings demonstrate a critical divergence between increasing age-standardized incidence and declining age-standardized mortality and DALY rates. While the individual-level risk of dying from BC has decreased globally, the continued increase in incidence and survivorship indicates that BC will remain a major and evolving public health challenge through 2030, particularly in regions undergoing rapid demographic and epidemiological transitions.

DISCUSSION

In the present study, data from the GBD study were used to examine the global burden of BC from 1990 to 2021 and to project trends from 2022 to 2030, stratified by age and country-level SDI. The primary contribution of this analysis is not etiological explanation, but the projection of future BC burden and the identification of widening inequalities across sociodemographic settings. The results showed that the absolute numbers of BC incidence and deaths increased by approximately 1.4% and 0.8% per year, respectively, from 1990 to 2021.

The increasing absolute number of total cases, alongside decreasing age-standardized mortality rates, highlights a key public health challenge. Although advances in therapy are enhancing individual outcomes, demographic changes are contributing to a growing population requiring medical care. This issue is especially pronounced in middle-SDI regions that are experiencing rapid epidemiological transitions.

This is also true in the study by Zhang *et al.*, who found that the burden of BC in women generally increases with age, with the highest burden in the 45 to 49 years age group.[12] In our study, this increasing trend was also observed, with the highest incidence and number of deaths in patients aged 40 to 59 years and 60 years or older.

Better screening and early detection of BC have led to more accurate counts in high-SDI areas; however, the results showed that the number of deaths has increased less in high-SDI areas than in other areas, which may be due to more advanced medical technology, effective preventive measures, and greater health awareness among the population in these areas. This increase is projected to be greater in low- and medium-SDI areas by 2030.[13]

The pronounced disparities observed across SDI regions are likely driven by structural determinants of health rather than biological differences alone. Limited access to organized screening programs, delayed diagnosis, and inadequate health care infrastructure contribute to higher mortality and DALY burdens in low- and middle-SDI settings. In addition, financial barriers, including out-of-pocket costs and limited insurance coverage, restrict access to timely and effective treatment, while shortages of trained oncology workforce further exacerbate inequalities in BC outcomes.[14–16]

To mitigate the projected increase in BC burden in low-SDI regions, targeted and context-specific interventions are urgently needed. These include the expansion of cost-effective screening strategies such as mobile mammography and community-based clinical breast examination programs, particularly in underserved and rural areas. Strengthening health care capacity through workforce training, task shifting, and integration of cancer services into primary health care systems may improve early detection and continuity of care. In parallel, subsidized treatment programs and improved financial protection mechanisms are essential to reduce treatment delays and prevent catastrophic health expenditures among vulnerable populations.[17–19]

The substantial rise in DALYs observed in low- to middle-SDI regions, particularly among women aged 40 to 59 years, likely reflects structural

inequalities in health care access and capacity rather than direct environmental or psychosocial influences. Lower-SDI regions frequently face multiple challenges, including limited screening availability, delays in diagnosis, less comprehensive treatment options, and higher rates of modifiable risk factors such as obesity. These systemic barriers often result in later-stage diagnoses and increased disability among survivors, thereby contributing to a higher DALY burden. In contrast, regions with higher SDI benefit from well-established screening programs, earlier detection, and access to advanced multidisciplinary care, which together mitigate disability and mortality. Accordingly, our projection of a continued increase in DALYs through 2030 highlights the pressing need to address these health care disparities at a systemic level.[20]

The AAPC of deaths increased between 1990 and 2021, with the highest rate in the 60 years or older age group. This increase is also expected to continue in this age group from 2022 to 2030 and to be higher than in other age groups. These findings suggest that the increase in BC prevalence is associated with population aging, as people in this age group are more exposed to genetic changes and environmental factors. As a result, the overall risk of cancer increases with age. The results also showed that the lowest increase in the AAPC of deaths was observed in countries with a high SDI, suggesting that the impact of BC varies according to the SDI of the region.[12]

The observed increase in age-standardized BC mortality rates in low- and middle-SDI regions represents a critical public health concern. Unlike high-SDI settings, where mortality declines reflect advances in early detection and treatment, many low- and middle-SDI countries continue to face systemic barriers, including limited screening coverage, delayed diagnosis, inadequate referral pathways, and restricted access to effective therapies. These structural constraints contribute to later-stage presentation and poorer survival outcomes, despite rising diagnostic capacity. From a policy perspective, these findings underscore the need for targeted investments in cost-effective screening strategies, strengthening of primary health care systems, expansion of oncology treatment infrastructure, and integration of BC services into universal health coverage frameworks. Addressing these systemic gaps will be essential to reverse unfavorable mortality trends and reduce global inequities in BC outcomes.[21–26]

The results based on age-standardized BC rates show that the incidence rate is increasing overall, from 40.28 per 100 000 people in 1990 to 46.43 per 100 000 people in 2021, and this trend is projected to increase to 47.97 per 100 000 people in 2030. Interestingly, the incidence rate is decreasing in areas with a high SDI, which may be due to the socioeconomic and health conditions of these areas. In particular, the BC mortality rate has decreased over the years studied, so that the DALY and YLL parameters also show a decreasing trend. This decreasing trend was more pronounced in people 60 years or older and in areas with a high SDI, which may be due to advances in medical technology and treatment methods and changes in public health strategies that affect mortality and the overall burden of the disease.[27,28]

Therefore, in light of these findings, it is predicted that global disparities in the burden of BC in women will emerge, with some regions experiencing a higher burden owing to limited health resources and preventive measures, and others experiencing a lower burden owing to improved health care, preventive measures, and early detection.[12] However, the establishment of the Global BC Initiative in 2021, which emphasizes health promotion, early and rapid detection, and comprehensive treatment of BC, may reduce this global disparity and the incidence of the disease through effective screening programs in the global fight against BC.

This study found a significant association between BC trends in women from 1990 to 2021 and the projected burden from 2022 to 2030. This positive association underscores the potential link between past and future trends and suggests a continuing influence of disease pathogenesis and long-term lifestyle stability,[29] genetic factors, environmental factors,[30] and socioeconomic conditions.[31] These findings highlight the importance of using historical data to predict future trends in order to develop appropriate global strategies for the prevention and treatment of BC in women, taking into account regional disparities and long-term patterns.

Our projections suggest that by 2030, the annual number of new cases requiring management will increase by approximately 457 000 compared with 2021, placing a significant demand on oncology services. In resource-limited settings, emphasis on cost-effective approaches, such as clinical breast examination and the enhancement of referral systems, will be essential. Across all regions, integrating survivorship care to address the growing burden of YLDs should become a core component of cancer control planning. These forecasts provide evidence to guide the strategic priorities of the WHO Global BC Initiative, particularly in efforts to reduce disparities.

CONCLUSION

This study provides a comprehensive assessment of the global burden of BC among women from 1990 to 2021 and projects future trends through 2030 using a Bayesian modeling framework. While age-standardized mortality and DALY rates are projected to decline, the absolute number of BC cases and deaths is expected to continue increasing worldwide, largely driven by population growth and aging. Substantial disparities persist across SDI regions, with the greatest future increases projected in low- and middle-SDI settings, reflecting structural inequities in screening, diagnosis, and access to effective treatment. These findings underscore the urgent need for targeted, context-specific interventions—particularly in resource-limited regions—to strengthen early detection, expand affordable treatment, and reduce widening inequalities in BC outcomes globally.

ETHICAL CONSIDERATIONS

The study was approved by the Ethics Committee of the Hamadan University of Medical Sciences (IR.UMSHA.REC.1403.245).

DATA AVAILABILITY

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

CONFLICT OF INTERESTS

The authors have no conflicts of interest to declare.

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AI DISCLOSURE

The authors declare that no artificial intelligence (AI) tools were used for statistical modeling, data analysis, result interpretation, or decision-making processes in this study. All statistical analyses were conducted using R software, including established statistical packages, without any AI-based analytical assistance. The scientific content of the manuscript, including study design, data interpretation, and conclusions, was entirely developed by the authors based on previously published literature and validated analytical methods. AI tools were used solely for language editing and grammar correction. The authors take full responsibility for the accuracy, integrity, and originality of the work.

AUTHOR CONTRIBUTION

FS: Conceptualization, data curation, formal analysis, methodology, project administration, visualization, writing the original draft, writing the review and editing. FH: Data curation. SM: Conceptualization, funding acquisition, project administration, visualization. AS: Conceptualization, funding acquisition, project administration, visualization. SK: Conceptualization, funding acquisition, project administration, visualization. AK: Conceptualization, funding acquisition, project administration, visualization, writing the original draft, writing the review and editing.

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