Global, Regional, and National Burden of Breast Cancer and Its Attributable Risk Factors Among Women, 1990–2017

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Abstract

Introduction: Breast cancer is the most common cancer in women worldwide. However, no comprehensive study has been conducted to compare the incidence, mortality, and disability-adjusted life years (DALYs) for female breast cancer among different countries. The current study examined the level and trends of incidence, death, and DALYs for breast cancer and its attributable risk factors among women in 195 countries from 1990 to 2017 by age, socio-demographic index (SDI; a composite of socio-demographic factors), and healthcare access and quality (HAQ; an indicator of health system performance) index.

Methods: Vital registration, verbal autopsy, and cancer registries were used across the globe to generate estimates. Incidence, mortality, and DALYs were estimated. All estimates are presented as counts and age-standardised rates per 100,000 person-years.

Results: Between 1990 and 2017 the global incidence of breast cancer increased significantly by 17.1% (95% uncertainty interval [UI]: 7.1–23.6; with 1.9 million incidences in 2017 [95% UI 1.9–2.0]; age-standardised rate of 45.9 [95% UI: 44.2–47.4]). However, over this same period the age-standardised death rate significantly decreased by 10.6% (95% UI: -19.5 to -4.4), with 600.7 thousand deaths in 2017 (95% UI: 578.7–630.0; age-standardised death rate of 14.1 95% UI: 13.6–14.8). Global DALYs also significantly decreased between 1990 and 2017 by 9.3% (95% UI: -19.9 to -1.6) with 17.4 million DALYs reported in 2017 (95% UI: 16.6–18.4; age-standardised rate of 414.7; 95% UI: 395.5– 437.6). Lebanon [138.3 (95% UI: 106.5–170.7)], the Netherlands [109.8 (95% UI: 97.4–122.7)], and the UK [102.6 (95% UI: 99.6–105.8)] had the three highest age-standardised incidence rates in 2017. Meanwhile, Pakistan [34.1 (95% UI: 20.9–71.3)], Tonga [34.0 (95% UI: 26.8–41.9)], and the Bahamas [33.3 (95% UI: 28.9–37.8)] had the three highest age-standardised death rates in 2017. Between 1990 and 2017, Saudi Arabia [232% (95% UI: 93–410)], Mauritius [174% (95% UI: 134–222)], and Taiwan [172% (95% UI: 141–208)] showed an increasing trend for the highest age-standardised incidence rate of breast cancer. Meanwhile, Mauritius [90% (95% UI: 66–117)], Philippines [76% (95% UI: 43–115)], and the Dominican Republic [69% (95% UI: 11–125)] produced the greatest significant increasing trend in age-standardised death rates. An increasing trend between population ageing and age-standardised incidence and death rates were observed globally, peaking among the oldest population grouping [incidence: 535.6 (95% UI: 511.8– 560.7); death: 251.4 (95% UI: 242.6–260.9)]. Non-linear associations were observed between age-standardised DALY rates with SDI and HAQ. Alcohol consumption [9.2% (95% UI: 7.7–10.7)], high fasting plasma glucose [6.1% (95% UI: 1.1–13.6)], and high body mass index [4.5% (95% UI: 1.4–8.5)] were the three largest contributors to breast cancer DALYs globally.

Conclusions: Remarkable inter-country variation exists in the burden of breast cancer. While there is a global downward trend in breast cancer age-standardised mortality rates, some countries are experiencing increases in age-standardised incidence and death rates from breast cancer. Prevention measures should be tailored to national-level estimates specific for each country and strengthened through early detection and treatment and public policy awareness campaigns aimed to reduce exposure to modifiable risk factors, particularly for countries with high incidence levels and/or increasing trends.

Introduction

Cancer accounted for 9.6 million deaths globally in 2017 according to the GBD 2017 study, 43% of which occurred in women [1, 2]. For women, breast cancer was found to be the most common cancer type (1.9 million incident cases) as well as the leading cause of cancer deaths (600.7 thousands deaths) and DALYs (17.4 million DALYs) [2]. Understanding global variations and trends in incidence, mortality, and disability-adjusted life years (DALYs) for breast cancer is important as it can be used to identify factors contributing to these variations as well as to inform evidence-based and nationally-tailored public policy interventions. Typically, breast cancer is studied in comparison with other cancers among women [3–5]. A few studies have examined the global burden of breast cancer over the last two decades, however, their estimates were in regional-level or selected countries up to 2012 and need to be updated [6–11]. Moreover, breast cancer trends have not been studied homogeneously and their time intervals are different across the countries studied [7, 12]. No comprehensive study has been conducted to compare the incidence, mortality, and DALYs for female breast cancer among different countries. Previous studies reported the only breast cancer incidence using GBD data for males and female combined [13]; and the associations of breast cancer burden, measured by DALYs, with socio-demographic Index (SDI; a composite of socio-demographic factors) and Healthcare Access and Quality (HAQ; an indicator of health system performance) index were not examined at country-level [14]. Therefore, the present study has considered these issues and provides global, regional, and national incidence, mortality, and DALYs for female breast cancer and its attributable risk factors in terms of counts and age-standardised rates across 195 countries between 1990 and 2017 by age, SDI and HAQ index.

Methods

Overview

The Global Burden of Diseases, Injuries, and Risk Factors (GBD) study is a comprehensive evaluation of 359 diseases and injuries, 282 causes of death, and 84 risk factors across 195 countries and territories, 21 regions, and seven super-regions. GBD 2017 provides the latest estimates for 2017, as well as updates for 1990–2016 data through additional data sources and new estimation methodology; features of which have been described in previous publications [15, 16]. In the current GBD 2017 study, 29 cancer groups were estimated, one of which was breast cancer, which is examined in the current study with 95% uncertainty intervals (UIs) calculated for all estimates and rates defined per 100,000 women.

Estimation framework

All cancers coded as C50–C50.629, C50.8–C50.929, Z12.3–Z12.39, Z80.3, Z85.3, Z86.000 from International Classification of Diseases (ICD) 10 were included in the breast cancer estimates [15]. Five sequalae with different disability weights (DWs) were defined for breast cancer (Appendix Table 1) [15]. Different data sources were used to estimate the non-fatal and fatal burden of breast cancer: vital

registration (19,327 site-years), vital registration-sample (793 site-years), verbal autopsy (445 site-years) and cancer registries (5,507 site-years) [15].

Table 1

Incident cases of female breast cancer and percentage change in age-standardised rates by location, 1990–2017

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Global	870,183	39·2	1,937,574	45·9	17·1
	(837,709, 927,102)	(37·8, 41·7)	(1,868,019, 2,000,363)	(44·2, 47·4)	(7·1, 23·6)
High-income North America	196,257	106·3	273,480	92·9	-12·6
	(193,078, 199,414)	(104·6, 108)	(263,517, 284,405)	(89·2, 96·6)	(-16·7, -8·8)
Canada	15,145	88·1	24,886	81·3	-7·8
	(14,262, 16,111)	(82·8, 93·7)	(22,239, 27,825)	(72·6, 91·2)	(-18·8, 4·7)
Greenland	10	49·6	13	39·5	-20·3
	(8, 11)	(37·8, 56·6)	(11, 18)	(32, 54·7)	(-39, 38·9)
USA	181,097	108·2	248,577	94·3	-12·8
	(178,011, 184,028)	(106·4, 110)	(239,289, 258,997)	(90·5, 98·4)	(-17·2, -8·7)
Australasia	9,668	80·1	18,659	84·7	5·8
	(9,358, 9,996)	(77·5, 83)	(16,261, 21,292)	(73·4, 97·2)	(-9·1, 21·8)
Australia	7,697	76·1	15,635	84·2	10·6
	(7,413, 8,005)	(73·3, 79·2)	(13,300, 18,360)	(71·2, 99·6)	(-7·8, 31·3)
New Zealand	1,970	100·1	3,024	87·2	-12·9
	(1,836, 2,117)	(93·4, 108)	(2,720, 3,383)	(78·3, 97·2)	(-23·7, -0·4)
High-income Asia-Pacific	33,899	30·8	91,510	52·4	69·9
	(32,869, 34,958)	(29·9, 31·8)	(85,434, 97,448)	(49, 55·8)	(57·5, 82·3)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Brunei	29 (23, 39)	41·3 (32·1, 55·5)	160 (130, 188)	74·7 (61·2, 86·5)	81·1 (28·1, 139·8)
Japan	29,588 (28,581, 30,623)	33·6 (32·4, 34·8)	71,762 (66,483, 76,949)	56·6 (52·6, 60·8)	68·6 (55·4, 82·3)
Singapore	633 (585, 685)	43·6 (40·5, 47·2)	2,038 (1,802, 2,298)	55·4 (49·1, 62·5)	27 (9·6, 46·7)
South Korea	3,648 (3,420, 3,889)	18·2 (17·1, 19·4)	17,549 (15,322, 19,962)	41·7 (36·5, 47·3)	128·8 (97·3, 165)
Western Europe	231,678 (227,674, 235,670)	80·8 (79·4, 82·3)	338,131 (321,227, 355,134)	86 (81·7, 90·2)	6·4 (0·9, 12)
Andorra	22 (16, 29)	75·5 (53·6, 100)	60 (42, 82)	93·4 (65·6, 127·1)	23·8 (-12, 71·2)
Austria	4,639 (4,368, 4,954)	78·2 (73·2, 83·8)	5,848 (5,264, 6,504)	72·8 (65, 81·5)	-6·9 (-18, 5·3)
Belgium	7,441 (6,971, 7,905)	99·7 (93·4, 106·3)	9,106 (8,127, 10,186)	90·3 (80·4, 101·5)	-9·4 (-20·7, 2·8)
Cyprus	258 (212, 304)	59·3 (48·9, 70)	813 (669, 970)	88·9 (72·9, 106·6)	50 (14·5, 105·4)
Denmark	3,321 (3,203, 3,444)	86·6 (83·3, 90)	4,584 (4,086, 5,096)	91·2 (81·2, 101·9)	5·3 (-6·8, 18·5)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Finland	2,495 (2,383, 2,602)	67·9 (64·5, 71)	4,325 (3,853, 4,874)	84 (74·7, 95·1)	23·7 (8·7, 40·8)
France	29,668 (27,985, 31,519)	72 (67·6, 76·7)	47,871 (43,091, 53,554)	81·3 (72·5, 91·6)	12·8 (-1·1, 29·6)
Germany	49,638 (47,765, 51,569)	75·2 (72·2, 78·2)	75,702 (64,147, 88,061)	93 (78·1, 109·5)	23·7 (4·2, 45·4)
Greece	4,252 (3,985, 4,540)	58·8 (55, 62·8)	7,896 (7,039, 8,808)	79·7 (71, 89·1)	35·6 (19, 54·4)
Iceland	126 (115, 138)	90·2 (82·4, 99·1)	183 (163, 203)	75 (66·8, 83)	-16·9 (-28·1, -4·3)
Ireland	1,773 (1,660, 1,889)	89·2 (83·3, 95·3)	3,267 (2,876, 3,725)	93·6 (82·2, 106·5)	5 (-8·9, 21·5)
Israel	1,733 (1,620, 1,845)	70·3 (65·6, 74·9)	4,004 (3,555, 4,491)	73·6 (65·3, 82·6)	4·7 (-8·7, 18·8)
Italy	35,688 (33,530, 37,903)	83·1 (77·9, 88·7)	49,500 (44,121, 55,000)	83·3 (74·3, 93·1)	0·1 (-12·5, 13·5)
Luxembourg	252 (233, 273)	89·3 (82·3, 97·1)	445 (370, 524)	96·8 (80·1, 113·9)	8·4 (-11·8, 30·6)
Malta	194 (180, 210)	83 (76·7, 89·7)	379 (337, 424)	96·2 (86, 107)	16 (1·1, 34·1)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Netherlands	10,579 (9,966, 11,311)	104·4 (97·9, 111·6)	16,269 (14,363, 18,201)	109·8 (97·5, 122·7)	5·2 (-8, 18·9)
Norway	1,976 (1,913, 2,044)	63·3 (61·2, 65·6)	3,100 (2,890, 3,330)	74·7 (69·5, 80·4)	18 (8·6, 27·9)
Portugal	4,261 (4,011, 4,516)	63 (59·2, 66·8)	6,816 (6,041, 7,700)	67·6 (59·6, 76·6)	7·2 (-6·6, 23·6)
Spain	16,315 (15,700, 16,909)	61·7 (59·2, 64·1)	26,390 (23,646, 29,458)	62·6 (56·1, 70·1)	1·4 (-9·6, 14·3)
Sweden	5,336 (5,153, 5,532)	78·3 (75·4, 81·3)	7,907 (7,220, 8,704)	90·8 (82·9, 99·7)	16 (5·1, 28)
Switzerland	4,539 (4,326, 4,738)	86·8 (82·6, 91)	5,683 (5,045, 6,354)	73·8 (65·3, 82·7)	-15 (-25·3, -3·7)
United Kingdom	46,950 (45,942, 47,934)	107·7 (105·3, 110·1)	57,633 (55,977, 59,376)	102·6 (99·6, 105·8)	-4·7 (-8·1, -1·3)
Southern Latin America	10,821 (10,415, 11,246)	42·5 (40·9, 44·2)	22,499 (20,093, 25,353)	52·8 (47·1, 59·6)	24·3 (10, 41·4)
Argentina	7,839 (7,453, 8,258)	44·4 (42·2, 46·8)	15,613 (13,281, 18,263)	56·3 (47·7, 66)	26·7 (6·8, 49·8)
Chile	1,748 (1,649, 1,854)	30·1 (28·4, 32)	5,025 (4,197, 5,938)	41·5 (34·5, 49)	37·7 (13·8, 65)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Uruguay	1,234	62	1,860	71·1	14·7
	(1,167, 1,306)	(58·4, 65·8)	(1,550, 2,176)	(58·8, 84·4)	(-6, 37·6)
Eastern Europe	62,637	39·6	96,422	53·2	34·3
	(59,859, 65,400)	(37·7, 41·5)	(92,737, 100,065)	(51·1, 55·4)	(26·7, 42·7)
Belarus	2,689	38·1	3,496	41·9	10
	(2,503, 2,872)	(35·3, 41)	(3,087, 3,964)	(36·8, 47·7)	(-5, 26·2)
Estonia	544	47·4	683	54·7	15·4
	(506, 581)	(43·8, 50·7)	(567, 823)	(44·9, 66·7)	(-6·2, 41·7)
Latvia	864	42·1	1,050	52·1	23·8
	(813, 922)	(39·6, 44·9)	(877, 1,247)	(43·2, 62·3)	(1·5, 49·4)
Lithuania	1,146	45·7	1,458	53·8	17·8
	(1,071, 1,223)	(42·6, 48·9)	(1,303, 1,628)	(47·6, 60·2)	(2·5, 34·4)
Moldova	972	37·4	1,229	40	6·8
	(914, 1,037)	(35·2, 40)	(1,104, 1,343)	(35·9, 43·7)	(-5·4, 19·3)
Russia	39,798	38·3	69,872	56·3	46·9
	(37,400, 42,267)	(35·8, 40·8)	(66,842, 72,847)	(53·8, 58·9)	(36·5, 58·9)
Ukraine	16,625	43	18,633	47·1	9·3
	(15,648, 17,566)	(40·5, 45·8)	(16,913, 20,527)	(42·6, 52·1)	(-3, 23)
Central Europe	36,280	45·8	59,660	59·5	29·8
	(35,302, 37,324)	(44·6, 47·1)	(56,933, 62,745)	(56·8, 62·6)	(23·3, 36·8)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Albania	211 (185, 237)	17·2 (15·2, 19·4)	685 (485, 931)	36·7 (25·7, 50·1)	113·1 (45·6, 199·5)
Bosnia and Herzegovina	583 (523, 641)	23·7 (21·3, 26)	1,430 (1,056, 1,656)	49·8 (36·6, 57·6)	110 (55·2, 145·5)
Bulgaria	2,908 (2,752, 3,065)	47·3 (44·8, 49·9)	4,299 (3,856, 4,811)	65·8 (58·9, 73·5)	38·9 (23·1, 57·7)
Croatia	1,989 (1,866, 2,129)	57·6 (54, 61·7)	2,681 (2,403, 2,995)	65·2 (58·1, 73·1)	13·1 (-0·3, 29)
Czech Republic	4,522 (4,268, 4,786)	61·7 (58, 65·5)	5,873 (5,249, 6,544)	60·8 (54·5, 67·8)	-1·6 (-13·7, 11·6)
Hungary	4,794 (4,530, 5,085)	61·6 (58·2, 65·5)	5,765 (5,181, 6,392)	61·5 (55·2, 68·5)	-0·1 (-11·7, 12·3)
Macedonia	439 (363, 485)	41·6 (34·9, 45·8)	907 (759, 1,067)	57·8 (47·9, 67·8)	38·9 (12·8, 73·7)
Montenegro	172 (147, 205)	49·4 (42·4, 58·5)	330 (268, 402)	69·2 (55·8, 84·6)	40·1 (17·1, 67·4)
Poland	9,763 (9,251, 10,307)	40·4 (38·2, 42·8)	19,139 (17,108, 21,381)	57·8 (51·8, 64·9)	43 (25·7, 62·2)
Romania	5,193 (4,890, 5,500)	35·8 (33·6, 38)	8,992 (8,132, 9,973)	53·2 (48·1, 59·1)	48·8 (33·2, 66·8)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Serbia	3,469	57·2	5,537	75·8	32·5
	(2,972, 4,081)	(49·1, 66·7)	(4,876, 6,343)	(66·8, 87)	(11·1, 56)
Slovakia	1,410	43·6	2,851	61·6	41·4
	(1,250, 1,509)	(38·7, 46·7)	(2,376, 3,277)	(52·4, 71·3)	(16·4, 67·1)
Slovenia	826	61·6	1,171	63·1	2·5
	(769, 886)	(57·3, 66·3)	(1,035, 1,335)	(55·3, 72·5)	(-11·9, 19)
Central Asia	7,678	27·1	16,504	35·9	32·6
	(7,431, 7,951)	(26·2, 28)	(15,400, 17,691)	(33·6, 38·4)	(23·2, 42·6)
Armenia	768	46·9	1,329	60·6	29
	(710, 831)	(43·5, 50·8)	(1,212, 1,453)	(55·3, 66·2)	(14·5, 45·9)
Azerbaijan	688	22·5	2,052	34·7	54·2
	(614, 756)	(19·9, 24·7)	(1,717, 2,433)	(29·1, 40·6)	(28·8, 81·6)
Georgia	1,776	52·1	1,835	63·2	21·2
	(1,634, 1,925)	(48, 56·6)	(1,657, 2,009)	(57·1, 69·1)	(7, 36·8)
Kazakhstan	2,195	27·2	3,764	36·5	34·4
	(2,066, 2,338)	(25·6, 28·9)	(3,333, 4,189)	(32·4, 40·6)	(18·4, 51)
Kyrgyzstan	456	25·8	624	22·4	-13·3
	(418, 498)	(23·6, 28·2)	(559, 694)	(20·2, 24·7)	(-23·7, -1)
Mongolia	78	12·7	261	17·2	36·1
	(65, 103)	(10·6, 16·6)	(208, 340)	(14, 21·4)	(0·4, 73)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Tajikistan	228 (198, 250)	14·1 (12·1, 15·5)	742 (606, 874)	21·3 (17·4, 24·9)	51·2 (24, 80·3)
Turkmenistan	210 (195, 226)	17·1 (15·9, 18·4)	872 (749, 1,004)	35·9 (31, 41·1)	109·4 (77·6, 144·4)
Uzbekistan	1,279 (1,196, 1,370)	18·4 (17·3, 19·7)	5,023 (4,171, 6,016)	33·2 (27·6, 39·5)	80·1 (48·9, 116·9)
Central Latin America	13,081 (12,794, 13,404)	25·6 (25·1, 26·3)	51,179 (48,491, 53,899)	39·5 (37·4, 41·6)	54 (45·5, 62·3)
Colombia	3,266 (3,088, 3,470)	31·1 (29·4, 32·9)	11,102 (9,357, 13,131)	38·6 (32·5, 45·5)	24·2 (3·9, 48·5)
Costa Rica	387 (360, 417)	38·7 (35·9, 41·7)	1,526 (1,353, 1,707)	56·9 (50·4, 63·6)	46·9 (28·3, 67·9)
El Salvador	265 (242, 295)	15·2 (13·9, 16·9)	1,115 (855, 1,439)	34·1 (26·2, 44)	124 (70·5, 192·7)
Guatemala	270 (253, 290)	12·3 (11·5, 13·2)	1,252 (1,055, 1,460)	19·6 (16·5, 22·9)	59·2 (33·4, 87·7)
Honduras	217 (182, 259)	17·5 (14·8, 20·6)	883 (605, 1,521)	26·4 (18·2, 43·4)	51·2 (2·1, 158·4)
Mexico	6,422 (6,273, 6,582)	24·2 (23·6, 24·8)	25,473 (24,625, 26,323)	39·4 (38·1, 40·7)	62·7 (56·5, 68·4)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Nicaragua	157 (134, 185)	15·8 (13·5, 18·4)	712 (579, 856)	26·8 (21·8, 32·1)	69·5 (30·8, 113·8)
Panama	244 (226, 262)	29·6 (27·5, 31·7)	899 (799, 1,010)	44 (39·2, 49·4)	49 (29·3, 70·5)
Venezuela	1,852 (1,727, 1,992)	30·8 (28·8, 33)	8,217 (6,552, 10,114)	52·3 (41·9, 64·4)	69·8 (34·9, 111·3)
Andean Latin America	2,129 (1,925, 2,393)	17·4 (15·8, 19·5)	8,216 (7,172, 9,507)	28·5 (24·9, 33)	64 (38·3, 95·5)
Bolivia	390 (253, 623)	19·9 (13·1, 31·3)	1,452 (1,057, 1,915)	30·3 (22, 40·1)	52·4 (-2·1, 135·1)
Ecuador	475 (450, 503)	15 (14·2, 15·9)	2,325 (2,004, 2,723)	29·5 (25·4, 34·5)	96·2 (66·9, 133·3)
Peru	1,264 (1,097, 1,440)	17·8 (15·4, 20·3)	4,439 (3,512, 5,685)	27·6 (21·9, 35·2)	55·3 (21·3, 100·6)
Caribbean	5,426 (5,056, 5,962)	38·4 (35·8, 42·1)	14,041 (12,497, 15,796)	52·6 (46·7, 59·3)	37 (22·6, 51·2)
Antigua and Barbuda	12 (11, 14)	44·1 (39·6, 49·3)	37 (33, 42)	66·9 (59·7, 74·7)	51·6 (30·7, 76·8)
The Bahamas	67 (61, 73)	67·8 (61·7, 74)	213 (181, 246)	96·8 (83·1, 111·7)	42·7 (19·4, 71·2)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Barbados	93 (86, 101)	62·2 (57·4, 67·7)	208 (181, 235)	87 (75·4, 98·4)	39·9 (18·1, 62·6)
Belize	8 (7, 9)	16·4 (14·3, 18·9)	37 (32, 42)	24·5 (21·6, 27·6)	49·1 (19·8, 80·8)
Bermuda	26 (24, 29)	73·3 (66·9, 80·2)	38 (32, 44)	59 (50·2, 68·3)	-19·6 (-33·4, -3·2)
Cuba	2,438 (2,287, 2,614)	46·1 (43·2, 49·4)	5,376 (4,560, 6,320)	57·8 (49, 68·4)	25·4 (4·9, 50·2)
Dominica	16 (14, 17)	42·2 (38·4, 46·2)	27 (23, 30)	61·6 (53·2, 69·9)	46·2 (25·1, 71)
Dominican Republic	369 (318, 452)	16·4 (14·2, 20·6)	2,151 (1,623, 2,693)	43·1 (32·6, 53·8)	162·7 (71·2, 250·5)
Grenada	16 (14, 17)	42·4 (38·3, 46·6)	43 (39, 48)	63·5 (57, 70·9)	49·8 (28·1, 74)
Guyana	57 (52, 61)	24·3 (22·5, 26·1)	133 (110, 160)	37·6 (31·3, 45·3)	55·2 (26·6, 90·4)
Haiti	524 (265, 1,004)	27·4 (14·7, 51·6)	1,478 (845, 2,397)	35·4 (21·2, 55·9)	29·3 (-16·8, 101·7)
Jamaica	359 (327, 397)	39·5 (35·9, 43·7)	1,009 (793, 1,266)	66·9 (52·5, 84·3)	69·4 (31·9, 117·8)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Puerto Rico	921 (860, 989)	47·3 (44·2, 50·8)	1,993 (1,757, 2,248)	63·4 (55·9, 71·7)	33·9 (15·1, 54·6)
Saint Lucia	22 (20, 24)	45·5 (41·6, 49·3)	60 (53, 68)	54·9 (48·3, 61·8)	20·5 (4·1, 39·9)
Saint Vincent and the Grenadines	18 (17, 20)	46·2 (42·1, 50·8)	39 (34, 44)	59·4 (52·8, 66·8)	28·5 (10·2, 48·4)
Suriname	35 (31, 39)	24·5 (21·8, 27·2)	109 (93, 127)	34·4 (29·5, 40·1)	40·7 (16·4, 70·2)
Trinidad and Tobago	231 (215, 248)	49·3 (45·9, 52·8)	513 (376, 681)	56 (41·1, 75·1)	13·7 (-16·3, 52)
Virgin Islands	28 (24, 32)	54·6 (47·6, 62·7)	73 (61, 85)	79·9 (67, 95·6)	46·2 (15·3, 84·9)
Tropical Latin America	16,327 (15,916, 16,740)	29·6 (28·9, 30·3)	53,787 (51,962, 55,667)	41·6 (40·2, 43·1)	40·6 (35·6, 46·1)
Brazil	16,035 (15,621, 16,448)	29·8 (29, 30·5)	52,607 (50,787, 54,481)	41·7 (40·2, 43·1)	40 (34·9, 45·4)
Paraguay	292 (257, 328)	23 (20·3, 26)	1,180 (879, 1,508)	40·6 (30·4, 51·8)	76·7 (33, 130·1)
East Asia	98,553 (89,015, 119,397)	19 (17·2, 23·1)	380,032 (319,781, 410,357)	35·9 (30·2, 38·8)	89·5 (17·4, 117·5)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
China	92,620 (83,418, 112,754)	18·9 (17, 23·1)	357,569 (298,190, 388,083)	35·6 (29·6, 38·6)	88·8 (14·6, 117·9)
North Korea	2,262 (1,622, 3,067)	20·9 (15·2, 28·3)	5,036 (3,527, 6,806)	29·1 (20·5, 39·6)	39·6 (-10, 106·7)
Taiwan (Province of China)	2,029 (1,947, 2,118)	22·5 (21·7, 23·5)	11,304 (10,128, 12,674)	61·4 (54·8, 68·7)	172·2 (141·1, 208)
Southeast Asia	41,129 (33,999, 51,023)	24·7 (20·6, 30·2)	124,436 (114,126, 134,729)	35·6 (32·7, 38·5)	44·3 (12·3, 77·2)
Cambodia	613 (355, 1,189)	19·4 (11·4, 37·9)	2,068 (1,610, 2,729)	28·3 (22·2, 37)	46 (-19·6, 154·1)
Indonesia	17,573 (13,982, 22,162)	26·1 (21, 32·6)	39,856 (35,922, 45,317)	30·3 (27·3, 35·3)	15·9 (-12·6, 50·2)
Laos	273 (144, 530)	21 (11·4, 40·4)	727 (517, 996)	26·7 (19·3, 36)	26·8 (-24·2, 123)
Malaysia	1,867 (1,380, 2,257)	32·6 (23·1, 39·5)	8,129 (5,958, 9,802)	57·6 (41·6, 69)	76·8 (43·5, 110·4)
Maldives	11 (4, 23)	20·8 (8·8, 43·1)	44 (36, 53)	27·1 (22·4, 32·3)	30·5 (-44·1, 232·2)
Mauritius	106 (97, 116)	23·2 (21·2, 25·3)	555 (488, 626)	63·6 (55·8, 71·7)	173·8 (134·1, 221·8)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Myanmar	6,055 (3,603, 9,317)	41·3 (25·4, 62·4)	12,788 (9,968, 16,100)	45·5 (35·6, 57·1)	10·1 (-32·2, 90·3)
Philippines	4,548 (4,088, 5,008)	23·6 (21·4, 25·9)	23,085 (18,451, 28,261)	52·8 (42·5, 64·8)	123·4 (79·7, 177)
Sri Lanka	1,116 (995, 1,295)	17·2 (15·3, 19·8)	4,009 (2,805, 5,297)	29·7 (20·9, 38·9)	73·4 (22·2, 128)
Seychelles	9 (8, 11)	30·3 (26·8, 36·1)	35 (28, 40)	59·9 (48·2, 68·2)	97·4 (44·2, 138·8)
Thailand	4,468 (3,981, 5,154)	19·2 (17·2, 21·8)	18,056 (14,073, 21,547)	34·9 (27·2, 41·8)	81·5 (31·5, 122·1)
East Timor	28 (17, 58)	14·1 (9, 28·8)	97 (58, 140)	22·8 (14, 32·5)	61·4 (-10·3, 176·1)
Vietnam	4,407 (3,276, 5,888)	18·2 (13·5, 24·2)	14,823 (11,295, 18,754)	27 (20·6, 34)	48·6 (-2·4, 112·8)
Oceania	611 (482, 866)	33·4 (27·6, 45·6)	1,704 (1,264, 2,367)	40·7 (31·9, 53·9)	22 (-0·2, 49·5)
American Samoa	5 (4, 6)	34·9 (28·4, 45·3)	16 (14, 19)	67·8 (57·9, 78·3)	94·1 (38·2, 159·7)
Federated States of Micronesia	8 (6, 12)	29·2 (21·7, 44·4)	18 (11, 27)	43·8 (29, 62·9)	49·7 (-7·7, 127·8)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Fiji	112 (58, 146)	46·7 (24·4, 60·3)	253 (115, 327)	60·5 (27·4, 77·9)	29·6 (-9·2, 78·7)
Guam	17 (14, 21)	35·2 (29·3, 42·8)	50 (41, 58)	55·5 (46·2, 64·6)	57·8 (18·1, 104·5)
Kiribati	6 (5, 8)	26·9 (23, 31·3)	14 (10, 19)	31 (22·2, 40·5)	15·5 (-21, 59·4)
Marshall Islands	3 (3, 5)	31·5 (25, 48·6)	11 (7, 16)	51·1 (34·5, 75·4)	62·2 (15·7, 120·1)
Northern Mariana Islands	6 (4, 8)	45·8 (35·1, 59·5)	16 (13, 20)	57·7 (47·9, 70)	26·2 (-8·5, 71·8)
Papua New Guinea	353 (232, 576)	30·1 (21, 47·5)	1,079 (695, 1,686)	36 (25·7, 52·7)	19·7 (-9·9, 61·9)
Samoa	12 (9, 15)	24·2 (18·3, 30·3)	19 (13, 25)	25·8 (18, 33·8)	6·7 (-25·1, 52·1)
Solomon Islands	19 (12, 33)	23·9 (16·5, 39·7)	63 (42, 101)	31·1 (22·8, 47·1)	30·4 (-9·8, 86)
Tonga	16 (14, 20)	53·2 (45·3, 62·7)	29 (23, 37)	67·1 (52·5, 84·2)	26·2 (-8·3, 67·8)
Vanuatu	13 (9, 19)	32·6 (22·4, 47·4)	41 (27, 62)	43 (28·6, 63·2)	31·7 (-6·7, 83·4)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
North Africa and Middle East	20,086 (16,508, 27,443)	19·7 (16·4, 26·8)	90,417 (84,474, 99,765)	36·9 (34·5, 41·5)	86·9 (33·5, 129·5)
Afghanistan	780 (243, 2,316)	22·1 (7·2, 64·6)	2,206 (917, 5,077)	27·8 (13·2, 62·3)	25·9 (-15·5, 143·7)
Algeria	1,318 (1,136, 1,545)	18·2 (15·7, 21·4)	6,701 (5,738, 7,665)	35·5 (30·5, 40·3)	95·4 (53·9, 137·4)
Bahrain	41 (35, 48)	38·8 (32·1, 46·2)	246 (205, 295)	50·5 (42·1, 59·3)	30·2 (0·4, 67·9)
Egypt	2,639 (2,221, 4,430)	14·4 (12·2, 26·1)	10,512 (8,117, 15,817)	28·4 (21·8, 45·6)	97 (52·1, 151·2)
Iran	2,753 (2,163, 3,735)	17·4 (13·9, 23·5)	16,048 (12,407, 17,620)	39·8 (31, 43·4)	128·3 (61·3, 189·5)
Iraq	1,657 (1,014, 2,588)	35·2 (22·5, 54)	3,596 (3,078, 4,293)	25·2 (21·7, 30·1)	-28·4 (-56·7, 24·7)
Jordan	301 (217, 426)	33 (24·3, 46·3)	1,731 (1,328, 2,216)	50 (38·4, 63·5)	51·6 (-8·3, 140·9)
Kuwait	170 (142, 198)	40·4 (34·6, 46·2)	577 (491, 662)	36 (31, 41·1)	-10·8 (-23·5, 5·6)
Lebanon	754 (557, 994)	53·8 (40·6, 70·6)	4,958 (3,812, 6,124)	138·3 (106·5, 170·7)	156·9 (63, 286)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Libya	207 (154, 306)	20·3 (15·3, 29·7)	1,510 (1,161, 1,901)	50·9 (39·6, 63·9)	150·7 (47·5, 262·2)
Morocco	2,353 (1,582, 3,149)	27·7 (19·9, 36·8)	8,746 (6,252, 11,687)	48·5 (35·3, 64·3)	75·4 (8, 157·6)
Palestine	179 (117, 273)	33·6 (21·8, 50·4)	699 (584, 807)	47·8 (40, 55·2)	42·3 (-13·7, 118·4)
Oman	65 (44, 95)	16·5 (11·3, 24·1)	384 (292, 486)	36 (27·1, 45·1)	118·1 (35·9, 232·6)
Qatar	29 (20, 40)	49·9 (37·4, 67·2)	331 (254, 420)	89·2 (69·4, 112·1)	78·9 (13·5, 159·6)
Saudi Arabia	459 (334, 665)	13·8 (10·1, 20·3)	5,184 (3,864, 6,911)	45·6 (35·2, 59)	231·7 (93·4, 410·4)
Sudan	683 (340, 1,511)	12·7 (6·7, 27·2)	2,169 (1,295, 3,617)	19·6 (12·4, 31·5)	54·9 (-4·9, 141)
Syria	511 (377, 724)	16·3 (12·3, 22·9)	2,263 (1,694, 2,898)	30·8 (23·3, 38·9)	88·6 (16·8, 175·8)
Tunisia	618 (533, 740)	22·4 (19·4, 26·9)	2,880 (2,072, 3,941)	44 (31·6, 59·9)	96·4 (30·4, 178·2)
Turkey	4,130 (3,244, 5,741)	19·7 (15·5, 27·5)	16,762 (14,196, 20,596)	35·9 (30·5, 44·2)	82·3 (31·9, 140·4)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
United Arab Emirates	71 (50, 107)	30·7 (20·5, 47·3)	1,098 (802, 1,460)	64 (47·4, 82)	108·9 (19·4, 218·8)
Yemen	353 (161, 877)	11·4 (5·6, 27)	1,728 (1,059, 2,859)	20·8 (13·4, 33·4)	82·2 (-0·4, 211)
South Asia	52,678 (45,819, 66,276)	15·6 (13·7, 19·5)	207,970 (179,497, 246,149)	27·6 (23·8, 32·6)	76·7 (27, 110·1)
Bangladesh	3,205 (2,572, 4,189)	11·9 (9·5, 15·7)	13,749 (11,127, 16,786)	20·5 (16·6, 24·9)	73 (17·8, 139·7)
Bhutan	26 (17, 44)	17·7 (11·7, 29·2)	77 (50, 139)	22·4 (14·6, 40·1)	26·5 (-31·6, 120·6)
India	38,997 (31,931, 49,742)	14·1 (11·9, 17·9)	153,134 (135,472, 166,155)	25·3 (22·4, 27·5)	79·4 (29·3, 116·4)
Nepal	931 (589, 1,531)	16·5 (10·7, 27·5)	2,674 (1,896, 4,943)	21·4 (15·4, 39·6)	30·1 (-23·4, 101·1)
Pakistan	9,518 (6,641, 16,681)	31·9 (21·8, 57·3)	38,336 (24,035, 77,401)	56·8 (35·4, 116·4)	78 (7·8, 150·8)
Southern sub-Saharan Africa	4,168 (3,827, 4,562)	23·7 (21·7, 26·3)	10,320 (9,350, 11,228)	30·3 (27·4, 32·7)	27·7 (13·5, 39·6)
Botswana	69 (48, 97)	19·4 (13·9, 26·4)	297 (239, 363)	33·6 (27·4, 41·1)	73·6 (17·3, 163·9)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Lesotho	100 (77, 132)	17·5 (13·7, 23·1)	218 (144, 310)	29·7 (19·6, 41·6)	69·3 (12·5, 152·7)
Namibia	108 (75, 156)	25·8 (18, 37)	365 (253, 498)	41·6 (29, 56·8)	61·4 (-1·2, 158)
South Africa	3,420 (3,140, 3,735)	25·3 (22·9, 28·1)	8,157 (7,170, 9,270)	30·5 (26·8, 34·2)	20·5 (7·2, 32·4)
Swaziland	38 (28, 56)	20 (14·5, 29·4)	107 (69, 155)	29·7 (19·4, 42·4)	48·5 (-10·4, 138·3)
Zimbabwe	432 (355, 521)	17·3 (14·4, 20·9)	1,175 (734, 1,528)	26·3 (18·1, 33·4)	51·4 (-1·4, 106·8)
Western sub-Saharan Africa	14,437 (10,033, 20,540)	29·6 (20·6, 41·7)	45,786 (34,747, 60,607)	39·4 (30·2, 51·7)	33·1 (-11·3, 104·8)
Benin	192 (152, 241)	16·3 (12·9, 20·4)	665 (481, 865)	22·6 (16·5, 29·1)	38·8 (-1·8, 87·6)
Burkina Faso	737 (592, 976)	27 (21·8, 37)	1,840 (1,415, 2,453)	30·5 (23·6, 42·2)	13·1 (-18·2, 48·2)
Cameroon	575 (436, 737)	21 (15·9, 26·9)	1,889 (1,213, 2,655)	26·3 (17·1, 37·2)	25·6 (-13·4, 76)
Cape Verde	19 (16, 21)	15·1 (12·8, 17·5)	64 (55, 76)	26·2 (22·4, 30·7)	73·5 (41·5, 116·7)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Chad	243 (189, 341)	14·9 (11·5, 20·8)	608 (420, 927)	19·9 (13·9, 30·9)	33·5 (-5·1, 85·5)
Cote d'Ivoire	562 (436, 690)	22·4 (17·7, 27·4)	1,836 (1,283, 2,450)	29·5 (20·8, 38·9)	31·5 (-13, 83)
The Gambia	24 (18, 30)	11·9 (9·2, 15)	105 (69, 139)	19·5 (13, 25·8)	64 (1·9, 132·1)
Ghana	852 (616, 1,137)	21·1 (15·4, 28)	3,174 (2,412, 3,986)	30·5 (23·2, 38·2)	44·8 (-5·7, 109·6)
Guinea	333 (279, 393)	17·8 (14·9, 21·1)	786 (541, 999)	25·1 (17·3, 31·9)	40·9 (-4·1, 86·5)
Guinea-Bissau	52 (34, 77)	20·2 (13·8, 30)	130 (89, 182)	27·4 (19·1, 38·1)	35·6 (-6·7, 90·6)
Liberia	103 (79, 135)	18 (14, 23·2)	292 (207, 408)	24·2 (17·4, 33·3)	34·5 (-7·7, 90·5)
Mali	451 (380, 525)	18·8 (15·8, 21·9)	1,138 (771, 1,568)	23·4 (16, 31·5)	25 (-17·3, 78·1)
Mauritania	128 (95, 171)	22·3 (16·5, 29·6)	347 (265, 447)	29·9 (22·9, 38·7)	34·2 (-6·8, 87·2)
Niger	239 (185, 334)	14·1 (10·9, 19·8)	734 (518, 1,118)	16·2 (11·6, 24·6)	14·4 (-16·1, 52·4)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Nigeria	9,257	40·6	29,929	54·3	33·8
	(5,167, 15,002)	(22·8, 65)	(18,978, 44,365)	(35, 79·7)	(-23·4, 157·9)
Sao Tome and Principe	5	14·6	20	30·5	108·7
	(4, 6)	(12·1, 17·4)	(13, 26)	(19·3, 40·9)	(33·5, 184·6)
Senegal	329	17·7	1,097	25·5	44·1
	(260, 444)	(14, 23·8)	(800, 1,563)	(18·7, 36·3)	(6·6, 90·9)
Sierra Leone	181	17	548	26·9	58·3
	(143, 231)	(13·5, 21·6)	(392, 753)	(19·3, 37·1)	(6·9, 134·3)
Togo	156	18·4	584	24·4	32·5
	(128, 191)	(15·2, 22·7)	(430, 774)	(18·1, 32·2)	(-7·5, 81·9)
Eastern sub-Saharan Africa	10,009	21·2	24,820	24·1	13·7
	(7,722, 13,854)	(16·7, 29·2)	(21,561, 28,701)	(21·1, 27·9)	(-23·8, 56·9)
Burundi	336	23·2	541	21·3	-8
	(216, 505)	(15·3, 34·2)	(402, 731)	(16, 28·7)	(-38·9, 36·6)
Comoros	29	23·7	90	32·4	36·7
	(22, 39)	(17·9, 31·1)	(62, 120)	(22·4, 43·2)	(-20·5, 105·4)
Djibouti	24	23·3	113	31·6	35·4
	(16, 34)	(16·2, 33·5)	(73, 167)	(20·9, 45·6)	(-15·4, 110·8)
Eritrea	160	23·5	565	33·9	44·7
	(108, 230)	(16·3, 32·6)	(403, 766)	(24·8, 44·7)	(-10·5, 124·5)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Ethiopia	3,019	24	6,409	25·3	5·4
	(1,773, 5,223)	(14·9, 40·7)	(5,318, 8,109)	(21·3, 32·3)	(-42·7, 94·4)
Kenya	891	17·4	3,323	23·8	36·7
	(662, 1,307)	(13, 25·4)	(2,641, 4,080)	(19, 29·1)	(-5·9, 67·4)
Madagascar	653	21	1,654	23·2	10·2
	(519, 819)	(16·8, 26·4)	(1,240, 2,171)	(17·3, 30)	(-22·5, 49)
Malawi	337	13·5	758	16·1	19·4
	(190, 441)	(8·1, 17·4)	(486, 1,051)	(10·3, 22·2)	(-32·5, 110·4)
Mozambique	840	20·6	2,000	26·1	26·8
	(652, 1,043)	(16·2, 25·2)	(1,406, 2,676)	(18·6, 34·5)	(-13·3, 77·8)
Rwanda	424	22·3	932	23·6	5·7
	(308, 672)	(16·6, 34·8)	(548, 1,382)	(14·2, 34·3)	(-44·8, 89·1)
Somalia	336	18·9	910	22·7	19·8
	(173, 551)	(10·9, 30·6)	(646, 1,256)	(16·3, 31·2)	(-26·2, 106·8)
South Sudan	261	20·7	508	21	1·6
	(160, 425)	(13·4, 33·2)	(356, 741)	(14·9, 30·3)	(-32·1, 56·8)
Tanzania	1,247	18·8	3,523	22·9	21·8
	(840, 1,701)	(13·4, 25·3)	(2,665, 4,711)	(17·6, 30·2)	(-20·2, 81·2)
Uganda	930	23·9	2,345	25·6	7·2
	(694, 1,151)	(18, 29·2)	(1,703, 3,131)	(18·8, 33·9)	(-28, 65·4)

	1990		2017		Percentage change in age-standardized rates between
	Counts (95% UI)	Rate (95% UI)	Counts (95% UI)	Rate (95% UI)	1990 and 2017
Zambia	516 (349, 753)	28·4 (20·1, 40·7)	1,135 (875, 1,473)	26·6 (20·6, 34·3)	-6·1 (-43·6, 47·3)
Central sub-Saharan Africa	2,631 (1,848, 4,101)	18·3 (13·5, 27·5)	8,001 (6,084, 10,539)	24·4 (19·3, 31·4)	33·4 (-2, 71·9)
Angola	446 (266, 841)	18 (11·6, 32·8)	1,753 (1,281, 2,423)	23·9 (17·7, 32·3)	32·7 (-17·6, 113·8)
Central African Republic	175 (107, 280)	23·5 (15·5, 36·3)	387 (218, 653)	29·1 (17·5, 47)	24·1 (-19·1, 82·2)
Congo	185 (114, 292)	27·2 (17·7, 41·9)	647 (391, 1,010)	40·4 (26·5, 59·3)	48·6 (-1·8, 109·3)
DR Congo	1,725 (1,189, 2,664)	17·1 (12·4, 25·6)	4,900 (3,483, 6,919)	22·6 (16·7, 31)	32·5 (-7, 81)
Equatorial Guinea	24 (13, 46)	19·3 (11·1, 36·2)	111 (65, 176)	33·3 (19·7, 52·6)	72·7 (-22, 252·8)
Gabon	77 (58, 105)	23·8 (18·4, 32·2)	203 (142, 267)	32·9 (23·1, 42·7)	37·9 (-12·6, 94·8)

Mortality estimation

As there is less cancer mortality than incidence data available globally, mortality-to-incidence ratios (MIR) were used to transform incidence data to mortality estimates. These ratios were modeled by linear-step mixed effect models in locations where both incidence and death data existed for the same year and were adjusted for age, sex, and HAQ. Spatiotemporal Gaussian process regression (ST-GPR) was used to smooth estimates across space and time [15]. Mortality estimates were calculated by multiplication of 5-year age group, sex, and location-specific MIRs and incidence estimates. These mortality estimates as

well as direct mortality data from VR and VA sources were included in the Cause of Death Ensemble Model (CODEm) [15]. This model uses various individual models to provide a single model with the best fit using all available data and covariates. Covariates used in CODEm are listed in Appendix Table 2.

Incidence, prevalence, and disability estimation

Final incidence estimates were computed by dividing the final GBD 2017 breast cancer mortality estimates by the corresponding MIRs. Breast cancer prevalence was estimated by using the MIRs in each country to estimate survival. Prevalence was divided into four sequalae and mastectomy was not considered here (Appendix Table 1). Sequelae-specific years lived with disability (YLDs) were calculated as the product of sequelae-specific prevalence and corresponding DWs. Years of life lost (YLLs) were calculated by multiplying the estimated number of deaths by age with a standard life expectancy at that age. Finally, DALYs were calculated by summing YLDs and YLLs.

This study also examined the association of breast cancer burden in terms of DALYs with SDI and HAQ for 195 countries and determined the expected burden of breast cancer in each country based on their SDI and HAQ level. SDI is a composite indicator of lag-dependent income per capita, average years of schooling for the population older than 15 years of age, and total fertility rate under the age of 25. It ranges from 0 (less developed) to 1 (most developed). HAQ measures personal healthcare access and quality for 195 countries and is calculated based on amenable mortality i.e. deaths from causes that should not occur in the presence of effective medical care. This index ranged from 0 (worst) to 100 (best). Additional details for HAQ have been presented previously [17].

Risk factors

Risk factors that had evidence of causation with breast cancer were selected in the present study [16]. The percentage of breast cancer DALYs attributable to alcohol consumption, high fasting plasma glucose, high body mass index, secondhand smoke, smoking, and low physical activity are reported. Definitions for these risk factors and their relative risk for breast cancer can be found elsewhere [16].

Results

Global level

Breast cancer among women accounted for 1.9 million (95% UI: 1.9–2.0) incident cases in 2017 (age-standardised rate of 45.9 per 100,00 women [95% UI: 44.2–47.4]), which increased significantly by 17.1% (95% UI: 7.1–23.6) between 1990 and 2017 (Table 1). It was also reported as the cause of death among 600.7 thousand women in 2017 (95% UI: 578.7–630.0), with an age-standardised death rate of 14.1 per 100,000 women (95% UI: 13.6–14.8), which decreased by 10.6% between 1990 and 2017 (95% UI: -19.5 to -4.4) (Appendix Table 3). Furthermore, breast cancer accounted for 17.4 million (95% UI: 16.6–18.4) DALYs in 2017, with an age-standardised rate of 414.7 per 100,000 women (95% UI: 395.5–437.6), which was identified as a decrease of 9.3% globally between 1990 and 2017 (95% UI: -19.9 to -1.6; Appendix Table 4).

Regional level

The age-standardised incidence rate for breast cancer per 100,00 women in 2017 was highest in high-income North America (92.9 [95% UI: 89.2−96.6]), western Europe (86.0 [95% UI: 81.7−90.2]), and Australasia (84.7 [95% UI: 73.4−97.2]). In contrast, eastern sub-Saharan Africa (24.1 [95% UI: 21.1−27.9]), central sub-Saharan Africa (24.4 [95% UI: 19.3−31.4]), and south Asia (27.6 [95% UI: 23.8−32.6]) were found to have the lowest rates (Fig. 1A, Table 1). The age-standardised death rate for breast cancer per 100,00 women in 2017 was highest in western sub-Saharan Africa (23.9 [95% UI: 18.6−30.6]), Oceania (23.2 [95% UI: 18.9−29.5]), and southern Latin America (19.6 [95% UI: 17.6−22.1]). Meanwhile, east Asia (8.6 [95% UI: 7.2−9.2]), high-income Asia Pacific (9.0 [95% UI: 8.6−9.4]), and Andean Latin America (11.3 [95% UI: 10.0−13.0]) reported the lowest rates (Fig. 1A, Appendix Table 3). Regions reporting the highest percentage increase in age-standardised incidence rates between 1990 and 2017 were east Asia (89% [95% UI: 17−117]), north Africa and the Middle East (87% [95% UI: 33−130]), and south Asia (77% [95% UI: 27−110]). In contrast, a significant decrease in trend was observed for high-income North America (-13% [95% UI: -17 to -9]) (Fig. 1B, Table 1). Regions reporting the greatest significant increasing trends in age-standardised death rates were high-income Asia Pacific (17% [95% UI: 12−23]), southern sub-Saharan Africa (13% [95% UI: 0−25]), and central Asia (9% [95% UI: 3−16]). Meanwhile, high-income North America (-33% [95% UI: -35 to -30]), western Europe (-31% [95% UI: -35 to -28]), and Australasia (-31% [95% UI: -39 to -22]) experienced the greatest decreasing trend in age-standardised death rate during 1990−2017 (Fig. 1B, Appendix Table 3). The number of incident cases increased from 870,183 in 1990 to 1,937,574 in 2017 and east Asia, western Europe, and high-income North America were the regions with the highest number of incident cases between 1990 and 2017 (Fig. 2A, Table 1). The number of deaths increased from 344,905 in 1990 to 600,727 in 2017. Western Europe, high-income North America, and east Asia had the highest number of deaths in 1990 whereas south Asia, east Asia, and western Europe had the greatest number of deaths in 2017 (Fig. 2B, Appendix Table 3).

National level

The age-standardised incidence rate of breast cancer in 2017 ranged from 16.1 to 138.3 per 100,000 women among the 195 countries. Lebanon (138.3 [95% UI: 106.5−170.7]), the Netherlands (109.8 [95% UI: 97.4−122.7]), and the UK (102.6 [95% UI: 99.6−105.8]) had the highest age-standardised incidence rate. In contrast, Malawi (16.1 [95% UI: 10.3−22.2]), Niger (16.1 [95% UI: 11.6−24.6]), and Mongolia (17.2 [95% UI: 13.9−21.4]) showed the lowest age-standardised incidence rate (Fig. 3A, Table 1). The age-standardised death rate in 2017 also varied between countries (from 8.0 to 34.1 per 100,000 population). Pakistan (34.1 [95% UI: 20.9−71.3]), Tonga (34.0 [95% UI: 26.8−41.9]), and the Bahamas (33.3 [95% UI: 28.9−37.8]) had the highest age-standardised death rates. Meanwhile, South Korea (8.0 [95% UI: 7.2 to 8.8]), China (8.5 [95% UI: 7.1−9.1]), and Guatemala (8.5 [95% UI: 7.3−9.8]) showed the lowest age-standardised death rates (Fig. 3B, Appendix Table 3).

Countries with the highest increasing percentage change in age-standardised incidence rates for breast cancer during 1990−2017 were Saudi Arabia (232% [95% UI: 93−410]), Mauritius (174% [95% UI: 134−

222]), and Taiwan (172% [95% UI: 141–208]). Whereas Bermuda (-20% [95% UI: -33 to -3]), Iceland (-17% [95% UI: -28 to -4]), and Switzerland (-15% [95% UI: -25 to -4]) showed the greatest decreases (Table 1). Moreover, Mauritius (90% [95% UI: 66–117]), Philippines (76% [95% UI: 43–115]) and Dominican Republic (69% [95% UI: 11–125]) showed the greatest significant increases in age-standardised death rates. In contrast, Bermuda (-46% [95% UI: -55 to -37]), Switzerland (-44% [95% UI: -50 to -38]), and Iceland (-40.5% [95% UI: -47.2 to -33.8]) experienced the greatest decreasing trends in age-standardised death rates between 1990 and 2017 (Appendix Table 3).

Age pattern

Globally, the number of incident cases was highest in the 50–54 age group (240,104 [95% UI: 229,057–250,417]) and incidence rates showed increasing trends with population ageing, peaking in the oldest group (535.6 [95% UI: 511.8–560.7]) (Fig. 4A). The global number of deaths peaked in the 60–64 age group (70,295 [95% UI: 67,065–73,948]), and age-standardised death rates peaked in the oldest group (251.4 [95% UI: 242.6–260.9]) (Fig. 4B). YLLs were the primary contributor to DALYs, with the number of YLLs (2,439,926 [95% UI: 2,325,635–2,589,587]) and corresponding rate (1246.1 [95% UI: 1188.7–1315.9]) peaking in the 50–54 and 55–59 age groups respectively (Appendix Fig. 1).

Burden of breast cancer by SDI and HAQ

The current study identified a non-linear association between age-standardised DALY rate of breast cancer for GBD regions and SDI between 1990 and 2017. The global burden of breast cancer was higher than expected in the initial years of measurement but decreased to lower than expected levels after 2003. High-income North America, western Europe, Australasia, the Caribbean, southeast Asia, Oceania, and western sub-Saharan Africa had a higher than expected disease burden based on their SDI level throughout the estimated times series. Whereas central Europe, eastern Europe and central Asia, southern Latin America, Tropical Latin America, and central Asia had lower than expected levels in recent years (Fig. 5A). The association between age-standardised DALY rate and SDI in 2017 was also examined for 195 countries and non-linear associations were shown between two variables. There were countries with various level of SDI that had higher than expected levels of breast cancer burden, such as the Bahamas, Pakistan, Tonga, Nigeria, Lebanon, and Fiji. In contrast, some countries such as Mongolia, Guatemala, China, Maldives, Kuwait, and South Korea had much lower than expected breast cancer burden (Fig. 5B). Interestingly, non-linear and negative associations were found between age-standardised DALY rate and HAQ for 195 countries. There were many countries with higher than expected disease burden based on their HAQ, such as the Bahamas, Pakistan, Tonga, Nigeria, Lebanon, and Fiji, reporting the highest difference with their expected levels. In contrast, some countries such as Mongolia, Guatemala, China, Maldives, Kuwait, and South Korea had a much lower than expected level of breast cancer burden (Appendix Fig. 2).

Risk factors

Although the percentage of attributable breast cancer DALYs for risk factors were different in the GBD regions, alcohol consumption (9.2% [95% UI: 7.7–10.7]), high fasting plasma glucose (6.1% [95% UI: 1.1–13.6]), and high body mass index (4.5% [95% UI: 1.4–8.5]) were the top three contributors to percent of breast cancer DALYs globally (Fig. 6). Alcohol consumption had the greatest attributable burden in most of the GBD regions but high body mass index and high fasting plasma glucose were found to have higher attributable burden than alcohol consumption in Southeast Asia, East Asia and Oceania (Fig. 6). The percent of breast cancer DALYs attributable to risk factors showed variable patterns across age groups, particularly for high body mass index. The highest percentage of attributable DALYs due to breast cancer for alcohol use (11.5% [95% UI: 8.0–15.1]), high fasting plasma glucose (10.9% [95% UI: 2.2–23.8]), and high body mass index (11.5% [95% UI: 5.4–19.2]) were seen among the 95 plus, 85–89, and 60–64 age groups respectively (Appendix Fig. 3).

Discussion

The current study reports the incidence, deaths, and DALYs for age-standardised rates for breast cancer across 195 countries between 1990 and 2017. Globally, there was a significant increase in age-standardised incidence rates, while age-standardised death and DALY rates were found to have a declining trend. Several regions, such as south Asia, southern sub-Saharan Africa, and high-income Asia Pacific, Caribbean, central Asia, central Latin America, and eastern Europe showed different patterns with significant increase in both incidence and death age-standardised rates. Attempts were made to compare our findings with previous studies, however, no studies were available to allow a direct comparison at the country-specific level to determine the burden of breast cancer comprehensively. The closest comparator was from the Global Cancer Incidence, Mortality and Prevalence (GLOBOCAN) project. However, data is not annually updated to allow direct comparison of GBD with GLOBOCAN for the same time periods. In particular, despite availability of 2018 GLOBOCAN data no estimates have been reported for the time period 2013 to 2017. Based on available data, the GLOBOCAN 2018 estimated 2,088,849 (95% UI: 2,003,730–2,177,580) incident cases for breast cancer, which is relatively higher than our 2017 estimates (1,937,574 [95% UI: 1,868,019–2,000,363]). Likewise, GLOBOCAN 2018 estimated 626,679 (95% UI: 606,077–647,981) deaths in 2018, which is also higher than our 2017 estimates (600,728 [95% UI: 578,725–629,932]) [18]. Although the age-standardised rates reported in GLOBOCAN and GBD could not be compared due to differences in the standard population, the ranking of countries could be compared. Belgium, Luxembourg, and the Netherlands had the highest age-standardised incidence rates of breast cancer in GLOBOCAN 2018; while, in 2017, Lebanon, the Netherlands, and the UK were found to have the highest age-standardised incidence rate in our study. Age-standardised death rates were highest in Fiji, Barbados, and Somalia in GLOBOCAN 2018, while our 2017 data found Pakistan, Tonga, and the Bahamas to have the highest age-standardised death rates [18]. These differences may be attributed to different data sources and estimating methodology. However, other studies have also reported differences in breast cancer incidence and death rates for selected countries over time, across different iterations of the GLOBOCAN project, which are not comparable with our findings as their estimates are up to 2012 [4, 7, 9–12, 19, 20]. An important point is that both GLOBOCAN and GBD studies indicate that

incidence rates of breast cancer were highest in developed countries, while death rates were highest in some developing countries and some of these differences between the developed and developing countries could be explained by different prevalence of aetiological factors (i.e. alcohol consumption and high body-mass index), as well as the variations in cancer prevention, screening practice, advances in diagnosis, treatment, and oncology care, and management of health resources [12].

The trend of age-standardised incidence rate is also reported in some studies across the selected countries. A study reported increasing trends of age-standardised incidence rate for breast cancer in Australia, Ireland, Japan, the Netherlands, England, Sweden, and the USA during 1980–2009 [7]. While our study found that all of the aforementioned countries had increasing trends in age-standardised incidence rate during 1990–2017, except the USA (-13% [95% UI: -17 to -9]) and the UK (-5% [95% UI: -8 to -1]), which showed significant decreasing trends in the measurement period. Another study [11] examined the trend in age-standardised incidence and death rate for some selected countries with various time intervals, mainly during 1980–2010. They reported that age-standardised incidence rate increased for the USA, Denmark, Italy, Australia, Russia, Costa Rica, and China. Again, our study identified somewhat conflicting results finding that age-standardised incidence rates increased for all of the aforementioned countries, with the exception of the USA (-13% [95% UI: -17 to -9]) between 1990 and 2017. They also reported that age-standardised death rates are decreasing for Denmark, Italy, the USA, and Australia. In contrast, Japan, Russia, the Philippines, and China experienced an increasing trend in their study period (mainly 1980–2010) [11]. The decline in breast cancer mortality among women in developed countries may be explained by a number of reasons, most notably the introduction of a screening program (mammography) and improvement in therapy [21]. Our study found that age-standardised death rates decreased for all of these countries, except for the Philippines (76% [95% UI: 43–115]), Japan (22% [95% UI: 17–28]), and Russia (11% [95% UI: 7–14]).

Besides a considerable decrease in the mortality of breast cancer in the world during the period 1990–2017, global incidence increased over the period of study. The significant differences in breast cancer burden observed between countries could be explained by different applied methodology and the varying data quality worldwide. Also, the considerable variations in breast cancer burden can be attributed to differences in prevalence of risk factors, differences in cancer prevention and treatment, and management of health resources. Therefore, it is imperative that policy makers consult multiple data sources and consider results that provide the most representative and comprehensive information available for their country. Global- or regional-level estimates of breast cancer burden may be misleading for national policy, as there are some countries that follow completely different patterns compared to their regional estimates. When making public health policy decisions, individual countries should consider trends in breast cancer burden as well as their expected levels of burden as part of informed judgments. Modifiable risk factors such as alcohol use [22], high fasting plasma glucose [23], high body mass index [24], smoking [25], second hand smoke exposure [26], and low physical activity [27], are all reported to be associated with breast cancer burden. Breast cancer incidence and mortality increase with age and have a distinctive age-specific curve, with the age group 50–54 dividing the trends of mortality into premenopausal and postmenopausal periods. According to our results, this observation could be

related to, besides the hormonal milieu, exposure to all of the described risk factors which generally increased after the age of 50. Therefore, country-level health professionals could be promoting community awareness regarding prevention programs and associated risk factors through using appropriate health education plans to decrease the breast cancer burden as much as possible. Data from this study can be used to determine trends over time, benchmarking with other similar countries and regions. In addition, this evidence can be used by policy makers to determine factors contributing to country-specific differences within regions and subsequently inform a matrix of policy options that will best meet the economic, public health, political, and societal needs of the country.

Associations between the socioeconomic development level of each country and breast cancer incidence/death rate has been studied previously, in which a positive association between breast cancer incidence and a country's development level in 2012 was reported [28]. These results should be interpreted with caution as income alone was used as the determining factor, which on its own is an inadequate indicator of a country's level of development. In our study we used SDI to examine socioeconomic development, which more comprehensively reflects socioeconomic development because it is a composite indicator of education, income, and fertility rate. In addition to SDI, we also report breast cancer burden by HAQ, which shows the burden of breast cancer may be decreasing with successive increments of HAQ. This suggests that publicly funded interventions such as breast cancer screening and appropriate treatment services can decrease breast cancer burden. The previous studies indicate that all of the observed reductions could not be attributable to screening alone [29–31] and it need to be considered along with education, treatment and care. For example, a study in Norway found that screening itself accounted for only about a fourth of the total reduction [32]. However, some studies reported larger contribution of screening measures, up to 60%, in decreasing the breast cancer mortality rates [33, 34]. The national-level analysis found that although SDI of countries may not be associated with breast cancer age-standardised DALY rate, it is negatively associated with HAQ. Therefore, this approach allowed us to compare the observed breast cancer burden with corresponding expected levels based on SDI (in regional- and country-level) and HAQ (in country-level) for the first time across the globe.

The present study is the most comprehensive and up-to-date study to examine level and trends of incidence, mortality, and DALYs associated with breast cancer during the last three decades globally. As with all research, this study had a number of limitations, including the fact that some variations in incidence and mortality may be due to detection biases, such as changes in screening protocols. GBD accounts for ascertainment bias by adjusting single cause estimates to the all-cause mortality envelope. There was data sparsity in some countries such as Iraq and Afghanistan and their estimations were subsequently conducted based on predictive covariates and neighboring locations and should be interpreted with caution. Moreover, HAQ was not available for 2017 and as such we had to examine the association between HAQ and corresponding age-standardised DALY rate for 2016. Finally, there are several other and stronger risk factors for breast cancer, e.g. age at menarche, age at first pregnancy, breast feeding history, use of contraceptives and low number of pregnancies that were not considered in the paper because their associations with breast cancer risk are not fully established.

Conclusion

Remarkable inter-country variation was observed in the burden of breast cancer. Globally, the age-standardised rates of death and DALYs due to breast cancer is decreasing, while the corresponding age-standardised incidence rate is increasing. Despite clear global patterns, national-level data does not always fit the same regional or global trends, particularly among countries such as Mauritius, the Philippines, and the Dominican Republic that showed remarkable increasing trends in both age-standardised incidence and death rates. Prevention measures should be planned based on national-level estimates in every country and strengthened through early detection and treatment and increasing population awareness regarding reducing exposure to modifiable risk factors, especially in countries with high level or increasing trends in disease burden. A broad population-wide approach to breast cancer indicates a contribution of exposures to selected risk factors, while leaving space for future examinations of the contribution of genetic and some other lifestyle factors, as well as the diagnosis and treatment patterns to the differences on regional and country level.

Abbreviations

DALYs
Disability-adjusted life years
SDI
Socio-demographic index
UI
Uncertainty interval
GBD
Global Burden of Disease
ICD
International Classification of Diseases
MIR
Mortality-to-incidence ratios
ST-GPR
Spatiotemporal Gaussian process regression
YLDs
Years lived with disability
YLLs
Years of life lost

Declarations

Ethics approval and consent to participate

This study was approved by ethics committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.RETECH.REC.1399.459).

Consent to publication

Not applicable.

Availability of data and materials

All of the data we used in this article are publicly available online on the official website of Institute of Health Metrics and Evaluation (http://ghdx.healthdata.org/gbd-results-tool).

Competing interests

The conflict of interest forms will be gathered from collaborators in the revision process.

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Authors' contributions

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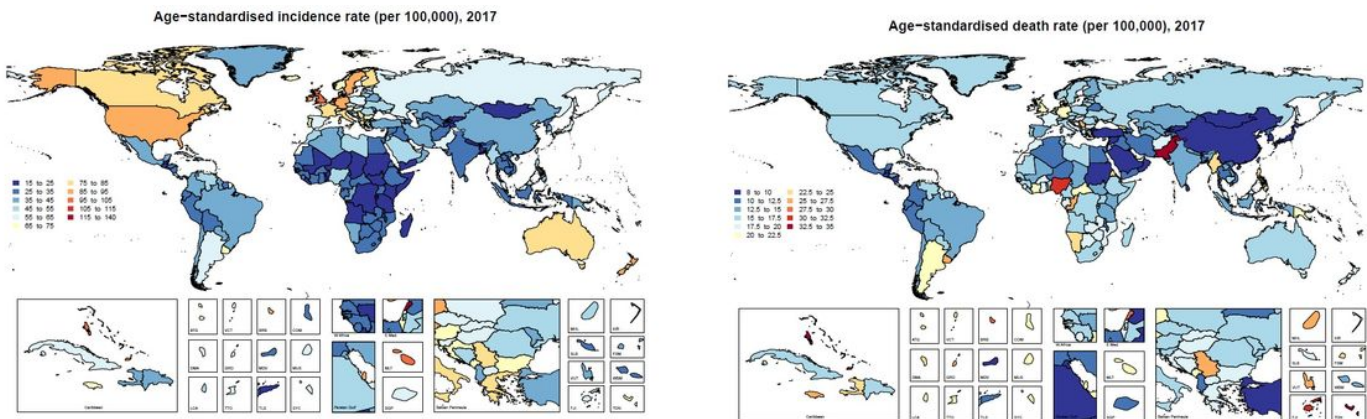
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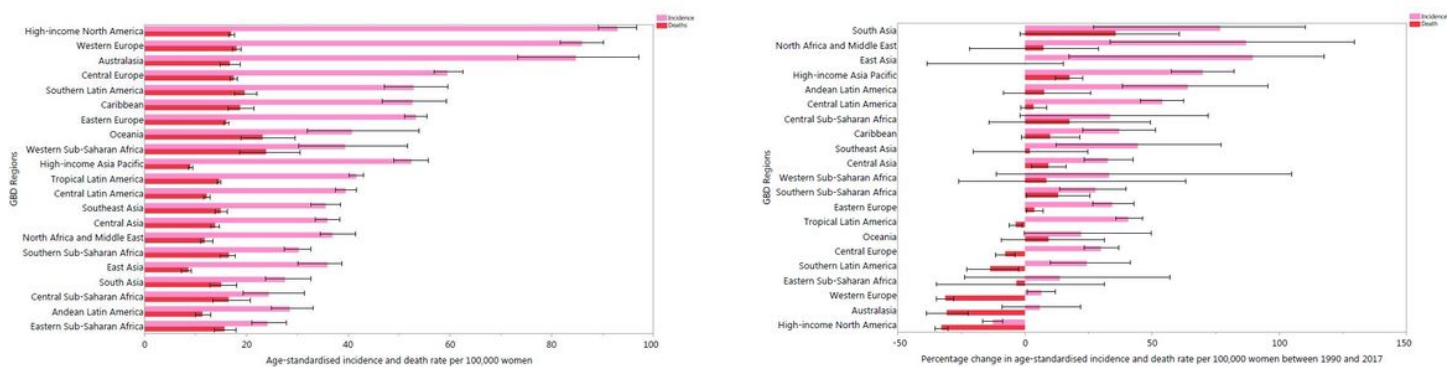
Figure 1

Age-standardised incidence and death rate of breast cancer in 2017 (A) and percent changes from 1990 to 2017 (B) per 100,000 women by Global Burden of Disease regions.
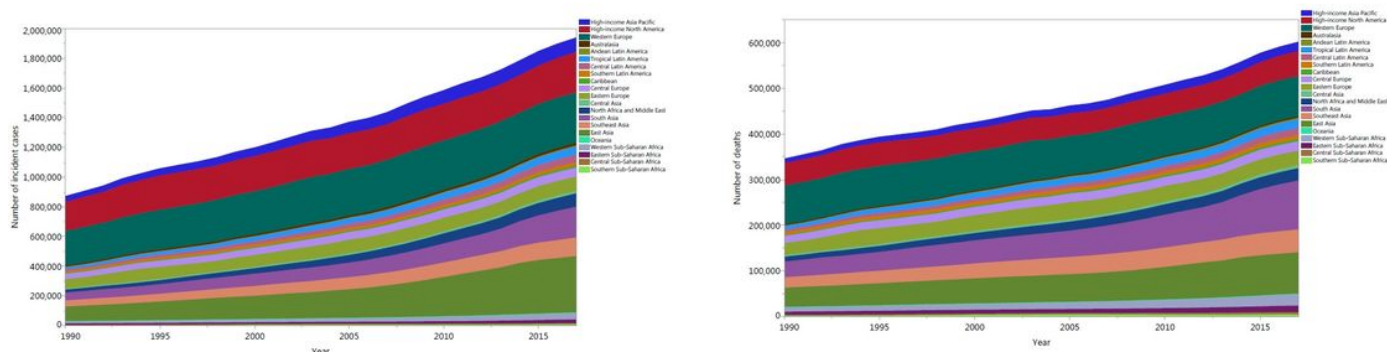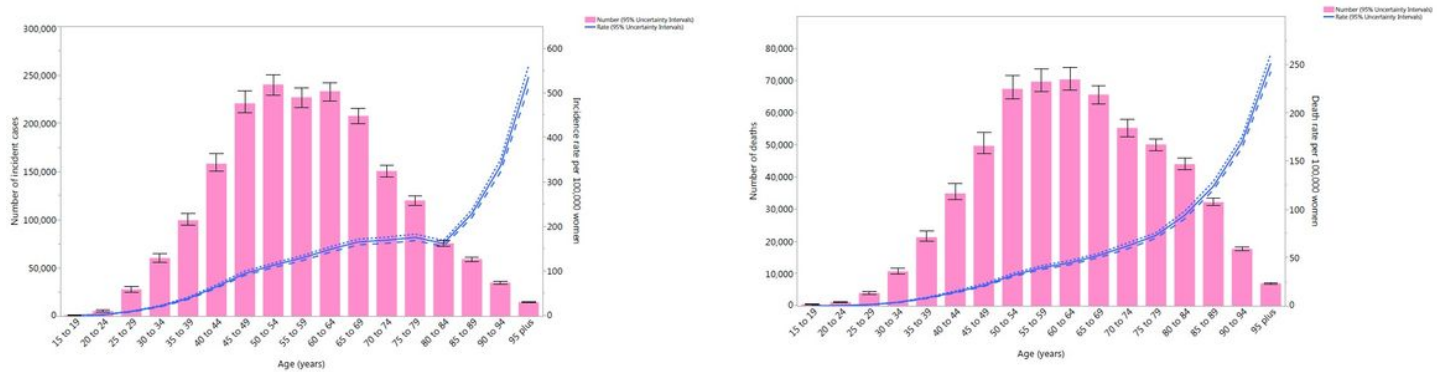
Figure 2

Number of incident cases (A) and deaths (B) of breast cancer among women by Global Burden of Disease regions, 1990-2017.
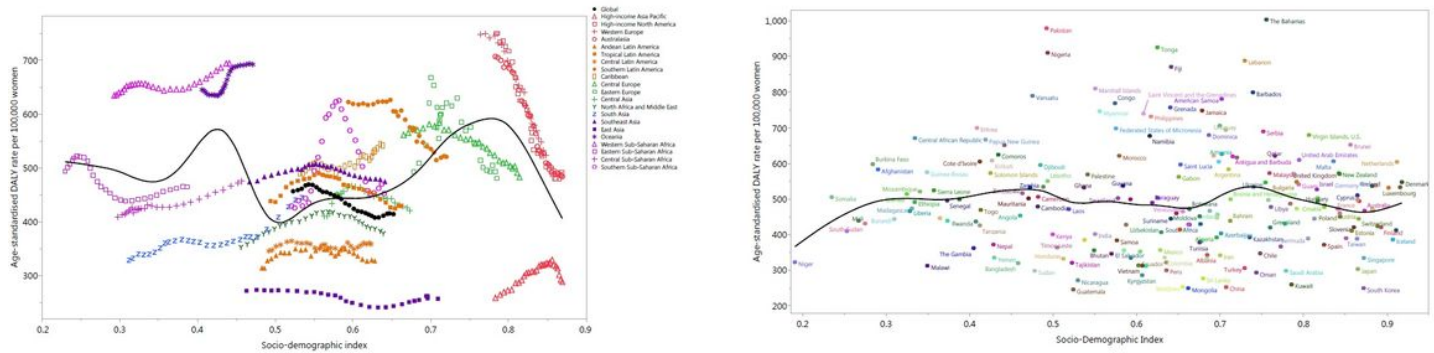

Figure 3

Age-standardised incidence (A) and death (B) rate of breast cancer per 100,000 women by location, 2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
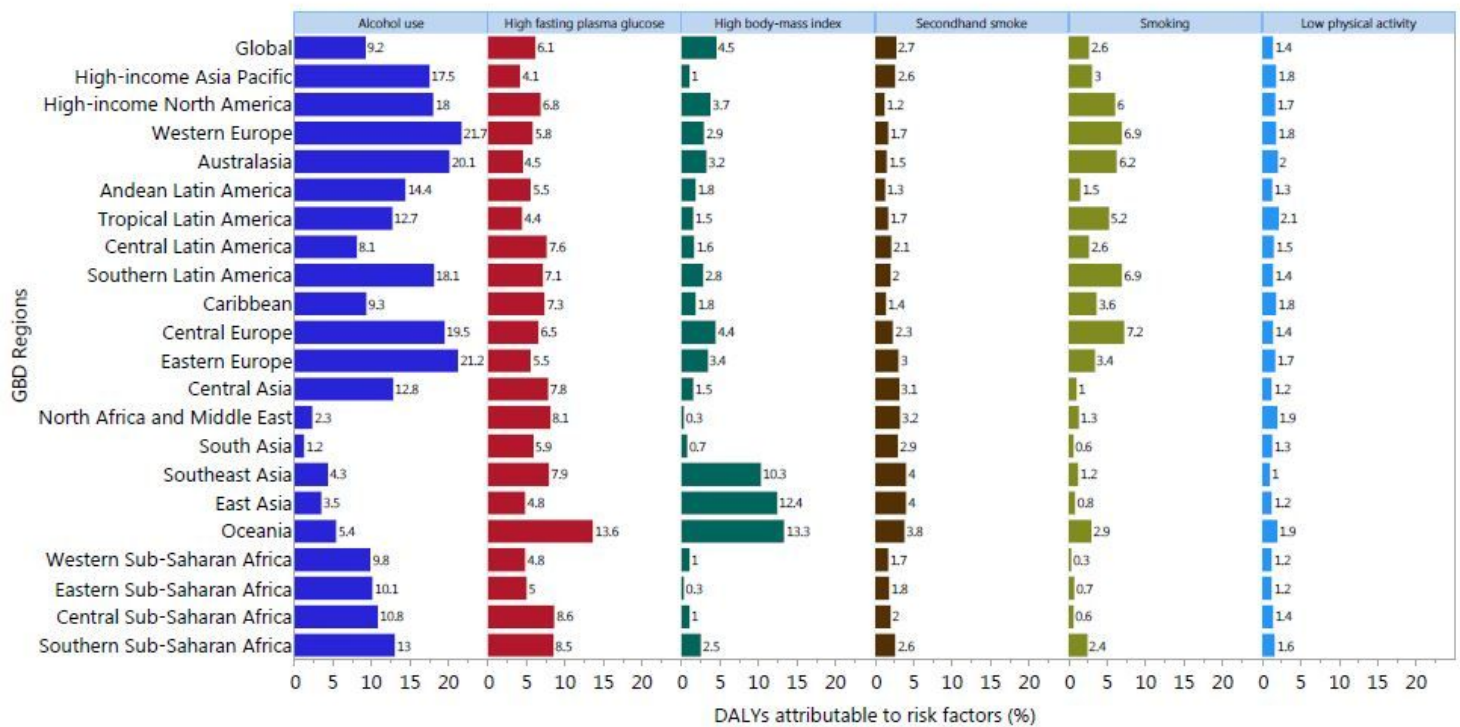

Figure 4

Global number and age-standardised rate per 100,000 women of incidence (A) and death (B) for breast cancer, by age, 2017; Dotted and dashed lines indicate 95% upper and lower uncertainty intervals, respectively.

Figure 5

Age-standardised DALY rates of breast cancer for 21 Global Burden of Disease regions during 1990–2017 (A) and for 195 countries in 2017 (B) by Socio-demographic Index; Expected values based on Socio-demographic Index and disease rates in all locations are shown as the black line. DALY=disability-adjusted life-year.

Figure 6

Percentage of age-standardised DALYs due to breast cancer attributable to risk factors for 21 Global Burden of Disease regions, 2017; DALY=disability-adjusted life-year.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AppendixFigure3RiskFactorsBreastCancer.pdf
- AppendixFigure2DALYHAQ2016BreastCancer.pdf
- AppendixFigure1YLLYLDratecountBreastCancer.pdf
- AppendixTable4DALYsBreastCancer.doc
- AppendixTable3DeathsBreastCancer.doc
- AppendixTable2BreastCancer.doc
- AppendixTable1BreastCancer.doc