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Breast cancer burden among women of reproductive age in China, Japan, and South Korea, 1990–2021: a systematic analysis from the Global Burden of Disease Study 2021

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Abstract

Background Breast cancer is the most common cancer among women globally, with incidence rates rising annually. However, systematic comparative studies on the burden of breast cancer among women of reproductive age in East Asian countries are currently lacking.

Methods This study utilized the Global Burden of Disease (GBD) 2021 database to extract incidence, prevalence, mortality, disability-adjusted life years (DALYs) for breast cancer among women of reproductive age in China, Japan, and South Korea. Cross-national comparisons were conducted using age-standardized rates (ASR), and estimated annual percentage change (EAPC) and average annual percentage change (AAPC) were calculated. Joinpoint regression analysis identified trend turning points, and ARIMA models projected trends for 2022–2036.

Results From 1990 to 2021, China, Japan, and South Korea exhibited upward trends in age-standardized incidence rates (ASIR) and age-standardized prevalence rates (ASPR) for breast cancer (ASIR: China's EAPC = 2.17, Japan's EAPC = 0.93, South Korea's EAPC = 3.86). Age-standardized mortality rates (ASMR) and age-standardized DALYs rates (ASDR) generally declined in China and Japan but increased in South Korea (ASMR: China's EAPC = −1.10, Japan's EAPC = −0.64, South Korea's EAPC = 0.11). Projections for the next 15 years indicate rising ASIR and ASPR in China, declining trends in Japan, and stabilization in South Korea; overall declines in ASMR and ASDR across all three countries.

Conclusion The findings emphasize the importance of enhanced, country-specific screening and prevention efforts for breast cancer among reproductive-age women in East Asia to address disparities in disease burden and early detection.

Keywords Breast cancer · Women of reproductive age · GBD 2021 · East Asian countries · Risk factors · Future projections

Introduction

Breast cancer has become the most common cancer among women globally, with approximately 2.3 million new cases in 2022, constituting a substantial share in the global cancer burden. Among female cancers, breast cancer ranks first in incidence and also first in mortality [1, 2]. Notably, approximately 15–20% of new cases occur in women aged 15–49 during their childbearing years [3]. This group not only plays vital roles in reproduction and family life but is also crucial to socioeconomic development, making the epidemiological characteristics of breast cancer in this population particularly noteworthy.

East Asian nations—China, Japan, and South Korea—share geographical proximity and similar dietary patterns, lifestyles, and cultural mindsets. However, they occupy distinct developmental stages: China remains a developing nation, South Korea has recently entered the ranks of developed countries, while Japan is a long-established developed economy. This may result in notable differences in healthcare systems, screening coverage, and lifestyles. For instance, Japan's mature screening programs facilitate early detection [4, 5], while rapid urbanization in China and South Korea may amplify the impact of risk factors.

Despite these shared and differing characteristics, key unknowns remain regarding the long-term trends in breast cancer burden (incidence, prevalence, mortality, and disability-adjusted life years (DALYs)) among women of

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reproductive age in these countries, how these trends differ across nations, and what future projections imply for policy. Prior studies have examined global or multinational patterns but lack detailed cross-comparisons focused on East Asia's reproductive-age women, limiting insights into region-specific drivers and interventions. Comparing the breast cancer burden across these three nations—examining disparities in incidence, prevalence, and mortality rates—offers valuable insights for public health policy development, such as identifying transferable strategies from advanced systems (e.g., Japan's screening) to reduce burdens in emerging economies like China.

This study systematically and comprehensively compared the burden of breast cancer and attributable risk factors in China, Japan, and South Korea from 1990 to 2021 using the Global Burden of Disease (GBD) 2021 database. We employed Joinpoint regression analysis to examine temporal trends in breast cancer incidence. Additionally, this study projected future trends in breast cancer incidence, prevalence, mortality, and DALYs for China, Japan, and South Korea over the next 15 years. These findings provide valuable insights for public health policy development in China, informing more targeted screening programs and strengthening preventive measures. Our objective is to promote women's health and longevity.

Materials and methods

Data sources

This study utilized data from the GBD 2021 database, which provides cross-sectional datasets on incidence, prevalence, mortality, and DALYs from 1990 to 2021 across 204 countries and regions. The database is accessible through the Global Health Data Exchange (GHDx) platform (https://vizhub.healthdata.org/gbd-results/) [6]. The World Health Organization defines women of reproductive age as those aged 15–49 years.

We extracted specific breast cancer data for women of reproductive age (15–19 years, 20–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years, 45–49 years) from East Asian countries, including incidence, prevalence, mortality, DALYs. This study was based on publicly available aggregated data from the GBD database and did not involve individual human subjects; therefore, ethical approval and informed consent were not required.

Statistical analysis

Age-standardized rates (ASR) facilitate comparisons of disease rates across countries and regions by applying a global standard population structure. These include age standardized incidence rates (ASIR), age-standardized prevalence rates (ASPR), age-standardized mortality rates (ASMR), and age-standardized DALYs rates (ASDR).

The formula is:

$$ASR = \frac{\sum_{p=1}^{N} n_p w_p}{\sum_{p=1}^{N} w_p} \times 100{,}000$$

In this equation, n_p represents the age-specific rate for age group p in the population, w_p denotes the population size for age group p (based on the World Standard Population provided by the World Health Organization (WHO)), and N indicates the number of age groups.

We calculated the ASR and 95% uncertainty interval (UI) for the years 1990 and 2021. Furthermore, we also calculated the estimated annual percentage change (EAPC) in ASR along with 95% confidence interval (CI) to describe trends in ASR reflecting the breast cancer burden among women of reproductive age. EAPC is calculated via log-linear regression of ASR: $EAPC = 100 \times (\exp(\beta) - 1)$, where β is the regression coefficient. If EAPC > 0, it indicates annual increase (upward trend); if EAPC < 0, it indicates annual decrease (downward trend). The absolute value of EAPC reflects the annual rate of change.

We also employed the Joinpoint regression analysis model to calculate annual percentage change (APC) and annual average percentage change (AAPC), along with their respective 95% confidence interval (CI), to identify long-term trends in significant changes such as breast cancer incidence or mortality [7]. This model establishes segmented regression based on the temporal characteristics of disease distribution, dividing the total time span into distinct intervals. By performing trend fitting and optimization for each interval, it facilitates precise identification of trend shifts.

To forecast trends in breast cancer among women of reproductive age from 2022 to 2036, we employed the Autoregressive Integrated Moving Average (ARIMA) model from time series analysis [8]. The ARIMA model comprises three components: the autoregressive term (p) reflecting the relationship between current and past values; the number of differences (d) applied to the data to make it stationary; and the moving average term (q) used to smooth random fluctuations. This enables optimization under information conditions to search for the optimal combination of model parameters, thereby avoiding potential biases from subjective selection.

All statistical analyses were performed using R software (version 4.3.2) and Joinpoint software (version 5.4.0.0). *P*-values < 0.05 were considered statistically significant.

Results

Breast cancer burden in China, Japan, and South Korea

In 1990, the incidence of breast cancer among women of reproductive age in China was 36,689 (95% UI: 29,142, 45,383). By 2021, this figure had risen to 110,371 (95% UI: 82,543, 142,345), representing a 200.83% increase. The prevalence increased by 218.36%, closely aligning with the incidence data. During the same period, mortality increased from 13,567 (95% UI: 10,747, 16,803) to 16,439 (95% UI: 12,282, 21,420), representing a 21.17% growth rate. The number of DALYs in 2021 was 861,867 (95% UI: 648,610, 1,119,103), representing a 23.22% increase compared to 1990. The growth rates for absolute numbers of incidence, prevalence, mortality, and DALYs were comparable between China and South Korea, whereas Japan exhibited significantly lower figures. Notably, Japan experienced declines in mortality and DALYs despite increases in incidence and prevalence (Table 1).

Regarding age-standardized rates, Japan recorded the highest figures among the three countries in 1990: ASIR at 29.78 (95% UI: 25.62, 34.69) and ASPR at 275.07 (95% UI: 237.16, 316.34). During the same period, China recorded the highest ASMR and ASDR at 5.23 (95% UI: 4.12, 6.49) and 264.54 (95% UI: 208.10, 329.19), respectively. These patterns shifted in 2021, with Japan exhibiting the highest standardized rates across all four metrics. Compared to 1990, South Korea saw increases in ASIR, ASPR, ASMR, and ASDR, while China experienced increases in all metrics except ASDR, which declined. Japan followed its previous absolute trend: ASIR

Table 1 Number of cases, age-standardized incidence rates (ASIR), age-standardized prevalence rates (ASPR), age-standardized mortality rates (ASMR), age-standardized DALYs rates (ASDR), and estimated annual percentage changes (EAPC) and average annual percentage changes (AAPC) for women of reproductive age in China, Japan, and South Korea in 1990 and 2021

Year	China	Japan	Korea
1990			
Incidence (n,95%UI)	36,689 (29,142, 45,383)	11,234 (10,286, 12,123)	1,374 (1,156, 1,636)
Prevalence (n,95%UI)	305,790 (243,723, 375,168)	104,091 (95,485, 112,038)	12,576 (10,722, 14,786)
Mortality (n,95%UI)	13,567 (10,747, 16,803)	1,792 (1,749, 1,836)	424 (363, 503)
DALYs (n,95%UI)	699,470 (554,281, 866,933)	93,340 (89,927, 96,903)	22,102 (18,988, 26,132)
ASIR (per 100 000 people,95%UI)	14.06 (11.07,17.41)	29.78 (25.62,34.69)	12.64 (9.64,16.29)
ASPR (per 100 000 people,95%UI)	117.62 (93.82,144.53)	275.07 (237.16,316.34)	116.88 (92.66,147.72)
ASMR (per 100 000 people,95%UI)	5.23 (4.12,6.49)	4.72 (4.55,4.89)	3.95 (3.11,4.96)
ASDR (per 100 000 people,95%UI)	264.54 (208.10,329.19)	248.75 (237.16,261.12)	202.11 (158.10,255.68)
2021			
Incidence (n,95%UI)	110,371 (82,543, 142,345)	14,133 (12,903, 15,317)	5,620 (4,508, 6,854)
Prevalence (n,95%UI)	973,499 (738,133, 1,253,253)	130,748 (119,755, 141,104)	51,548 (42,190, 62,036)
Mortality (n,95%UI)	16,439 (12,282, 21,420)	1,459 (1,417, 1,494)	616 (506, 734)
DALYs (n,95%UI)	861,867 (648,610, 1,119,103)	78,164 (74,117, 82,299)	33,110 (27,033, 39,822)
ASIR (per 100 000 people,95%UI)	27.78 (20.51,36.38)	41.42 (35.40,46.83)	37.12 (27.07,49.59)
ASPR (per 100 000 people,95%UI)	244.59 (182.70,316.94)	380.90 (328.77,427.70)	338.91 (251.24,446.08)
ASMR (per 100 000 people,95%UI)	4.10 (3.04,5.37)	4.19 (4.05,4.33)	4.01 (3.09,5.15)
ASDR (per 100 000 people,95%UI)	218.02 (160.94,286.20)	230.04 (216.87,244.80)	219.65 (167.90,283.21)
1990–2021			
ASIR (EAPC,95%CI)	2.17 (2.09,2.24)	0.93 (0.59,1.27)	3.86 (3.48,4.25)
ASPR (EAPC,95%CI)	2.37 (2.30,2.44)	0.95 (0.64,1.27)	3.86 (3.50,4.21)
ASMR (EAPC,95%CI)	−1.10 (−1.23, −0.98)	−0.64 (−0.87, −0.42)	0.11 (0.02,0.19)
ASDR (EAPC,95%CI)	−0.93 (−1.05, −0.82)	−0.48 (−0.71, −0.26)	0.34 (0.25,0.44)
AAPC for Incidence (n,95%CI)	2.25 (1.99, 2.52)	1.19 (0.85, 1.52)	3.54 (3.29, 3.79)
AAPC for Prevalence (n,95%CI)	2.44 (2.24, 2.64)	1.05 (0.63, 1.47)	3.50 (3.28, 3.73)
AAPC for Mortality (n,95%CI)	−0.82 (−1.09, −0.54)	−0.34 (−0.45, −0.22)	0.10 (−0.20, 0.40)
AAPC for DALYs (n,95%CI)	−0.63 (−0.93, −0.33)	−0.18 (−0.29, −0.07)	0.32 (0.04, 0.60)

and ASPR increased, while ASMR and ASDR decreased (Table 1).

Trends in Breast Cancer Burden, 1990–2021

China exhibited an increasing trend in ASIR from 1990 to 2021 (EAPC = 2.17, 95% UI: 2.09, 2.24; AAPC = 2.25, 95% UI: 1.99, 2.52) (Table 1, Fig. 1a). Similarly, ASPR showed the same trend (EAPC = 2.37, 95% UI: 2.30, 2.44; AAPC = 2.44, 95% UI: 2.24, 2.64) (Table 1, Fig. 1b). Similar trends were observed in Japan and South Korea, though Japan's growth flattened while South Korea exhibited the highest growth rate (Table 1, Fig. 1a, b). ASMR (EPAC = −1.10, 95% UI: −1.23, −0.98; AAPC = −0.82, 95% UI: −1.09, −0.54) and ASDR (EPAC = −0.93, 95% UI: −1.05, −0.82; AAPC = −0.63, 95% UI: −0.93, −0.33) showed a declining trend in China, with a similar trend observed in Japan, while an increasing trend was noted in South Korea (Table 1, Fig. 1c, d).

Joinpoint regression analysis of breast cancer burden

From 1990 to 2021, China and South Korea exhibited a gradual upward trend in ASIR and ASPR (Fig. 2a, c, d, f); Japan, however, demonstrated a wave-like increase. Specifically, from 1990 to 1998, both ASIR and ASPR in Japan showed a significant upward trend (ASIR: APC = 4.97, $P < 0.05$; ASPR: APC = 3.34, $P < 0.05$ (1990–1993); ASPR: APC = 5.16, $P < 0.05$ (1993–1998)); trended toward stabilization or even decline from 1998 to 2003; however, a marked increase occurred from 2003 to 2006 or 2007 (ASIR: APC = 2.79, $P < 0.05$ (2003–2007); ASPR: APC = 3.58, $P < 0.05$ (2003–2006)); Subsequently, both ASIR and ASPR in Japan showed a gradual decline (Fig. 2b, e). Meanwhile, ASMR and ASDR exhibited identical trends across countries from 1990 to 2021. China exhibited a gradual decline, reaching a low point around 2014 or 2015 before slowly rising again (Fig. 2g, j); Japan showed an initial rise followed by a decline, peaking in 1998 (Fig. 2h, k); South Korea demonstrated a wave-like increase, reaching its peak in 2009 (Fig. 2i, l).

Prediction of ASIR, ASPR, ASMR, and ASDR of breast cancer over the next 15 years

We employed ARIMA modeling to forecast the burden of breast cancer among women of reproductive age from 2022 to 2036. According to ARIMA projections, both ASIR and ASPR in China show an overall upward trend

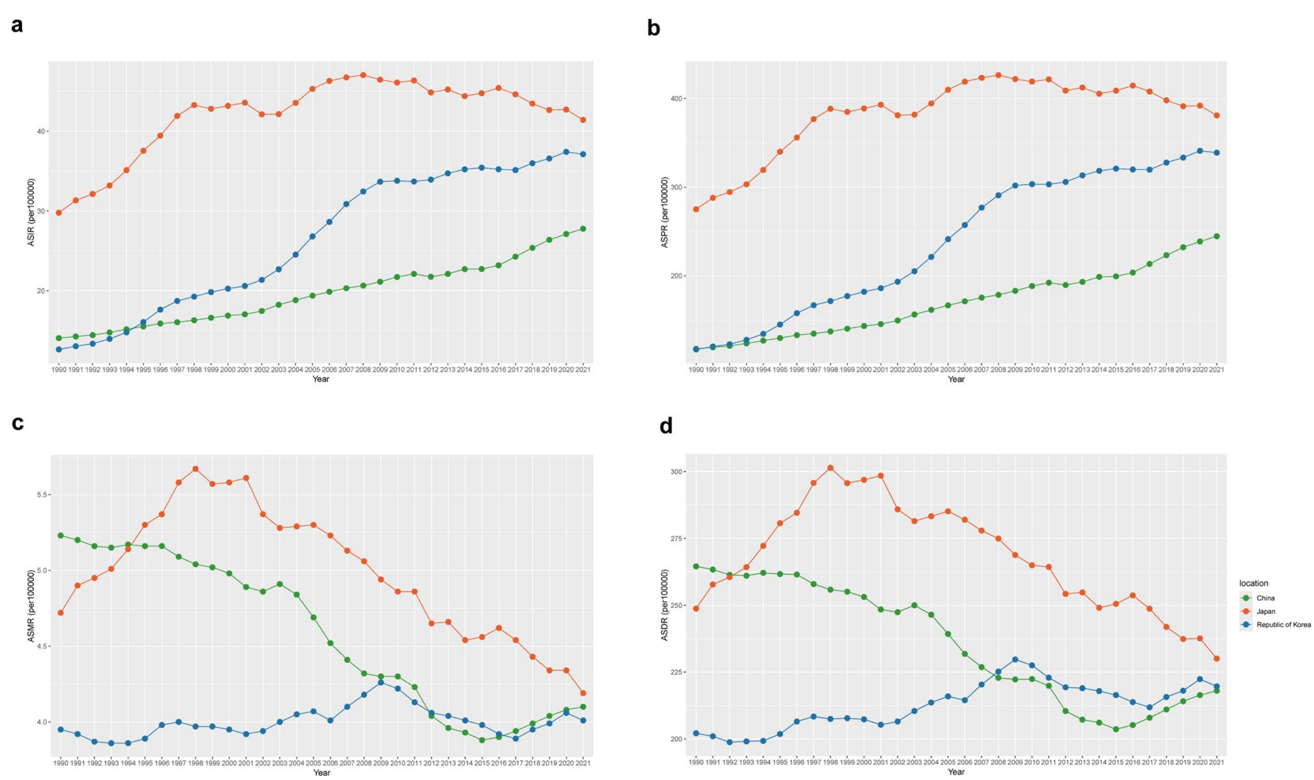

Fig. 1 Comparison of trends in ASIR, ASPR, ASMR, ASDR for breast cancer in China, Japan, and South Korea, 1990–2021. **A** ASIR trend. **B** ASPR trend. **C** ASMR trend. **D** ASDR trend. ASIR: age-standardized incidence rates; ASPR: age-standardized prevalence rates; ASMR: age-standardized mortality rates; ASDR: age-standardized DALYs rates

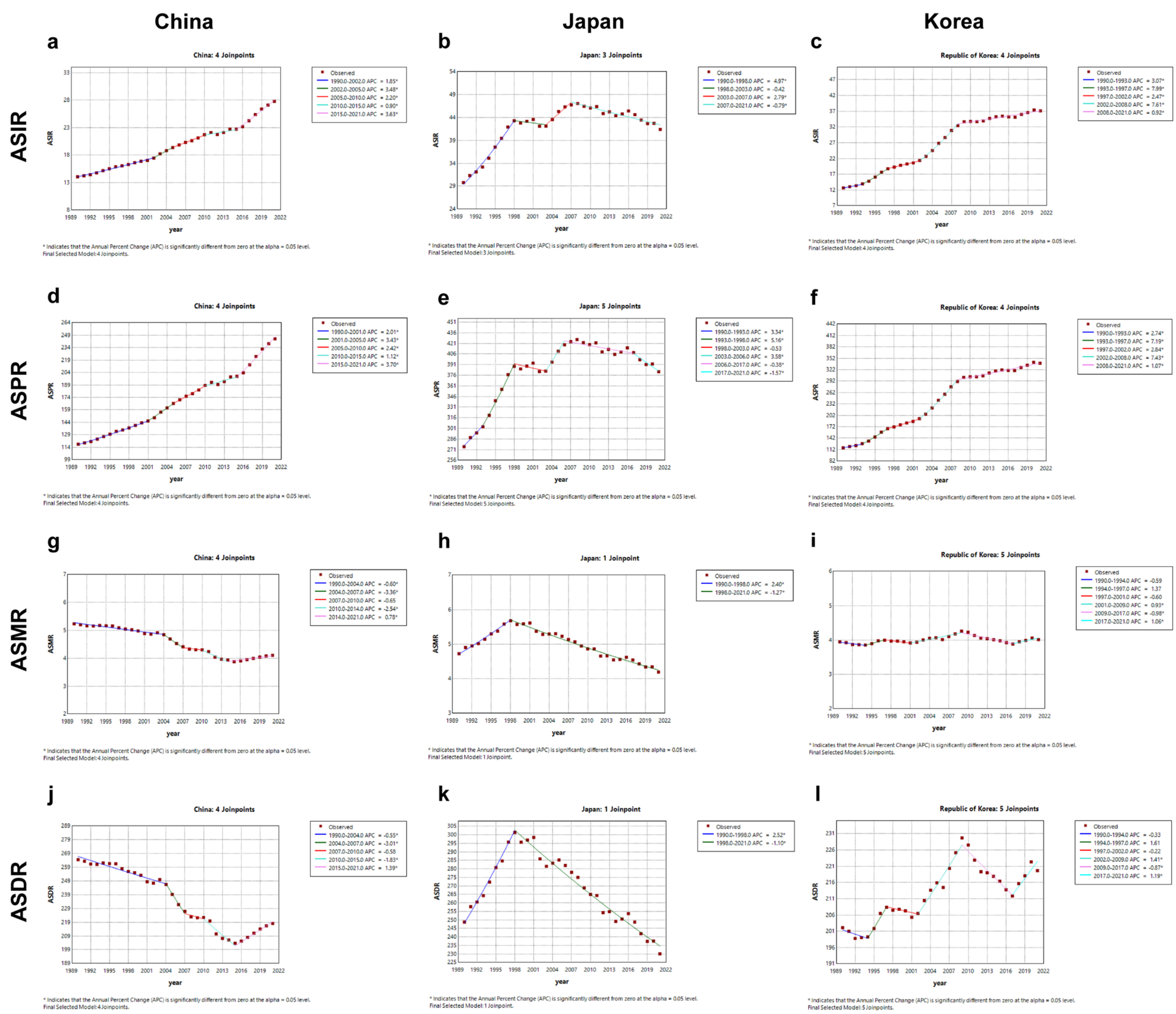

Fig. 2 Joinpoint regression analysis of ASIR, ASPR, ASMR, and ASDR for breast cancer in China, Japan, and South Korea, 1990–2021. **A**–**C** represent joinpoint regression analyses for ASIR in China, Japan, and South Korea, respectively. **D**–**F** represent Joinpoint regression analyses of breast cancer ASPR in China, Japan, and South Korea, respectively. **G**–**I** represent Joinpoint regression analyses of breast cancer ASMR in China, Japan, and South Korea, respectively. **J**–**L** represent Joinpoint regression analyses of breast cancer ASDR in China, Japan, and South Korea, respectively. ASIR, age-standardized incidence rates; ASPR, age-standardized prevalence rates; ASMR, age-standardized mortality rates; ASDR, age-standardized DALYs rates. *indicates $P < 0.05$

during this period (Fig. 3a, d), while Japan exhibits a downward trend (Fig. 3b, e). South Korea demonstrates a stable or slightly increasing trend (Fig. 3c, f). However, both ASMR and ASDR show a declining trend in China and Japan (Fig. 3g, h, j, k), while South Korea remains stable (Fig. 3i, l). Overall, mortality rates are projected to decrease in the future due to advances in medical technology.

Discussion

This study systematically compared the burden of breast cancer among women of reproductive age in China, Japan, and South Korea from 1990 to 2021 based on the GBD 2021 database and projected future trends. Results indicate increases in incidence and prevalence in China and South

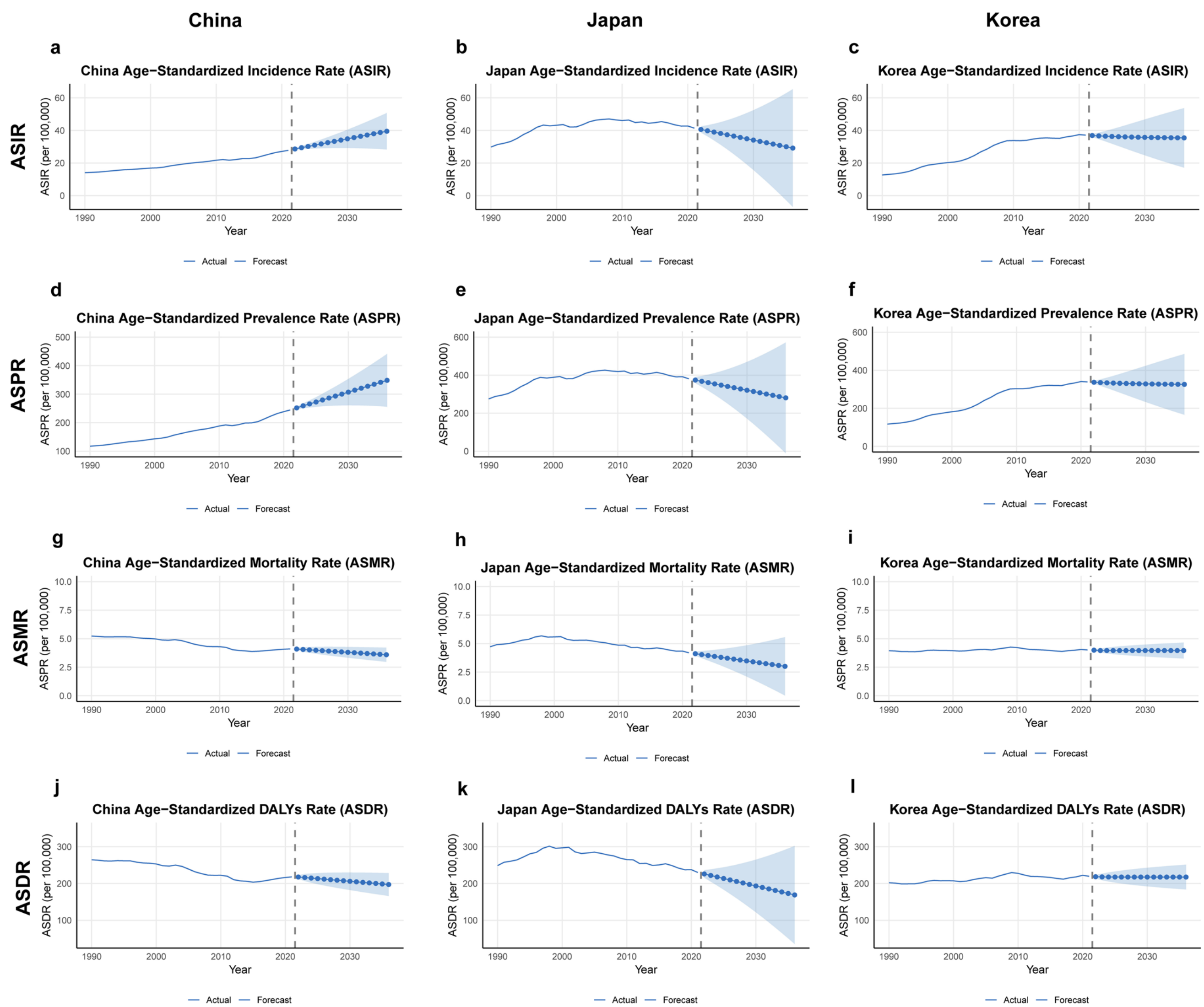

Fig. 3 Time trends of ASIR, ASPR, ASMR, and ASDR for breast cancer in China, Japan, and South Korea from 1990 to 2021, with projections for 2022–2036. **A-C** Time trends of ASIR for breast cancer in China, Japan, and South Korea from 1990 to 2021, with projections for 2022–2036. **D–F** Breast cancer ASPR trends in China, Japan, and South Korea from 1990 to 2021 and projections for 2022–2036. **G–I** Breast cancer ASMR trends in China, Japan, and South Korea from 1990 to 2021 and projections for 2022–2036. **J–L** Breast cancer ASDR trends in China, Japan, and South Korea from 1990 to 2021 and projections for 2022–2036. ASIR, age-standardized incidence rates; ASPR, age-standardized prevalence rates; ASMR, age-standardized mortality rates; ASDR, age-standardized DALYs rates

Korea, while Japan showed fluctuating patterns followed by stabilization. Mortality and DALYs decreased in China and Japan but increased in South Korea. These disparities reflect the heterogeneity in socioeconomic development stages, healthcare systems, and lifestyles across East Asian countries [9].

Regarding incidence and prevalence, China's ASIR and ASPR exhibited EAPCs of 2.17 and 2.37. These trends could be influenced by improved healthcare access, expanded diagnostic capacity, and detection of previously undiagnosed cases, particularly in China where healthcare infrastructure has rapidly developed [10, 11]. Respectively, South Korea's ASIR and ASPR showed greater growth rates. This may be associated with rapid urbanization, Westernized diets, and delayed childbearing. Japan's wave-like trend (rapid rise from 1990 to 1998 followed by steady increase) may benefit from early implementation of screening programs. Since the 1990 s, Japan introduced nationwide breast cancer screening with coverage ranging from 40 to 50% [12], leading to increased early diagnoses and reduced late-stage cases [13]. While, China has lower screening coverage (approximately 20–30%) [14],which may underestimate true burdens or delay diagnoses. The breast cancer screening rate among the South Korean women has demonstrated a consistent annual increase, reaching 63.5% in 2020 [15]. This upward trend in screening participation has coincided with a rising ASIR and ASPR of breast cancer in the South Korean.

Trends in mortality and DALYs indicate that declines in ASMR and ASDR in China and Japan (EPAC < 0) are attributable to medical advances; however, Japan's breast cancer mortality rate increased annually until 1998 before declining year after year thereafter, potentially attributable to the approved application of targeted therapies and the widespread adoption of hormone therapy [16]. The increase in ASMR and ASDR in South Korea may be attributable to the impact of diagnostic delays among disadvantaged populations and risk factors, such as Westernized dietary habits, postmenopausal obesity, and the low fertility rates [17–20].

Future projections indicate rising ASIR/ASPR in China, declining rates in Japan, and stabilization in South Korea. Overall mortality is projected to decrease, reflecting continuation of current trends in healthcare improvements. However, these projections assume current trends persist and do not account for sudden public health events.

This study has several limitations. First, the GBD 2021 database relies on model estimates and national reporting data, which may introduce uncertainty—particularly in developing countries like China where data quality is lower, leading to potential reporting bias and wider uncertainty interval (UI) [21]. Second, the analysis did not account for heterogeneity across population subgroups, such as urban–rural disparities (lower screening coverage in rural China), ethnic diversity, or economic stratification, which may mask higher burdens in specific groups [22]. Third, Joinpoint and ARIMA models assume linear or stable trends, whereas real-world trends may be influenced by policy changes (e.g., new screening guidelines) or external factors (e.g., diagnostic delays due to the COVID-19 pandemic), potentially introducing prediction biases [23]. Furthermore, risk factor assessment is limited to the 12 defined by GBD, potentially overlooking emerging factors like environmental pollutants, endocrine disruptors, or genetic variations [24]. Future research integrating real-time data and cohort studies could address these limitations.

In conclusion, the observed trends underscore the need for enhanced screening and preventive strategies in East Asia, particularly tailoring interventions to reproductive-age women based on national disparities in detection.

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Author contributions This study was conducted by ZYR.

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Data availability The data are available online on the website of the Institute for Health Metrics and Evaluation (IHME) (https://ghdx.healthdata.org/gbd-2021).

Declarations

Conflict of interests The author declares no competing interests.

Ethics approval and consent to participate The data we used were secondary data publicly released from GBD 2021 did not require additional human subject research ethics review or informed consent. Consent for publication.

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