cancers from 1990 to 2021

Tianye Li^{1,2}, Haoxiang Zhang³, Mengyi Lian^{1,2}, Qionghua He^{1,2}, Mingwei Lv⁴, Lingyun Zhai^{1,2}, Jianwei Zhou^{1,2*}, Kongming Wu^{5,6*} and Ming Yi^{7*}

Global status and attributable risk factors

of breast, cervical, ovarian, and uterine

Abstract

Background Female-specific cancers, particularly breast, cervical, ovarian, and uterine cancers, account for nearly 40% of all cancers in women. This study aimed to analyze the global epidemiological trends of these cancers from 1990 to 2021, offering insights into their evolving patterns and providing valuable information for health policymakers to allocate healthcare resources more effectively.

Methods Data from the Global Burden of Disease Study 2021 (GBD 2021) were used to comprehensively assess the global incidence, mortality, and disability-adjusted life years (DALYs) of female-specific cancers. Age-standardized rates facilitated cross-regional comparisons, accounting for differences in population size and demographics. The socio-demographic index (SDI) was employed to categorize regions and evaluate correlations between cancer burden and economic level. In addition, risk factors attributable to female-specific cancer deaths and DALYs were assessed based on the comparative risk assessment model of the GBD project.

Results From 1990 to 2021, the global burden of female-specific cancers increased at varying rates. In 2021, breast cancer accounted for 2.08 million incident cases, 0.66 million deaths, and 20.25 million DALYs globally. In comparison, cervical, ovarian, and uterine cancers had lower burdens, with 0.67 million, 0.30 million, and 0.47 million incident cases, respectively. Age-standardized rates of breast, ovarian, and uterine cancers showed positive correlations with SDI, while cervical cancer exhibited a negative correlation. Attributable risk factors for breast cancer-associated deaths in 2021 included dietary risks, high body-mass index (BMI), high fasting plasma glucose, alcohol use, tobacco use, and low physical activity. Additional risk factors were unsafe sex and tobacco use for cervical cancer, high BMI and occupational risks for ovarian cancer, and high BMI for uterine cancer.

*Correspondence: Jianwei Zhou Jianwei-zhou@zju.edu.cn Kongming Wu kmwu@tjh.tjmu.edu.cn Ming Yi mingyi_onco@outlook.com; 1322068@zju.edu.cn

Full list of author information is available at the end of the article



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Conclusions The burden of female-specific cancers has increased in recent decades, with significant demographic and regional discrepancies. These findings highlight the urgent need for targeted public health interventions to mitigate the global impact of these cancers.

Keywords Female-specific cancer, Breast cancer, Cervical cancer, Ovarian cancer, Uterine cancer, Socio-demographic index, Cancer epidemiology

Background

According to the latest World Health Organization (WHO) estimates, breast cancer is the most common malignant tumor in women worldwide, accounting for 23.8% of new cases in 2022 [1]. Cervical cancer ranks as the fourth most frequently diagnosed cancer among women (6.8%), followed by uterine (4.3%) and ovarian (3.4%) cancers [1]. Together, these four female-specific cancers represent nearly 40% of all cancers affecting women [1]. Notably, the epidemiological patterns of cancer incidence, mortality, and morbidity exhibit significant geographical variations and temporal shifts [2, 3]. For instance, while breast cancer is the most commonly diagnosed cancer among women in most countries [1], cervical cancer surpasses breast cancer in incidence in certain regions of sub-Saharan Africa, South America, and South-Eastern Asia [1]. This is closely linked to the high prevalence of human papillomavirus (HPV) infection and limited access to cervical cancer vaccination and screening programs [1]. Thus, analyzing the epidemiological characteristics of female-specific cancers is critical to understanding their public health implications across diverse populations.

In our previous work, we systematically analyzed the epidemiological trends of these four female-specific cancers using the Global Burden of Disease 2019 (GBD 2019) database [4]. The burden of all four cancers has increased over the past three decades, with breast cancer being the most prominent. Its high incidence and strong positive correlation with socioeconomic development have posed substantial challenges to global cancer prevention and treatment efforts [4]. In contrast, the incidence of cervical cancer has been effectively controlled in many regions, particularly in developed economies, due to the widespread implementation of HPV vaccination programs and other preventive measures [4]. Nevertheless, two years later, an updated analysis is necessary, especially considering the profound impact of the coronavirus disease 2019 (COVID-19) pandemic on global public health resources.

As the updated version of GBD 2019, GBD 2021 database provides comprehensive epidemiological data on 371 diseases and 88 attributable risk factors across 204 countries and territories, spanning the years 1990 to 2021 [5–7]. In this study, we leveraged the latest GBD 2021 database to examine the global and regional epidemiological trends of female-specific cancers. These findings aim to provide a critical foundation for evaluating the global and regional cancer burdens and supporting policymakers in designing targeted public health interventions that address the specific needs of their populations.

Methods

Data acquisition

GBD 2021 is a comprehensive epidemiological study providing data on 371 diseases and injuries worldwide. Its extensive data sources include vital registration systems, epidemiological surveys, disease surveillance systems, cancer registries, police records, and open-source databases. Detailed methodologies for data collection and processing have been described in previous publications [8, 9]. Downstream data analysis is performed using advanced statistical models such as meta-regression-Bayesian, regularized, trimmed (MR-BRT), DisMod-MR 2.1, and spatiotemporal Gaussian process regression (ST-GPR). All disease terms were standardized using International Classification of Diseases (ICD) codes to ensure accuracy and comparability. The project adheres to the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER).

This study utilized data from the GBD 2021 database, including the number of incident cases, deaths, and disability-adjusted life years (DALYs) for breast, cervical, ovarian, and uterine cancers from 1990 to 2021, along with their corresponding age-standardized rates (ASRs). These metrics were extracted via the GBD visualization platform (https://vizhub.healthdata.org/gbd-results/). ICD codes for female-specific cancers are listed in Supplementary Table S1.

Moreover, to assess the level of development across regions, the socio-demographic index (SDI) was employed, with values ranging from 0 to 1. This parameter was calculated as the geometric mean of three key indicators: fertility rate, mean years of education, and per capita income. Based on the SDI values, countries and territories were categorized into five distinct groups: low, low-middle, middle, high-middle, and high SDI. These classifications were sourced from the Institute for Health Metrics and Evaluation, covering the period of 1990–2021.

Disease-attributable risk factors

The GBD 2021 database provides a comprehensive evaluation of the impact of risk factor exposure on specific health outcomes [10]. This analysis covers 88 risk factors categorized into four hierarchical levels. At Level 1, risk factors are grouped into environmental and occupational, behavioral, and metabolic categories. Level 2 further subdivides these into 20 specific factors, with additional granularity provided at Levels 3 and 4. For this study, Level 2 risk factors associated with female-specific cancers were summarized as follows: (1) Breast cancer: dietary risks, high alcohol use, high body-mass index (BMI), high fasting plasma glucose, low physical activity, and tobacco; (2) Cervical cancer: tobacco and unsafe sex; (3) Ovarian cancer: high BMI and occupational risks; (4) Uterine cancer: high BMI.

The GBD 2021 database employs advanced statistical models to estimate exposure levels, relative risks, population attributable fractions (PAFs), and disease burden in terms of DALYs and deaths. To address interdependence among risk factors, mediation effects are accounted for to prevent the overestimation of PAFs. This ensures accurate attribution of disease burdens to individual and combined risk factors.

Statistical analysis

Annual incident cases, deaths, and DALYs were analyzed to assess the burden of female-specific cancers. ASRs were used to account for differences in age distribution and population size, enabling meaningful comparisons over time and across regions. To evaluate temporal trends, the estimated annual percentage change (EAPC) of ASRs, including age-standardized incidence rate (ASIR), death rate (ASDR), and DALY rate (ASDALYR) per 100,000 female population, was calculated. The formula $Y = \alpha X + \beta$ was used, where *Y* represents the *Log10(ASR)* value, and *X* denotes the calendar year. EAPC values were derived from the formula $EAPC = 100 \times (10^{\alpha} -$ 1). Positive EAPC values with 95% confidence intervals (CIs) above zero indicated increasing trends, while negative values signified decreases [11, 12]. Statistical analyses were conducted using R software (version 4.4.0), with data visualization performed via the ggplot2 package. A two-tailed *P*-value < 0.05 was considered statistically significant.

Results

Breast cancer burden

Over the past three decades, breast cancer has consistently been the female-specific cancer with the highest global burden in terms of incidence, mortality, and DALYs (Fig. 1a). Between 1990 and 2021, global incident cases rose from 0.87 million to 2.08 million, with the ASIR increasing from 39.99 to 46.40 (EAPC = 0.40). The highest incidence and ASIR were observed in high SDI countries (Fig. 1b). East Asia reported the largest number of incident cases in 2021, totaling 401,076 (Table 1).

However, high-income North America had the highest ASIR at 94.93, nearly double the global average. Nationally, China recorded the highest number of new cases (385,838), followed by the United States (269,012) and India (156,160) (Fig. 2a), collectively accounting for nearly 40% of global incident cases.

Between 1990 and 2021, breast cancer-related deaths increased from 350,577 to 660,925, although the ASDR declined from 16.60 to 14.55 (EAPC = -0.55) (Table 2). Middle SDI countries recorded the highest number of deaths in 2021 (181,470), surpassing high SDI countries, while low SDI countries had the highest ASDR at 16.00. Significant geographical disparities were observed across the 21 global regions. South Asia reported the highest number of deaths (105,497), while southern sub-Saharan Africa had the highest ASDR at 24.93. Nationally, China (88,107), India (78,879), and the United States (52,869) (Fig. 2b) accounted for approximately 33% of global breast cancer deaths. Interestingly, Palau and the United Arab Emirates had the highest ASDRs globally, while Western European countries and the United States, despite high incidence rates, reported relatively lower ASDRs (Fig. S1a-1b).

DALY trends mirrored those of mortality. In 2021, global DALYs for breast cancer reached 20.25 million, with an ASDALYR of 455.56. Middle SDI countries recorded the highest DALYs (6.04 million), whereas low SDI regions had the highest ASDALYR (488.24). South Asia contributed 3.71 million DALYs, while southern sub-Saharan Africa had the highest ASDALYR at 728.94 (Table 3). Nationally, China, India, and the United States had the highest DALYs (Fig. 2c). Notably, American Samoa recorded the highest ASDALYR worldwide in 2021 (Fig. S1c).

Cervical cancer

Among the four female-specific cancers, cervical cancer ranks second in global cancer burden after breast cancer. The total incidence of cervical cancer remains substantial and continues to grow slowly, reaching 0.67 million cases in 2021. However, when accounting for population size and structure, its ASIR has shown a declining trend, decreasing from 18.11 in 1990 to 15.32 in 2021 (EAPC = -0.54) (Table 4). Stratified by SDI region, middle SDI areas recorded the highest incidence, while low SDI regions had the highest ASIR. Geographically, East Asia reported the largest number of incident cases in 2021, totaling 137,864, while southern sub-Saharan Africa had the highest ASIR at 42.40, nearly three times the global average. At the national level, China, India, and the United States accounted for the highest number of cervical cancer cases globally in 2021, reporting 132,788, 112,103, and 27,262 cases, respectively (Fig. 3a).



Fig. 1 Global and regional trends in female cancer incidences, deaths, and disability-adjusted life years (DALYs). **a**. The absolute numbers for incidences, deaths, and DALYs across different socio-demographic index (SDI) regions and globally were displayed. **b**. displays the age-standardized incidence rates (ASIRs), age-standardized death rates (ASDRs), and age-standardized DALY rates (ASDALYR), showcasing the varying trends by SDI regions

Page 5 of 25

Table 1	The incidence	of breast cancer ir	n 1990 and 2021
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Region	1990 incident cases (×1000, 95% Cl)	1990 ASIR (95% CI)	2021 incident cases (×1000, 95% Cl)	2021 ASIR (95% CI)	1990–2021 EAPC (95% Cl)
Global	865.88	39.99 (38.01~41.60)	2082.74	46.40 (43.26~49.56)	0.399 (0.348~0.451)
	(824.34~900.79)		(1940.35~2225.08)		
SDI					
High SDI	456.07 (434.96~466.93)	79.28 (76.17~80.97)	724.29 (661.77~756.43)	77.08 (71.83~79.93)	-0.12 (-0.247~0.008)
High-middle SDI	212.69 (201.93~222.71)	38.85 (36.86~40.71)	506.49 (457.36~565.10)	51.05 (46.06~57.18)	0.816 (0.747~0.884)
Middle SDI	123.71 (113.64~136.09)	20.55 (18.91~22.56)	539.06 (484.45 ~ 597.13)	37.16 (33.42~41.13)	1.822 (1.768~1.876)
Low-middle SDI	52.22 (46.89~59.10)	14.72 (13.21~16.62)	235.45 (212.86~257.15)	28.29 (25.52~30.93)	2.126 (2.078~2.174)
Low SDI	20.12 (17.07~23.65)	15.59 (13.28~18.15)	75.29 (66.49~84.81)	24.09 (21.34~26.87)	1.367 (1.219~1.516)
Geographic region					
Andean Latin America	2.34 (2.01 ~ 2.72)	19.81 (16.98~22.94)	10.81 (8.46~13.76)	33.61 (26.29~42.87)	1.512 (1.354~1.671)
Australasia	9.82 (9.29~10.35)	82.12 (78.10~86.35)	19.63 (17.43~21.87)	80.89 (72.46~90.05)	-0.082 (-0.27~0.107)
Caribbean	6.03 (5.64~6.45)	43.47 (40.67~46.46)	15.00 (12.74~17.18)	53.78 (45.62~61.72)	0.773 (0.683~0.864)
Central Asia	9.82 (9.24~10.31)	35.39 (33.31 ~ 37.23)	15.36 (13.71 ~ 17.20)	30.97 (27.75~34.61)	-0.19 (-0.263~-0.116)
Central Europe	36.08 (34.60~37.57)	45.40 (43.55~47.26)	64.59 (59.37~69.90)	61.24 (56.41~66.53)	0.905 (0.752~1.058)
Central Latin America	14.97 (14.51~15.40)	29.84 (28.87~30.67)	76.89 (66.94~86.94)	55.03 (47.96~62.21)	1.778 (1.669~1.887)
Central Sub-Saharan Africa	2.43 (1.71 ~ 3.32)	17.46 (12.63~23.16)	9.87 (7.33~12.94)	27.13 (20.26~35.41)	1.487 (1.255~1.72)
East Asia	88.62 (72.20~107.16)	17.92 (14.67~21.59)	401.08 (311.44~503.57)	37.12 (28.82~46.70)	2.349 (2.267~2.432)
Eastern Europe	64.43 (62.41~66.33)	40.65 (39.36~41.83)	100.23 (90.10~111.44)	52.53 (47.15~58.60)	0.489 (0.36~0.618)
Eastern Sub-Saharan Africa	8.47 (6.94 ~ 10.26)	19.35 (16.07~23.18)	32.05 (26.93~38.66)	29.33 (25.14~34.59)	1.269 (1.128~1.41)
High-income Asia Pacific	31.23 (29.58~32.78)	28.83 (27.31~30.19)	96.69 (84.85 ~ 104.79)	55.62 (50.49~59.45)	2.222 (1.976~2.468)
High-income North America	219.84	121.98	294.45 (271.12~308.29)	94.93 (89.02~98.93)	-0.971
	(208.81~226.43)	(116.68~125.23)			(-1.072~-0.87)
North Africa and Middle East	16.28 (14.53~18.62)	16.37 (14.69~18.53)	126.98 (113.31~143.15)	48.35 (43.13~54.48)	4.041 (3.802~4.281)
Oceania	0.54 (0.43~0.68)	29.90 (23.80~37.16)	1.57 (1.28~1.96)	33.39 (27.74~40.88)	0.22 (0.093~0.348)
South Asia	43.74 (38.84~49.29)	13.11 (11.57~14.78)	205.36 (179.41 ~ 235.44)	24.62 (21.52~28.32)	1.971 (1.806~2.137)
Southeast Asia	32.37 (27.34~38.92)	20.30 (17.19~24.16)	138.06 (115.12~167.27)	36.15 (30.20~43.68)	1.84 (1.768~1.912)
Southern Latin America	12.04 (11.36~12.66)	47.93 (45.22~50.36)	22.70 (20.87~24.51)	50.25 (46.22~54.26)	0.186 (0.036~0.336)
Southern Sub-Saharan Africa	4.22 (3.53~4.91)	25.13 (20.85~29.48)	15.04 (13.50~16.66)	42.12 (37.89~46.56)	2.21 (1.978~2.443)
Tropical Latin America	16.18 (15.57~16.79)	29.98 (28.74~31.15)	61.67 (57.71~65.33)	43.87 (41.05~46.50)	0.948 (0.842~1.054)
Western Europe	236.44 (225.09~243.38)	83.23 (79.75~85.41)	331.71 (299.15~352.01)	81.81 (76.45~86.11)	-0.02 (-0.215~0.175)
Western Sub-Saharan Africa	9.99 (8.13 ~ 11.90)	21.28 (17.42~25.23)	43.02 (32.32~56.63)	34.59 (26.92~44.38)	1.643 (1.519~1.767)

Annotations ASIR: Age-standardized incidence rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

Conversely, the highest ASIRs were observed in Kiribati and Lesotho (Fig. S2a).

The number of deaths from cervical cancer increased from 211,484 in 1990 to 296,667 in 2021, while the ASDR declined from 9.68 to 6.62 (EAPC = -1.27) (Table 5). Middle SDI regions reported the highest number of deaths, whereas low SDI regions consistently exhibited the highest ASDR over the past three decades. Geographically, South Asia recorded the largest number of cervical cancer deaths in 2021, while central sub-Saharan Africa reported the highest ASDR worldwide. At the national level, China, India, and Brazil had the highest cervical cancer mortality in 2021, with 49,841, 60,041, and 11,248 deaths, respectively (Fig. 3b). Conversely, Kiribati and Lesotho reported the highest ASDRs globally (Fig. S2b).

The trends in cervical cancer DALYs closely mirrored those of cervical cancer mortality. Globally, cervical cancer DALYs increased from 7.42 million in 1990 to 9.91 million in 2021, while the ASDALYR declined from 330.11 to 226.28 (EAPC = -1.27) (Table 6). Low SDI regions consistently exhibited the highest ASDALYR. Geographically, South Asia recorded the highest total DALYs in 2021, while southern sub-Saharan Africa, including countries like Lesotho, reported the highest ASDALYR (Fig. S2c). Notably, southern sub-Saharan Africa remains the only region where cervical cancer ASIR, ASDR, and ASDALYR are still rapidly increasing. At the national level, China, India, and Brazil had the highest cervical cancer DALYs in 2021, with 1.55 million, 2.06 million, and 0.38 million DALYs, respectively





Fig. 2 Global distribution of breast cancer incidences, deaths, and disability-adjusted life years (DALYs) in 2021. a. The incidences of breast cancer. b. The breast cancer mortality. c. The breast cancer DALYs

Table 2 The death of breast cancer in 1990 and 2021

Region	1990 Death cases (×1000, 95% Cl)	1990 ASDR (95% Cl)	2021 Death cases (×1000, 95% Cl)	2021 ASDR (95% CI)	1990–2021 EAPC (95% Cl)
Global	350.58 (330.51 ~ 368.43)	16.60 (15.60~17.45)	660.93 (609.17~707.18)	14.55 (13.45~15.56)	-0.55 (-0.604~-0.495)
SDI					
High SDI	143.89 (135.64~148.57)	23.63 (22.46~24.31)	171.46 (151.34~182.07)	15.44 (14.01 ~ 16.21)	-1.459 (-1.502~-1.416)
High-middle SDI	93.26 (88.19~97.89)	17.10 (16.11~17.96)	145.94 (132.53~158.86)	13.87 (12.63~15.13)	-0.863 (-0.97~-0.756)
Middle SDI	64.52 (59.30~71.14)	11.44 (10.53~12.51)	181.47 (163.85~201.76)	12.68 (11.44~14.10)	0.18 (0.12~0.24)
Low-middle SDI	33.67 (29.97~38.29)	10.09 (8.94~11.41)	115.82 (103.99~127.35)	14.59 (13.07~16.04)	1.2 (1.15 ~ 1.249)
Low SDI	14.74 (12.51~17.32)	12.22 (10.48~14.13)	45.42 (40.17~50.79)	16.00 (14.15~17.91)	0.846 (0.721~0.971)
Geographic region					
Andean Latin America	1.37 (1.17 ~ 1.59)	12.18 (10.37~14.16)	4.07 (3.22~5.15)	12.91 (10.20~16.33)	-0.038 (-0.167~0.091)
Australasia	3.26 (3.06~3.45)	26.39 (24.87~27.88)	4.32 (3.70~4.88)	15.53 (13.68~17.26)	-1.786 (-1.849~-1.723)
Caribbean	2.61 (2.40~2.85)	19.39 (17.88~21.12)	5.59 (4.72~6.57)	19.62 (16.51~23.09)	0.154 (0.085~0.223)
Central Asia	5.16 (4.86~5.43)	18.65 (17.57~19.61)	6.61 (5.91~7.37)	13.83 (12.41~15.37)	-0.715 (-0.811~-0.62)
Central Europe	17.49 (16.76~18.24)	21.46 (20.56~22.40)	24.87 (22.63~26.98)	20.26 (18.54~21.98)	-0.355 (-0.453~-0.256)
Central Latin America	5.61 (5.44~5.75)	12.18 (11.75~12.52)	19.33 (16.88~21.78)	14.06 (12.28~15.82)	0.354 (0.238~0.47)
Central Sub-Saharan Africa	1.82 (1.29~2.47)	14.02 (10.28~18.25)	6.20 (4.59~8.21)	18.73 (14.12~24.76)	1.002 (0.824~1.18)
East Asia	42.12 (34.52~51.05)	9.00 (7.42~10.82)	92.96 (73.23~115.38)	8.38 (6.59~10.40)	-0.541 (-0.672~-0.411)
Eastern Europe	29.62 (28.66~30.48)	17.89 (17.33~18.40)	35.83 (31.99~40.50)	17.37 (15.49~19.72)	-0.551 (-0.789~-0.312)
Eastern Sub-Saharan Africa	6.31 (5.17~7.68)	15.61 (12.95~18.71)	19.59 (16.71 ~ 23.39)	20.18 (17.52~23.63)	0.781 (0.669~0.893)
High-income Asia Pacific	7.77 (7.41~8.01)	7.09(6.76~7.31)	20.09 (16.72~22.02)	9.26 (8.26~9.86)	0.867 (0.722~1.012)
High-income North America	53.61 (50.17~55.61)	28.07 (26.51~28.97)	58.94 (52.68~62.51)	17.02 (15.54~17.93)	-1.742 (-1.803~-1.68)
North Africa and Middle East	6.77 (6.06~7.73)	7.35 (6.61 ~ 8.30)	29.52 (26.06~33.51)	12.20 (10.79~13.79)	2.113 (1.888~2.337)
Oceania	0.32 (0.25~0.40)	19.69 (15.69~24.68)	0.95 (0.78~1.18)	22.22 (18.44~26.97)	0.414 (0.336~0.491)
South Asia	29.53 (26.08~33.36)	9.41 (8.21 ~ 10.65)	105.50 (92.01 ~ 121.29)	13.24 (11.54~15.28)	1.019 (0.89~1.148)
Southeast Asia	20.12 (16.81~24.44)	13.41 (11.24~16.12)	65.44 (54.27~79.83)	17.72 (14.76~21.52)	0.855 (0.777~0.933)
Southern Latin America	7.09 (6.68 ~ 7.43)	28.14 (26.48~29.46)	9.96 (8.96~10.83)	20.59 (18.69~22.27)	-0.943 (-1.065~-0.821)
Southern Sub-Saharan Africa	2.69 (2.23 ~ 3.17)	17.06 (13.98~20.16)	8.41 (7.61~9.30)	24.93 (22.64~27.46)	1.673 (1.439~1.907)
Tropical Latin America	8.45 (8.10~8.76)	16.64 (15.83~17.33)	23.99 (22.18~25.49)	16.96 (15.70~18.02)	-0.127 (-0.193~-0.062)
Western Europe	91.46 (85.68~94.79)	29.11 (27.58~29.98)	92.83 (79.70~100.09)	18.01 (16.15~19.11)	-1.615 (-1.664~-1.565)
Western Sub-Saharan Africa	7.40 (6.08~8.74)	16.63 (13.72~19.51)	25.93 (20.17~33.02)	23.07 (18.69~28.77)	1.126 (1.03~1.222)

Annotations ASDR: Age-standardized death rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

(Fig. 3c). Kiribati and Lesotho continued to sustain the highest ASDALYRs worldwide in 2021 (Fig. S2c).

Ovarian cancer

From 1990 to 2021, the global incidence of ovarian cancer increased from 159,096 to 298,876 cases, while the ASIR declined from 7.22 to 6.71 (EAPC = -0.38) (Table 7). Middle SDI regions experienced rapid growth in ovarian cancer incident cases, surpassing high SDI regions in 2021 to rank first in total incident cases. However, high SDI regions continued to report the highest ASIR for ovarian cancer. Regionally, South Asia recorded the largest number of cases (49,664) in 2021, while Central Europe reported the highest ASIR at 10.80. Nationally, China accounted for the highest number of new ovarian cancer cases in 2021 (41,236), followed by India (36,777) and the United States (25,213) (Fig. 4a). Collectively, these three countries represented approximately 35% of global new cases. The highest ASIRs were observed in the United Arab Emirates and Seychelles (Fig. S3a).

In the past 32 years, ovarian cancer-related deaths increased from 100,584 to 185,609, while the ASDR declined from 4.73 to 4.06 (EAPC = -0.62) (Table 8). Mortality increased across all SDI regions, with high SDI regions reporting both the highest number of deaths and the highest ASDR in 2021. Among the 21 global regions, South Asia recorded the largest number of ovarian cancer deaths (30,585), while Central Europe had the highest ASDR at 7.40. Nationally, China led in ovarian cancer deaths (25,144), followed by India (23,219) and the United States (17,229) (Fig. 4b). The United Arab Emirates exhibited the highest ASDR globally (Fig. S3b).

Ovarian cancer DALYs followed a similar trend, increasing steadily from 1990 to 2021, while the ASDALYR declined (EAPC = -0.59) (Table 9). In 2021, global DALYs reached 5.16 million, with an ASDALYR

Table 3 The DALY of breast cancer in 1990 and 2021

Region	1990 DALY (×1000, 95% CI)	1990 ASDALYR (95% CI)	2021 DALY (×1000, 95% CI)	2021 ASDALYR (95% Cl)	1990–2021 EAPC (95% CI)
Global	11036.40 (10434.96~11671.32)	503.81 (475.91 ~ 532.23)	20254.80 (18963.38~21574.43)	455.56 (426.64 ~ 485.30)	-0.459 (-0.518~-0.4)
SDI					
High SDI	4035.88 (3869.69~4187.23)	718.69 (692.65 ~ 744.01)	4323.11 (3982.60~4606.05)	467.07 (437.15~493.59)	-1.472 (-1.51~-1.433)
High-middle SDI	2926.00 (2755.03 ~ 3087.07)	535.73 (504.24~565.74)	4190.12 (3830.41~4646.70)	424.81 (387.63~471.97)	-0.955 (-1.047~-0.863)
Middle SDI	2302.01 (2103.23~2548.04)	371.04 (339.73~409.18)	6040.96 (5448.28~6714.09)	415.76 (375.54~461.93)	0.279 (0.15 ~0.279)
Low-middle SDI	1233.45 (1099.56 ~ 1403.56)	331.98 (296.62~377.97)	4061.11 (3659.39~4465.15)	478.06 (430.12~525.81)	1.173 (1.121 ~ 1.225)
Low SDI	523.81 (441.49~620.57)	380.05 (322.42~447.89)	1616.94 (1414.47~1832.52)	488.24 (431.45 ~ 547.92)	0.755 (0.634~0.877)
Geographic region					
Andean Latin America	46.51 (39.41 ~ 54.21)	379.97 (323.46~444.09)	128.30 (101.49~161.61)	396.61 (313.90~498.23)	-0.09 (-0.218~-0.09)
Australasia	94.52 (89.35 ~ 99.61)	808.55 (765.86~850.99)	112.26 (100.17~125.18)	467.24 (421.83~517.78)	-1.857 (-1.91~-1.804)
Caribbean	82.57 (75.14~91.47)	587.75 (535.83~650.32)	164.24 (137.00~194.97)	595.42 (495.22 ~ 709.33)	0.138 (0.08~0.196)
Central Asia	172.58 (163.12~181.55)	618.67 (584.14~651.16)	218.12 (193.87~245.24)	435.31 (387.95~487.61)	-0.995 (-1.089~-0.901)
Central Europe	516.68 (494.99~540.07)	654.18 (626.93~682.96)	601.49 (554.53~650.98)	568.54 (521.85~618.20)	-0.598 (-0.697~-0.499)
Central Latin America	194.72 (189.32~200.53)	377.85 (367.03~389.50)	631.82 (546.30~712.82)	451.67 (390.99~509.57)	0.436 (0.326~0.546)
Central Sub-Saha- ran Africa	64.41 (45.51 ~ 88.03)	429.94 (309.02~578.03)	220.89 (162.60~290.79)	570.70 (422.23 ~ 755.79)	0.981 (0.799~1.162)
East Asia	1530.66 (1238.54~1864.75)	302.75 (246.16~367.91)	3077.42 (2410.86 ~ 3867.30)	286.25 (223.86~360.41)	-0.458 (-0.572~-0.343)
Eastern Europe	932.67 (901.49~962.96)	599.00 (580.01~618.67)	982.06 (875.90~1114.90)	528.83 (468.97~603.45)	-0.901 (-1.134~-0.667)
Eastern Sub-Saha- ran Africa	224.37 (181.24~276.57)	471.25 (385.61 ~ 575.62)	696.92 (580.91 ~ 850.82)	592.34 (503.90 ~ 706.84)	0.645 (0.528 ~0.762)
High-income Asia Pacific	282.74 (270.99~295.99)	262.83 (251.76~275.13)	539.25 (480.46~585.17)	320.10 (294.49 ~ 344.12)	0.616 (0.449 ~0.783)
High-income North America	1547.48 (1473.48~1618.77)	885.64 (846.87 ~ 923.17)	1556.04 (1449.56 ~ 1659.97)	515.66 (484.07~546.49)	-1.86 (-1.923~-1.797)
North Africa and Middle East	251.97 (222.75~291.04)	247.17 (220.16~284.18)	1066.15 (928.28~1226.83)	396.09 (347.10~453.96)	1.923 (1.723 ~ 2.124)
Oceania	12.27 (9.44~15.49)	639.30 (503.35 ~ 808.25)	36.05 (29.02~45.91)	722.36 (592.29~892.63)	0.406 (0.325~0.487)
South Asia	1106.16 (979.67~1249.65)	314.91 (278.56~355.58)	3710.90 (3235.64~4263.86)	436.69 (380.59~501.46)	0.964 (0.833~1.096)
Southeast Asia	733.10 (608.73~890.82)	445.55 (370.50~540.44)	2231.17 (1841.70~2734.84)	577.98 (476.91 ~ 706.99)	0.79 (0.713~0.867)
Southern Latin America	203.06 (192.93~212.46)	813.73 (772.98~851.79)	260.52 (239.74~280.14)	584.98 (538.52~628.69)	-1.012 (-1.103~-0.922)
Southern Sub- Saharan Africa	89.79 (75.79~104.17)	515.08 (429.93~600.45)	267.24 (238.40~298.69)	728.94 (653.43~810.05)	1.704 (1.419~1.989)
Tropical Latin America	282.85 (272.84~292.58)	508.71 (489.88~527.42)	747.27 (700.61~785.92)	532.52 (499.38 ~ 559.90)	-0.087 (-0.157~-0.017)
Western Europe	2424.71 (2323.87~2512.02)	874.68 (842.50~905.23)	2124.40 (1917.42~2287.18)	519.33 (479.72~554.46)	-1.742 (-1.796~-1.689)
Western Sub- Saharan Africa	242.56 (197.20~291.10)	492.61 (402.68~586.39)	882.28 (663.00~1145.79)	668.25 (516.54~854.90)	1.045 (0.938~1.151)

Annotations DALY: disability-adjusted life-year; ASDALYR: age-standardized disability-adjusted life-year rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

Region	1990 incident cases (×1000, 95%	1990 ASIR (95% CI)	2021 incident cases (×1000, 95% Cl)	2021 ASIR (95% CI)	1990–2021 EAPC (95% CI)
Clabel	CI)	10.11/16.04 10.40	((7,42)((12,02,-72(,42))	15.22 (14.00 16.60)	0.526 (0.626 - 0.426)
GIODAI	409.55 (383.21~438.51)	18.11 (16.94 ~ 19.40)	667.43 (613.03 ~ 726.42)	15.32 (14.08~16.68)	-0.536 (-0.636~-0.436)
SDI					
High SDI	87.38 (84.82~89.25)	16.43 (16.04~16.77)	78.01 (73.68~81.04)	10.30 (9.91 ~ 10.66)	-1.411 (-1.571~-1.25)
High-middle SDI	73.63 (68.69~78.72)	13.37 (12.47~14.29)	120.15 (103.65~137.73)	13.27 (11.44~15.16)	0.206 (0.113~0.3)
Middle SDI	114.37 (105.12~123.88)	18.09 (16.67~19.56)	228.24 (204.62~254.21)	15.94 (14.30~17.75)	-0.469 (-0.544~-0.395)
Low-middle SDI	84.75 (73.56~97.34)	22.48 (19.49~25.79)	152.72 (136.72~169.31)	17.79 (15.94~19.70)	-0.784 (-0.932~-0.635)
Low SDI	48.87 (41.63~59.34)	34.34 (29.27~41.62)	87.63 (73.98~103.87)	25.47 (21.57~30.12)	-1.169 (-1.29~-1.048)
Geographic region					
Andean Latin America	4.15 (3.64~4.66)	33.19 (29.05 ~ 37.34)	9.76 (7.48~12.36)	29.79 (22.83~37.66)	-0.646 (-0.819~-0.472)
Australasia	2.00 (1.86~2.18)	17.18 (15.98~18.67)	1.75 (1.58~1.92)	8.51 (7.66~9.35)	-1.923 (-2.188~-1.657)
Caribbean	4.64 (4.19~5.20)	31.51 (28.52~35.21)	7.38 (6.19~8.71)	27.58 (23.09~32.63)	-0.449 (-0.527~-0.371)
Central Asia	5.17 (4.95~5.42)	18.21 (17.43~19.11)	7.18 (6.27~8.08)	14.17 (12.38~15.92)	-0.445 (-0.614~-0.276)
Central Europe	16.32 (15.59~17.02)	21.66 (20.68~22.61)	14.20 (12.93~15.55)	15.93 (14.45~17.53)	-1.1 (-1.321~-0.879)
Central Latin America	22.43 (21.86~23.00)	41.85 (40.60~42.84)	40.34 (34.55~46.25)	28.89 (24.76~33.10)	-1.581 (-1.766~-1.396)
Central Sub-Saharan Africa	6.10 (4.56~7.96)	39.39 (29.59~51.35)	15.33 (10.59~20.55)	38.00 (26.28~50.98)	-0.167 (-0.197~-0.137)
East Asia	61.91 (50.41 ~ 76.00)	12.16 (9.94 ~ 14.88)	137.86 (101.14~177.75)	13.40 (9.86~17.38)	0.727 (0.557~0.898)
Eastern Europe	23.50 (22.66~24.26)	14.94 (14.42~15.45)	25.34 (22.88~27.76)	16.49 (14.80~18.10)	0.309 (0.187~0.431)
Eastern Sub-Saharan Africa	22.64 (18.82~27.48)	45.69 (37.95~55.48)	41.37 (33.12~52.88)	33.45 (27.17~42.12)	-1.343 (-1.47~-1.217)
High-income Asia Pacific	12.72 (12.01 ~ 13.52)	11.85 (11.18~12.58)	15.58 (14.04~16.88)	11.03 (10.25~11.95)	0.021 (-0.091~0.134)
High-income North America	32.70 (31.77~33.48)	19.65 (19.11~20.10)	30.42 (29.10~31.62)	12.69 (12.19~13.22)	-1.339 (-1.558~-1.12)
North Africa and Middle East	6.24 (5.46~7.54)	5.98 (5.25 ~ 7.24)	12.91 (11.01 ~ 15.18)	4.72 (4.04~5.50)	-0.732 (-0.779~-0.685)
Oceania	0.67 (0.51~0.93)	34.17 (26.78~47.56)	1.37 (1.07~2.02)	27.31 (21.47~39.68)	-0.802 (-0.867~-0.738)
South Asia	83.51 (69.58~96.97)	23.70 (19.53~27.50)	132.48 (114.54~151.29)	15.54 (13.47~17.71)	-1.476 (-1.808~-1.142)
Southeast Asia	30.36 (26.33 ~ 34.80)	18.06 (15.61~20.64)	58.02 (49.19~67.75)	15.17 (12.91~17.65)	-0.777 (-0.888~-0.665)
Southern Latin America	6.03 (5.64~6.41)	24.43 (22.84~25.99)	9.30 (8.57 ~ 10.07)	22.80 (21.07~24.73)	-0.218 (-0.385~-0.052)
Southern Sub-Saharan Africa	5.53 (4.62~6.83)	29.89 (25.13~37.34)	16.25 (14.19~18.42)	42.40 (37.16~47.85)	1.895 (1.387~2.405)
Tropical Latin America	13.35 (12.84~13.86)	23.08 (22.14~23.96)	27.82 (26.28~29.20)	20.27 (19.16~21.27)	-0.846 (-1.021~-0.672)
Western Europe	35.62 (34.39~36.71)	14.25 (13.83~14.66)	27.92 (26.00~29.39)	8.71 (8.25~9.11)	-1.271 (-1.488~-1.053)
Western Sub-Saharan Africa	13.97 (11.42~17.09)	26.20 (21.40~31.65)	34.84 (26.67~42.61)	24.11 (18.93~29.10)	-0.243 (-0.284~-0.202)

Table 4 The incidence of cervical cancer in 1990 and 2021

Annotations ASIR: Age-standardized incidence rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

of 115.15. Population in middle SDI regions sustained the most DALYs in 2021 at 1.42 million, whereas high SDI regions maintained the highest ASDALYR despite a declining trend (EAPC = -1.48). Regionally, South Asia reported the highest number of DALYs (960,208), while Central Europe recorded the highest ASDALYR. Nationally, China had the highest ovarian cancer DALYs in 2021 (750,549), followed by India and the United States (Fig. 4c). The United Arab Emirates continued to report the highest ASDALYR globally (Fig. S3c).

Uterine cancer

Uterine cancer is the fastest-growing female-specific cancer, with the number of cases rising from 191,291 in 1990 to 473,614 in 2021. Correspondingly, the ASIR increased from 8.87 to 10.36 during this period (EAPC = 0.54) (Table 10). High SDI regions reported both the highest number of cases and the highest ASIR, with rates

continuing to rise significantly (EAPC = 1.36). Geographically, high-income North America recorded the largest number of cases in 2021, totaling 103,521, and the highest ASIR at 31.78. Nationally, the United States reported the highest number of new cases in 2021 (96,331), followed by China (72,019) and Russia (46,639) (Fig. 5a). Collectively, these three countries accounted for approximately 45% of global new cases. The highest ASIRs were observed in the United Arab Emirates and Russia (Fig. S4a).

Between 1990 and 2021, global deaths from uterine cancer increased from 54,849 to 97,672, while the ASDR declined from 2.60 to 2.11 (EAPC = -0.78) (Table 11). Mortality increased across all SDI regions, with high SDI regions reporting both the highest number of deaths (31,632) and the highest ASDR. In 2021, the East Asia region recorded the largest number of deaths globally, totaling 14,233, while the Caribbean had the





Region	1990 Death cases (×1000, 95% Cl)	1990 ASDR (95% CI)	2021 Death cases (×1000, 95% Cl)	2021 ASDR (95% CI)	1990–2021 EAPC (95% Cl)
Global	211.48 (195.72~229.84)	9.68 (8.97~10.51)	296.67 (272.06~321.91)	6.62 (6.07~7.18)	-1.269 (-1.357~-1.18)
SDI					
High SDI	29.78 (28.34~30.63)	5.03 (4.82~5.16)	25.89 (23.32~27.33)	2.62 (2.44~2.74)	-2.048 (-2.162~-1.935)
High-middle SDI	37.77 (35.12~40.43)	6.83 (6.35~7.31)	46.30 (40.58~52.54)	4.59 (4.02~5.20)	-1.201 (-1.253~-1.148)
Middle SDI	60.36 (55.53~65.57)	10.47 (9.64~11.37)	96.29 (86.73~106.49)	6.72 (6.05~7.43)	-1.505 (-1.57~-1.44)
Low-middle SDI	51.19 (44.12~59.06)	14.70 (12.60~16.94)	78.18 (69.94~86.26)	9.71 (8.67~10.70)	-1.35 (-1.487~-1.213)
Low SDI	32.11 (27.38~39.06)	24.51 (20.89~29.82)	49.69 (42.21 ~ 59.25)	16.36 (13.94~19.38)	-1.486 (-1.593~-1.379)
Geographic region					
Andean Latin America	2.39 (2.10~2.69)	20.85 (18.31~23.48)	4.44 (3.43~5.55)	14.02 (10.85~17.51)	-1.572 (-1.726~-1.419)
Australasia	0.65 (0.61~0.71)	5.34 (4.98~5.83)	0.47 (0.41~0.51)	1.85 (1.66~2.02)	-3.207 (-3.443~-2.97)
Caribbean	2.30 (2.03 ~ 2.62)	16.36 (14.47~18.57)	3.40 (2.86~4.03)	12.31 (10.33~14.68)	-0.877 (-0.958~-0.796)
Central Asia	2.65 (2.53~2.78)	9.53 (9.08~10.02)	3.09 (2.73~3.50)	6.33 (5.62~7.13)	-1.059 (-1.212~-0.907)
Central Europe	8.15 (7.80~8.46)	10.15 (9.73~10.54)	6.59 (6.05~7.12)	6.02 (5.53~6.53)	-1.851 (-2.011~-1.692)
Central Latin America	9.52 (9.23~9.74)	20.38 (19.63~20.92)	13.11 (11.29~14.97)	9.52 (8.21~10.86)	-2.783 (-2.932~-2.635)
Central Sub-Saharan Africa	4.06 (3.05~5.27)	28.67 (21.87~37.26)	8.91 (6.17~12.10)	25.10 (17.45~33.97)	-0.467 (-0.522~-0.412)
East Asia	33.63 (27.76~41.12)	7.10 (5.86~8.64)	52.03 (39.40~66.51)	4.68 (3.55~5.98)	-1.119 (-1.264~-0.975)
Eastern Europe	12.90 (12.42~13.34)	7.58 (7.30~7.84)	9.93 (8.99~10.95)	5.50 (4.96~6.07)	-1.218 (-1.31~-1.125)
Eastern Sub-Saharan Africa	14.86 (12.35~18.15)	32.97 (27.43~40.13)	23.27 (18.79~29.15)	21.68 (17.79~26.85)	-1.668 (-1.786~-1.55)
High-income Asia Pacific	4.74 (4.40~5.06)	4.27 (3.96~4.57)	5.07 (4.30~5.60)	2.53 (2.28~2.73)	-1.675 (-1.778~-1.571)
High-income North America	6.83 (6.49~7.05)	3.75 (3.59~3.85)	7.96 (7.39~8.35)	2.64 (2.50~2.75)	-1.003 (-1.113~-0.893)
North Africa and Middle East	3.72 (3.24~4.51)	3.96 (3.43~4.86)	6.27 (5.33~7.27)	2.55 (2.17~2.93)	-1.391 (-1.437~-1.344)
Oceania	0.33 (0.26~0.48)	19.77 (15.75~27.86)	0.66 (0.52~0.98)	15.27 (12.10~22.32)	-0.824 (-0.876~-0.772)
South Asia	52.12 (42.81~60.83)	15.97 (13.02~18.72)	70.31 (61.03~79.86)	8.72 (7.57~9.88)	-2.058 (-2.367~-1.749)
Southeast Asia	16.46 (14.23~18.81)	10.70 (9.27~12.18)	27.51 (23.67~31.86)	7.45 (6.43~8.59)	-1.323 (-1.43~-1.215)
Southern Latin America	3.02 (2.84 ~ 3.20)	12.10 (11.39~12.83)	3.83 (3.52~4.17)	8.56 (7.89~9.28)	-1.1 (-1.238~-0.962)
Southern Sub-Saharan Africa	2.94 (2.47 ~ 3.72)	17.43 (14.74~22.24)	8.52 (7.48~9.54)	23.90 (21.02~26.67)	1.705 (1.22~2.194)
Tropical Latin America	6.93 (6.63~7.21)	13.25 (12.61~13.80)	11.76 (10.95~12.43)	8.38 (7.82~8.86)	-1.784 (-1.903~-1.666)
Western Europe	14.37 (13.56~14.90)	4.70 (4.48~4.86)	10.36 (9.19~11.14)	2.29 (2.11~2.43)	-2.019 (-2.239~-1.798)
Western Sub-Saharan Africa	8.89 (7.36 ~ 10.72)	18.33 (15.26~21.84)	19.16 (15.04~23.01)	15.57 (12.55~18.53)	-0.475 (-0.539~-0.411)

Annotations ASDR: Age-standardized death rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

highest ASDR at 5.38. Nationally, China recorded the highest number of deaths in 2021 (13,599), followed by the United States (11,886) and Russia (7,356) (Fig. 5b). The United Arab Emirates consistently exhibited the highest ASDR globally (Fig. S4b).

Over the past 32 years, the DALYs for uterine cancer increased from 1.50 million in 1990 to 2.56 million in 2021 (Table 12). Correspondingly, the ASDALYR declined from 69.17 to 56.15 (EAPC = -0.78). High SDI regions reported both the highest DALYs and ASDALYR. In 2021, East Asia recorded the highest DALYs among all regions, totaling 425,142, while the Caribbean had the highest ASDALYR. Nationally, China reported the highest DALYs in 2021 (405,490), followed by the United States and Russia (Fig. 5c). Similarly, the United Arab Emirates recorded the highest ASDALYR globally (Fig. S4c).

Correlation between ASRs of female-specific cancers and socio-demographics

To explore the role of socio-economic development (measured by SDI) on the incidence and mortality trends of female-specific cancers, we generated scatter plots to illustrate the dynamic changes in SDI and agestandardized rates (ASIR, ASDR, and ASDALYR) across 21 global regions over the past 32 years. Across most regions, a positive correlation was observed between SDI and the ASIRs of breast and uterine cancers, both of which showed a gradual increase as SDI rose. However, the relationship between SDI and ovarian cancer was more complex: while higher SDI was generally associated with higher ASIR, in regions where SDI exceeded 0.7, such as high-income regions like North America, Western Europe, and Australia, additional increases in SDI were associated with a decline in ASIR. In contrast, the incidence of cervical cancer consistently decreased as SDI increased across different regions (Fig. 6). Additionally, a significant negative correlation was observed

Table 6 The DALY of cervical cancer in 1990 and 2021

Region	1990 DALY (×1000, 95% CI)	1990 ASDALYR (95% CI)	2021 DALY (×1000, 95% Cl)	2021 ASDALYR (95% CI)	1990–2021 EAPC (95% Cl)
Global	7416.29 (6841.38~8071.40)	330.11 (304.67~359.10)	9911.65 (9053.32~10798.31)	226.28 (206.51 ~ 246.86)	-1.269 (-1.365~-1.173)
SDI					
High SDI	888.17 (860.27~911.52)	163.46 (158.83~167.80)	707.65 (664.62~741.91)	86.41 (82.45~90.30)	-1.989 (-2.102~-1.877)
High-middle SDI	1221.30 (1133.35~1316.83)	222.34 (206.21 ~ 239.84)	1432.11 (1252.62~1634.55)	152.90 (133.88~174.32)	-1.119 (-1.172~-1.066)
Middle SDI	2165.69 (1982.38~2359.90)	342.74 (314.41 ~ 372.39)	3167.32 (2856.72~3510.38)	218.95 (197.60~242.31)	-1.521 (-1.6~-1.443)
Low-middle SDI	1924.36 (1669.28~2212.53)	505.86 (438.95~583.11)	2751.15 (2455.07 ~ 3056.56)	321.36 (287.11 ~ 356.77)	-1.475 (-1.618~-1.333)
Low SDI	1207.23 (1031.67~1473.49)	833.33 (711.27~1016.61)	1843.21 (1552.01~2199.87)	535.11 (454.02~638.34)	-1.64 (-1.748~-1.531)
Geographic regior	ı				
Andean Latin America	83.46 (73.06~94.12)	667.44 (585.28~752.00)	140.30 (107.73~176.56)	431.74 (331.78~543.15)	-1.709 (-1.871~-1.546)
Australasia	20.69 (19.37 ~ 22.51)	178.43 (166.82~193.54)	13.29 (12.05~14.53)	61.68 (56.34~67.50)	-3.126 (-3.401~-2.85)
Caribbean	82.43 (72.18~94.67)	561.02 (491.47~642.93)	115.95 (95.88~140.76)	433.17 (356.80~526.53)	-0.8 (-0.88~-0.721)
Central Asia	89.74 (86.42~94.11)	318.71 (306.47~334.38)	108.29 (94.72~122.65)	213.84 (187.54 ~ 241.95)	-1.051 (-1.209~-0.893)
Central Europe	263.43 (252.75~272.81)	344.13 (330.25 ~ 356.19)	181.66 (166.21 ~ 196.95)	191.83 (175.35 ~ 209.14)	-2.052 (-2.244~-1.859)
Central Latin America	330.67 (322.53 ~ 338.29)	627.39 (610.20~641.61)	441.93 (380.72~508.81)	315.97 (272.32~363.77)	-2.546 (-2.713~-2.378)
Central Sub- Saharan Africa	150.92 (112.94~196.16)	950.65 (718.75~1233.27)	330.69 (228.13~448.10)	813.59 (562.84 ~ 1104.29)	-0.543 (-0.594~-0.491)
East Asia	1178.71 (958.92~1452.78)	231.92 (189.37~285.51)	1616.24 (1195.41~2080.06)	151.15 (111.80~195.41)	-1.128 (-1.271~-0.984)
Eastern Europe	378.04 (365.24~390.08)	239.05 (230.85 ~ 246.89)	320.24 (289.15 ~ 353.81)	200.77 (180.38~221.47)	-0.699 (-0.81~-0.587)
Eastern Sub-	564.51 (469.05~691.07)	1117.94	876.85	709.49 (572.26 ~ 890.60)	-1.805 (-1.931~-1.68)
Saharan Africa		(929.76~1367.77)	(701.73~1106.31)		
High-income Asia Pacific	144.58 (135.08~155.15)	133.71 (124.78~143.46)	132.81 (119.52~144.70)	87.68 (81.63~94.36)	-1.265 (-1.358~-1.172)
High-income North America	223.50 (215.89~230.64)	133.17 (129.02~137.29)	240.10 (229.39~250.58)	92.68 (88.88~96.91)	-1.054 (-1.18~-0.928)
North Africa and Middle East	137.47 (119.84~167.28)	131.01 (113.82~159.07)	217.74 (182.98~258.59)	80.04 (67.65~93.68)	-1.594 (-1.629~-1.559)
Oceania	12.84 (9.71~18.35)	654.65 (511.97~937.93)	25.25 (19.49~37.77)	499.47 (390.49~739.25)	-0.864 (-0.916~-0.812)
South Asia	1967.17 (1640.30~2286.75)	552.66 (457.21~642.70)	2432.06 (2097.85 ~ 2773.13)	285.98 (247.23 ~ 325.23)	-2.232 (-2.539~-1.925)
Southeast Asia	613.11 (526.60~699.79)	362.63 (313.26~413.29)	931.50 (800.26~1086.33)	241.92 (207.75~281.44)	-1.478 (-1.588~-1.367)
Southern Latin America	103.03 (97.01 ~ 109.28)	417.99 (393.15~442.82)	123.08 (114.52 ~ 133.16)	296.76 (276.24~321.05)	-1.08 (-1.224~-0.935)
Southern Sub- Saharan Africa	110.03 (92.07~137.14)	600.46 (503.72~750.80)	300.88 (260.87 ~ 338.89)	788.82 (685.47~885.31)	1.71 (1.167~2.256)
Tropical Latin America	242.80 (233.83~252.34)	422.16 (406.02~438.79)	395.39 (372.67 ~ 414.91)	285.57 (269.19~299.68)	-1.636 (-1.779~-1.492)
Western Europe	391.72 (376.29~403.41)	148.36 (143.69~152.94)	257.41 (240.18~272.44)	72.71 (68.94~76.61)	-2.017 (-2.227~-1.807)
Western Sub- Saharan Africa	327.43 (269.23 ~ 399.72)	608.91 (502.55~737.46)	710.00 (548.75~865.46)	490.75 (383.61 ~ 591.44)	-0.677 (-0.741~-0.613)

Annotations DALY: disability-adjusted life-year; ASDALYR: age-standardized disability-adjusted life-year rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

Region	1990 incident cases (×1000, 95% Cl)	1990 ASIR (95% CI)	2021 incident cases (×1000, 95% Cl)	2021 ASIR (95% CI)	1990–2021 EAPC (95% Cl)
Global	159.10	7.22 (6.65 ~ 7.87)	298.88	6.71 (6.07~7.28)	-0.375 (-0.434~-0.317)
	(145.71~174.06)		(270.73~324.50)		
SDI					
High SDI	69.47 (66.20~71.85)	11.96 (11.45~12.34)	80.65 (73.42~85.36)	8.40 (7.84~8.81)	-1.207 (-1.327~-1.087)
High-middle SDI	43.72 (39.64~47.14)	7.87 (7.13~8.49)	67.78 (60.03 ~ 75.75)	6.93 (6.10~7.76)	-0.534 (-0.615~-0.452)
Middle SDI	27.39 (23.08~32.67)	4.33 (3.73~5.12)	82.37 (71.88~92.30)	5.81 (5.07~6.50)	0.728 (0.648~0.808)
Low-middle SDI	13.41 (10.57~18.20)	3.69 (2.90~5.02)	50.27 (43.48~59.05)	6.01 (5.22~7.07)	1.513 (1.447~1.58)
Low SDI	4.89 (3.30~7.06)	3.67 (2.47~5.24)	17.47 (13.14~20.89)	5.42 (4.12~6.43)	1.184 (1.086~1.283)
Geographic region					
Andean Latin America	0.46 (0.36~0.61)	3.65 (2.93~4.78)	2.23 (1.71~2.82)	6.90 (5.27~8.68)	2.122 (1.723 ~ 2.522)
Australasia	1.80 (1.66~1.91)	14.75 (13.63~15.69)	1.83 (1.61 ~ 1.99)	7.18 (6.51 ~ 7.81)	-2.212 (-2.584~-1.839)
Caribbean	0.69 (0.63~0.85)	4.78 (4.37~5.88)	1.83 (1.57~2.22)	6.66 (5.70~8.07)	0.91 (0.726~1.094)
Central Asia	1.22 (1.11~1.34)	4.28 (3.90~4.68)	3.00 (2.60~3.42)	6.10 (5.31~6.94)	1.224 (1.065~1.383)
Central Europe	8.65 (8.35~8.95)	10.92 (10.54~11.30)	11.44 (10.52 ~ 12.32)	10.80 (9.93~11.68)	0.001 (-0.172~0.174)
Central Latin America	2.85 (2.77~2.93)	5.35 (5.19~5.51)	11.43 (9.94 ~ 12.92)	8.23 (7.16~9.29)	1.379 (1.289~1.47)
Central Sub-Saharan Africa	0.41 (0.27~0.62)	2.83 (1.87~4.32)	1.64 (0.95 ~ 2.33)	4.38 (2.49~6.25)	1.49 (1.278~1.703)
East Asia	21.07 (15.07~27.40)	4.13 (3.06~5.34)	44.24 (33.12~57.36)	4.21 (3.15~5.46)	-0.346 (-0.495~-0.197)
Eastern Europe	16.39 (15.67 ~ 17.09)	10.30 (9.83 ~ 10.75)	18.02 (16.13 ~ 20.27)	9.83 (8.77~11.03)	-0.22 (-0.402~-0.038)
Eastern Sub-Saharan Africa	2.41 (1.43~3.48)	5.23 (3.16~7.47)	8.62 (5.98~10.75)	7.48 (5.31 ~ 9.25)	1.083 (0.994~1.171)
High-income Asia Pacific	6.80 (6.49~7.08)	6.28 (6.01 ~ 6.54)	11.23 (9.78~12.24)	6.36 (5.69~6.75)	-0.008 (-0.165~0.15)
High-income North America	23.99 (22.70~24.74)	13.09 (12.52~13.44)	27.98 (25.61 ~ 29.33)	8.88 (8.29~9.27)	-1.333 (-1.514~-1.151)
North Africa and Middle East	3.37 (2.68~4.79)	3.43 (2.72~4.84)	12.44 (10.10~14.42)	4.87 (3.96~5.63)	1.257 (1.193~1.321)
Oceania	0.05 (0.03~0.07)	2.73 (1.89~3.77)	0.19 (0.11~0.26)	3.90 (2.32~5.28)	1.136 (1.012~1.261)
South Asia	12.51 (9.36~16.33)	3.77 (2.80~4.87)	49.66 (42.26~59.35)	5.99 (5.13~7.14)	1.365 (1.273~1.458)
Southeast Asia	10.05 (7.84~14.36)	5.85 (4.63~8.13)	35.03 (26.27 ~ 45.64)	9.28 (6.97 ~ 12.04)	1.386 (1.273 ~ 1.499)
Southern Latin America	2.20 (2.02~2.40)	8.71 (8.00~9.49)	3.41 (3.15~3.64)	7.69 (7.14~8.23)	-0.253 (-0.427~-0.079)
Southern Sub-Saharan Africa	0.87 (0.72~1.07)	4.98 (4.05~6.25)	2.78 (2.12~3.22)	7.71 (5.88~8.93)	1.606 (1.468~1.744)
Tropical Latin America	3.14 (3.02 ~ 3.25)	5.56 (5.34~5.75)	8.89 (8.35 ~ 9.35)	6.43 (6.05~6.77)	0.202 (0.089~0.315)
Western Europe	39.09 (36.93~40.64)	13.41 (12.79~13.88)	38.28 (34.49~40.72)	8.99 (8.35~9.44)	-1.345 (-1.443~-1.248)
Western Sub-Saharan Africa	1.11 (0.76~1.40)	2.25 (1.55~2.83)	4.73 (3.18~6.13)	3.62 (2.40~4.64)	1.591 (1.504~1.677)

Table 7 The incidence of ovarian cancer in 1990 and 2021

Annotations ASIR: Age-standardized incidence rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

between SDI and both ASDR and ASDALYR for cervical cancer, with both indicators decreasing markedly as SDI increased (Fig. S5). For the other three cancers, both ASDR and ASDALYR increased with SDI until it reached 0.7, after which they began to decline.

Age distribution

Age is a key factor influencing tumor burden. Therefore, we interrogated the age distribution patterns for female-specific cancers globally. Except for the super-elderly population (aged 80 years and older), the incidence, mortality, and DALYs for breast cancer peaked in the 55–59 year age group (Fig. 7a). For cervical cancer, the incidence remained consistently high between the ages of 40 and 59 years, with mortality peaking at 55–59 years and the DALY peak occurring at 50–54 years. In ovarian cancer, the incidence similarly peaked at 55–59 years, while the highest mortality was observed in those aged 80 years and older. The DALY peak for ovarian cancer also

occurred in the 55–59 year age group. For uterine cancer, the incidence peaked at 60–64 years, with the highest mortality observed in the population aged 80 years and older, and the DALY peak occurring at 60–64 years.

Overall, the ASIRs, ASDRs, and ASDALYRs for most female-specific cancers increased progressively with age (Fig. 7b). Notably, both the ASIR and ASDALYR for cervical cancer peaked at 55–59 years, while these indicators for uterine cancer reached their highest values at 70–74 years. Additionally, the ASDALYR for ovarian cancer also peaked at 70–74 years. Although the age distribution for cancer in regions with different SDI values might vary slightly from the global trend, the overall pattern remained largely consistent across regions (Fig. S6-S10).

Attributable risk factors

Based on GBD 2021 data, we analyzed the Level 2 attributable risk factors for female-specific cancers. Six Level 2 risk factors were identified for breast cancer mortality,



Fig. 4 Global distribution of ovarian cancer incidences, deaths, and disability-adjusted life years (DALYs) in 2021. a. The incidences of ovarian cancer. b. The ovarian cancer mortality. c. The DALYs of ovarian cancer

Page 1	5 of	25
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Region	1990 Death cases (×1000, 95% Cl)	1990 ASDR (95% CI)	2021 Death cases (×1000, 95% CI)	2021 ASDR (95% Cl)	1990–2021 EAPC (95% Cl)
Global	100.58 (92.97 ~ 109.09)	4.73 (4.38~5.12)	185.61	4.06 (3.67~4.40)	-0.624 (-0.682~-0.566)
			(167.96~201.01)		
SDI					
High SDI	46.77 (44.01~48.56)	7.54 (7.15~7.82)	56.43 (50.33~60.25)	5.08 (4.62~5.37)	-1.341 (-1.435~-1.246)
High-middle SDI	27.65 (25.35~29.47)	4.95 (4.54~5.29)	44.09 (38.88~48.93)	4.16 (3.68~4.63)	-0.699 (-0.801~-0.597)
Middle SDI	15.05 (13.13~17.72)	2.67 (2.35~3.12)	45.54 (39.96~51.22)	3.18 (2.78~3.57)	0.321 (0.234~0.408)
Low-middle SDI	7.83 (6.20~10.59)	2.43 (1.93~3.25)	28.94 (25.19~34.13)	3.72 (3.24~4.40)	1.336 (1.272~1.401)
Low SDI	3.15 (2.11~4.51)	2.65 (1.78~3.76)	10.38 (7.91 ~ 12.36)	3.74 (2.87~4.43)	1.062 (0.972~1.152)
Geographic region					
Andean Latin America	0.27 (0.22~0.36)	2.48 (1.99~3.22)	1.33 (1.03~1.65)	4.22 (3.27~5.26)	1.771 (1.412~2.131)
Australasia	1.23 (1.13~1.31)	9.64 (8.89~10.26)	1.34 (1.15~1.46)	4.68 (4.12~5.08)	-2.225 (-2.573~-1.876)
Caribbean	0.43 (0.40~0.53)	3.17 (2.91 ~ 3.85)	1.18 (1.02~1.40)	4.17 (3.59~4.95)	0.785 (0.634~0.936)
Central Asia	0.80 (0.72~0.88)	2.86 (2.58~3.15)	1.95 (1.71 ~ 2.22)	4.08 (3.57~4.63)	1.253 (1.097~1.409)
Central Europe	5.98 (5.76~6.20)	7.22 (6.96~7.48)	8.86 (8.11~9.52)	7.40 (6.79~7.96)	0.111 (-0.049~0.271)
Central Latin America	1.62 (1.58~1.67)	3.54 (3.42~3.64)	6.73 (5.93~7.56)	4.90 (4.32~5.50)	1.047 (0.963~1.131)
Central Sub-Saharan Africa	0.27 (0.18~0.41)	2.09 (1.38~3.15)	1.00 (0.56~1.43)	3.10 (1.69~4.42)	1.361 (1.166~1.556)
East Asia	12.26 (9.32~15.68)	2.61 (2.02~3.31)	26.34 (19.52~34.08)	2.33 (1.72~3.01)	-0.902 (-1.088~-0.716)
Eastern Europe	10.68 (10.19~11.13)	6.25 (5.96~6.52)	12.18 (10.93~13.64)	6.00 (5.37~6.73)	-0.206 (-0.394~-0.018)
Eastern Sub-Saharan Africa	1.54 (0.92 ~ 2.20)	3.84 (2.33~5.36)	5.02 (3.55~6.18)	5.21 (3.74~6.35)	0.946 (0.867~1.025)
High-income Asia Pacific	4.17 (3.94~4.34)	3.75 (3.55 ~ 3.90)	7.20 (6.06~7.97)	3.26 (2.87~3.50)	-0.53 (-0.608~-0.451)
High-income North America	15.63 (14.55~16.22)	7.95 (7.50~8.21)	19.23 (17.24~20.31)	5.44 (4.96~5.71)	-1.282 (-1.468~-1.097)
North Africa and Middle East	2.03 (1.64~2.85)	2.34 (1.88~3.26)	7.25 (5.92~8.44)	3.14 (2.54~3.65)	1.105 (1.033~1.177)
Oceania	0.02 (0.02~0.03)	1.49 (1.03 ~ 2.00)	0.08 (0.05~0.11)	1.97 (1.23~2.64)	0.987 (0.895 ~ 1.079)
South Asia	7.79 (5.83 ~ 10.08)	2.63 (1.95~3.41)	30.59 (26.42~36.40)	3.92 (3.39~4.67)	1.161 (1.066~1.255)
Southeast Asia	4.22 (3.43~5.82)	2.84 (2.32~3.85)	14.52 (11.29~18.87)	3.96 (3.07~5.12)	1.01 (0.933~1.087)
Southern Latin America	1.53 (1.39~1.67)	5.98 (5.46~6.54)	2.28 (2.09~2.45)	4.82 (4.44~5.17)	-0.515 (-0.678~-0.352)
Southern Sub-Saharan Africa	0.54 (0.42~0.68)	3.45 (2.64~4.39)	1.82 (1.38~2.09)	5.38 (4.05~6.16)	1.634 (1.502~1.765)
Tropical Latin America	1.88 (1.80~1.95)	3.70 (3.50~3.84)	5.61 (5.17~5.93)	3.97 (3.67~4.20)	-0.003 (-0.121~0.115)
Western Europe	26.96 (25.35~28.15)	8.31 (7.85~8.65)	28.24 (24.79~30.47)	5.55 (5.03~5.90)	-1.35 (-1.416~-1.284)
Western Sub-Saharan Africa	0.74 (0.51 ~ 0.94)	1.66 (1.14 ~ 2.10)	2.87 (1.91 ~ 3.69)	2.58 (1.69~3.28)	1.482 (1.404~1.56)

Table 8 The death of ovarian cancer in 1990 and 202	21
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Annotations ASDR: Age-standardized death rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

including dietary risks, high alcohol use, high BMI, high fasting plasma glucose, low physical activity, and tobacco use. Among these, dietary risks were the most significant contributor to breast cancer mortality globally and across regions with different SDI values (Fig. 8a). Notably, high alcohol use was a more significant contributor to breast cancer mortality in high than in low SDI regions. For cervical cancer, unsafe sex was the most important risk factor, contributing substantially to cervical cancer mortality. However, in high SDI regions, tobacco exposure also played a role in cervical cancer mortality (Fig. 8b). High BMI and occupational risks were the major risk factors for ovarian cancer mortality. Globally, high BMI contributed more to ovarian cancer mortality, but with increasing SDI levels, the contribution of occupational risks to ovarian cancer mortality gradually increased (Fig. 8c). High BMI was the only Level 2 risk factor for uterine cancer mortality. While its contribution to uterine cancer mortality was higher in high SDI regions, the growth rate was faster in low SDI regions (Fig. 8d). The contribution of risk factors to cancer DALYs was similar to their contribution to cancer mortality (Fig. <u>S11</u>).

Discussion

In this study, we report the epidemiological trends and attributable risk factors for four major female-specific cancers: breast, cervical, ovarian, and uterine cancer. The key findings are as follows: First, breast cancer bears the highest global disease burden, followed by cervical, ovarian, and uterine cancer. Over the past three decades, both incidence and mortality for these cancers have consistently increased worldwide. Second, after accounting for population growth and demographic changes, the ASIR reveals distinct patterns. The ASIR for breast and uterine cancer has risen, while that for cervical and ovarian cancer has declined. Simultaneously, ASDR and ASDALYR for all four cancers have decreased. Third, the ASIR for breast, ovarian, and uterine cancer increases with SDI, while cervical cancer follows an inverse trend. Finally, the ASIR and ASDR for all four cancers show a positive

Table 9 The DALY of ovarian cancer in 1990 and 2021

Region	1990 DALY (×1000, 95% CI)	1990 ASDALYR (95% CI)	2021 DALY (×1000, 95% CI)	2021 ASDALYR (95% Cl)	1990–2021 EAPC (95% Cl)
Global	2909.24	132.48	5163.26	115.15 (104.58~125.21)	-0.592
	(2662.22~3199.43)	(121.34~145.63)	(4692.42~5608.30)		(-0.642~-0.543)
	1101 40	20 22	1075.65	122 00 (125 22 140 06)	1 402
nigh sol	(1141.76~1230.21)	(200.58~214.57)	(1173.21~1343.08)	155.00 (125.52 ~ 140.00)	(-1.57~-1.395)
High-middle SDI	830.37	149.55	1194.24	119.79 (105.13~134.14)	-0.871
	(750.60~895.93)	(135.03~161.63)	(1054.54~1335.95)		(-0.956~-0.786)
Middle SDI	513.12 (436.89~612.21)	82.58 (71.58~97.89)	1416.15 (1244.40~1587.04)	97.76 (85.77 ~ 109.48)	0.309 (0.222 ~ 0.396)
Low-middle SDI	265.37 (208.67 ~ 360.51)	73.74 (58.18~99.58)	925.85 (802.38~1091.39)	111.40 (96.54~131.20)	1.288 (1.231 ~ 1.345)
Low SDI	104.80 (70.72~151.78)	78.39 (52.96~112.38)	345.37 (259.74~413.46)	108.72 (82.67~129.40)	0.985 (0.89~1.08)
Geographic region					
Andean Latin America	9.01 (7.22~11.92)	73.36 (58.97~96.23)	40.48 (30.83~50.87)	125.60 (95.71~158.01)	1.796 (1.427 ~ 2.165)
Australasia	31.39 (29.12 ~ 33.21)	261.75 (242.26~276.49)	29.40 (26.40~31.86)	116.72 (106.15~125.99)	-2.499 (-2.833~-2.164)
Caribbean	13.27 (12.02~16.78)	93.47 (84.91 ~ 116.94)	34.33 (29.35~41.70)	124.35 (106.00~151.66)	0.803 (0.649~0.958)
Central Asia	25.76 (23.41 ~ 28.17)	90.99 (82.60~99.60)	61.88 (53.81 ~ 70.56)	124.11 (108.08~141.31)	1.053 (0.897 ~ 1.209)
Central Europe	175.95 (169.92~182.18)	221.23 (213.40~228.69)	215.73 (198.22~232.09)	205.22 (189.37~221.33)	-0.204 (-0.363~-0.045)
Central Latin America	54.24 (52.81 ~ 55.62)	104.05 (101.06~106.84)	210.43 (183.01~237.78)	150.76 (131.25~170.19)	1.189 (1.115 ~ 1.263)
Central Sub-Saharan Africa	8.89 (5.89~13.78)	60.64 (40.14~93.43)	33.66 (19.26~49.08)	90.01 (50.59~129.58)	1.368 (1.166~1.57)
East Asia	416.57 (301.04~542.96)	82.65 (61.08~107.10)	787.10 (580.91 ~ 1024.66)	72.07 (53.13~94.15)	-0.918 (-1.09~-0.745)
Eastern Europe	321.43 (306.64 ~ 335.97)	200.42 (191.08~209.58)	332.15 (296.37~371.97)	180.89 (160.79~203.55)	-0.437 (-0.621~-0.253)
Eastern Sub-Saharan Africa	51.35 (30.35~74.64)	111.66 (66.58 ~ 160.61)	170.26 (117.55~211.89)	150.96 (106.18~185.66)	0.911 (0.828~0.995)
High-income Asia Pacific	128.56 (123.65~132.90)	118.37 (114.08~122.28)	168.12 (148.70~180.43)	98.97 (89.26~104.57)	-0.625 (-0.697~-0.554)
High-income North America	388.43 (371.83~399.71)	216.72 (208.63~222.32)	439.44 (409.03~459.51)	139.13 (131.42 ~ 145.12)	-1.488 (-1.648~-1.328)
North Africa and Middle East	66.81 (53.28~94.96)	68.09 (54.20 ~ 96.89)	225.63 (183.82~261.75)	88.12 (71.92~102.25)	0.945 (0.882 ~ 1.008)
Oceania	0.78 (0.52~1.09)	43.87 (29.72~60.65)	2.76 (1.58~3.79)	59.04 (35.09~80.86)	0.996 (0.905 ~ 1.087)
South Asia	264.39 (200.20~344.16)	79.51 (59.99~102.65)	960.21 (822.85~1142.39)	116.00 (99.82~138.16)	1.092 (1.003 ~ 1.182)
Southeast Asia	150.72 (119.30~213.94)	91.18 (73.07~126.59)	484.77 (368.98~633.79)	126.63 (96.38~165.18)	0.993 (0.912 ~ 1.073)
Southern Latin America	42.61 (39.17~46.56)	169.10 (155.56 ~ 184.70)	60.64 (56.17~64.79)	137.30 (127.41 ~ 146.65)	-0.514 (-0.668~-0.36)
Southern Sub-Saharan Africa	16.95 (14.15~21.27)	98.60 (79.59~124.62)	54.38 (41.72~63.22)	150.23 (114.98~174.11)	1.587 (1.447 ~ 1.728)
Tropical Latin America	61.10 (58.94~63.14)	109.27 (105.00~113.00)	163.85 (153.85~172.30)	117.39 (110.28~123.42)	-0.025 (-0.126~0.077)
Western Europe	658.05 (626.53 ~ 683.83)	227.51 (217.90 ~ 236.02)	594.07 (542.48~629.98)	140.16 (131.08 ~ 146.93)	-1.614 (-1.685~-1 544)
Western Sub-Saharan Africa	22.98 (15.95~29.31)	47.14 (32.69~59.94)	93.97 (63.29~121.19)	72.64 (48.64~93.39)	1.462 (1.374~1.551)

Annotations DALY: disability-adjusted life-year; ASDALYR: age-standardized disability-adjusted life-year rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

Region	1990 incident cases (×1000, 95% Cl)	1990 ASIR (95% CI)	2021 incident cases (×1000, 95% Cl)	2021 ASIR (95% CI)	1990–2021 EAPC (95% Cl)
Global	191.29 (175.00~201.94)	8.87 (8.12~9.35)	473.61 (429.92~513.67)	10.36 (9.42 ~ 11.24)	0.54 (0.497 ~ 0.584)
SDI					
High SDI	82.78 (78.11~85.59)	13.74 (13.06~14.18)	192.35 (176.60~200.77)	19.55 (18.28~20.35)	1.361 (1.274~1.449)
High-middle SDI	66.63 (62.42~70.41)	11.84 (11.07~12.51)	148.23 (134.70~163.71)	14.23 (12.89~15.75)	0.561 (0.452~0.67)
Middle SDI	28.48 (21.37~33.25)	4.90 (3.74~5.70)	89.60 (73.11~106.23)	6.09 (4.97 ~ 7.20)	0.534 (0.439~0.629)
Low-middle SDI	9.62 (7.93 ~ 10.99)	2.96 (2.48~3.38)	32.82 (28.27~40.11)	4.13 (3.56~5.08)	0.985 (0.882~1.088)
Low SDI	3.49 (2.68~4.14)	2.95 (2.29~3.51)	9.98 (7.95~12.81)	3.58 (2.87~4.59)	0.5 (0.381~0.619)
Geographic region					
Andean Latin America	0.94 (0.80~1.09)	8.45 (7.22~9.87)	3.14 (2.33~4.07)	9.97 (7.40~12.90)	0.411 (0.202~0.621)
Australasia	1.21 (1.10~1.32)	9.84 (8.99~10.67)	3.75 (3.25~4.22)	14.65 (12.84~16.34)	1.377 (1.174~1.579)
Caribbean	1.60 (1.47 ~ 1.75)	11.68 (10.71~12.72)	4.93 (4.28~5.67)	17.48 (15.17~20.10)	1.071 (0.794~1.349)
Central Asia	2.93 (2.76~3.11)	10.40 (9.79~11.00)	4.81 (4.25~5.45)	9.71 (8.60~10.95)	-0.208 (-0.517~0.102)
Central Europe	11.43 (10.64~12.27)	13.61 (12.67~14.61)	23.18 (20.85 ~ 25.38)	20.70 (18.66~22.70)	1.369 (1.268~1.47)
Central Latin America	2.01 (1.93~2.09)	4.42 (4.23~4.62)	9.85 (8.61~11.23)	7.08 (6.19~8.06)	1.511 (1.136~1.889)
Central Sub-Saharan Africa	0.42 (0.31~0.58)	3.17 (2.35~4.45)	1.33 (0.86~1.94)	4.07 (2.64~5.92)	0.797 (0.655~0.94)
East Asia	27.19 (18.79~34.14)	5.60 (3.92~6.99)	75.54 (56.83 ~ 103.40)	6.73 (5.02~9.23)	0.482 (0.159~0.807)
Eastern Europe	34.19 (32.97 ~ 35.20)	20.04 (19.34~20.62)	58.60 (52.90~64.77)	29.70 (26.77~32.90)	0.91 (0.466~1.355)
Eastern Sub-Saharan Africa	1.41 (0.98~1.72)	3.53 (2.46~4.28)	3.92 (2.83~5.44)	4.10 (3.00~5.59)	0.337 (0.223~0.45)
High-income Asia Pacific	4.83 (4.38~5.24)	4.35 (3.94~4.72)	13.82 (12.30~15.05)	8.31 (7.57~9.04)	2.461 (2.328~2.594)
High-income North America	37.68 (35.44~38.99)	20.02 (18.98~20.66)	103.52 (96.17~108.66)	31.78 (29.88~33.21)	1.655 (1.561 ~ 1.75)
North Africa and Middle East	3.58 (2.81 ~ 4.30)	3.95 (3.12~4.74)	17.29 (12.67~20.57)	7.07 (5.17~8.40)	2.069 (1.882~2.255)
Oceania	0.12 (0.07~0.16)	6.93 (4.33~9.44)	0.35 (0.20~0.54)	8.19 (4.75 ~ 12.27)	0.528 (0.466~0.59)
South Asia	6.01 (4.77~7.12)	2.04 (1.62~2.42)	23.67 (19.82~31.54)	2.99 (2.50~3.97)	1.035 (0.819~1.252)
Southeast Asia	7.22 (5.14~8.70)	4.71 (3.40~5.64)	25.17 (17.37~30.77)	6.55 (4.56~7.99)	0.927 (0.872~0.982)
Southern Latin America	1.87 (1.72~2.01)	7.32 (6.74~7.87)	3.33 (3.01 ~ 3.67)	7.20 (6.50~7.96)	-0.073 (-0.215~0.07)
Southern Sub-Saharan Africa	0.57 (0.45~0.74)	3.61 (2.86~4.65)	2.24 (1.69~2.63)	6.47 (4.86~7.56)	2.373 (2.113~2.633)
Tropical Latin America	2.95 (2.80~3.10)	5.89 (5.58~6.20)	10.34 (9.59~10.99)	7.27 (6.74~7.72)	0.338 (0.161~0.516)
Western Europe	42.06 (39.44~44.00)	13.60 (12.83~14.22)	80.97 (72.64~85.89)	18.48 (17.01 ~ 19.49)	1.409 (1.228~1.589)
Western Sub-Saharan Africa	1.08 (0.87~1.45)	2.47 (1.98~3.32)	3.84 (2.95~4.94)	3.55 (2.73~4.50)	1.27 (1.224~1.316)

Table 10 The incidence of uterine cancer in 1990 and 2021

Annotations ASIR: Age-standardized incidence rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

correlation with age, highlighting the growing burden in aging populations. The attributable risk factors for these cancers vary significantly, with notable differences between high and low SDI regions.

These findings align with our previous reports [4], notably the steady increase in global breast cancer incidence between 1990 and 2021, while ASDR and ASDALYR continued to decline. This increase in breast cancer incidence can be attributed to the widespread implementation of screening technologies, such as mammography and ultrasound, alongside improvements in cancer registries. These advancements have led to more diagnoses, contributing to the persistent high prevalence of breast cancer. Concurrently, progress in molecular subtyping, targeted therapies, and immunotherapies has markedly improved survival rates [13–15]. These developments explain the contrast between rising ASIR and declining ASDR, underscoring the positive impact of early detection and therapeutic innovations.

A close relationship between breast cancer incidence and SDI is evident, with high-income regions such as North America and Western Europe exhibiting breast cancer ASIRs significantly higher than the global average. Additionally, both ASIR and ASDR increase with age, raising concerns as the global population ages. Six Level 2 risk factors, including dietary risks, alcohol use, high BMI, high fasting plasma glucose, low physical activity, and tobacco use, were identified as major contributors to breast cancer mortality. These risk factors are closely associated with modern lifestyles, socio-economic development, and urbanization, consistent with previous studies highlighting the influence of age, fertility, diet, and tobacco exposure on breast cancer mortality [16–18].

Cervical cancer, though less burdensome globally than breast cancer, exhibits a higher ASIR than breast





Fig. 5 Global distribution of uterine cancer incidences, deaths, and disability-adjusted life years (DALYs) in 2021. a. The uterine cancer incidences. b. The uterine cancer mortality. c. The uterine cancer DALYs

Table 11 The death of uterine cancer in 1990 and 2021

Region	1990 Death cases (×1000, 95% Cl)	1990 ASDR (95% Cl)	2021 Death cases (×1000, 95% Cl)	2021 ASDR (95% Cl)	1990–2021 EAPC (95% Cl)
Global	54.85 (48.80~59.12)	2.60 (2.32 ~ 2.80)	97.67 (86.52~108.06)	2.11 (1.87~2.34)	-0.776 (-0.849~-0.702)
SDI					
High SDI	18.35 (16.94~19.16)	2.79 (2.60~2.91)	31.63 (27.72~33.74)	2.69 (2.41 ~ 2.84)	0.038 (-0.134~0.211)
High-middle SDI	17.91 (16.42~19.15)	3.18 (2.92~3.41)	26.21 (23.40~29.08)	2.39 (2.13~2.66)	-1.174 (-1.282~-1.065)
Middle SDI	11.84 (8.89~13.83)	2.20 (1.69~2.55)	22.90 (19.10~26.70)	1.61 (1.35~1.87)	-1.238 (-1.351~-1.125)
Low-middle SDI	4.66 (3.93~5.39)	1.58 (1.33~1.84)	12.19 (10.48~15.34)	1.64 (1.42~2.07)	0.028 (-0.042~0.098)
Low SDI	1.99 (1.53~2.37)	1.84 (1.42~2.21)	4.58 (3.65~5.91)	1.83 (1.46~2.36)	-0.101 (-0.181~-0.02)
Geographic region					
Andean Latin America	0.45 (0.38~0.53)	4.33 (3.69~5.12)	0.98 (0.73~1.26)	3.17 (2.37~4.10)	-1.111 (-1.313~-0.909)
Australasia	0.27 (0.24~0.30)	2.04 (1.84~2.22)	0.63 (0.52~0.71)	2.12 (1.78~2.39)	0.255 (-0.01~0.521)
Caribbean	0.57 (0.52~0.64)	4.28 (3.88~4.78)	1.54 (1.33 ~ 1.79)	5.38 (4.63~6.24)	0.708 (0.533~0.883)
Central Asia	1.02 (0.96~1.08)	3.67 (3.44~3.90)	1.24 (1.11~1.40)	2.68 (2.40~3.01)	-0.998 (-1.291~-0.704)
Central Europe	3.60 (3.34~3.85)	4.18 (3.88~4.46)	5.52 (4.95~6.02)	4.17 (3.77~4.57)	-0.092 (-0.289~0.105)
Central Latin America	0.88 (0.84~0.92)	2.10 (1.99~2.20)	2.92 (2.55 ~ 3.30)	2.15 (1.88~2.42)	0.135 (-0.24~0.51)
Central Sub-Saharan Africa	0.24 (0.18~0.33)	2.01 (1.50~2.85)	0.62 (0.41~0.90)	2.14 (1.41 ~ 3.16)	0.239 (0.176~0.303)
East Asia	10.90 (7.64~13.59)	2.37 (1.71~2.95)	14.23 (10.58~19.16)	1.25 (0.93~1.69)	-2.46 (-2.804~-2.116)
Eastern Europe	8.00 (7.66~8.28)	4.43 (4.25~4.59)	10.28 (9.28~11.43)	4.65 (4.18~5.20)	-0.396 (-0.784~-0.006)
Eastern Sub-Saharan Africa	0.83 (0.57~1.00)	2.27 (1.58~2.76)	1.85 (1.35~2.53)	2.17 (1.59~2.95)	-0.244 (-0.322~-0.166)
High-income Asia Pacific	2.09 (1.88~2.28)	1.84 (1.66~2.01)	3.94 (3.19~4.38)	1.65 (1.44~1.80)	-0.111 (-0.309~0.086)
High-income North America	6.22 (5.67~6.52)	2.94 (2.72~3.07)	13.05 (11.66~13.87)	3.57 (3.23~3.77)	0.739 (0.571 ~ 0.907)
North Africa and Middle East	1.11 (0.88~1.36)	1.37 (1.09~1.71)	2.90 (2.19~3.44)	1.34 (1.01 ~ 1.60)	0.107 (-0.106~0.32)
Oceania	0.05 (0.03~0.06)	3.16 (1.96~4.25)	0.13 (0.08~0.20)	3.55 (2.06~5.32)	0.431 (0.393~0.469)
South Asia	3.21 (2.56~3.84)	1.21 (0.96~1.45)	9.24 (7.69~12.34)	1.24 (1.03~1.66)	-0.121 (-0.274~0.033)
Southeast Asia	2.80 (2.01 ~ 3.38)	1.99 (1.47~2.40)	7.38 (5.31 ~ 9.00)	2.03 (1.47~2.47)	-0.064 (-0.149~0.021)
Southern Latin America	0.76 (0.70~0.81)	2.95 (2.69~3.15)	1.00 (0.89~1.09)	2.00 (1.79~2.18)	-1.258 (-1.379~-1.137)
Southern Sub-Saharan Africa	0.28 (0.22~0.36)	1.89 (1.46~2.44)	0.96 (0.71~1.11)	2.94 (2.15~3.41)	1.864 (1.521 ~ 2.21)
Tropical Latin America	1.33 (1.26~1.40)	2.85 (2.67~3.01)	3.42 (3.12~3.66)	2.40 (2.19~2.57)	-0.764 (-0.897~-0.631)
Western Europe	9.60 (8.84~10.17)	2.71 (2.51~2.85)	14.03 (11.93~15.20)	2.53 (2.23~2.71)	0.135 (-0.01~0.28)
Western Sub-Saharan Africa	0.64 (0.51~0.86)	1.55 (1.25 ~ 2.10)	1.81 (1.40~2.28)	1.90 (1.48~2.37)	0.802 (0.745~0.859)

Annotations ASDR: Age-standardized death rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

cancer in low SDI regions. Fortunately, the ASIR, ASDR, and ASDALYR for cervical cancer are rapidly declining worldwide. As a virus-associated malignancy, cervical cancer is preventable through interventions targeting HPV. The promotion of HPV vaccination, early screening, and treatment of precancerous lesions has led to significant reductions in incidence and mortality [19–21]. However, there is a negative correlation between cervical cancer burden and SDI, with lower-income regions bearing a heavier burden due to inadequate public health resources. In certain areas, such as southern sub-Saharan Africa, the incidence of cervical cancer continues to rise, emphasizing the need for expanded international support for vaccination and screening programs, including training healthcare professionals and improving facilities.

Ovarian cancer incidence and mortality have decreased globally, with high SDI regions contributing the most to this decline. In contrast, middle, low-middle, and low SDI regions continue to experience rising ASIR and ASDR. Despite a general positive correlation between ASIR and SDI, ovarian cancer ASIR declines in regions with SDI values above 0.7. As with breast cancer, both ASIR and ASDR for ovarian cancer increase with age. Major risk factors for ovarian cancer-related deaths include high BMI and occupational risks. At the same time, some behaviors, such as breastfeeding and tubal ligation, have been identified as protective factors for ovarian cancer [22, 23]. At the present stage, ovarian cancer remains one of the female-specific cancers with a high mortality rate, with limited effective early diagnostic and screening measures. Recent advancements in genetic testing for patient stratification, neoadjuvant chemotherapy, hyperthermic intraperitoneal chemotherapy, targeted therapy, immunotherapy, and advanced surgical techniques have contributed to reductions in ovarian cancer mortality [24–26].

Uterine cancer incidence has steadily increased, particularly in high SDI regions. In fact, the ASIR for uterine cancer shows a positive correlation with SDI, with a notable rise in regions such as high-income North America. High BMI is a key risk factor for uterine cancer death, with overweight or obese women more likely to develop

Table 12 The DALY of uterine cancer in 1990 and 2021

Region	1990 DALY (×1000, 95% CI)	1990 ASDALYR (95% CI)	2021 DALY (×1000, 95% Cl)	2021 ASDALYR (95% Cl)	1990–2021 EAPC (95% Cl)
Global	1501.43 (1297.89~1637.76)	69.17 (59.85 ~ 75.30)	2562.94 (2291.15~2846.49)	56.15 (50.07~62.37)	-0.78 (-0.847~-0.713)
SDI					
High SDI	430.70 (407.15~451.44)	70.51 (66.85~73.87)	734.54 (668.47~783.44)	71.79 (66.24~76.26)	0.264 (0.106~0.422)
High-middle SDI	503.90 (456.10 ~ 544.05)	89.58 (80.92~96.87)	687.61 (619.01~767.23)	65.74 (58.93~73.57)	-1.266 (-1.378~-1.154)
Middle SDI	368.06 (264.70~436.45)	62.44 (45.97 ~ 73.43)	657.00 (537.31 ~ 770.07)	45.05 (36.88~52.70)	-1.293 (-1.404~-1.183)
Low-middle SDI	138.08 (114.27 ~ 159.54)	41.92 (34.80~48.38)	347.31 (295.31 ~ 429.62)	43.77 (37.41~54.37)	0.041 (-0.031~0.112)
Low SDI	58.22 (44.14~69.78)	47.92 (36.72~57.18)	132.39 (105.24~170.18)	46.80 (37.40~60.25)	-0.186 (-0.271~-0.1)
Geographic region					
Andean Latin America	12.75 (10.88~15.00)	113.77 (97.42~133.39)	26.09 (19.39~33.75)	82.94 (61.69~107.41)	-1.135 (-1.339~-0.93)
Australasia	6.37 (5.82~6.95)	50.82 (46.55~55.28)	14.29 (12.38~16.06)	53.92 (47.26~60.21)	0.316 (0.07~0.563)
Caribbean	16.10 (14.46~18.03)	116.00 (104.25~130.39)	40.33 (34.53~47.03)	144.02 (122.94~168.01)	0.639 (0.45~0.829)
Central Asia	29.87 (28.02~31.66)	106.10 (99.50~112.42)	36.94 (32.39~42.25)	75.47 (66.42~85.96)	-1.14 (-1.397~-0.884)
Central Europe	92.86 (86.49~99.77)	110.21 (102.77~118.42)	124.60 (112.86~136.80)	105.93 (95.65 ~ 116.22)	-0.191 (-0.363~-0.019)
Central Latin America	24.34 (23.35 ~ 25.44)	53.04 (50.68~55.52)	81.39 (70.36~92.79)	58.74 (50.83~66.90)	0.384 (-0.014~0.783)
Central Sub-Saharan Africa	7.18 (5.31 ~ 9.95)	53.13 (39.52~73.78)	18.47 (11.86~26.67)	55.82 (36.31~80.74)	0.173 (0.102~0.244)
East Asia	353.04 (232.77 ~ 446.23)	71.74 (48.48~89.95)	425.14 (320.03~571.29)	38.29 (28.87 ~ 51.57)	-2.39 (-2.719~-2.059)
Eastern Europe	222.36 (213.51 ~ 231.21)	129.19 (124.14~134.30)	270.21 (242.69~303.33)	133.05 (118.82~149.61)	-0.475 (-0.88~-0.069)
Eastern Sub-Saharan Africa	24.25 (16.76~29.63)	58.82 (40.79~71.32)	53.31 (38.47~74.53)	54.81 (39.90~75.48)	-0.356 (-0.443~-0.269)
High-income Asia Pacific	53.34 (47.43 ~ 58.59)	47.48 (42.05~52.23)	88.36 (77.56~96.56)	47.34 (42.79~51.08)	0.303 (0.115~0.49)
High-income North America	147.89 (138.37~156.79)	76.39 (71.95~80.84)	329.72 (303.83 ~ 353.33)	98.72 (91.50~105.63)	1.004 (0.846~1.163)
North Africa and Middle East	33.25 (26.25~40.40)	36.53 (28.96~44.38)	86.20 (65.58 ~ 103.00)	35.71 (27.12~42.52)	0.023 (-0.171~0.217)
Oceania	1.47 (0.89~2.05)	88.54 (54.41 ~ 122.11)	4.28 (2.40~6.67)	100.13 (56.81 ~ 152.20)	0.44 (0.402~0.478)
South Asia	94.30 (75.54~112.77)	31.44 (25.10~37.60)	256.84 (214.34~344.46)	32.35 (27.04~43.28)	-0.105 (-0.265~0.055)
Southeast Asia	89.10 (61.69~108.41)	58.02 (41.01 ~ 70.58)	226.68 (156.60~279.32)	59.51 (41.41 ~ 72.97)	-0.05 (-0.138~0.039)
Southern Latin America	19.39 (17.90~20.75)	75.66 (69.88~80.87)	23.38 (21.12~25.64)	49.91 (45.26~55.08)	-1.308 (-1.456~-1.159)
Southern Sub-Saharan Africa	7.47 (6.01 ~ 9.65)	46.98 (37.35~60.86)	25.00 (18.91 ~ 29.45)	72.06 (54.21~84.72)	1.897 (1.552~2.244)
Tropical Latin America	35.14 (33.19~37.07)	69.81 (65.68~73.63)	87.48 (80.86~92.65)	61.58 (56.94~65.20)	-0.661 (-0.813~-0.508)
Western Europe	213.76 (200.44~225.81)	66.83 (63.19~70.50)	294.93 (260.75~317.61)	63.54 (57.66~68.10)	0.235 (0.085~0.385)
Western Sub-Saharan Africa	17.20 (13.79~23.08)	38.55 (30.85~51.77)	49.29 (37.91 ~ 63.48)	45.23 (34.73~57.30)	0.624 (0.577~0.672)

Annotations DALY: disability-adjusted life-year; ASDALYR: age-standardized disability-adjusted life-year rate (per 100,000 females); EAPC: Estimated annual percentage change; SDI: Socio-demographic index

uterine cancer [27–29]. A lack of physical activity and the high prevalence of diabetes also contribute to increased risk [30, 31]. Public health initiatives focused on weight management and promoting physical activity could help mitigate the growing burden of uterine cancer.

Over the past 32 years, the disease burden of femalespecific cancers has risen rapidly. Given the positive correlation between age and cancer incidence rate, coupled with the aging global population, the burden of these cancers is expected to continue increasing in the coming decades. Projections indicate that the economic burden of female-specific cancers will account for 0.073% of the global gross domestic product (GDP) from 2020 to 2050, further exacerbating economic pressure on



Fig. 6 Global trends in age-standardized incidence rates (ASIRs) and socio-demographic index (SDI) from 1990 to 2021. The Rho values (Spearman's rho correlation coefficient) indicate the strength of the correlation between the SDI and ASIRs



Fig. 7 Age distribution of incidences, mortality, and disability-adjusted life years (DALYs) for female-specific cancers in 2021. a. Global incidences, deaths, and DALYs for breast, cervical, ovarian, and uterine cancers across different age groups in 2021. b. Global age-standardized rates of incidence, death, and DALYs for breast, cervical, ovarian, and uterine cancers across different age groups in 2021.





Fig. 8 Level 2 risk factors contributing to female-specific cancer-related death. The trends in risk factors contributing to deaths for breast, cervical, ovarian, and uterine cancers globally and across different regions from 1990 to 2021, a. Breast cancer, b. Cervical cancer, c. Ovarian cancer d. Uterine cancer

individuals and healthcare systems [32]. The emergence of new infectious diseases, such as COVID-19, may further strain already limited public health resources, posing additional challenges to cancer prevention and treatment. Global mobilization of medical resources is crucial to address these challenges, alongside the enhancement of screening strategies, optimization of diagnostic tools, and the development of targeted, personalized therapies.

This study has several limitations. First, data from the GBD 2021 project, while comprehensive and statistically refined, may underestimate cancer burden in underdeveloped regions due to incomplete cancer registries and limited public database resources. Second, there is a paucity of epidemiological statistics of pathological subtype of each cancer, leading to a compromised analysis, exemplified by the lack of data on non-HPV-associated cervical cancer. Third, our analysis focuses on four major female-specific cancers, excluding rarer cancer types. Finally, the analysis of attributable risk factors is based on the available Level 2 risk factors in the GBD 2021 database, which may not capture all clinically relevant factors. Therefore, caution should be exercised in interpreting these results.

Conclusion

The present work provides a comprehensive overview of the global burden and attributable risk factors for four major female-specific cancers: breast, cervical, ovarian, and uterine cancers. Our findings show that breast cancer bears the highest global disease burden, especially in high-SDI regions, while the incidence of cervical cancer remains high in low-income areas, despite declining in most parts of the world. There are rising trends in the incidence of ovarian and uterine cancer, with age and lifestyle-related factors contributing significantly to their burden. Addressing these challenges requires expanding prevention and early detection programs, particularly in resource-limited regions. With the aging global population, there is a pressing need for age-appropriate interventions and improved cancer care infrastructure. This study highlights the importance of targeted policies, lifestyle changes, and ongoing research to reduce the global burden of female-specific cancers and improve outcomes for women worldwide.

Abbreviations

WHO	World Health Organization
GBD	Global Burden of Disease
MR-BRT	Meta-regression-Bayesian, regularized, trimmed
ST-GPR	Spatiotemporal Gaussian process regression
ICD	International Classification of Diseases
GATHER	Guidelines for Accurate and Transparent Health Estimates
	Reporting
DALY	Disability-adjusted life year
ASR	Age-standardized rate
ASIR	Age-standardized incidence rate
ASDR	Age-standardized death rate
ASDALYR	Age-standardized disability-adjusted life year rate
SDI	Socio-demographic index
EAPC	Estimated annual percentage change
HPV	Human papillomavirus

Supplementary Information

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Supplementary Material 1

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Not applicable.

Author contributions

T.L. performed the selection of literature, drafted the manuscript and prepared the figures and tables. H.Z., M.L., Q.H., M.L. and L.Z. collected the related references and participated in discussion. M.Y., K.W. and J.Z. conceived and designed this project, and revised the manuscript. All authors contributed to this manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Gynecology, The Second Affiliated Hospital, Zhejiang University School of Medicine, Zhejiang University, Hangzhou 310009, People's Republic of China

Zhejiang Provincial Clinical Research Center for Obstetrics and Gynecology, Hangzhou 310000, People's Republic of China ³Department of Hepatopancreatobiliary Surgery, Fujian Provincial Hospital, Fuzhou 350001, People's Republic of China ⁴Department of Gynecological Oncology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430000, People's Republic of China ⁵Cancer Center, Shanxi Bethune Hospital, Shanxi Academy of Medical Science, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan 030032, People's Republic of China ⁶Department of Oncology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, People's Republic of China ⁷Department of Breast Surgery, The First Affiliated Hospital, College of Medicine, Zhejiang University, Hangzhou 310000, People's Republic of China

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References

- Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2024;74:229–63.
- Zhou T, Wang X, Zhang J, Zhou E, Xu C, Shen Y, et al. Global burden of thyroid cancer from 1990 to 2021: a systematic analysis from the global burden of Disease Study 2021. J Hematol Oncol. 2024;17:74.
- Li W, Liang H, Wang W, Liu J, Liu X, Lao S, et al. Global cancer statistics for adolescents and young adults: population based study. J Hematol Oncol. 2024;17:99.
- Yi M, Li T, Niu M, Luo S, Chu Q, Wu K. Epidemiological trends of women's cancers from 1990 to 2019 at the global, regional, and national levels: a population-based study. Biomark Res. 2021;9:55.
- Murray CJL. Findings from the global burden of Disease Study 2021. Lancet. 2024;403:2259–62.
- Zhou Y, Huang G, Cai X, Liu Y, Qian B, Li D. Global, regional, and national burden of acute myeloid leukemia, 1990–2021: a systematic analysis for the global burden of disease study 2021. Biomark Res. 2024;12:101.
- Wu Z, Xia F, Lin R. Global burden of cancer and associated risk factors in 204 countries and territories, 1980–2021: a systematic analysis for the GBD 2021. J Hematol Oncol. 2024;17:119.
- GBD 2021 Causes of Death Collaborators. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of Disease Study 2021. Lancet. 2024;403:2100–32.
- GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of Disease Study 2021. Lancet. 2024;403:2133–61.
- GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of Disease Study 2021. Lancet. 2024;403:2162–203.
- Yi M, Li A, Zhou L, Chu Q, Song Y, Wu K. The global burden and attributable risk factor analysis of acute myeloid leukemia in 195 countries and territories from 1990 to 2017: estimates based on the global burden of disease study 2017. J Hematol Oncol. 2020;13:72.
- 12. Bai X, Yi M, Dong B, Zheng X, Wu K. The global, regional, and national burden of kidney cancer and attributable risk factor analysis from 1990 to 2017. Exp Hematol Oncol. 2020;9:27.
- Zhu S, Wu Y, Song B, Yi M, Yan Y, Mei Q, et al. Recent advances in targeted strategies for triple-negative breast cancer. J Hematol Oncol. 2023;16:100.
- Yi M, Wu Y, Niu M, Zhu S, Zhang J, Yan Y, et al. Anti-TGF-β/PD-L1 bispecific antibody promotes T cell infiltration and exhibits enhanced antitumor activity in triple-negative breast cancer. J Immunother Cancer. 2022;10:e005543.
- Ye F, Dewanjee S, Li Y, Jha NK, Chen ZS, Kumar A, et al. Advancements in clinical aspects of targeted therapy and immunotherapy in breast cancer. Mol Cancer. 2023;22:105.
- Macacu A, Autier P, Boniol M, Boyle P. Active and passive smoking and risk of breast cancer: a meta-analysis. Breast Cancer Res Treat. 2015;154:213–24.

- Chlebowski RT, Aragaki AK, Anderson GL, Pan K, Neuhouser ML, Manson JE, et al. Dietary modification and breast Cancer mortality: long-term Follow-Up of the women's Health Initiative Randomized Trial. J Clin Oncol. 2020;38:1419–28.
- Blumenfeld Z, Gleicher N, Adashi EY. Transiently increased risk of breast cancer after childbirth: implications for fertility treatments and surrogacy. Hum Reprod. 2020;35:1253–5.
- 19. Viveros-Carreño D, Fernandes A, Pareja R. Updates on cervical cancer prevention. Int J Gynecol Cancer. 2023;33:394–402.
- Abu-Rustum NR, Yashar CM, Arend R, Barber E, Bradley K, Brooks R, et al. NCCN Guidelines[®] insights: Cervical Cancer, Version 1.2024. J Natl Compr Canc Netw. 2023;21:1224–33.
- Castle PE, Einstein MH, Sahasrabuddhe W. Cervical cancer prevention and control in women living with human immunodeficiency virus. CA Cancer J Clin. 2021;71:505–26.
- Babic A, Sasamoto N, Rosner BA, Tworoger SS, Jordan SJ, Risch HA, et al. Association between Breastfeeding and Ovarian Cancer Risk. JAMA Oncol. 2020;6:e200421.
- Cibula D, Widschwendter M, Májek O, Dusek L. Tubal ligation and the risk of ovarian cancer: review and meta-analysis. Hum Reprod Update. 2011;17:55–67.
- Wang L, Wang X, Zhu X, Zhong L, Jiang Q, Wang Y, et al. Drug resistance in ovarian cancer: from mechanism to clinical trial. Mol Cancer. 2024;23:66.
- Kobayashi Y, Shimada M, Tamate M, Cho HW, Zhu J, Chou HH, et al. Current treatment strategies for ovarian cancer in the East Asian Gynecologic Oncology Trial Group (EAGOT). J Gynecol Oncol. 2024;35:e87.
- 26. Kuroki L, Guntupalli SR. Treatment of epithelial ovarian cancer. BMJ. 2020;371:m3773.

- 27. Eakin CM, Liao CI, Salani R, Cohen JG, Kapp DS, Chan JK. The association of obesity with type I uterine cancer-is this an oversimplification? Am J Obstet Gynecol. 2022;227:538–9.
- Masuda T, Ogawa K, Kamatani Y, Murakami Y, Kimura T, Okada Y. A mendelian randomization study identified obesity as a causal risk factor of uterine endometrial cancer in Japanese. Cancer Sci. 2020;111:4646–51.
- 29. Papatla K, Huang M, Slomovitz B. The obese endometrial cancer patient: how do we effectively improve morbidity and mortality in this patient population? Ann Oncol. 2016;27:1988–94.
- Schmid D, Behrens G, Keimling M, Jochem C, Ricci C, Leitzmann M. A systematic review and meta-analysis of physical activity and endometrial cancer risk. Eur J Epidemiol. 2015;30:397–412.
- Kim JY, Lee DW, Kim MJ, Shin JE, Shin YJ, Lee HN. Secondhand smoke exposure, diabetes, and high BMI are risk factors for uterine cervical cancer: a cross-sectional study from the Korea national health and nutrition examination survey (2010–2018). BMC Cancer. 2021;21:880.
- Chen S, Cao Z, Prettner K, Kuhn M, Yang J, Jiao L, et al. Estimates and projections of the Global Economic cost of 29 cancers in 204 countries and territories from 2020 to 2050. JAMA Oncol. 2023;9:465–72.

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