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The global, regional, and national patterns of change in the burden of chronic kidney disease from 1990 to 2021

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Abstract

Background Chronic kidney disease (CKD) is a major global public health problem with increasing prevalence and a huge health and economic burden. Diabetes mellitus and hypertension are major risk factors for CKD, and CKD is associated with cardiovascular disease and end-stage renal disease. Understanding the prevalence and burden of CKD is essential for the development of prevention and control strategies.

Methods Using data from the Global Burden of Disease Study (GBD) 2021 study, this study analyzed the incidence, prevalence, and disability-adjusted life years (DALYs) of CKD at global, regional, and national levels between 1990 and 2021. Decomposition analysis, health inequalities and frontier analysis were used to analyse the changes.

Results This study analyzed the global regional and national burden, trends, and disparities of CKD from 1990 to 2021 and found that the global burden of CKD had increased significantly, in line with trends in population ageing and population growth, and with significant variations between regions. There were 673.7 million people with CKD worldwide in 2021, accounting for 8.54% of the global population, a 92.0% increase from 1990. Despite a slight decline in age-standardized prevalence rate (ASPR), the absolute number of CKD cases increased. Central Asia had the highest prevalence of CKD, while Central Latin America had the highest rate of DALYs and incidence for CKD. In 2021, At the national level, China had the highest number of new CKD cases. The country with the highest ASPR and age-standardized DALYs rate (ASDR) of CKD was Mauritius. Globally, age-standardized incidence rate (ASIR) and ASDR were on the rise in almost all countries/regions, suggesting that the impact of CKD on global health is increasing. Population growth and ageing were major factors contributing to the increasing burden of CKD, especially in China and low Socio-demographic Index (SDI) regions. In addition, the cross-national study of health inequalities in CKD showed that, although there have been improvements in global health over time, health inequalities continue to exist. The frontier analysis revealed a considerable degree of heterogeneity in the effective differences across the spectrum of socio-demographic indices.

Conclusion CKD is a global health problem, the burden of which varies between regions and countries. A multifaceted approach is necessary to prevent and control CKD, including population-level interventions targeting risk factors, improvements in the accessibility and quality of health care, and measures to address health inequalities.

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Keywords Disability-adjusted life-years, Health inequality, Disease burden, Epidemiological trend, Chronic kidney disease

Introduction

CKD is a major public health problem. The incidence, prevalence, mortality and DALYs of CKD have increased significantly over the past 30 years, largely due to population growth and aging. The number of new cases of CKD has increased significantly from 7.8 million in 1990 to 18.99 million in 2019 [1]. More people, especially the elderly who are more prone to chronic diseases, are at high risk of developing CKD. CKD is defined as persistent abnormalities in kidney structure or function, lasting for more than 3 months, characterized by a glomerular filtration rate (GFR) < 60 mL/min/1.73 m² and/or an albumin-to-creatinine ratio (ACR) ≥ 30 mg/g, and encompassing various renal structural or functional impairments [2]. The most common causes of CKD are diabetes and hypertension [3]. However, in certain geographical areas, other factors such as herbs and environmental pollutants also lead to CKD [4]. Moreover, CKD is associated with an increased risk of cardiovascular diseases, such as stroke, myocardial infarction, and heart failure, and rather invariably towards end-stage renal disease (ESRD) in a majority of cases [5].

There are significant regional differences in the burden of CKD. The majority of people with CKD live in low- and middle-income countries (LMICs), accounting for approximately 78% of all cases [6]. The burden is higher in Southeast Asia, Central and South America and the Middle East and North Africa, and lower in high-income Asia and Europe [7]. In high SDI regions, high BMI, dietary risks, and low physical activity have a greater impact, while in low SDI regions, environmental risks such as air pollution and water contamination are more significant [7]. CKD is linked to a considerable economic burden on a global scale, particularly upon reaching kidney failure, due to the necessity for resource-intensive kidney replacement therapy (KRT, including dialysis or kidney transplantation) [8]. According to the statistics from GBD, CKD was responsible for 1.5 million deaths in 2021, rising in the rankings of leading causes of age-standardized mortality from 18th in 1990 to 11th in 2021 [9], and years of life lost (YLLs) are forecasted to more than double globally by 2040 [10].

Measures to support the prevention and treatment of CKD are therefore needed. Comprehensive and up-to-date data on the prevalence and burden of CKD by country, age, sex and sociodemographic factors are also required for policy makers and academics to develop response strategies. We analyzed CKD incidence, prevalence, and DALYs at the national, regional, and world-wide levels from 1990 to 2021 using the most recent data

from the GBD 2021 study. Moreover, we will examine how the epidemiology of CKD has changed over time due to variations in population growth and aging, and how the burden of disease varies by region and level of socioeconomic development.

Methods

Data source

This study employed data from the GBD 2021 study, obtained from the Institute for Health Metrics and Evaluation (IHME) at the University of Washington (<http://ghdx.healthdata.org/>), to present the most recent epidemiological insights on 371 diseases and injuries across 21 GBD regions and 204 countries and territories from 1990 to 2021. This study adheres to the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) statement [11].

Statistical analysis

Our primary study goal was to delineate the prevalence, incidence, and disease burden of CKD at the global, regional, and national level in 2021, as well as the trends from 1990 to 2021. We selected (code B.8.2 “chronic kidney disease”) as the cause, and prevalence, incidence, and DALYs as measures.

CKD cases were identified using the International Classification of Diseases, the 9th revision (ICD-9) codes, including 403-404.9, 581-583.9, 585-585.9, 589-589.9, 753-753.3. And the 10th revision (ICD-10) codes encompassed D63.1, E10-E11.9, I12-I13.9, N00-N08.8, N15.0, N18-N18.9, P70.2, Q61-Q62.8 [12].

The GBD estimates for prevalence, incidence, and fatal outcomes were calculated using DisMod-MR 2.1 and CODEm. These are standardized tools for modelling health data in accordance with demographic and temporal factors [13]. Data were reported as age-standardized incidence, prevalence, and DALY rates per 100,000 population. DALYs are calculated by adding (YLLs due to disease and years of life lived with disability (YLDs), which approximate the gap between the current health status of the population and the desired health status, where $YLL = \sum(N \times L)$, N represents the number of deaths from disease, and L denotes the gap between the age of death and the life expectancy of the standard life table death age group; $YLD = P \times DW$, P stands for the number of people affected by a disease, and DW symbolizes the disability weight [13]. To illustrate the long-term trend in the ASRs of CKD burden, the estimated average percentage change (EAPC) was derived from a regression model fitting the natural logarithm of the ASR to the calendar

year. The natural logarithm of rate is assumed to fit a linear regression model, $Y = \alpha + \beta X + \varepsilon$, where Y is equal to $\ln(\text{rate})$, β indicates the positive or negative changing trends, X refers to calendar year, and ε is error. Thus, $\text{EAPC} = 100 \times (\exp(\beta) - 1)$ and its 95% confidence interval (CI) were obtained from the linear regression model.

Then, using the decomposition method, we calculated the relative contributions of the 3 components (population growth, aging, and epidemiological shifts) to the difference in number of original DALYs for CKD from 1990 to 2021 for the global and China population [14].

To further assess the effects of socioeconomic factors, we employed the SDI. The SDI is a composite measure that encapsulates three key indicators: a total fertility rate under 25 (TFU 25), lag-distributed income per capita (LDI), and mean education for individuals aged 15 and above (EDU 15+), which exhibited a strong correlation with population health outcomes and social development status [15]. The SDI is used to categorize countries into quintiles: low SDI (low income, low education, high fertility); low-middle SDI; middle SDI; high-middle SDI; and high SDI [16]. The GBD 2021 results are available in an online visualization on GBD Compare and can be downloaded from the GBD Results Tool.

Then, the Slope Index of Inequality (SII) and Concentration index (CI) were used as standardized indicators to quantify the distributive inequality of CKD disease burden across countries. The SII is calculated using a regression analysis that relates a country's DALY rates to its relative SDI position, defined by the population's midpoint in a cumulative distribution ranked by SDI. The examination of heteroscedasticity is conducted through the implementation of a weighted regression model. The CI is calculated by numerical integration of the area under the Lorenz concentration curve and ranges from -1 to 1 , which was fitted using the cumulative fraction of DALYs and cumulative relative distribution of the population ranked by SDI. A negative CI value indicates a higher concentration of CKD burden among populations residing in countries with a lower SDI.

Furthermore, to examine the relationship between CKD prevalence and sociodemographic trends, we constructed a frontier analysis based on ASDR and SDI using data from 1990 to 2021. This approach enables a more nuanced understanding of potential shifts at the national or regional level.

All statistical analyses and graphics were performed in R (version 4.3.3 R Foundation).

Results

Prevalence, incidence, and dalys of the global CKD burden from 1990 to 2021

In 2021, there were 19,935,037.76 [95% uncertainty interval (UI): 18,702,792.56–21,170,794.11] incident cases of

CKD in 2021. The ASIR was 233.56 per 100,000 population (95% UI: 220.02–247.24), representing a 21.5% increase since 1990 (Table 1). Furthermore, the global prevalence of CKD in 2021 was 673,722,703.23 (95% UI: 629,095,119.06–722,364,095.72), accounting for 8.54% of the global population. This represents a substantial increase of 92.0% from the 1990 estimates. The ASPR was 8,006.00 per 100,000 population (95% UI: 7,482.12–8,575.62), indicating a 0.83% decrease since 1990 (Table 2). Furthermore, there were 44,453,683.61 (95% UI: 40,840,761.54–48,508,462.34) cases of CKD DALYs in 2021. The ASDR was 529.62 per 100,000 population (95% UI: 486.25–577.42), representing a 10.4% increase since 1990 (Table 3). From 1990 to 2021, the EAPCs in the ASPR, ASIR and ASDR were 0.01 (95% CI: -0.02 – 0.04), 0.64 (95% CI: 0.63–0.65), and 0.37 (95% CI: 0.33–0.41), respectively (Tables 1, 2 and 3). These figures illustrate an increase in the global burden due to CKD.

In 2021, notable disparities in the incidence, prevalence and DALYs of CKD were observed across 204 countries and territories (Fig. 1). Regional-level estimates are presented in Tables 1 and 2, and 3, while country-level data are provided in Supplementary Tables S1, S2, and S3. Among these regions, Central Latin America had the highest ASIR of CKD, with 411.41 cases per 100,000 population (95%UI: 390.17–431.32). The EAPC for CKD in Central Latin America was 1.43 (95%CI: 1.36–1.5) (Table 1; Fig. 1A). The highest ASPR of CKD was reported in Central Asia, at 10,698.24 cases per 100,000 population (95% UI: 10,022.94–11,348.10), with the EAPC of 0.02 (95% CI: 0.01–0.03) (Table 2; Fig. 1C). Within the 21 GBD super-region, Central Latin America had the highest ASDR [1171.14 (95% UI: 1054.82–1316.26)]. The EAPC for ASDR in this region was 1.75 (95% CI: 1.32–2.18) (Table 3; Fig. 1E). From 1990 to 2021, there had been notable variations in the changes observed in ASDR, with a decrease of 30.1% in East Asia super-region and an increase of 90.8% in High-income North America super-region (Table 3). Figure 2 illustrates the negative relationship between ASDR and SDI, showing the observed and projected levels for each site from 1990 to 2021.

At the national level, India and China had the highest prevalence of CKD, with 128.03 million (95% UI: 118.51–138.72) and 118.40 million (95% UI: 109.39–127.48) cases, respectively (Supplementary Table S1). In 2021, China recorded the highest number of new CKD cases, totaling 3.32 million (95% UI: 3.07–3.56), followed by India with 2.24 million (95% UI: 2.06–2.41) (Supplementary Table S2). Furthermore, India and China also had the highest burden of CKD in terms of DALYs, with 6.49 million (95% UI: 5.59–7.50) and 6.13 million (95% UI: 5.18–7.21) DALYs, respectively (Supplementary Table S3). Saudi Arabia had the highest ASIR of CKD in 2021, at 495.83

Table 1 Global and regional incidence of CKDs in 1990 and 2021, and EAPC of ASR from 1990 to 2021

Location	1990		2021		EAPC, 1990–2021	
	Number	ASR	Number	ASR		
Global	7790704.89	(7226165.09–8402567.56)	19935037.76	(18702792.56–21170794.11)	233.56	(220.02–247.24)
High SDI	2789647.87	(2576787.58–3024433.44)	5666653.07	(5273251.35–6033381.21)	277.75	(260.70–295.01)
High-middle SDI	1574443.81	(1447924.77–1709190.14)	3917149.27	(3653356.50–4175391.28)	205.90	(194.10–218.61)
Middle SDI	1963348.07	(1808277.45–2127370.05)	6251147.39	(5866963.97–6655539.11)	232.96	(219.53–246.12)
Low-middle SDI	1107201.33	(1026640.41–1198009.42)	3130959.84	(2912349.56–3362301.38)	204.97	(189.81–220.29)
Low SDI	348934.28	(324143.02–375457.82)	950556.84	(888493.96–1011543.29)	155.00	(143.40–167.34)
Andean Latin America	36899.55	(33960.50–40276.55)	177933.90	(165435.30–192798.19)	298.18	(276.18–322.60)
Australasia	62420.61	(59022.79–66438.19)	160661.44	(146984.43–172346.05)	297.30	(274.48–317.56)
Caribbean	46852.24	(43425.58–50526.22)	145322.04	(136425.08–154426.77)	274.22	(257.52–291.86)
Central Asia	64439.42	(59474.80–69704.56)	168442.40	(154019.54–183299.66)	187.28	(173.80–201.56)
Central Europe	193168.51	(174647.49–213352.00)	458515.89	(423618.40–495453.41)	218.39	(203.44–234.06)
Central Latin America	266578.78	(245612.65–291022.86)	1056442.80	(1000772.59–1110305.52)	411.41	(390.17–431.32)
Central Sub-Saharan Africa	28155.16	(26056.67–30336.80)	88402.20	(82070.77–94884.74)	130.46	(120.30–142.08)
East Asia	1331855.25	(1207021.61–1453259.13)	3505755.94	(3245782.63–3750967.25)	166.60	(156.01–176.80)
Eastern Europe	277461.17	(253751.32–306742.40)	548050.63	(501350.79–595626.98)	180.10	(167.54–193.25)
Eastern Sub-Saharan Africa	94221.33	(87688.32–101005.57)	244189.04	(228098.08–260056.87)	118.08	(108.97–127.55)
High-income Asia Pacific	538465.20	(494807.90–584025.32)	1249339.90	(1151297.67–1346530.64)	274.49	(255.82–293.59)
High-income North America	1050737.28	(962034.56–1145711.44)	2026545.69	(1868598.16–2175326.51)	316.15	(294.31–338.42)
North Africa and Middle East	482949.93	(445182.95–524327.86)	1988922.68	(1863402.90–2127840.11)	411.19	(385.40–438.45)
Oceania	5052.08	(4664.97–5451.63)	15011.15	(13904.79–16087.52)	162.83	(151.06–174.45)
South Asia	1016074.80	(938359.07–1099033.11)	2755182.56	(2545113.04–2967870.63)	177.65	(164.06–192.03)
Southeast Asia	466173.53	(432762.70–502980.26)	1568475.42	(1457741.06–1685244.77)	231.28	(215.53–247.34)
Southern Latin America	97989.80	(89314.30–107373.74)	244516.86	(224582.28–263090.11)	281.73	(260.45–302.55)
Southern Sub-Saharan Africa	52502.27	(48770.00–56527.80)	142810.74	(132637.67–152028.70)	233.60	(216.73–248.74)
Tropical Latin America	194243.96	(179335.42–210103.66)	663468.08	(620123.90–707785.55)	259.33	(242.85–275.61)
Western Europe	1328467.34	(1221422.92–1459691.94)	2271236.63	(2122274.86–2425620.93)	238.55	(223.94–254.27)
Western Sub-Saharan Africa	155996.70	(145848.79–167784.81)	455811.78	(426701.65–486021.25)	179.77	(165.43–194.20)

Table 2 Global and regional prevalence of CKDs in 1990 and 2021, and EAPC of ASR from 1990 to 2021

Location	1990		2021		EAPC, 1990–2021	
	Number	ASR	Number	ASR		
Global	350962673.93 (326973785.19–376155722.96)	8072.75 (7560.37–8634.07)	673722703.23 (629095119.06–722364095.72)	8006.00 (7482.12–8575.62)		0.01 (-0.02 to 0.04)
High SDI	72796005.22 (68039542.49–77665593.71)	6883.99 (6452.03–7322.72)	120879406.64 (113333443.31–127967826.93)	6733.55 (6322.09–7159.65)		-0.03 (-0.07 to 0.01)
High-middle SDI	78208074.60 (72803156.07–84086890.13)	7641.21 (7149.96–8188.95)	127111061.12 (118337579.54–136309239.33)	7267.74 (6782.08–7816.70)		-0.09 (-0.14 to -0.04)
Middle SDI	105819341.56 (98201189.67–113755650.09)	8450.59 (7891.90–9069.19)	220823053.60 (205500731.60–237345633.79)	8280.06 (7728.02–8885.29)		0.01 (-0.03 to 0.05)
Low-middle SDI	70588689.99 (65338439.52–76043936.98)	9292.53 (8660.54–9952.48)	149861034.16 (139108421.91–161539153.73)	9171.03 (8543.99–9848.15)		-0.07 (-0.1 to -0.05)
Low SDI	23236078.20 (21506137.83–25034231.83)	8090.37 (7566.41–8624.95)	54528959.60 (50362039.92–59039887.65)	7984.37 (7449.39–8549.73)		-0.07 (-0.09 to -0.05)
Andean Latin America	1465459.08 (1365797.84–1575972.59)	5766.55 (5377.83–6181.01)	3743589.44 (3478925.75–4028408.11)	5946.06 (5524.81–6371.54)		0.14 (0.12 to 0.16)
Australasia	1399739.19 (1315064.17–1481428.75)	6084.38 (5719.40–6456.26)	2810776.56 (2637789.18–2995328.91)	5910.04 (5548.15–6301.57)		-0.06 (-0.08 to -0.04)
Caribbean	1867235.87 (1741663.49–2000226.98)	6480.16 (6037.62–6925.81)	3468704.64 (3235452.36–3720719.90)	6632.98 (6181.25–7112.38)		0.09 (0.08 to 0.1)
Central Asia	5534239.83 (5182702.23–5905059.93)	10649.08 (10005.67–11309.29)	9356434.16 (8704145.56–9969947.88)	10698.24 (10022.94–11348.10)		0.02 (0.01 to 0.03)
Central Europe	8932586.77 (8363724.07–9525233.47)	6368.64 (5978.05–6771.96)	11481266.40 (10766158.86–12145281.21)	6205.18 (5841.05–6596.24)		-0.16 (-0.18 to -0.14)
Central Latin America	8628112.87 (8065183.13–9238846.53)	8477.01 (7931.03–9062.77)	22101800.95 (20701762.98–23422153.23)	8642.90 (8089.33–9163.75)		0.11 (0.09 to 0.12)
Central Sub-Saharan Africa	2633227.85 (2443845.20–2831335.82)	9221.98 (8598.75–9806.74)	6811951.39 (6363747.33–7313186.52)	9165.20 (8640.85–9709.73)		-0.08 (-0.09 to -0.06)
East Asia	69797869.24 (64858255.16–75190144.94)	7083.56 (6610.07–7593.48)	122849231.61 (113607491.21–132118614.72)	6258.13 (5823.13–6729.82)		-0.19 (-0.32 to -0.05)
Eastern Europe	24173787.94 (22444048.34–26062970.97)	9327.55 (8680.03–10050.13)	27312842.55 (25403077.61–29335270.38)	9266.31 (8619.37–9989.49)		-0.02 (-0.03 to -0.02)
Eastern Sub-Saharan Africa	5981605.69 (5488506.81–6503181.56)	5677.22 (5266.15–6113.13)	15017845.93 (13741758.82–16422383.80)	5821.27 (5404.49–6293.60)		0.11 (0.1 to 0.12)
High-income Asia Pacific	16878162.37 (15709632.50–18083495.73)	8566.14 (7979.52–9169.53)	29276225.74 (27336161.52–31020669.65)	7920.71 (7393.74–8457.44)		-0.28 (-0.32 to -0.24)
High-income North America	25125238.42 (23432070.59–26893288.36)	7401.06 (6920.42–7900.28)	42488578.32 (39404535.07–45165702.02)	7434.68 (6959.33–7911.44)		0.17 (0.12 to 0.22)
North Africa and Middle East	19739135.38 (18244353.50–21279745.73)	9119.72 (8490.94–9769.64)	49668756.30 (45835432.59–53616785.79)	9180.02 (8523.53–9830.12)		0.03 (0.02 to 0.04)
Oceania	306814.31 (282467.02–332776.58)	7742.43 (7231.44–8304.17)	776660.80 (715870.21–846878.10)	7950.68 (7408.82–8567.73)		0.12 (0.1 to 0.14)
South Asia	72584181.55 (67087414.23–78502263.42)	9936.56 (9252.61–10645.69)	158803353.90 (147190731.71–171556958.91)	9565.26 (8903.67–10265.71)		-0.19 (-0.25 to -0.14)
Southeast Asia	33768821.17 (31068003.37–36689891.83)	10225.21 (9474.04–11022.10)	73561437.10 (67779796.39–79733436.32)	10474.65 (9718.92–11301.72)		0.1 (0.09 to 0.11)
Southern Latin America	2695843.08 (2510441.22–2883800.85)	5784.40 (5397.31–6182.95)	4860630.70 (4530776.97–5214538.73)	5970.43 (5543.08–6414.98)		0.16 (0.14 to 0.18)
Southern Sub-Saharan Africa	2945199.05 (2740170.14–3170275.00)	8946.44 (8370.42–9563.71)	5972950.69 (5547456.01–6415523.52)	9037.91 (8440.60–9647.06)		0.03 (0.02 to 0.04)
Tropical Latin America	8408162.91 (7820460.83–9015638.54)	7763.01 (7240.67–8281.35)	19295702.68 (18022780.86–20680041.68)	7576.23 (7080.97–8107.55)		-0.07 (-0.09 to -0.05)
Western Europe	29093593.63 (27230515.14–30911867.66)	5469.90 (5132.58–5799.43)	41591466.01 (39070950.25–43910753.66)	5226.19 (4924.43–5544.20)		-0.16 (-0.2 to -0.13)
Western Sub-Saharan Africa	9003657.73 (8381320.31–9663357.18)	8310.65 (7767.39–8851.61)	22472497.35 (20882526.49–24191820.7)	8324.27 (7782.26–8871.02)		0.06 (0.04 to 0.07)

Table 3 Global and regional DALYs of CKDs in 1990 and 2021, and EAPC of ASR from 1990 to 2021

Location	1990		2021		EAPC, 1990–2021	
	Number	ASR	Number	ASR		
Global	20739894.95 (18843683.87–22588532.52)	479.85 (439.18–523.79)	44453683.61 (40840761.54–48508462.34)	529.62 (486.25–577.42)	0.37 (0.33 to 0.41)	
High SDI	2898450.08 (2605440.23–3169018.04)	277.64 (250.03–303.24)	7115740.28 (6464111.90–7759250.39)	358.51 (324.74–390.20)	1.07 (0.99 to 1.16)	
High-middle SDI	3534405.55 (3184087.13–3954974.96)	360.84 (325.48–401.53)	5944276.73 (5372850.02–6623407.05)	324.64 (293.58–360.92)	-0.35 (-0.42 to -0.28)	
Middle SDI	7031757.57 (6325501.23–7794726.64)	585.56 (531.80–652.64)	15700568.39 (14206921.00–17147168.62)	596.45 (540.33–650.48)	0.12 (0.04 to 0.2)	
Low-middle SDI	4690095.23 (4056126.33–5163160.31)	609.44 (545.07–686.29)	10611259.95 (9599821.34–11771755.08)	686.98 (622.50–765.20)	0.4 (0.38 to 0.42)	
Low SDI	2564544.82 (2265146.37–2870454.35)	853.94 (760.14–971.76)	5042405.18 (4408652.60–5841516.01)	791.80 (704.14–909.10)	-0.34 (-0.42 to -0.25)	
Andean Latin America	190986.48 (174176.59–211376.66)	753.97 (688.02–838.66)	524246.30 (434446.42–625013.32)	872.44 (723.54–1037.91)	0.39 (0.12 to 0.67)	
Australasia	46404.56 (42217.28–50551.00)	211.12 (192.43–229.58)	113692.61 (101513.70–125300.69)	216.61 (193.23–239.24)	0.53 (0.36 to 0.7)	
Caribbean	161590.45 (149056.01–180711.98)	565.09 (523.55–636.63)	385285.74 (331557.83–454109.22)	735.85 (631.01–867.89)	1.25 (1.13 to 1.37)	
Central Asia	176292.08 (152244.26–202201.34)	326.08 (278.46–378.79)	427633.16 (377524.18–490696.19)	493.20 (435.99–565.47)	1.02 (0.68 to 1.36)	
Central Europe	469644.12 (436515.73–504841.09)	342.78 (318.66–368.53)	539981.50 (472193.38–612672.21)	266.92 (233.43–306.23)	-0.74 (-0.84 to -0.64)	
Central Latin America	779859.32 (736752.26–822191.32)	767.86 (724.18–811.62)	2993750.33 (2691662.81–3371707.83)	1171.14 (1054.82–1316.26)	1.75 (1.32 to 2.18)	
Central Sub-Saharan Africa	349929.34 (293392.94–410516.07)	1158.69 (983.37–1367.04)	783700.03 (622594.67–996531.92)	1124.70 (899.03–1436.09)	-0.19 (-0.26 to -0.12)	
East Asia	4372607.81 (3843677.64–4996867.48)	461.27 (406.84–529.07)	6486167.09 (5538059.55–7597380.41)	322.36 (275.35–377.34)	-1.18 (-1.27 to -1.1)	
Eastern Europe	521704.93 (463249.74–581791.27)	207.42 (184.74–230.89)	642466.76 (562943.09–726951.94)	204.68 (180.40–232.13)	-0.58 (-0.77 to -0.38)	
Eastern Sub-Saharan Africa	1117668.72 (975468.16–1248903.63)	1095.23 (965.94–1254.96)	2047628.55 (1792019.35–2374163.96)	948.36 (838.71–1090.36)	-0.66 (-0.73 to -0.58)	
High-income Asia Pacific	599581.07 (550356.29–643830.01)	315.66 (289.04–339.18)	1146612.81 (990343.36–1268311.89)	235.57 (206.04–259.61)	-0.92 (-0.98 to -0.87)	
High-income North America	895097.39 (798640.37–986360.03)	266.63 (238.28–293.17)	3120983.24 (2864206.84–3351576.16)	508.81 (467.04–545.39)	2.45 (2.3 to 2.6)	
North Africa and Middle East	1493457.01 (1272351.27–1963220.17)	759.90 (642.73–1059.21)	3925988.16 (3427227.46–4413621.85)	846.64 (747.17–948.02)	0.51 (0.41 to 0.61)	
Oceania	22679.55 (16686.00–29124.72)	583.66 (445.79–741.99)	65814.56 (55557.95–77795.95)	699.04 (597.93–821.29)	0.52 (0.42 to 0.62)	
South Asia	3674401.19 (3157460.34–4115105.57)	509.78 (449.63–573.28)	8443339.19 (7372314.70–9681828.33)	540.57 (473.83–620.42)	0.13 (0.08 to 0.17)	
Southeast Asia	2408833.88 (2133711.97–2690990.76)	751.94 (672.31–850.85)	5703263.23 (5028656.95–6329024.78)	846.26 (753.05–940.53)	0.38 (0.35 to 0.41)	
Southern Latin America	281092.00 (266405.27–294525.37)	612.71 (580.90–641.72)	441138.34 (411344.87–467913.37)	515.22 (481.75–546.80)	-0.37 (-0.59 to -0.15)	
Southern Sub-Saharan Africa	202977.80 (179954.89–234849.17)	623.85 (548.64–742.10)	551466.19 (494225.99–622064.28)	895.96 (807.34–996.98)	1.32 (0.99 to 1.65)	
Tropical Latin America	594892.45 (560161.00–631009.06)	562.72 (527.93–598.67)	1311915.44 (1220675.20–1401164.05)	516.97 (480.55–552.11)	-0.31 (-0.43 to -0.18)	
Western Europe	1267566.09 (1125408.47–1409086.10)	234.12 (206.76–260.11)	2361341.78 (2067097.82–2638162.69)	241.72 (209.82–271.06)	0.38 (0.29 to 0.47)	
Western Sub-Saharan Africa	1112628.72 (952298.20–1275994.65)	928.71 (800.33–1067.12)	2437268.60 (1992651.87–2893648.79)	930.73 (788.43–1081.08)	-0.04 (-0.08 to 0)	

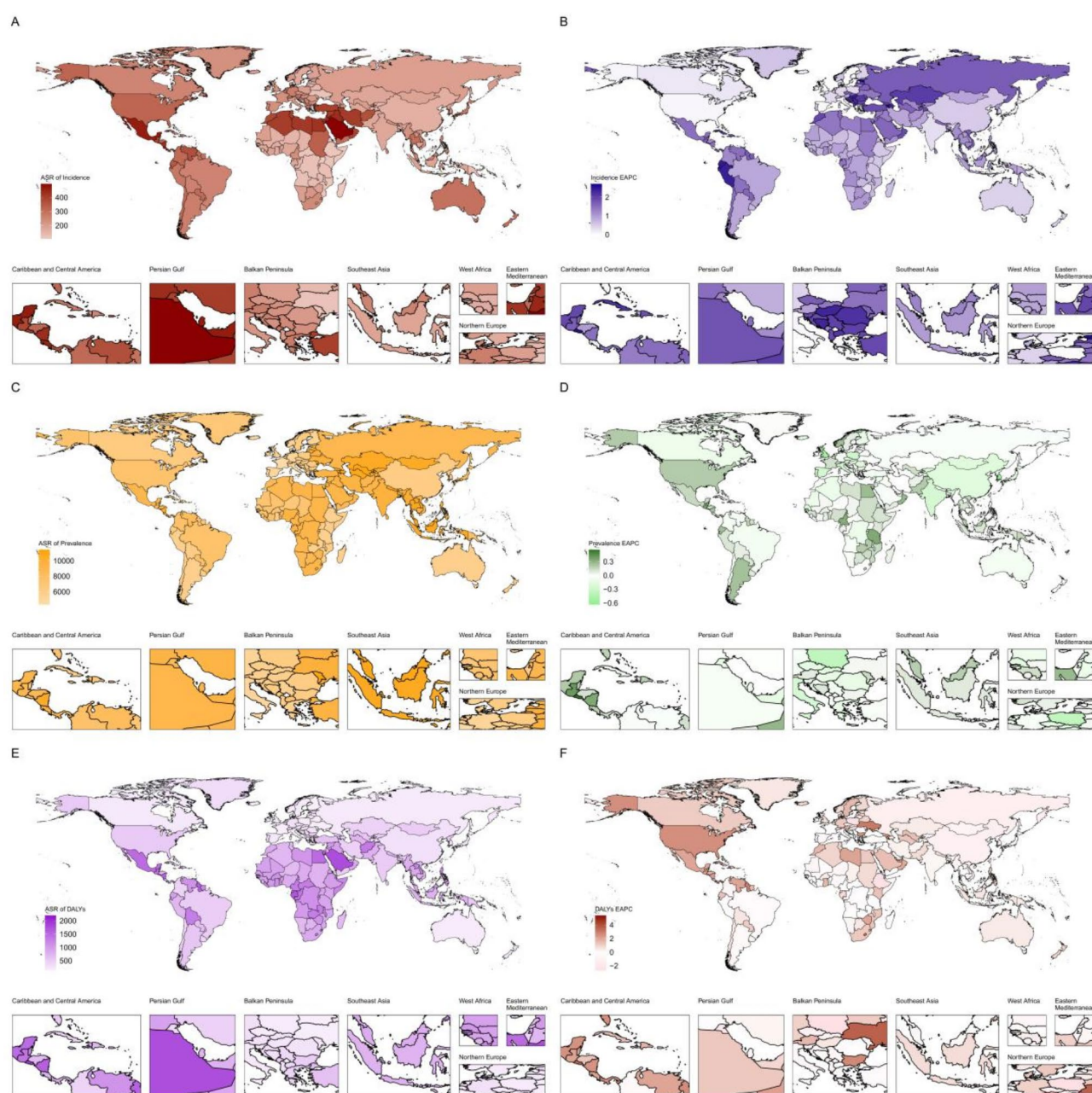


Fig. 1 The global incidence, prevalence and DALYs burden of CKD in 204 countries and territories. **(A)** The ASIR (per 100,000 population) of CKD in 2021. **(B)** The EAPC of ASIR for CKD between 1990 and 2021. **(C)** The ASPR (per 100,000 population) of CKD in 2021. **(D)** The EAPC of ASPR for CKD between 1990 and 2021. **(E)** The ASDR (per 100,000 population) of CKD in 2021. **(F)** The EAPC of ASDR for CKD between 1990 and 2021. DALYs: disability-adjusted life years; ASIR: age-standardized incidence rate; ASPR: age-standardized prevalence rate; ASDR: age-standardized DALYs rate; EAPC: estimated annual percentage change; CKD: chronic kidney disease

cases per 100,000 population (95% UI: 465.09–529.64), with the EAPC of 1.58 (95% CI: 1.47–1.69) (Supplementary Table S1, Fig. 1A). Mauritius reported the highest ASPR, with 11,411.55 cases per 100,000 population (95% UI: 10,649.12–12,263.72) and the EAPC of 0.24 (95% CI: 0.21–0.28) (Supplementary Table S2, Fig. 1C). The highest ASDR is in Mauritius (2,196.12 per 100,000 population; 95% UI: 2,043.11–2,318.87), with the EAPC of 2.02

(95% CI: 1.66–2.37) (Supplementary Table S3, Fig. 1E). Over the past three decades, China experienced a significant reduction in the ASDR of CKD, with a decline of 31.1%. El Salvador has experienced the most significant increase in CKD ASDR, with a 142.8% rise, highlighting the country's growing burden of CKD. (Supplementary Table S3).

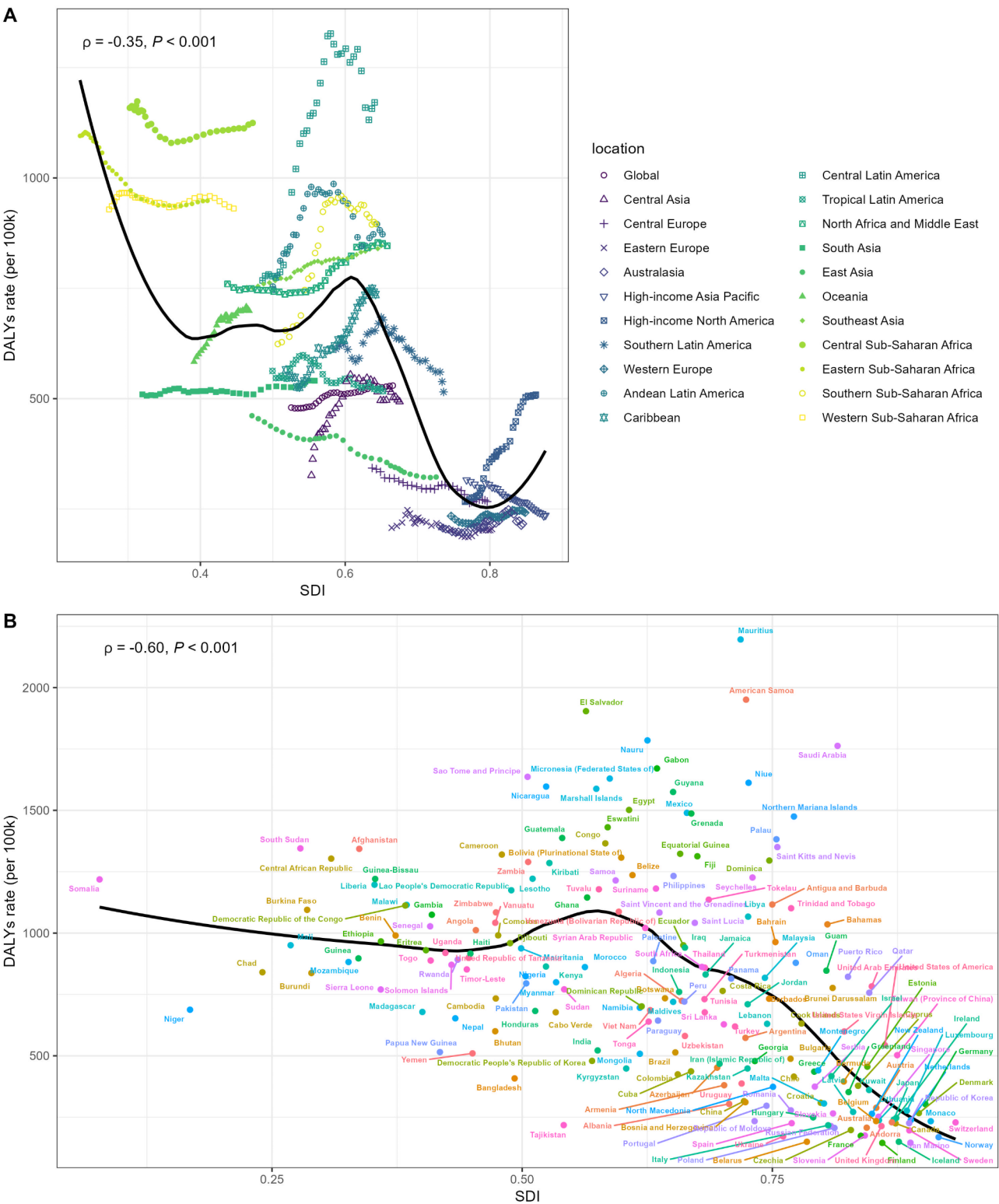


Fig. 2 (A) The ASDR due to CKD globally and for 21 GBD regions by SDI from 1990 to 2021. For each region, points from left to right depict estimates from each year from 1990 to 2021. (B) The ASDR due to CKD for 204 countries by SDI in 2021. The expected age-standardized rates in 2021 based solely on SDI were represented by the black line. DALYs: disability-adjusted life years; ASDR: age-standardized DALYs rate; CKD: chronic kidney disease; GBD: Global Burden of Disease; SDI: socio-demographic index

Decomposition analysis of CKD burden

Decomposition analysis of the DALYs for CKD showed that, globally, population growth accounted for 50.82% of the increase in disease burden, while aging contributed 37.48% (Fig. 3, Supplementary Table S4). In China, population growth and aging contributed 51.17% and 150.82%, respectively. The impact of aging varied across different SDI regions, with the highest impact in low-SDI regions (119.41%), followed by 60.63%, 43.54%, 39.19%, and 24.34% in low-middle, middle, high-middle, and high-SDI regions, respectively (Supplementary Table S4). The adverse effect of aging on disease burden diminishes with lower SDI levels. Epidemiological changes led to a global increase in disease burden, particularly in high-SDI regions, where the rise was 31.8% (Supplementary Table S4).

Cross-national CKD health inequality

The study also revealed significant absolute and relative inequalities in CKD burden associated with SDI. The inequality slope index indicated a reduction in the DALYs rate gap between the highest and lowest SDI countries, from -242.43 (95% CI: -310.45 to -174.41) in 1990 to 16.42 (95% CI: -107.89 to 140.73) in 2021 (Fig. 4A). The crude DALY rates declined with increasing SDI levels, both in 1990 and 2021. This indicates that countries with higher SDI levels typically have lower crude DALY rates. The concentration index changed slightly from -0.06 (95% CI: -0.08 to -0.04) in 1990 to 0.03 (95% CI: 0 to 0.03) by 2021 (Fig. 4B). China and India showed some improvements over these three decades. The change in the concentration index suggests that, while DALY rates were more concentrated among countries with lower SDI levels in 1990, the distribution of DALY rates across different SDI levels had become more balanced by 2021.

Frontier analysis for the relationship between CKD dalys and the status of the countries' development

A frontier analysis was conducted using data from 1990 to 2021, employing DALYs and SDI to assess disparities between nations and regions and the optimal frontier. This research evaluated the potential for mitigating the burden of CKD in relation to distinct stages of development. From 1990 to 2021, DALYs decreased globally across various SDI levels, suggesting an overall decline in CKD burden (Fig. 5A). As sociodemographic development progresses, the effective difference increases, indicating that countries or regions with a higher SDI have greater potential for reducing the burden of CKD. The top five countries or regions with the largest effective difference from their frontier in 2021 (range of effective difference: 2,117.80 to 332.72) included Mauritius, American Samoa, El Salvador, Nauru, and Saudi Arabia (Fig. 5B, Supplementary Table S5). The solid black line represents the frontier, and the dots represent the countries and regions. The blue dots indicate an upward trend, while the red dots indicate the opposite. DALYs tended to decrease with increasing socioeconomic development. However, the trend in DALYs varied across countries, with some countries experiencing further reductions and others experiencing increases. This variability in DALY trends may reflect uneven progress in global health development, particularly in reducing the burden of CKD.

Discussion

Based on the GBD data, this study systematically analyzed the trends in incidence, prevalence, and DALYs of CKD worldwide from 1990 to 2021. The results showed that the global incidence and prevalence of CKD increased significantly by 21.5% and 92.0%, respectively, in 2021 compared with 1990. In addition, global DALYs for CKD also showed an upward trend, increasing by 10.4% since 1990. These data suggest that the burden of CKD continues to increase, particularly in LMICs. This

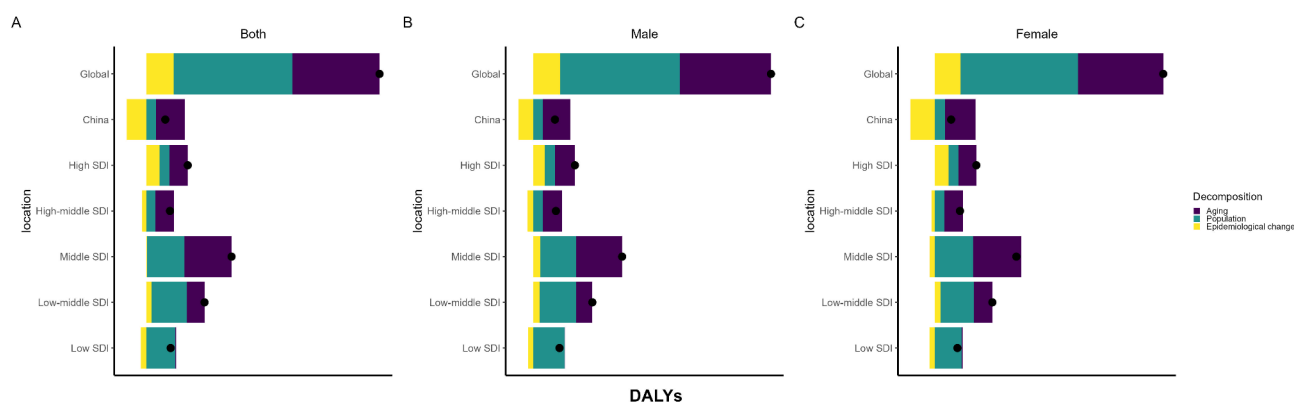


Fig. 3 Changes in CKD DALYs according to population-level determinants of population growth, aging, and epidemiological change from 1990 to 2021 at the global level, China, and by SDI quintile. (A) Both, (B) Male, and (C) Female. The black dot represents the overall value of change contributed by all 3 components. DALYs: disability-adjusted life years; CKD: chronic kidney disease; SDI: socio-demographic index

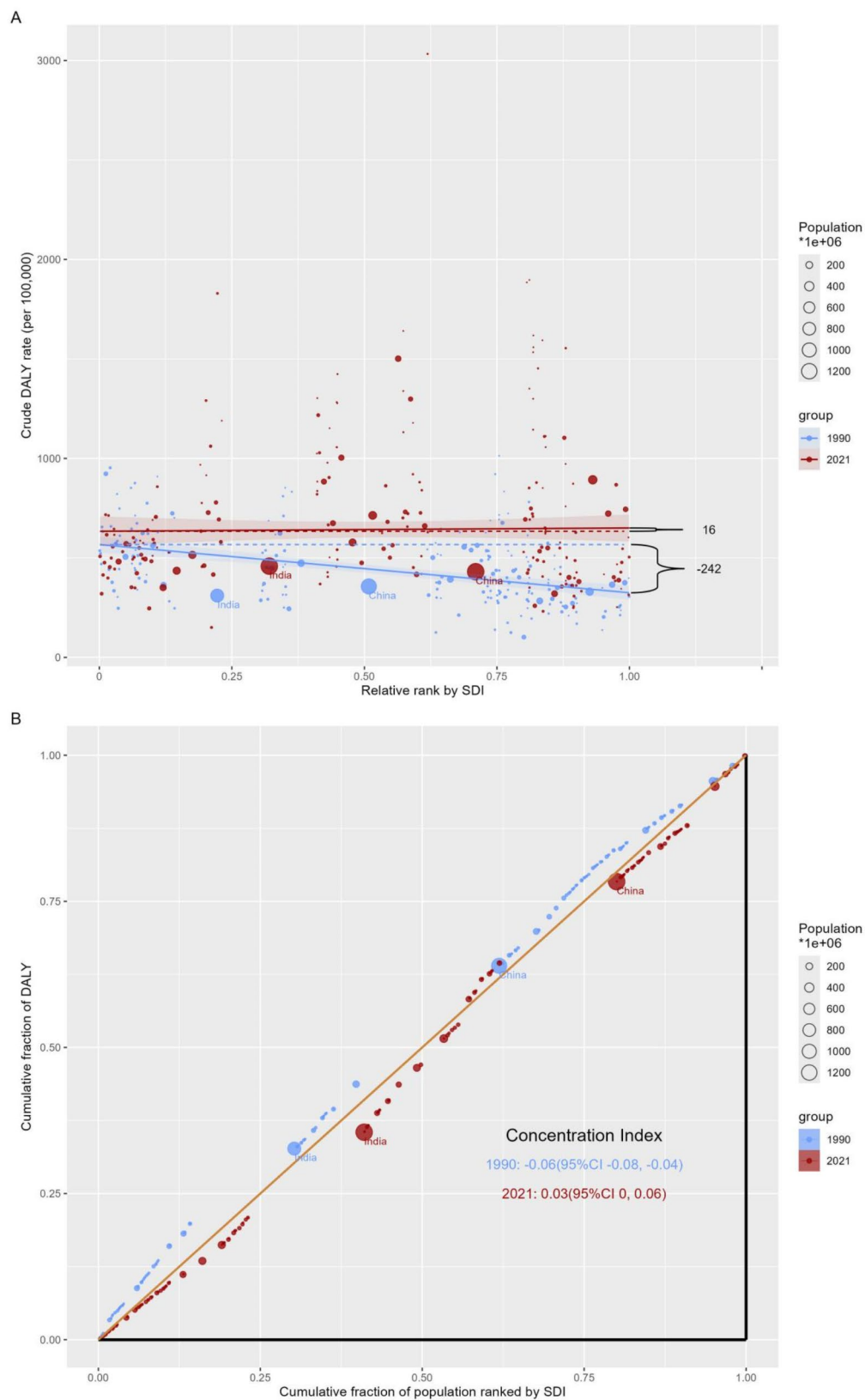


Fig. 4 Cross-national CKD health inequality. **(A)** Absolute income-related healthy inequality in CKD burden, presented using regression lines, 1990 vs. 2021. **(B)** Relative income-related healthy inequality in CKD burden, presented using concentration curves, 1990 vs. 2021

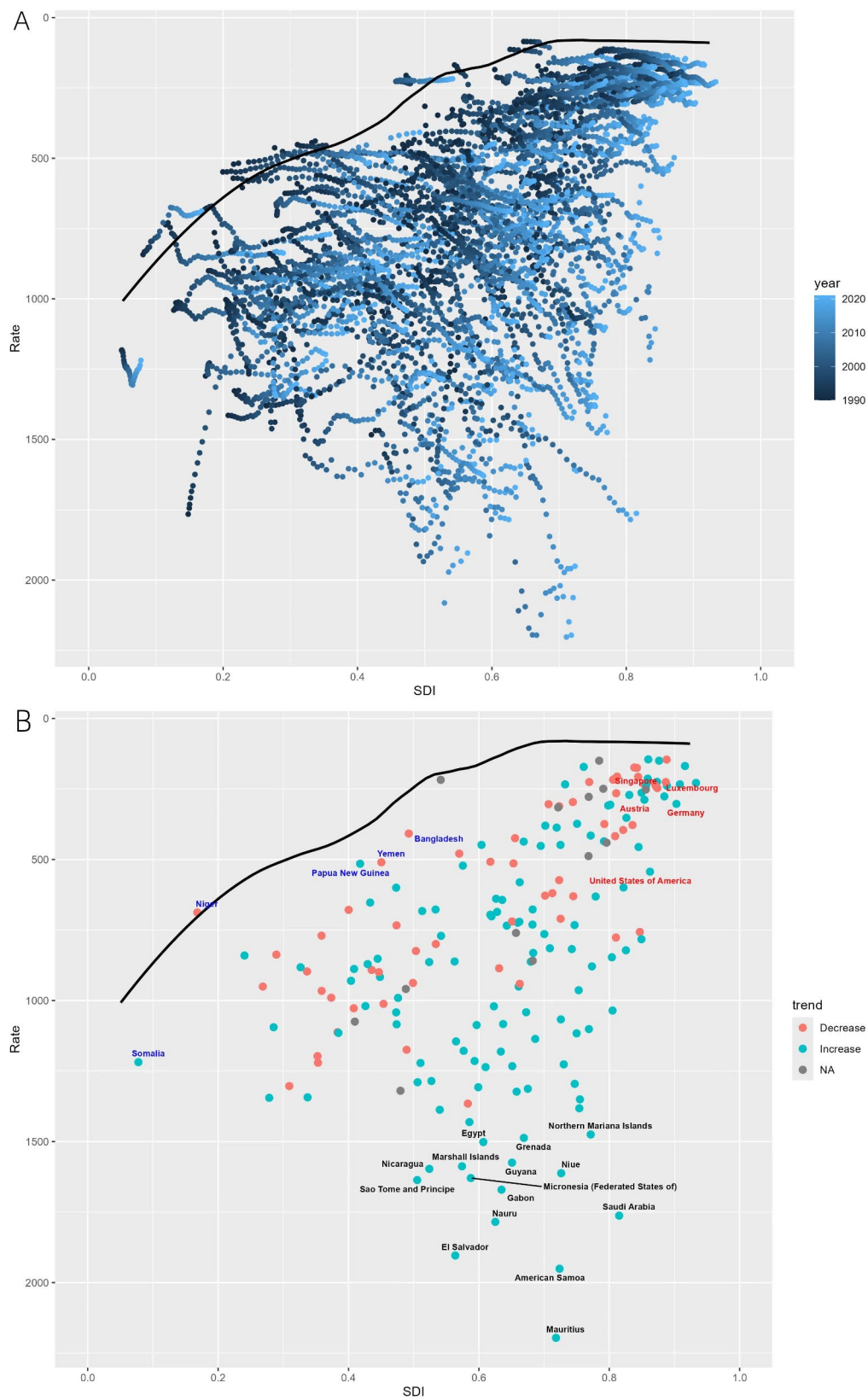


Fig. 5 (See legend on next page.)

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Fig. 5 (A) Frontier analysis based on SDI and CKD DALYs rate from 1990 to 2021. (B) Frontier analysis based on SDI and CKD DALYs rate in 2021. The frontier is delineated in solid black color; countries and territories are represented as dots. The top 15 countries with the largest effective difference (largest CKD DALYs gap from the frontier) are labeled in black; examples of frontier countries with low SDI (< 0.5) and low effective difference are labeled in blue, and examples of countries and territories with high SDI (> 0.85) and relatively high effective difference for their level of development are labeled in red. Red dots indicate a decrease in ASDR from 1990 to 2021; blue dots indicate an increase in ASDR from 1990 to 2021. DALYs: disability-adjusted life years; ASDR: age-standardized DALYs rate; CKD: chronic kidney disease; SDI: Socio-demographic index

increase may be attributed to factors such as population growth, ageing and lifestyle changes [17]. Although the ASPR decreased slightly, it did not fully compensate for the increase in the absolute number of CKD cases. Moreover, almost all countries/regions experienced an increase in the ASIR and in the ASDR, suggesting that the impact of CKD on global health is increasing. Despite this, this study showed a 30% decline in ASDR in East Asia over the past three decades. The negative correlation between the SDI and ASDR indicates that social development has a positive impact on human health and longevity.

The global burden of diabetes and hypertension will continue to rise as the population ages and life expectancy increases, with a corresponding increase in the burden of CKD [18]. Decomposition analysis revealed that population growth and aging contributed 50.82% and 37.48%, respectively, to the increase in the global burden of CKD. In China, these factors had an even greater impact, contributing 51.17% and 150.82%, respectively. This might partly be due to large population. The ageing population has led to a significant increase in the prevalence and mortality from CKD in China. Moreover, China and India together account for nearly half of the global CKD deaths and DALYs attributable to high sodium intake [19]. This phenomenon may be related to a number of factors, including dietary habits and food processing methods. Nevertheless, the burden of disease in China has decreased over the past three decades. This decline may be partly attributed to improvements in education, health care, and environmental protection [20]. The prevalence and mortality of CKD are projected to continue to increase until 2029 [21]. Aging had a particularly pronounced effect in low-SDI regions. Epidemiological changes also played a role, especially in high-SDI regions, suggesting that improvements in healthcare and lifestyle factors were sufficient to counteract the rising burden of CKD. This finding highlights the need to take demographic change into account when developing public health strategies. To lower the disease burden of CKD, a comprehensive strategy is required, including risk factor prevention in primary care, CKD screening in the elderly and high-risk population. Elderly patients with CKD require an integrated multidisciplinary strategy to manage their multimorbidity, polypharmacy and high rates of poor outcomes.

There are significant differences in the prevalence of CKD and DALYs between different GBD regions. For

example, Central Asia has the highest ASPR, while Central Latin America has the highest ASIR and ASDR of CKD in 2021. These differences may be related to factors such as economic development, the availability of medical resources, environmental exposures, and lifestyle in these regions. Diabetes, hypertension, cardiovascular disease, smoking, and obesity are among the known risk factors for kidney disease. Moreover, ambient air pollution, particularly PM_{2.5} pollution, is estimated to account for 17–20% of the global burden of CKD [22]. Large epidemiological studies have shown that PM_{2.5} exposure is associated with an increased risk of incident CKD, CKD progression and development of ESKD [23, 24]. The underlying mechanisms include elevated blood pressure, increased oxidative stress and inflammatory response, insulin resistance [25]. In Central Asia, these health challenges may be exacerbated by the region's industrial profile. Central Asia is a key region for the extraction of mineral resources, especially copper, gold, uranium, and other metal ores. As a result, the region has well-developed power plants and metallurgical industries, and high levels of coal consumption can lead to air pollution with NO_x, SO₂, and PM [26]. In contrast, the higher burden of disease in Central Latin America may be related to inadequate public health funding, low uptake of peritoneal dialysis, and a shortage of health workers [17]. These geographic disparities should be considered in targeted public health initiatives and the allocation of health care resources.

In terms of inequality between countries, the disease distribution map and cross-regional comparisons showed that the burden of CKD was closely related to the socioeconomic index, which was consistent with previous findings [27]. In LMICs, the prevalence of CKD has risen, primarily due to the increasing burden of non-communicable diseases like diabetes and hypertension, as well as communicable and infectious diseases such as HIV and various types of hepatitis. Environmental and occupational exposures, including heavy metals, traditional (herbal) medicines, and pesticides, have also contributed to this trend [28]. Consequently, the number of years lost to illness, disability, or premature death from CKD is substantially higher in these regions compared to high-income countries [29]. The combination of these factors, together with the fragility of health systems and lack of funding, hinders progress in the prevention and early detection of CKD in LMICs [30]. Interestingly, the

decrease in the inequality slope index indicates that the rate of DALYs between high and low SDI nations was narrowing, which was a positive trend. However, the changes in the concentration index and the inequality slope index have shifted from a negative to a positive correlation, suggesting that the DALY rate has increased in high-income regions instead. Since 1990, the burden of CKD has increased in high-income areas, largely due to risk factors such as diabetes, hypertension, obesity, AKI, kidney stones, preeclampsia, population ageing, which are more commonly in areas with higher SDI regions [18]. This suggests that despite global progress in reducing health inequality, targeted interventions in low-SDI areas are needed to further reduce the burden of CKD.

The frontier analysis showed an overall trend of decreasing DALYs in CKD with increasing SDI. Despite this trend, there remains a degree of heterogeneity in the differences in effectiveness across SDI levels. Remarkably, low-SDI countries including Somalia, Niger, Papua New Guinea, Yemen, and Bangladesh have demonstrated outstanding management of CKD burden. Despite limited resources, these countries and territories have performed admirably in managing the burden of CKD, and their policies and practices deserve further study. Conversely, upper-middle-income countries, such as Mauritius, Nauru, American Samoa, and Saudi Arabia, did not perform as expected in controlling the CKD burden. In 2017, Mauritius ranked second in the world for CKD prevalence and mortality. Mauritius also had the highest ASDR of CKD attributable to high sodium intake in 2019 [19]. For many years, Mauritius has ranked among the top five countries in terms of diabetes prevalence [31]. Factors such as geographical location and lifestyles may play a role in this discrepancy. These differences may reflect variations in the burden of CKD across countries and regions, possibly related to disparities in access to healthcare and socioeconomic development.

CKD is a global problem with significant regional and national variations in burden, which are influenced by a variety of factors including socioeconomic status, lifestyle, environmental exposures, and access to healthcare. The disease burden of CKD can be effectively reduced through several key strategies: strengthening risk factor management, optimizing health care resource allocation, developing strategies to address the needs of aging populations, reducing health inequalities, and implementing data-driven policies. These policy recommendations will not only improve the prognosis of patients with CKD but also contribute to more equitable health outcomes worldwide.

There are some limitations of this study that need to be discussed. First, there was some bias between the GBD estimate of CKD burden and the actual data due to differences in data collection tools and methods over time

and across countries/regions. For example, the burden of CKD may be underestimated in LMICs areas due to the lack of healthcare resources, such as diagnostic equipment and specialized nephrologists. Second, the definition of disease impairment in this study was limited by simple disease descriptions that ignored comorbidities and disease complexity, which may lead to inaccurate burden estimates. Moreover, although the relationship between DALYs and SDI was interpretive, it cannot be considered causal. Further research is needed to elucidate how socioeconomic factors influence the burden of CKD. Lastly, the global model used in this study may not fully capture the complexity and diversity of specific regions, such as differences in access to health care or local environmental factors, which may lead to inaccurate estimates of burden in some regions. Despite these limitations, the GBD 2021 database remains valuable for health system officials to develop interventions, address modifiable risk factors, and effectively prevent CKD.

Conclusion

In conclusion, the burden of CKD has increased globally over the past 30 years as the population ages. Our findings underscore the importance of CKD as a global health problem and highlight differences in the burden of CKD between regions and countries. The findings highlight the need for a multifaceted approach to the prevention and management of CKD, including population-level interventions targeting risk factors, improved access to health services, and policies to address health inequalities.

Abbreviations

ACR	Albumin-to-creatinine ratio
ASDR	Age-standardized DALYs rate
ASIR	Age-standardized incidence rate
ASPR	Age-standardized prevalence rate
CI	Concentration index
CI	Confidence interval
CKD	Chronic kidney disease
DALYs	Disability-adjusted life years
EAPC	Estimated average percentage change
EDU 15+	Education for individuals aged 15 and above
ESRD	End-stage renal disease
GATHER	Guidelines for Accurate and Transparent Health Estimates Reporting
GBD	Global Burden of Disease Study
GFR	Glomerular filtration rate
ICD-10	The 10th revision
ICD-9	The 9th revision
IHME	Institute for Health Metrics and Evaluation
KRT	Kidney replacement therapy
LDI	Lag-distributed income per capita
LMICs	Low- and middle-income countries
SDI	Socio-demographic Index
SII	Slope Index of Inequality
TFU 25	Total fertility rate under 25
YLDs	Life lived with disability
YLLs	Years of life lost

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12882-025-04028-z>.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

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Author contributions

J.G, W.J and Q.S conceived of and designed the project. S.X and X.X collected the data. Y.Z and X.G analysed and interpreted the data. J.G and W.J drafted the manuscript. All authors read and approved the final manuscript.

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Data availability

Publicly available data sets were used in this study. The data can be found here: (<http://ghdx.healthdata.org/>)

Declarations

Ethics approval

As this study is based entirely on published data and literature, an ethical statement is not relevant to this publication.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

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