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Changes in the global burden of polycystic ovary syndrome from 1990 to 2021

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Abstract

Background Polycystic ovary syndrome (PCOS) is a chronic, multifaceted condition influenced by epigenetic and environmental factors that is responsible for a significant proportion of anovulatory infertility cases. Here, we analyzed the global, regional, and national burdens of PCOS from 1990 to 2021 using data from the Global Burden of Disease 2021 (GBD 2021).

Methods Incidence, prevalence, and Disability-Adjusted Life Years (DALYs) data relevant to PCOS from 204 countries and 21 territories from 1990 to 2021 were obtained from the GBD 2021 study. Here, we considered age-standardized rates (per 100,000 individuals) with 95% uncertainty intervals (95% UIs) obtained from the aforementioned research and presented trends based on age and Socio-demographic Index (SDI) parameters.

Results In 2021, the global age-standardized incidence and prevalence rates of PCOS were 30.7 per 100,000 and 867.7 per 100,000, respectively, representing an increase of 26.77% and 28.21% since 1990. Additionally, age-standardized disability-adjusted life years stood at 7.6 per 100,000 globally in 2021, marking a 27.58% increase from 1990. Age-standardized prevalence of PCOS varied across countries, ranging from 93.1 to 3978.9 cases per 100,000 women, with Italy (3978.9), Japan (3104.7), and New Zealand (2789.7) having the highest rates. Notably, PCOS prevalence was noted to peak globally among females 15–19 years of age. Regions with a high SDI exhibited the highest age-standardized incidence (70.2), prevalence (1720.7), and DALY (15.2) rates of PCOS. Furthermore, a non-linear correlation between PCOS burden and SDI was noted, with prevalence rates peaking around an SDI of approximately 0.9.

Conclusion Our findings highlight the growing global impact of PCOS and underscore the need for concerted efforts to attenuate the increasing global prevalence of this condition. Significantly divergent PCOS disease burdens were observed across different age groups and SDI regions, with high SDI regions bearing heavier burdens. The increased disease burden among younger age groups and regional disparities underscore urgency for targeted intervention and formulation of policies to effectively address this public health issue.

Keywords Polycystic ovary syndrome, Global burden of disease, Disability-adjusted life years, Socio-demographic index

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Introduction

Polycystic ovary syndrome (PCOS), a common hormonal condition affecting women of reproductive age, exhibits a prevalence range from 8 to 13% [1]. Increasing evidence has revealed PCOS to be a complex, heterogeneous, and lifelong condition that strongly associates with epigenetic and environmental variables [2–4]. Importantly, PCOS is the most common cause of anovulatory infertility [3]. Apart from adversely affecting female reproductive function, PCOS also increases the risk of various comorbidities, such as obesity, insulin resistance, diabetes, and cardiovascular disease, thus exacerbating global health and economic burdens [2, 3].

Screening and health management needs of PCOS patients remain unmet. The reproductive-related effects of PCOS include an increased risk of irregular menstrual cycles, anovulatory infertility, pregnancy complications [5, 6], and endometrial cancer [7]. Furthermore, PCOS associates with anxiety, depression, eating disorders, psychosexual disorders, and negative body image perception [8, 9], all of which impact quality of life. Clinical management of PCOS is no longer limited to promotion of ovulatory regularity and pregnancy; increasing focus has been placed on the importance of glycolipid metabolism and complication management in this patient population [1], highlighting a need for studies to accurately characterize PCOS disease burden.

Importantly, a comprehensive understanding of PCOS disease burden would provide a more solid rationale for developing future women's health plans and better accommodating needs of PCOS patients, thereby assisting high-burden countries strengthen PCOS screening and management operations to achieve early detection, diagnosis, and treatment goals.

The accuracy of PCOS global prevalence and incidence data previously reported has often been inconsistent due to discrepancies in research methodologies, regional differences and shifting diagnostic criteria [1, 3, 10]. The Global Burden of Disease (GBD) database is a comprehensive database organized by the Global Health Research Institute to assess and analyze the health impact of diseases, injuries, and risk factors globally and regionally. To facilitate comprehensive assessment, the GBD divides the world into 21 regions and 204 countries and territories. The Socio-demographic Index (SDI) is used to link developmental status to health outcomes, while disability-adjusted life years (DALYs), the sum of years lost due to premature death and years survived due to disability, are used to denote years of healthy life lost. Previous research utilizing GBD data has made important contributions to understanding the PCOS burden worldwide [11–15]. Liu et al. [12] utilized GBD 2017 data and reported that the global age-standardized PCOS incidence rate increased by 1.45% between 1990 and 2017, highlighting substantial geographic variations in disease burden. Safiri et al. [14] expanded this research using GBD 2019 data, documenting a concerning 30.4% increase in global age-standardized point prevalence and a 29.5% increase in annual incidence rates since 1990. Other researchers have explored regional patterns, with Miazgowski et al. [13] analyzing European trends that revealed marked variations across countries, with some experiencing increases of up to 11.4% while others showed decreases of up to 9.6%. While these studies established foundational knowledge about PCOS burden, our study uniquely contributes by extending the temporal analysis to 2021, incorporating the most recent GBD data, and providing more granular analysis of age-specific patterns and sociodemographic correlations. We furthermore assessed global, regional and national PCOS burdens among women 15–49 years old in 21 regions and 204 countries and territories from 1990 to 2021 via analysis of GBD 2021 data to highlight incidence, prevalence, and DALYs relevant to this patient population and facilitate more effective future formulation of policy, resource allocation, and health system planning.

Materials and methods

Overview

PCOS data were obtained from GBD 2021 using the Global Health Data Exchange website (http://ghdx.healthdata.org). The database systematically compiles the health burden of 369 conditions from 1990 to 2021 and includes samples obtained from 204 countries and territories. Relevant methods for estimating incidence, prevalence and DALY rates have been previously detailed [16]. This study was conducted in accordance with the 1975 Declaration of Helsinki. As this study evaluated publicly available datasets, ethical committee approval was not required. Informed consent was waived as GBD 2021 compiled de-identified pooled data.

Case definitions and data sources

Collectively, PCOS is characterized by androgenesis, anovulation and polycystic ovarian morphology [1, 2]. The reference definition of PCOS was standardized in GBD 2021 and is based on the definition set forth by the American College of Obstetricians and Gynecologists, where the diagnosis may be established using any of the three accepted methods (i.e. NIH, Rotterdam or AE-PCOS) [1].

Data processing and presentation

To derive a comprehensive understanding in the burden of PCOS, a descriptive analysis was performed according to 204 countries, 5 SDI regions, 21 GBD regions, and

different age groups. The global case number, crude rate, and age-standardized rate (ASR) of incidence, prevalence, and DALYs for PCOS in SDI from 1990 to 2019 were visually illustrated. The estimated annual percentage change was calculated to track temporal trends.

The SDI was assessed based on total fertility rate for females younger than 25 years of age, educational attainment of females aged 15 years and older, as well as per capita lagged distribution income. The 204 geographical regions were categorized into five groups based on SDI: low; medium–low; medium; medium–high; and high SDI. Based on GBD classification, women of childbearing age were categorized as 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, or 45–49 years old.

Each estimate was calculated 1000 times in GBD 2021; final data were presented as a mean of these estimates. A 95% uncertainty interval (95% UI) was calculated for each analysis, determined using 25 th and 97.5 th values of a set of ordered 1000 extractions. A two-sided $P < 0.05$ was considered statistically significant. Data were downloaded from the GBD website and Excel software (Microsoft, USA) was used for descriptive analysis. Other statistical analyses were performed using R version 4.4.1 (The R Foundation, Austria).

Results

Global burden

In 2021, there were 2.3 million new cases of PCOS at an age-standardized rate of 30.7 per 100,000, an increase of 26.77% since 1990 (Table 1; Fig. 1). In 2021, there were 69.47 million prevalent cases of PCOS globally at an age-standardized rate of 867.7 per 100,000 women, an increase of 28.21% since 1990 (Table 1; Fig. 1). In 2021, the total number of PCOS-associated DALYs was 610,000 at an age-standardized rate of 7.6 cases per 100,000 women, an increase of 27.58% since 1990 (Table 1; Fig. 1).

Regional burdens

In 2021, the high-income Asia Pacific [109.2 (95% UI: 77.9–153.9)], Australasia [98.2 (95% UI: 70.4–135.4)], and Western Europe [75.2 (95%UI: 53.1–105)] regions had the greatest age-standardized PCOS incidence rates. In contrast, the regions of Central Europe [4.3 (95% UI: 3–6.1)], Eastern Europe [5.3 (95% UI: 3.7–7.5)], and Central Asia [9.1 (95% UI: 6.3–12.7)] had the lowest age-standardized PCOS incidence rates (Table 1). In 2021, the age-standardized PCOS prevalence rates were greatest in the high-income Asia Pacific [2544.9 (95% UI: 1836.1–3551.3)], Australasia [2387 (95% UI: 1708.4–3297.5)], and Western Europe [1944.3 (95% UI: 1361.7–2726.7)] regions. Conversely, the regions of Central Europe [111.7 (95% UI: 77–159.2)], Eastern Europe [132.4 (95% UI: 91.2–190.5)], and Central Asia [240.5 (95% UI: 164.6–337.3)] exhibited the lowest age-standardized PCOS prevalence rates (Table 1). In 2021, the high-income Asia Pacific [22.2 (95% UI: 10.1–45.2)], Australasia [20.8 (95% UI: 9.3–43.0)] and Western Europe [17.3 (95% UI: 7.8–35.9)] regions had the greatest age-standardized DALY rates for PCOS, while those of Central Europe [1 (95% UI: 0.4–2)], Eastern Europe [1.2 (95% UI: 0.5–2.5)], and Central Asia [2.1 (95% UI: 0.9–4.5)] had the lowest (Table 1).

The greatest increases in the rates of age-standardized incidence and prevalence of PCOS from 1990 to 2021 were found in Southeast Asia [incidence: 82.8% (95% UI: 69.3–97.25); prevalence: 81.61% (95% UI: 68.92–94.86)], East Asia [incidence: 75.02% (95% UI: 62.37–86.34); prevalence: 81.5% (95% UI: 70.23–93.05)], and South Asia [incidence: 66.10% (95% UI: 56.5–77.13); prevalence: 80.44% (95% UI: 69.61–94.73)], with no regional declines through this time period (Table 1). In addition, the regions with the largest increases in age-standardized DALY rates for PCOS from 1990 to 2021 were East Asia [82.86% (95% UI: 71.06–94.3)], Southeast Asia [80.53% (95% UI: 68.47–93.64)], and South Asia [78.54% (95% UI: 67.27–91.55)], with no regional declines through this time period (Table 1).

National burden

At the national level, the countries with the greatest age-standardized incidence rates for PCOS in 2021 were Italy [158 (95% UI: 110.1–222.2)], Japan [129.5 (95% UI: 92.2–182.4)], and New Zealand [114.6 (95% UI: 81.2–158.4)]; those with the lowest rates were Albania [3.7 (95% UI: 2.5–5.4)], Serbia [3.7 (95% UI: 2.5–5.3)], and Bosnia and Herzegovina [3.7 (95% UI: 2.5–5.4)]. The percentage change for age-standardized PCOS incidence rates from 1990 to 2021 varied widely between countries, with the Maldives [125.23% (95% UI: 94.68–161.28)], Myanmar [104.11% (95% UI: 78.02–133.16)], and Vietnam [95.03% (95% UI: 70.01–118.06)] exhibiting the largest increases; Italy [− 10.53% (95% UI: − 17.1- − 5.29)], Mexico [− 1.93% (95% UI: − 7.84–2.72)], and New Zealand [− 1.39% (95% UI: − 14.34–10.98)] exhibited negative trends (Fig. 2; Supplementary Table S1).

In 2021, the age-standardized prevalence rates of PCOS ranged from 93.1 to 3978.9 cases per 100,000 women among different countries. Countries with the greatest prevalence rates were Italy [3978.9 (95% UI: 2823.1–5523.3)], Japan [3104.7 (95% UI: 2244.2–4312.7)], and New Zealand [2789.7 (95% UI: 2008.7–3805.9)]; those with the lowest were Albania [93.1 (95% UI: 61.5–141.7)], Bosnia and Herzegovina [94 (95% UI: 61.5–144.2)], and North Macedonia [94.6 (95% UI: 61.6–144.2)]. Furthermore, a significant disparity was observed in the percentage alteration of age-standardized PCOS prevalence between 1990 and 2021. The largest increases were in

Table 1 Burden of PCOS, 1990–2021, by Global Burden of Disease study region

Location	Numbers (95% UI)			Age-standardized rate (per 100 000)(95% UI)		
	1990	2021	Percentage change 1990–2021 (%)	1990	2021	Percentage change 1990–2021 (%)
Global						
Incidence	1,476,225.3 (1,057,983.5, 2,045,276.9)	2,301,505.6 (1,655,989.2, 3,167,177.8)	55.9 (51.62, 60.11)	24.2 (17.4, 33.5)	30.7 (22.1, 42.4)	26.77 (23.87, 29.7)
Prevalence	36,651,157.2 (26,227,943.2, 50,603,929.8)	69,473,252.4 (49,531,420, 95,724,479.2)	89.55 (85.03, 94.22)	676.8 (485.5, 932.6)	867.7 (618.7, 1195.3)	28.21 (25.21, 31.27)
DALYs	323,798.6 (144,342.1, 675,926.8)	607,756.9 (272,745.2, 1,268,607.2)	87.7 (82.87, 92.43)	6 (2.7, 12.4)	7.6 (3.4, 15.9)	27.58 (24.23, 30.92)
SDI region						
Low SDI						
Incidence	61881.6 (43355.6, 87726)	205,458.3 (144,223.9, 291,379.8)	232.02 (218.67, 247.71)	9.9 (7.2, 13.9)	13.8 (9.8, 19.3)	38.67 (32.84, 44.94)
Prevalence	1,121,931 (784,807, 1,611,458.4)	3,938,251.3 (2,745,129.9, 5,589,751.2)	251.02 (236.82, 268.69)	252.4 (178.4, 359.2)	361.6 (255.3, 509.8)	43.23 (37.5, 50.28)
DALYs	9836.5 (4213.8, 20,814.4)	34,425.2 (14,799.7, 72,773.1)	249.97 (234.59, 268.42)	2.2 (0.9, 4.7)	3.1 (1.4, 6.6)	43.08 (36.76, 50.38)
Low-middle SDI						
Incidence	209,333.5 (148,000.1, 293,837.3)	481,689 (338,285.7, 670,310.3)	130.11 (121.91, 140.99)	14.4 (10.4, 20)	22.1 (15.5, 30.7)	53.18 (47.29, 59.46)
Prevalence	4,094,311.3 (2,868,780.9, 5,765,430.7)	12,118,405.4 (8,434,181, 17,027,257.3)	195.98 (184.92, 209.49)	368.3 (260.4, 514.5)	592.4 (413, 831.8)	60.83 (54.5, 68.32)
DALYs	36,511.8 (15,811.4, 76,977.5)	106,509.7 (46,621.4, 223,924.9)	191.71 (180.2, 205.95)	3.3 (1.4, 6.8)	5.2 (2.3, 10.9)	59.32 (53.04, 67.07)
Middle SDI						
Incidence	505,653.9 (359,588, 703,114.3)	812,669 (572,963.7, 1,126,099.7)	60.72 (54.21, 68.04)	23.8 (16.9, 33.1)	37.2 (26.2, 51.8)	56.46 (50.38, 63.04)
Prevalence	10,580,143.2 (7,410,905.3, 14,674,450.8)	24,613,369.9 (17,452,531.6, 34,074,253.7)	132.64 (123.22, 142.88)	576.7 (404.4, 798.9)	970.2 (687.2, 1340.9)	68.24 (61.4, 76.16)
DALYs	93,350.2 (41,377, 195,580.3)	214,898.8 (95,592.6, 450,661.8)	130.21 (120.7, 140.81)	5.1 (2.2, 10.7)	8.5 (3.8, 17.8)	67.85 (61.12, 75.67)
High-middle SDI						
Incidence	261,030.5 (187,118.7, 358,760.3)	305,810 (216,061.4, 424,907.9)	17.15 (12.65, 21.25)	24.2 (17.3, 33.5)	34.5 (24.3, 48.3)	42.71 (38, 47.09)
Prevalence	7,047,030 (4,981,606.3, 9,727,416.6)	11,180,894.9 (7,874,794.9, 15,590,881.4)	58.66 (53.33, 64.9)	621.7 (439.3, 859.5)	877.5 (616.7, 1221.5)	41.15 (36.51, 45.95)
DALYs	61,793.6 (27,718.6, 128,454.5)	97,184.5 (43,255.1, 205,403.8)	57.27 (51.09, 63.33)	5.4 (2.4, 11.3)	7.7 (3.4, 16.1)	41.14 (36.19, 45.99)
High SDI						
Incidence	437,301.5 (319,330.7, 606,631.9)	494,212.2 (367,071.5, 670,948)	13.01 (6.88, 20.28)	58.8 (43, 81.4)	70.2 (52, 95.3)	19.41 (13.48, 27.17)

Table 1 (continued)

Location	Numbers (95% UI)			Age-standardized rate (per 100 000)(95% UI)		
	1990	2021	Percentage change 1990–2021 (%)	1990	2021	Percentage change 1990–2021 (%)
Prevalence	13,783,058.5 (10,021,809.4, 19,223,038.3)	17,573,919.8 (12,981,150.8, 23,876,520.6)	27.5 (21.32, 36.14)	1479.8 (1075.7, 2053.4)	1720.7 (1270.5, 2331.7)	16.28 (10.89, 23.54)
DALYs	122,087.1 (55,322.3, 254,195)	154,313.3 (70,664.1, 314,967.1)	26.4 (20.26, 34.33)	13.1 (5.9, 27.2)	15.2 (7, 31)	15.78 (10.54, 22.67)
21 GBD region						
Andean Latin America						
Incidence	25,250.9 (17,294.5, 36,023.1)	42,634.6 (29,473.4, 60,429.4)	68.84 (55.92, 84.57)	50 (34.4, 71)	64.7 (44.7, 91.9)	29.35 (19.52, 42.37)
Prevalence	466,365.8 (322,494, 653,112.7)	1,172,864.5 (808,337.4, 1,649,165.9)	151.49 (129.79, 175.33)	1230.4 (850.9, 1717.8)	1662.5 (1148.2, 2338.2)	35.12 (24.02, 47.98)
DALYs	4055.9 (1797.3, 8748.4)	10,129.2 (4423.9, 21,176.6)	149.74 (127.53, 174.94)	10.7 (4.8, 23)	14.4 (6.3, 30)	34.49 (22.66, 48.5)
Australasia						
Incidence	15,948.7 (11,745.5, 20,802.4)	21,492.9 (15,427.9, 29,606.8)	34.76 (16.73, 55.55)	85 (62.2, 112.1)	98.2 (70.4, 135.4)	15.5 (0.97, 33.08)
Prevalence	444,239.3 (326,487.4, 585,953.2)	701,618 (500,341, 974,913)	57.94 (38.59, 81.58)	2049.9 (1505.7, 2710)	2387 (1708.4, 3297.5)	16.44 (2.35, 33.44)
DALYs	3873.5 (1763.7, 8060.7)	6103.6 (2756.5, 12,632.8)	57.57 (38.47, 79.48)	17.9 (8.1, 37.2)	20.8 (9.3, 43)	16.39 (2.6, 32.87)
Caribbean						
Incidence	9226.7 (6288.1, 13042.8)	11,962.5 (8144.4, 16,730.1)	29.65 (22.74, 36.69)	22.2 (15.2, 31.3)	27.4 (18.6, 38.6)	23.49 (17.6, 30.26)
Prevalence	222,432.4 (149,139.1, 319,229.7)	360,981.8 (245,137.3, 520,033.5)	62.29 (53.64, 71.43)	605.7 (408.2, 869.3)	746.2 (506.3, 1073.5)	23.2 (16.95, 29.75)
DALYs	1979.8 (867.3, 4095.2)	3161.5 (1381.5, 6647.6)	59.69 (50.73, 69)	5.4 (2.3, 11.1)	6.5 (2.9, 13.7)	21.99 (15.17, 28.53)
Central Asia						
Incidence	5347.8 (3686.1, 7702.4)	8122.3 (5654.1, 11,355.5)	51.88 (40.1, 63.3)	6.8 (4.7, 9.7)	9.1 (6.3, 12.7)	34.83 (24.32, 44.09)
Prevalence	118,817.9 (79,820.2, 174,950)	237,958.9 (163,368.4, 333,464.7)	100.27 (84.89, 113.88)	175.7 (118.4, 257.8)	240.5 (164.6, 337.3)	36.84 (26.9, 46.84)
DALYs	1049.1 (438.1, 2236.9)	2079.4 (886.9, 4469.5)	98.2 (82.36, 113.87)	1.5 (0.6, 3.3)	2.1 (0.9, 4.5)	36.39 (26.18, 47.74)
Central Europe						
Incidence	4244.9 (2905.8, 6223.9)	3175.5 (2221.1, 4441)	− 25.19 (− 32.84, − 16.46)	3.6 (2.5, 5.3)	4.3 (3, 6.1)	20.88 (9.32, 33.99)
Prevalence	116,152 (76,721, 173,921.5)	119,149.2 (82,050.4, 168,514)	2.58 (− 8.58, 14.75)	91.9 (60.8, 137.8)	111.7 (77, 159.2)	21.52 (8.7, 35.59)
DALYs	1014.7 (425.9, 2088.9)	1032.7 (442.9, 2156.6)	1.77 (− 9.68, 15.06)	0.8 (0.3, 1.7)	1 (0.4, 2)	21.11 (8.12, 36.15)
Central Latin America						
Incidence	119,114.9 (81,948.2, 168,844.6)	143,013.7 (100,629.4, 200,290.7)	20.06 (15.38, 25.42)	53.7 (37, 75.9)	57.2 (40, 80)	6.46 (2.69, 10.37)

Table 1 (continued)

Location	Numbers (95% UI)			Age-standardized rate (per 100 000)(95% UI)		
	1990	2021	Percentage change 1990–2021 (%)	1990	2021	Percentage change 1990–2021 (%)
Prevalence	2,295,522 (1,578,370.6, 3,199,568.8)	4,072,957.2 (2,852,240.6, 5,662,452.4)	77.43 (70.23, 84.75)	1382.5 (952.5, 1915.8)	1518.7 (1063, 2110.8)	9.85 (5.86, 14.43)
DALYs	20,163.7 (9003.8, 42,043)	35,314.1 (15,577.8, 73,735.7)	75.14 (66.72, 83.06)	12.1 (5.4, 25.3)	13.2 (5.8, 27.5)	8.99 (4.69, 13.73)
Central Sub-Saharan Africa						
Incidence	6063 (4247.4, 8685.3)	23,871.9 (16,637.7, 33,976)	293.73 (259.69, 332.63)	8.8 (6.3, 12.4)	13 (9.2, 18.4)	48.2 (35.82, 62.24
Prevalence	110,521.9 (76,168.2, 160,819.7)	444,120.8 (305,191.6, 640,542)	301.84 (267.24, 341.66)	226.9 (157.8, 329.5)	337.7 (233.3, 485.4)	48.83 (36.5, 63.04)
DALYs	958.3 (406.3, 1975.2)	3861.9 (1673.7, 7930.5)	303.01 (261.05, 353.15)	1.9 (0.8, 4.1)	2.9 (1.3, 6)	49.6 (34.85, 67.72)
East Asia						
Incidence	218,485.8 (154,343.7, 301,132.9)	268,458.5 (190,157.1, 373,877.4)	22.87 (10.26, 35.34)	15.6 (11.1, 21.8)	27.3 (19.2, 38.4)	75.02 (62.37, 86.34)
Prevalence	5,607,180.9 (3,957,250.2, 7,863,221.6)	10,490,358.5 (7,423,407.5, 14,808,757.1)	87.09 (75.09, 98.72)	408.1 (290, 572.2)	740.8 (519.6, 1039.3)	81.5 (70.23, 93.05)
DALYs	48,225.9 (20,818.6, 100,143)	89,991.4 (39,441.8, 185,701.9)	86.6 (74.68, 98.29)	3.5 (1.5, 7.3)	6.4 (2.8, 13.2)	82.86 (71.06, 94.3)
Eastern Europe						
Incidence	8328.3 (5913.3, 11,639.2)	7596.1 (5457.5, 10,592.6)	− 8.79 (− 13.5, − 4.38)	4.2 (3, 5.9)	5.3 (3.7, 7.5)	25.78 (19.64, 31.1)
Prevalence	237,422.1 (160,523.3, 339,244.5)	265,678.7 (185,374.4, 381,763)	11.9 (6.13, 16.8)	103.8 (70, 149.6)	132.4 (91.2, 190.5)	27.48 (21, 33.15)
DALYs	2097.7 (868.6, 4466.8)	2323.7 (970, 4890.4)	10.77 (4.82, 17.26)	0.9 (0.4, 2)	1.2 (0.5, 2.5)	27.16 (20.16, 34.26)
Eastern Sub-Saharan Africa						
Incidence	25,902 (18,214, 36,986.2)	76,605.1 (53,945.1, 108,540.5)	195.75 (184.89, 208.9)	10.4 (7.5, 14.6)	13.1 (9.3, 18.4)	25.75 (20.85, 30.88)
Prevalence	448,071 (310,256.9, 646,236.2)	1,438,942.4 (1,001,296.8, 2,063,339.5)	221.14 (209.9, 235.3)	266.9 (188.2, 383.1)	342.7 (242, 486.2)	28.38 (23.73, 34.2)
DALYs	3903.3 (1645.1, 8198.6)	12,497.1 (5380.7, 26,310.2)	220.17 (206.43, 236.52)	2.3 (1, 4.9)	3 (1.3, 6.2)	28.27 (22.86, 34.73)
High-income Asia Pacific						
Incidence	158,931.2 (111,210.6, 226,424.2)	107,170.5 (75,693.7, 152,114.3)	− 32.57 (− 35.81, − 28.32)	94 (66.9, 131)	109.2 (77.9, 153.9)	16.15 (9.46, 22.97)
Prevalence	4,402,355.4 (3,172,199.1, 6,106,156.6)	4,104,982.7 (2,922,772.6, 5,775,182.1)	− 6.75 (− 12.08, − 1.5)	2341.7 (1690.8, 3246.4)	2544.9 (1836.1, 3551.3)	8.68 (3.25, 14.63)
DALYs	38,274.5 (16,930.4, 77,128.8)	35,520.5 (16,037.3, 72,064.2)	− 7.2 (− 12.48, − 2.08)	20.4 (9, 41.1)	22.2 (10.1, 45.2)	8.61 (3.18, 14.44)
High-income North America						
Incidence	134,112.7 (94,940.5, 187,144.2)	203,413.5 (150,004.6, 271,137.8)	51.67 (33.11, 83.31)	58.1 (40.9, 81.3)	73.2 (54.4, 96.6)	25.96 (10.83, 51.64)

Table 1 (continued)

Location	Numbers (95% UI)			Age-standardized rate (per 100 000)(95% UI)		
	1990	2021	Percentage change 1990–2021 (%)	1990	2021	Percentage change 1990–2021 (%)
Prevalence	4,469,583.7 (3,157,929.6, 6,274,672.9)	6,362,238.3 (4,742,961.9, 8,324,162.2)	42.35 (25.45, 68.36)	1483.6 (1046.5, 2088.2)	1855.7 (1382.3, 2426.4)	25.09 (10.41, 47.53)
DALYs	39,976.1 (17,688.8, 82,638.3)	56,162.2 (25,718.3, 113,710.2)	40.49 (24.03, 65.39)	13.3 (5.9, 27.3)	16.4 (7.6, 33.3)	23.85 (9.45, 45.29)
North Africa and Middle East						
Incidence	128,593.5 (88,937.3, 183,308.6)	242,427.1 (171,058.1, 342,784.6)	88.52 (79.82, 98.46)	28.7 (20.1, 40.6)	37.3 (26.3, 52.8)	29.73 (23.43, 35.91)
Prevalence	2,463,301.1 (1,707,181.3, 3,501,813.4)	6,673,431.5 (4,672,056.3, 9,434,543.5)	170.91 (157.81, 185)	754.3 (523, 1071.5)	990.2 (693.3, 1399.1)	31.28 (24.31, 37.86)
DALYs	22,386.5 (9812.9, 47,102.6)	59,116.3 (26,476.8, 125,706.8)	164.07 (148.49, 178.24)	6.8 (3, 14.3)	8.8 (3.9, 18.7)	29.13 (21.62, 36.66)
Oceania						
Incidence	2013.1 (1401.2, 2847)	5300.9 (3692.1, 7439.8)	163.31 (136.75, 185.25)	23.8 (16.7, 33.5)	32.9 (23, 46.3)	38.56 (25.1, 50.15)
Prevalence	40,226.7 (27,505, 56,891.6)	124,484.3 (86,570.2, 177,516.4)	209.46 (178.55, 236.12)	621.1 (428.1, 873.4)	870.3 (605, 1243.3)	40.12 (26.55, 52.1)
DALYs	352.2 (160.6, 738.9)	1083.5 (471.3, 2285.6)	207.65 (175.84, 238.86)	5.4 (2.5, 11.3)	7.6 (3.3, 15.9)	39.8 (26.15, 52.32)
South Asia						
Incidence	162,363.3 (116,293.1, 226,382.7)	416,258.4 (299,377.4, 573,874.2)	156.37 (142.93, 175.38)	12.2 (8.8, 16.8)	20.3 (14.4, 28.1)	66.1 (56.5, 77.13)
Prevalence	3,294,301.2 (2,344,772, 4,593,824.8)	11,291,117.1 (7,950,085.9, 15,832,639.8)	242.75 (222.38, 269.54)	309.1 (222.4, 429.6)	557.8 (392.8, 781)	80.44 (69.61, 94.73)
DALYs	29,342.1 (12,824.1, 62,333.8)	98,946.9 (43,231.5, 207,059.2)	237.22 (215.88, 262.7)	2.7 (1.2, 5.8)	4.9 (2.1, 10.2)	78.54 (67.27, 91.55)
Southeast Asia						
Incidence	174,333.2 (122,499, 243,431.4)	357,262.3 (254,498.6, 495,461.4)	104.93 (91.28, 118.81)	29.3 (20.6, 40.8)	53.6 (37.9, 74.9)	82.8 (69.3, 97.25)
Prevalence	3,682,948.8 (2,589,198.8, 5,201,509.9)	10,520,027.7 (7,378,813.9, 14,809,823.5)	185.64 (166.63, 205.02)	773.1 (546.2, 1094.3)	1404.1 (984.5, 1974.7)	81.61 (68.92, 94.86)
DALYs	32,853.8 (14,429.1, 66,791.8)	92,605.7 (41,149, 191,024.1)	181.87 (162.32, 202.42)	6.9 (3, 14)	12.4 (5.5, 25.5)	80.53 (68.47, 93.64)
Southern Latin America						
Incidence	12,429.8 (8602.2, 17,727.2)	21,574.4 (15,329.6, 30,970)	73.57 (59.28, 90.52)	23.3 (16.1, 33.3)	36.6 (25.9, 52.4)	57.18 (43.87, 72.8)
Prevalence	296,321.5 (204,840.7, 431,020.1)	667,604.8 (469,021.5, 956,761.4)	125.3 (107.55, 146.54)	600.5 (416.5, 874.7)	950.5 (666.4, 1360.4)	58.28 (46.09, 72.93)
DALYs	2627.8 (1179.4, 5421.3)	5893.5 (2574.8, 12,247.5)	124.27 (104.79, 146.08)	5.3 (2.4, 11)	8.4 (3.7, 17.4)	58.03 (44.42, 74.12)
Southern Sub-Saharan Africa						
Incidence	11,799.7 (8261, 16,787.8)	18,377.8 (12,888.4, 26,038)	55.75 (48.83, 64.41)	17.2 (12.1, 24.3)	21 (14.7, 29.8)	22.06 (16.26, 27.85)

Table 1 (continued)

Location	Numbers (95% UI)			Age-standardized rate (per 100 000)(95% UI)		
	1990	2021	Percentage change 1990–2021 (%)	1990	2021	Percentage change 1990–2021 (%)
Prevalence	232,808.6 (160,575, 334,631.4)	480,389.6 (328,945.2, 679,589.3)	106.35 (96.18, 116.82)	449.2 (310.3, 643.1)	551.2 (377.3, 779.2)	22.7 (17.12, 29.22)
DALYs	2047.4 (881.8, 4435.2)	4157.7 (1795.1, 8746)	103.07 (92.15, 114.77)	3.9 (1.7, 8.5)	4.8 (2.1, 10)	21.67 (15.51, 28.58)
Tropical Latin America						
Incidence	22,284.6 (15,199.8, 32,004)	23,769.1 (16,611.4, 32,960.1)	6.66 (− 0.26, 13.5)	11.7 (8, 16.7)	12.3 (8.4, 17.2)	5 (0.43, 10.38)
Prevalence	448,844.2 (304,409, 647,659.2)	746,471.7 (514,677, 1,057,462.8)	66.31 (57.21, 75.3)	283.9 (192.7, 407.2)	308.2 (211.9, 438.9)	8.56 (3.54, 14.09)
DALYs	4011.1 (1701.1, 8427.3)	6557.7 (2825.1, 13,831)	63.49 (54.8, 72.88)	2.5 (1.1, 5.3)	2.7 (1.2, 5.7)	7.48 (2.5, 13.07)
Western Europe						
Incidence	206,740.9 (146,330.9, 286,172.1)	206,192.2 (145,653.5, 286,689.1)	− 0.27 (− 3.7, 2.77)	69.9 (49.2, 97.8)	75.2 (53.1, 105)	7.56 (3.65, 10.89)
Prevalence	6,815,142.5 (4,796,290.8, 9,455,180.2)	7,455,929.3 (5,232,259.4, 10,460,556.8)	9.4 (5.38, 13.39)	1751.6 (1233.8, 2431.9)	1944.3 (1361.7, 2726.7)	11 (7.06, 14.84)
DALYs	60,788.9 (27,584.9, 126,652.6)	66,041.5 (29,857.2, 136,985.1)	8.64 (4.31, 12.51)	15.6 (7.1, 32.5)	17.3 (7.8, 35.9)	10.93 (6.72, 14.96)
Western Sub-Saharan Africa						
Incidence	24,710.3 (17,219.7, 35,159.5)	92,826.2 (65,226.5, 132,560.9)	275.66 (259.12, 296.05)	10.3 (7.4, 14.4)	14.2 (10.1, 20)	37.15 (30.95, 44.42)
Prevalence	438,598.3 (307,139.7, 633,877.8)	1,741,945.4 (1,209,889.2, 2,493,010.7)	297.16 (279.57, 319.43)	252.3 (177.7, 360.9)	378 (265.9, 537)	49.81 (43, 58.43)
DALYs	3816.2 (1629, 8015.4)	15,176.8 (6521.5, 32,235.9)	297.69 (279.03, 324.49)	2.2 (0.9, 4.6)	3.3 (1.4, 6.9)	50.04 (42.93, 60.11)
Age group (years)						
15–19						
Incidence	699,967.4 (431,670.5, 1,111,989.7)	1,056,349.2 (659,123.1, 1,642,603.1)	50.91 (45.07, 56.21)	134.8 (83.1, 214.1)	169.3 (105.6, 263.2)	25.63 (20.76, 30.03)
Prevalence	4,919,456.3 (3,335,366.3, 7,017,527.9)	7,663,403.4 (5,183,309.6, 10,971,947.3)	55.78 (51.38, 61.25)	947.1 (642.1, 1351)	1228.1 (830.7, 1758.4)	29.67 (26.02, 34.23)
DALYs	44,339.7 (19,608.2, 93,893.4)	68,812.1 (30,360.1, 145,846.7)	55.19 (49.87, 61.89)	8.5 (3.8, 18.1)	11 (4.9, 23.4)	29.19 (24.75, 34.76)
20–24						
Incidence	41,811.4 (17,487.9, 99,989.8)	50,237.3 (20,473.9, 124,736.4)	20.15 (13.68, 27.16)	8.5 (3.6, 20.3)	8.4 (3.4, 20.9)	− 0.99 (− 6.32, 4.79)
Prevalence	6,348,599.6 (4,514,512.4, 8,839,642.9)	10,146,098.6 (7,311,868.4, 13,931,506)	59.82 (55.45, 64.43)	1290.1 (917.4, 1796.4)	1699.1 (1224.4, 2333)	31.7 (28.1, 35.5)
DALYs	58,564.1 (26,050.4, 122,606.2)	93,151.4 (41,704.7, 193,793.4)	59.06 (53.75, 64.23)	11.9 (5.3, 24.9)	15.6 (7, 32.5)	31.07 (26.69, 35.33)

Table 1 (continued)

Location	Numbers (95% UI)			Age-standardized rate (per 100 000)(95% UI)		
	1990	2021	Percentage change 1990–2021 (%)	1990	2021	Percentage change 1990–2021 (%)
25–29						
Incidence	21,729.7 (11,240.8, 39,286.3)	29,014.2 (14,775.6, 53,887.6)	33.52 (28.55, 39.68)	4.9 (2.5, 8.9)	4.9 (2.5, 9.2)	0.45 (– 3.29, 5.09)
Prevalence	6,031,387.2 (4,318,569.1, 8,444,653.6)	10,422,751.7 (7,483,904, 14,456,356.8)	72.81 (68.01, 78.57)	1362.7 (975.7, 1907.9)	1771.5 (1272, 2457.1)	30.01 (26.4, 34.34)
DALYs	54,546.1 (23,758.2, 113,009.4)	93,527.1 (41,177.5, 191,945.3)	71.46 (65.44, 77.97)	12.3 (5.4, 25.5)	15.9 (7, 32.6)	29 (24.47, 33.89)
30–34						
Incidence	10,641.3 (4804.8, 17,088.4)	17,173.8 (7847.4, 27,563.5)	61.39 (56.05, 66.33)	2.8 (1.2, 4.4)	2.8 (1.3, 4.6)	2.9 (– 0.5, 6.05)
Prevalence	5,370,351.6 (3,850,998.3, 7,479,002.5)	10,763,002.8 (7,711,792.5, 14,968,296)	100.42 (95.02, 106.81)	1393.4 (999.2, 1940.5)	1780.5 (1275.8, 2476.2)	27.79 (24.35, 31.86)
DALYs	47,000.7 (20,894.2, 100,837.7)	93,268.5 (41,091.2, 198,717.1)	98.44 (91.98, 106.01)	12.2 (5.4, 26.2)	15.4 (6.8, 32.9)	26.53 (22.41, 31.35)
35–39						
Incidence	7395.9 (3376.8, 12,017.7)	12,015 (5526.7, 19,695)	62.45 (57.29, 67.49)	2.1 (1, 3.4)	2.1 (1, 3.5)	2.03 (– 1.22, 5.19)
Prevalence	4,926,665.3 (3,515,124.3, 6,836,122.2)	10,125,830.5 (7,189,684, 14,078,426.7)	105.53 (99.98, 111.43)	1398.6 (997.9, 1940.7)	1805.4 (1281.9, 2510.1)	29.08 (25.6, 32.79)
DALYs	42,192.9 (18,612.1, 88,156)	86,164.3 (38,070.1, 181,214.5)	104.22 (98.29, 111.16)	12 (5.3, 25)	15.4 (6.8, 32.3)	28.25 (24.53, 32.62)
40–44						
Incidence	3833.7 (1587.5, 6609.9)	6926.8 (2882.4, 11,912.9)	80.68 (74.9, 87.04)	1.3 (0.6, 2.3)	1.4 (0.6, 2.4)	3.47 (0.16, 7.11)
Prevalence	4,264,970.2 (3,079,692.5, 5,936,549.8)	9,147,146.3 (6,544,589.1, 12,706,765.1)	114.47 (108.54, 120.26)	1488.7 (1075, 2072.2)	1828.5 (1308.3, 2540.1)	22.82 (19.43, 26.14)
DALYs	36,292.5 (16,202.1, 75,930)	77,515.1 (34,496.4, 161,821.6)	113.58 (107.08, 119.28)	12.7 (5.7, 26.5)	15.5 (6.9, 32.3)	22.31 (18.59, 25.58)
45–49						
Incidence	1574.1 (335.1, 3224.8)	3358 (707.3, 6847.4)	113.33 (100.47, 121.99)	0.7 (0.1, 1.4)	0.7 (0.1, 1.4)	4.61 (– 1.7, 8.86)
Prevalence	2,945,077.9 (2,115,796.3, 4,066,634.4)	7,499,319.7 (5,414,709.8, 10,384,919.5)	154.64 (148.12, 161.47)	1268.4 (911.2, 1751.4)	1583.8 (1143.5, 2193.2)	24.87 (21.67, 28.22)
DALYs	25,008.4 (11,280.9, 50,070.8)	63,606.7 (28,676.8, 126,845.9)	154.34 (147.24, 161.54)	10.8 (4.9, 21.6)	13.4 (6.1, 26.8)	24.72 (21.24, 28.25)

The table shows incident cases, prevalent cases, and Disability-Adjusted Life Years (DALYs) owing to PCOS in 1990 and 2021, and the percentage change, from 1990 to 2021, in the age-standardized rates (ASRs) per 100,000 women (generated from data available from http://ghdx.healthdata.org/gbd-results-tool).UI, uncertainty intervals

Myanmar [108.01% (95% UI: 80.46–137.42)], Equatorial Guinea [97.11% (95% UI: 73.89–133.94)] and Thailand [96.44% (95% UI: 73.39–123)]; negative trends were noted in Italy [– 6.52% (95% UI: – 13.08- – 1.05)] and New Zealand [– 0.82% (95% UI: – 13.79 – 10.35)] (Fig. 2; Supplementary Table S1).

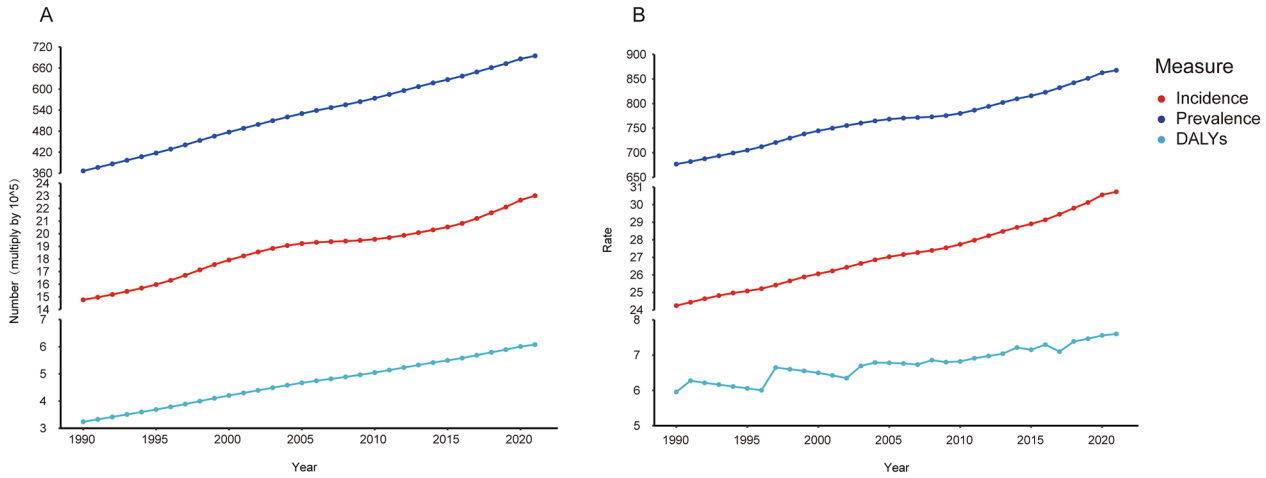

Fig. 1 Burden of PCOS from 1990 to 2021. **a** Numbers from 1990 to 2021. **b** Age-standardized rate from 1990 to 2021 (generated from data available from http://ghdx.healthdata.org/gbd-results-tool). DALYs, disability-adjusted life years

In 2021, the greatest age-standardized PCOS DALY rates were in Italy [35.1 (95% UI: 15.8–74.9)], Japan [27 (95% UI: 12.3–54.9)], and New Zealand [24.3 (95% UI: 11.1–50.6)]; Bosnia and Herzegovina [0.8 (95% UI: 0.3–1.8)], North Macedonia [0.8 (95% UI: 0.4–1.7)], and Albania [0.8 (95% UI: 0.3–1.8)] had the lowest rates. The percentage change for age-standardized PCOS DALY rates from 1990 to 2021 similarly varied by country. The largest increases were in Myanmar [108.27% (95% UI: 81.45–138.62)], Equatorial Guinea [97.49% (95% UI: 70.58–141.74)], and Thailand [92.4% (95% UI: 68.81–121.15)]; Italy [− 5.69% (95% UI: − 12.63–0.36)], New Zealand [− 0.74% (95% UI: − 12.75–10.31)], and Mexico [− 0.73% (95% UI: − 6.76–5.12)] exhibited negative trends (Fig. 2; Supplementary Table S1).

PCOS burden by SDI

In 2021, high SDI regions exhibited the greatest age-standardized incidence [70.2 (95% UI: 52–95.3)], prevalence [1720.7 (95% UI: 1270.5–2331.7)], and DALY [15.2 (95% UI: 7–31)] rates for PCOS, while low SDI regions exhibited the lowest age-standardized incidence [13.8 (95% UI: 9.8–19.3)], prevalence [361.6 (95% UI: 255.3–509.8)], and DALY [3.1 (95% UI: 1.4–6.6)] rates for PCOS. Increasing trends were noted in all regions (Table 1).

At the district level, a nonlinear association between SDI and age-standardized incidence, prevalence, and DALY rates for PCOS from 1990 to 2021 were noted, with age-standardized rates greatest at an SDI of approximately 0.9, indicating that a higher SDI associated with greater age-standardized incidence, prevalence, and DALY rates for PCOS (Fig. 3).

Age patterns

In 2021, the greatest rate of age-standardized incidence for PCOS was observed in the 15–19 age group [169.3 (95% UI: 105.6–263.2)]; the lowest was observed in the 45–49 age group [0.7 (95% UI: 0.1–1.4)]. In 2021, the 40–44 age group [1828.5 (95% UI: 1308.3–2540.1)] had the highest age-standardized prevalence, while the 15–19 age group [1228.1 (95% UI: 830.7–1758.4)] had the lowest. In 2021, the highest rate of age-standardized DALYs was in the 25–29 age group [15.9 (95% UI: 7–32.6)], while the lowest was in the 15–19 age group [11 (95% UI: 4.9–23.4)] (Table 1, Fig. 4).

The greatest increase in PCOS age-standardized incidence from 1990 to 2021 was in the 15–19 age group [25.63% (95% UI: 20.76–30.03)]; the smallest increase was in the 20–24 age group [− 0.99% (95% UI: − 6.32–4.79)]. In addition, the age group with the largest increase in rates of age-standardized prevalence and DALYs for PCOS from 1990 to 2021 was the 20–24 age group [prevalence: 31.7% (95% UI: 28.1–35.5); DALYs: 31.07% (95% UI: 26.69–35.33)]; the 40–44 age group exhibited the smallest increase [prevalence: 22.82% (95% UI: 19.43–26.14); DALYs: 22.31% (95% UI: 18.59–25.58)] (Table 1, Fig. 4).

Discussion

This study presents a thorough and updated analysis of PCOS prevalence on global, regional, and national scales spanning more than three decades. In 2021, the worldwide incidence, prevalence, and associated DALY rates for PCOS stood at 2.3 million, 69.47 million, and 610,000, respectively. The global age-standardized incidence,

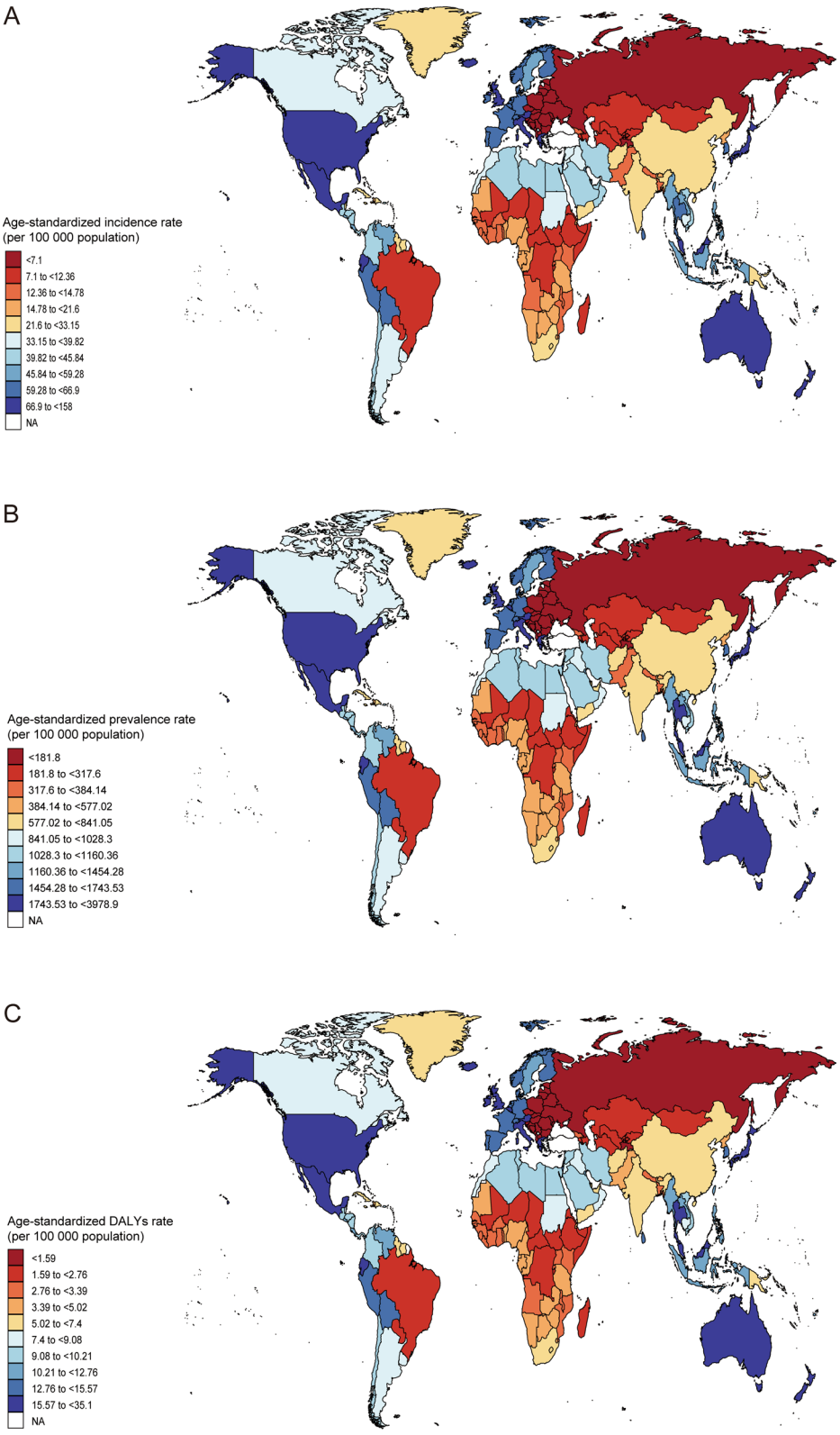

Fig. 2 Age-standardized burden of PCOS in 2021, by 204 countries and territories. **a** World map of ASIR for PCOS. **b** World map of ASPR for PCOS. **c** World map of ASDR for PCOS (generated from data available from http://ghdx.healthdata.org/gbd-results-tool).DALYs, disability-adjusted life years; ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate; ASDR, age-standardized rate of DALYs

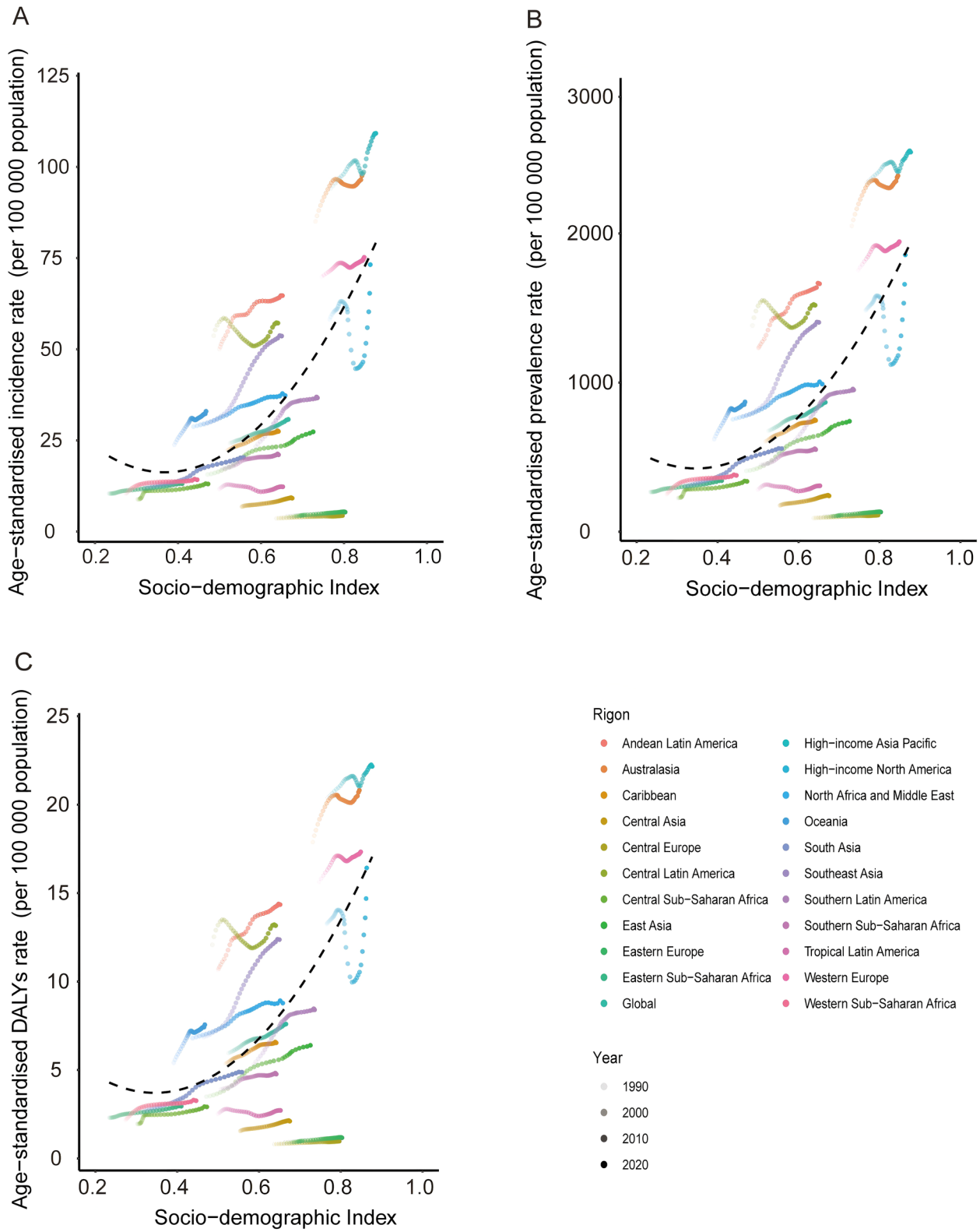

Fig. 3 Age-standardized burden of PCOS for the 21 Global Burden of Disease regions by socio-demographic index, 1990–2021. **a** ASIR for 21 GBD regions. **b** ASPR for 21 GBD regions. **c** ASDR for 21 GBD regions (generated from data available from http://ghdx.healthdata.org/gbd-results-tool). DALYs, disability-adjusted life years; ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate; ASDR, age-standardized rate of DALYs

prevalence, and DALY rates exhibited an increase from 1990 to 2021 by 26.77, 28.21, and 27.58%, respectively.

Our findings underscore the increasing prevalence of PCOS on global, regional, and national scales, revealing notable variations across different age groups and SDI regions. The highest prevalence of PCOS was observed in high SDI regions, contrasting with lower rates in regions with low SDI. The high-income Asia Pacific exhibited the greatest age-standardized prevalence rates, whereas Central Europe exhibited the lowest. Italy exhibited the greatest disease burden for PCOS in 2021, and there has indeed been a concerning upward trend in disease burden in Italy over the past 32 years. Importantly, from 1990 to 2021, the incidence, prevalence, and DALY rates for PCOS exhibited a marked increase across most age brackets, but particularly among the younger population.

The marked increase in global PCOS prevalence from 1990 to 2021 is a concerning trend that necessitates further study. Various factors likely contributed to this increase, including changes in the diagnostic criteria for this condition. The 1990 National Institutes of Health (NIH) criteria established the initial formal diagnostic guidelines for clinically identifying PCOS, mandating the presence of oligoovulation and hyperandrogenism. The introduction of the 2003 Rotterdam criteria [17] broadened diagnostic possibilities by incorporating polycystic ovarian morphology (PCOM) as a necessary characteristic while requiring the presence of 2 out of 3 criteria for PCOS diagnosis (i.e. irregular or absent ovulation; clinical or biochemical signs of hyperandrogenism; evidence of PCOM on ultrasound exam). As of 2018, collaboration among an Australian academic group, the American Society for Reproductive Medicine (ASRM), and the European Society of Human Reproduction and Embryology (ESHRE) [1] has advocated for continued clinical use of the 2003 Rotterdam criteria for diagnosis of adult patients, emphasizing a progressive approach based on clinical symptoms. Expanded diagnostic criteria and enhanced imaging capabilities have led to a substantial increase in PCOS diagnosis among women of reproductive age, rising from a range of 4%-8% to 21% [18]. Importantly, PCOS is recognized as a heritable condition, yet also multifactorial in etiology [19]. Emerging evidence suggests that susceptibility to PCOS is influenced not solely by genetic factors but also epigenetic modifications and developmental influences [20, 21]; such variables have likely contributed to the escalating prevalence of PCOS. Furthermore, environmental factors are understood to have contributed to the increase in PCOS incidence. Environmental exposure to perfluoroalkyl

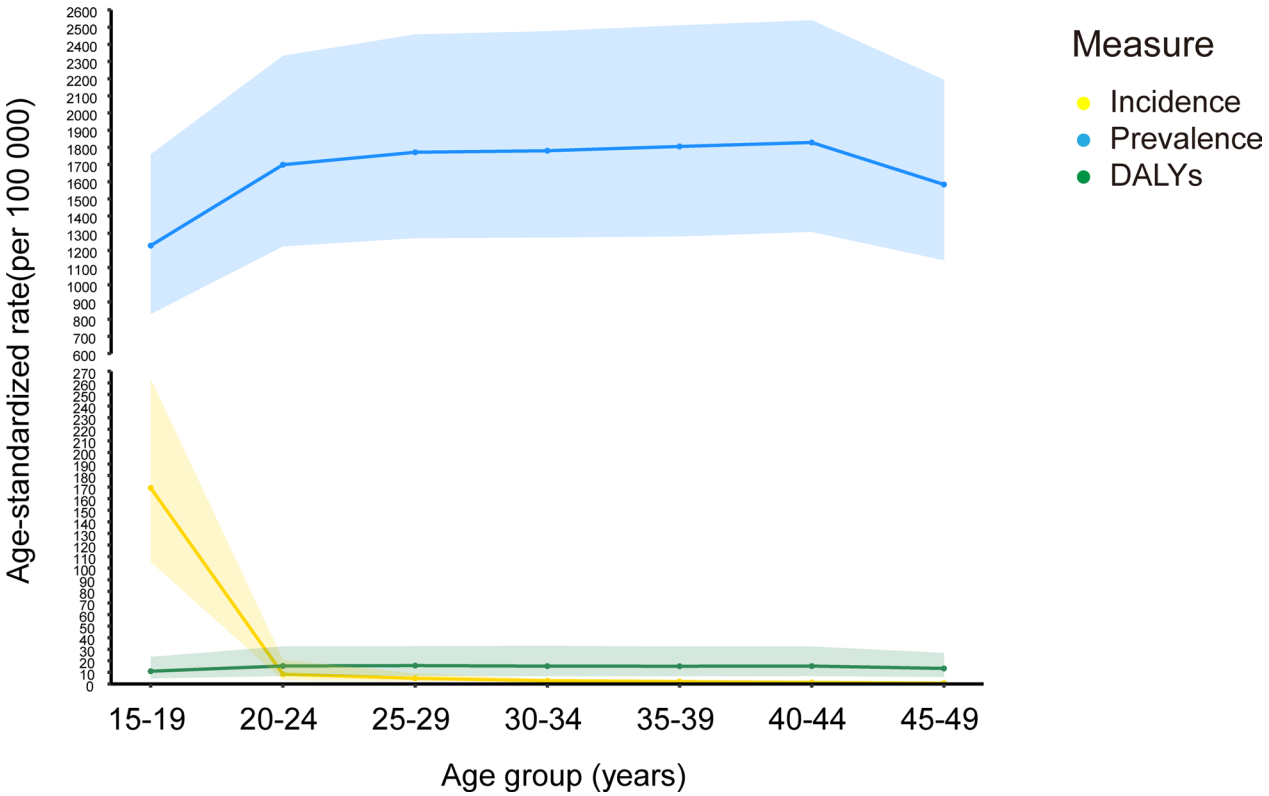

Fig. 4 Age-standardized burden of PCOS in 2021, by age pattern (generated from data available from http://ghdx.healthdata.org/gbd-results-tool)

substances (PFAS), polyfluoroalkyl substances (PFAS) [22, 23], and toxic metals (Pb, Hg, As, Ba, and Cd) [24] was reported to increase risk of developing PCOS.

The SDI of a region closely associates with population social development status and health outcomes for a given population. This parameter also serves as a composite measure, reflecting a delayed distribution of per capita income, average years of schooling, and total fertility rate among individuals less than 25 years old. PCOS affects 8–13% of women [1], resulting in over $8 billion in annual healthcare expenditures within the United States [25]. Geographic variations in PCOS phenotypes have been documented, with a higher incidence of PCOS-related hypertrichosis typically observed in high-income countries (e.g. Europe and North America) compared to the Asian region, and a lower incidence in East Asia [26–28]. Another study indicated comparable PCOS prevalence in high-income Europe and the United States, although the incidence of PCOS phenotype A was greater in the United States [29]. Our study revealed a higher PCOS burden in areas with a high SDI, which aligns with prior research [12]. This may be partially attributed to the prevalence of Western diets, obesity, insulin resistance, and metabolic disorders in developed countries. Furthermore, developed regions benefit from advanced medical technology, comprehensive health education, and improved access to medical resources, collectively contributing to a relatively high PCOS burden [29]. Conversely, the lower incidence of PCOS in countries with low SDI may reflect significant deficiencies in disease diagnosis, prevention, and health education within these regions [30]. To effectively address these health disparities, targeted policies and strategic allocation of medical resources are essential for regions with varying development levels.

The 2021 PCOS burden exhibited significant variation across geographic regions evaluated in the GBD 2021 study. The high-income Asia Pacific region exhibited the greatest age-standardized rates of PCOS, whereas Central Europe exhibited the lowest. An earlier meta-analysis [31] revealed varying accuracy in ultrasound diagnosis of PCOS among Asian, European, and North American studies, suggesting differences in age, BMI, and diagnostic criteria clinically utilized in these regions.

Although Italy carried the greatest PCOS disease burden in 2021, the disease burden decreased in the country over the past 32 years. The risk of diabetes for women with PCOS was found to resemble that of individuals otherwise at high risk for diabetes [32, 33]. A study in Sicily [34] revealed the prevalence rates of obesity, metabolic syndrome, diabetes mellitus, dysglycemia, and dyslipidemia to be 6.6, 6.6, 2.1, 13.1, and 60%, respectively. Furthermore, certain intronic variants of the NR3 C1 gene (rs10482672 and rs11749561) [35] as well as a history of growth hormone deficiency [36] have been linked to increased PCOS prevalence. Interestingly, our findings noted a marked decline in PCOS disease burden in Italy. Italy's health system, ranked second in the World Health Report 2000, as well as its efficiency [37] and greater adherence to the Mediterranean diet among the populace [38, 39], likely play crucial roles in mitigating Italy's national PCOS disease burden.

Here, we found increases in incidence, prevalence, and DALY rates for PCOS from 1990 to 2021 across various patient age groups, with the greatest increase among individuals aged 15–19 years. These findings align with those recently reported in an American study [40]. The challenges associated with diagnosing PCOS during adolescence stem from the overlap of diagnostic criteria with physiological changes seen in young individuals [41]. The updated International Evidence-Based Guidelines for PCOS Evaluation and Management have been instrumental in enhancing diagnostic precision and reducing instances of erroneous diagnosis [42, 43]. Importantly, obesity is prevalent among PCOS patients, with over 21.9% of adolescent PCOS cases also exhibiting dysglycemia [44]. Research has indicated that childhood obesity and adipose tissue dysfunction serve as early indicators of PCOS risk in later life [45]. Furthermore, the increased prevalence of obesity and abnormal glucose metabolism contribute to a diagnosis of early onset PCOS.

The COVID-19 pandemic has significantly impacted global health, and our research aims to elucidate the potential effects of the pandemic on the global burden of PCOS, a condition with multifaceted implications. Initially, from a mechanistic standpoint, PCOS and COVID-19 share common pathogenic and genetic features [46–48], potentially linked to comorbidities such as obesity, insulin resistance, hyperandrogenemia, and cardiovascular disease [49–52]. A bidirectional Mendelian randomization study has corroborated this association. However, the precise pathophysiological mechanisms underlying this relationship remain unclear [53]. Secondly, COVID-19 may represent a competing risk for PCOS [50], as fatalities from COVID-19 could preclude PCOS diagnosis or reporting. Thirdly, the management of PCOS requires a multidisciplinary approach to health care, but the COVID-19 pandemic and isolation restrictions have affected access to and delivery of health care [54], and some PCOS patients have voluntarily reduced their access to health services to reduce co-exposure, compared to their PCOS-related symptoms [55]. COVID-19 related health conditions are even more important, which may affect PCOS-related data collection systems in different countries.

In this study, we analyzed a comprehensive dataset spanning 32 years as well as various facets of relevant to global, regional, and national impact of PCOS on patient groups. Several limitations should be noted. Firstly, data on PCOS risk factors were unavailable, and our analysis predominantly focused on describing trends relevant to PCOS burden rather than elucidation of potential causative factors for the condition. Secondly, the potential misdiagnosis, missed diagnosis and documentation loss due to low medical performance in underdeveloped countries led to the underestimation of PCOS cases in GBD. Thirdly, the dynamic nature of PCOS diagnostic criteria may have introduced inconsistencies in determining PCOS prevalence rates [18]. Finally, the hysteresis property of GBD for that the present estimates were calculated using the past trends and covariates, should be noted. Consequently, augmented international collaboration, widespread dissemination of diagnostic criteria within resource-limited settings, and the implementation of robust health data collection strategies, particularly at the national level, could collectively facilitate more precise estimations of disease burden.

Conclusion

Our analysis indicates a substantial escalation in the global burden of PCOS over the past 32 years, marked by increases in incidence, prevalence, and DALYs, thereby amplifying its impact on global health. Significant variations were noted across age cohorts and SDI regions, with a particularly pronounced burden observed in younger populations and high-SDI regions. Furthermore, our investigation revealed the potential influence of the COVID-19 pandemic on the global PCOS burden. Our study have augmented the comprehension of PCOS epidemiology, thereby underscoring the imperative for further exploration of the etiological underpinnings of PCOS and the development of novel therapeutic interventions, alongside the judicious allocation of healthcare resources. These recommendations are poised to inform subsequent research endeavors and facilitate the ongoing advancement of this domain.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12978-025-02016-y.

Additional file 1

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Author contributions
TL conceptualised and supervised the study, and drafted the article. BX contributed data curation and formal analysis, and drafted the article. JY reviewed and revised the article. FC and JX conceptualised and supervised the study, and reviewed and revised the article.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

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References

1. Teede HJ, Misso ML, Costello MF, Dokras A, Laven J, Moran L, et al. Recommendations from the international evidence-based guideline for the assessment and management of polycystic ovary syndrome. Clin Endocrinol. 2018;89(3):251–68.
2. Huddleston HG, Dokras A. Diagnosis and treatment of polycystic ovary syndrome. Jama J Am Med Assoc. 2022;327(3):274–5.
3. Joham AE, Norman RJ, Stener-Victorin E, Legro RS, Franks S, Moran LJ, et al. Polycystic ovary syndrome. Lancet Diabetes Endocrinol. 2022;10(9):668–80.
4. Walter K. What is polycystic ovary syndrome? Jama J Am Med Assoc. 2022;327(3):294.
5. Appiah D, Hedderson MM, Kim C, Sidney S, Sternfeld B, Quesenberry CP, et al. The prospective association of hyperandrogenism, oligomenorrhea and polycystic ovary syndrome with incident gestational diabetes: the coronary artery risk development in young adults women's study. Diabetes Res Clin Pract. 2023;198: 110593.
6. Kazemi M, Kim JY, Wan C, Xiong JD, Parry SA, Azziz R, et al. Comprehensive evaluation of disparities in cardiometabolic and reproductive risk between Hispanic and White women with polycystic ovary syndrome in the United States: a systematic review and meta-analysis. Am J Obstet Gynecol. 2022;226(2):187-204.e15.
7. Khalenko VV, Guiglia RA, Alioto M. Are women with PCOS more at risk for endometrial cancer? What approach for such patients? Acta Bio Med Atenei Parmensis. 2023;94(2): e2023081.
8. Kazemi M, Kim JY, Wan C, Xiong JD, Michalak J, Xavier IB, et al. Comparison of dietary and physical activity behaviors in women with and without polycystic ovary syndrome: a systematic review and meta-analysis of 39 471 women. Hum Reprod Update. 2022;28(6):910–55.
9. Zaks N, Batuure A, Lin E, Rommel AS, Reichenberg A, Grice D, et al. Association between mental health and reproductive system disorders in women: a systematic review and meta-analysis. JAMA Netw Open. 2023;6(4): e238685.
10. Campbell RE. Beyond the ovary: rewiring our perspective on polycystic ovary syndrome. Nat Rev Endocrinol. 2024;20(5):257.
11. Gao Y, Liu H, Qiao L, Liang J, Yao H, Lin X, et al. Study of burden in polycystic ovary syndrome at global, regional, and national levels from 1990 to 2019. Healthcare (Basel). 2023;11(4):562.

12. Liu J, Wu Q, Hao Y, Jiao M, Wang X, Jiang S, et al. Measuring the global disease burden of polycystic ovary syndrome in 194 countries: global burden of disease study 2017. Hum Reprod. 2021;36(4):1108–19.
13. Miazgowski T, Martopullo I, Widecka J, Miazgowski B, Brodowska A. National and regional trends in the prevalence of polycystic ovary syndrome since 1990 within Europe: the modeled estimates from the Global Burden of Disease Study 2016. Arch Med Sci. 2021;17(2):343–51.
14. Safiri S, Noori M, Nejadghaderi SA, Karamzad N, Carson-Chahhoud K, Sullman MJM, et al. Prevalence, incidence and years lived with disability due to polycystic ovary syndrome in 204 countries and territories, 1990–2019. Hum Reprod. 2022;37(8):1919–31.
15. Zhang J, Zhu Y, Wang J, Hu H, Jin Y, Mao X, et al. Global burden and epidemiological prediction of polycystic ovary syndrome from 1990 to 2019: a systematic analysis from the Global Burden of Disease Study 2019. PLoS ONE. 2024;19(7): e0306991.
16. Collaborators GF. Burden of disease scenarios for 204 countries and territories, 2022–2050: a forecasting analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2204–56.
17. Group REA-SPcw. Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome (PCOS). Human Reprod. 2004;19(1):41–7.
18. Copp T, McCaffery K, Azizi L, Doust J, Mol BWJ, Jansen J. Influence of the disease label 'polycystic ovary syndrome' on intention to have an ultrasound and psychosocial outcomes: a randomised online study in young women. Hum Reprod. 2017;32(4):876–84.
19. Stener-Victorin E, Deng Q. Epigenetic inheritance of polycystic ovary syndrome—challenges and opportunities for treatment. Nat Rev Endocrinol. 2021;17(9):521–33.
20. Day FR, Hinds DA, Tung JY, Stolk L, Styrkarsdottir U, Saxena R, et al. Causal mechanisms and balancing selection inferred from genetic associations with polycystic ovary syndrome. Nat Commun. 2015;6:8464.
21. Stener-Victorin E, Deng Q. Transmission of polycystic ovary syndrome via epigenetic inheritance. Trends Mol Med. 2021;27(8):723–4.
22. Zhan W, Qiu W, Ao Y, Zhou W, Sun Y, Zhao H, et al. Environmental exposure to emerging alternatives of Per- and Polyfluoroalkyl substances and polycystic ovarian syndrome in women diagnosed with infertility: a mixture analysis. Environ Health Perspect. 2023;131(5):57001.
23. Zhang S, Gao F, Fu M, Zhang Q, Guan J, Shen H. Reproductive toxicology of environmental endocrine-disrupting chemicals in women: a cohort study protocol. Front Cell Dev Biol. 2024;12:1335028.
24. Liang C, Zhang Z, Cao Y, Wang J, Shen L, Jiang T, et al. Exposure to multiple toxic metals and polycystic ovary syndrome risk: endocrine disrupting effect from As, Pb and Ba. Sci Total Environ. 2022;849: 157780.
25. Riestenberg C, Jagasia A, Markovic D, Buyalos RP, Azziz R. Health care-related economic burden of polycystic ovary syndrome in the united states: pregnancy-related and long-term health consequences. J Clin Endocr Metab. 2022;107(2):575–85.
26. Bozdag G, Mumusoglu S, Zengin D, Karabulut E, Yildiz BO. The prevalence and phenotypic features of polycystic ovary syndrome: a systematic review and meta-analysis. Hum Reprod. 2016;31(12):2841–55.
27. Chen M, Nguyen W, Haq Z, Guo W, Briley J. Prevalence of female hirsutism and PCOS in the United States: a cross-sectional study. J Dtsch Dermatol Ges. 2025;23(3):330–8.
28. Wolf AT, Wang Z, Onnela JP, Baird DD, Jukic AMZ, Curry CL, et al. Signs of potential androgen excess across the lifespan in a US-based digital cohort study. J Clin Endocr Metab. 2024;00:1–13.
29. Chiaffarino F, Cipriani S, Dalmartello M, Ricci E, Esposito G, Fedele F, et al. Prevalence of polycystic ovary syndrome in European countries and USA: a systematic review and meta-analysis. Eur J Obstet Gyn R B. 2022;279:159–70.
30. Amiri M, Hatoum S, Buyalos RP, Sheidaei A, Azziz R. The influence of study quality, age, and geographic factors on pcos prevalence—a systematic review and meta-analysis. J Clin Endocr Metab. 2025;00:1–22.
31. Pea J, Bryan J, Wan C, Oldfield AL, Ganga K, Carter FE, et al. Ultrasonographic criteria in the diagnosis of polycystic ovary syndrome: a systematic review and diagnostic meta-analysis. Hum Reprod Update. 2024;30(1):109–30.
32. Glintborg D, Ollila MM, Møller JK, Pesonen P, Persson S, Elenis E, et al. Prospective risk of Type 2 diabetes in 99 892 Nordic women with polycystic ovary syndrome and 446 055 controls: national cohort study from Denmark, Finland, and Sweden. Hum Reprod. 2024;39(8):1823–34.
33. Thong EP, Codner E, Laven JSE, Teede H. Diabetes: a metabolic and reproductive disorder in women. Lancet Diabetes Endocrinol. 2020;8(2):134–49.
34. Carmina E, Nasrallah MP, Guastella E, Lobo RA. Characterization of metabolic changes in the phenotypes of women with polycystic ovary syndrome in a large Mediterranean population from Sicily. Clin Endocrinol. 2019;91(4):553–60.
35. Syed S, Gragnoli C. The glucocorticoid receptor gene (NR3C1) is linked to and associated with polycystic ovarian syndrome in Italian families. J Ovarian Res. 2024;17(1):13.
36. Ciresi A, Amato MC, Bianco J, Giordano C. Prevalence and clinical features of polycystic ovarian syndrome in adolescents with previous childhood growth hormone deficiency. J Pediatr Endocrinol Metab. 2016;29(5):571–8.
37. Bonora E, Monami M, Bruno G, Zoppini G, Mannucci E. Attending Diabetes Clinics is associated with a lower all-cause mortality. A meta-analysis of observational studies performed in Italy. Nutr Metabol Cardiovasc Dis. 2018;28(5):431–5.
38. Barrea L, Muscogiuri G, Pugliese G, de Alteriis G, Colao A, Savastano S. Metabolically Healthy Obesity (MHO) vs. Metabolically Unhealthy Obesity (MUO) Phenotypes in PCOS: Association with Endocrine-Metabolic Profile, Adherence to the Mediterranean Diet, and Body Composition. Nutrients. 2021;13(11):3925.
39. Che X, Chen Z, Liu M, Mo Z. Dietary interventions: a promising treatment for polycystic ovary syndrome. Ann Nutr Metab. 2021;77(6):313–23.
40. Yu O, Christ JP, Schulze-Rath R, Covey J, Kelley A, Grafton J, et al. Incidence, prevalence, and trends in polycystic ovary syndrome diagnosis: a United States population-based study from 2006 to 2019. Am J Obstet Gynecol. 2023;229(1):39.e1-.e12.
41. DiVall SA. Practical considerations for diagnosis and treatment of polycystic ovary syndrome in adolescence - distilling guidelines into clinical practice. Curr Opin Pediatr. 2023;35(4):494–9.
42. Peña AS, Witchel SF, Hoeger KM, Oberfield SE, Vogiatzi MG, Misso M, et al. Adolescent polycystic ovary syndrome according to the international evidence-based guideline. BMC Med. 2020;18(1):72.
43. Tay CT, Hart RJ, Hickey M, Moran LJ, Earnest A, Doherty DA, et al. Updated adolescent diagnostic criteria for polycystic ovary syndrome: impact on prevalence and longitudinal body mass index trajectories from birth to adulthood. BMC Med. 2020;18(1):389.
44. Gupta J, Antal Z, Censani M. Prevalence of impaired glucose tolerance in adolescent patients with polycystic ovary syndrome in an urban health care center. Diabetes. 2018;67(Supple 1):722.
45. Whooten RC, Rifas-Shiman SL, Perng W, Chavarro JE, Taveras E, Oken E, et al. Associations of childhood adiposity and Cardiometabolic biomarkers with adolescent PCOS. Pediatrics. 2024;153(5): e2023064894.
46. Bai H, Zhang S, Huang J, Diao K, Li C, Wang M. Unraveling the pathogenic interplay between SARS-CoV-2 and polycystic ovary syndrome using bioinformatics and experimental validation. Sci Rep. 2024;14(1):22934.
47. Huffman AM, Rezq S, Basnet J, Yanes Cardozo LL, Romero DG. SARS-CoV-2 viral entry proteins in hyperandrogenemic female mice: implications for women with PCOS and COVID-19. Int J Mol Sci. 2021;22:4472.
48. Rezq S, Huffman AM, Basnet J, Yanes Cardozo LL, Romero DG. Cardiac and Renal SARS-CoV-2 viral entry protein regulation by androgens and diet: implications for polycystic ovary syndrome and COVID-19. Int J Mol Sci. 2021;22(18):9746.
49. Alur-Gupta S, Boland MR, Dokras A. Risk of severe acute respiratory syndrome coronavirus 2 infection among women with polycystic ovary syndrome. Fertil Steril. 2023;119(5):847–57.
50. de Medeiros SF, Yamamoto MMW, de Medeiros MAS, Yamamoto A, Barbosa BB. Polycystic ovary syndrome and risks for COVID-19 infection: a comprehensive review : PCOS and COVID-19 relationship. Rev Endocr Metab Dis. 2022;23(2):251–64.
51. Morgante G, Troìa L, De Leo V. Coronavirus Disease 2019 (SARS-CoV-2) and polycystic ovarian disease: Is there a higher risk for these women? J Steroid Biochem. 2021;205: 105770.
52. Subramanian A, Anand A, Adderley NJ, Okoth K, Toulis KA, Gokhale K, et al. Increased COVID-19 infections in women with polycystic ovary syndrome: a population-based study. Eur J Endocrinol. 2021;184(5):637–45.
53. Si Y, Fei Y, Ma H, Xu Y, Ning L, Li X, et al. The causal association between polycystic ovary syndrome and susceptibility and severity of COVID-19:

a bidirectional Mendelian randomization study using genetic data. Front Endocrinol (Lausanne). 2023;14:1229900.
54. Kyrou I, Karteris E, Robbins T, Chatha K, Drenos F, Randeva HS. Polycystic ovary syndrome (PCOS) and COVID-19: an overlooked female patient population at potentially higher risk during the COVID-19 pandemic. BMC Med. 2020;18(1):220.
55. Sydora BC, Wilke MS, Ghosh M, Vine DF. The impact of the COVID-19 pandemic on health and health care experience in those with polycystic ovary syndrome. Int J Womens Health. 2025;17:287–98.

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