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Global Burden of Kidney Cancer Attributable to High Body Mass Index in Adults Aged 60 and Older from 1990 to 2021 and Projections to 2040: A Systematic Analysis for the Global Burden of Disease Study

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Background: With global aging, cancer burden rises. Kidney cancer is significantly influenced by high body mass index (BMI), especially in the elderly. This study analyzes the burden of kidney cancer attributable to high BMI in those aged ≥60, clarifying causes and future trends.

Methods: Using Global Burden of Disease (GBD) 2021 study, we assessed kidney cancer burden due to high BMI in population aged ≥60 from 1990 to 2021, comparing deaths, disability-adjusted life years (DALYs), age-standardized rate (ASR) of DALYs (ASDR), and mortality (ASMR). Stratified by Socio-Demographic Index (SDI), region, sex, and age, we evaluated spatiotemporal trends and inequalities. Finally, the Bayesian Age-Period-Cohort (BAPC) model predicted burden changes through 2040.

Results: From 1990 to 2021, DALYs and deaths from high BMI-induced kidney cancer in those aged ≥60 increased by 165.82% and 186.39%, driven by population growth. In 2021, ASDR was 45.55/100,000 and ASMR 2.39/100,000. Regional differences were significant. DALYs and deaths expanded, especially in those aged ≥95. Males had higher burden than females. SDI correlated positively with ASDR and ASMR ($r>0$, $P<0.05$). Health inequalities continue to rise. By 2040, burden is projected to rise, especially in low-middle and low SDI regions, more in males.

Conclusion: This study shows a significant increase in kidney cancer burden due to high BMI in those aged ≥60 over 32 years, driven by population growth. Disparities across regions, genders, and age groups highlight the need for targeted prevention and early intervention, especially for high-risk groups (males, elderly, low-middle SDI regions), to reduce burden and optimize healthcare resource allocation.

Keywords: kidney cancer, high BMI, elderly, SDI, gender differences, trend projection

Introduction

In recent years, due to the increasing population aging, the number of global cancer patients has surged further.[1] Kidney cancer is a common malignancy worldwide; in 2022, the number of new kidney cancer cases reached 434,419 (accounting for 2.2% of all cancers globally), while the number of deaths reached 155,702 (accounting for 1.6% of all cancers globally).[2] Among the various subtypes, renal cell carcinoma is the most common. Its insidious onset often leads to a diagnosis at an advanced stage, which contributes to the majority of the incidence and mortality associated with

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kidney cancer.[3] With advancing age, the incidence of kidney cancer gradually increases, beginning around the age of 40 and peaking between 60 and 70 years.[4,5] Owing to the combined effects of obesity and population aging, the incidence of kidney cancer is expected to continue rising in the future, imposing a substantial disease burden and economic cost.[6] Therefore, as a cancer highly prevalent among the elderly, it is imperative to understand the specific factors influencing kidney cancer survival in this population and their associations.

Epidemiological studies have demonstrated a clear link between obesity and the development of multiple malignancies, which in turn affects patient survival.[7] As one of the key modifiable risk factors for kidney cancer, obesity increases the risk of developing the disease through various mechanisms, including insulin resistance, chronic low-grade inflammation, and hormonal alterations.[8] Body mass index (BMI) is a crucial metric for assessing an individual's level of obesity. Numerous studies have indicated that a higher BMI correlates with an increased risk of kidney cancer.[9] Moreover, high BMI is associated with a range of chronic diseases, particularly in the elderly, where such comorbidities may further elevate the risk of kidney cancer.[10] However, some research suggests that patients with elevated BMI may experience a survival advantage in kidney cancer—a phenomenon often referred to as the "obesity paradox".[11] Additionally, in elderly populations, a high BMI appears to exert a protective effect that becomes more pronounced with advancing age.[12] This underscores why the cancer burden associated with high BMI in the elderly has become a focal point of global public health concern.

Up-to-date information on cancer mortality and disability-adjusted life years (DALYs) is critical for informed healthcare decision-making. The Global Burden of Disease (GBD) study provides essential data for this purpose.[13] According to GBD 2019, the global DALY rate and number of deaths attributable to high BMI have continued to rise, particularly among the elderly.[14] This trend is mainly associated with six major causes: ischemic heart disease, stroke, diabetes, chronic kidney disease, hypertensive heart disease, and low back pain.[15] The latest results from GBD 2021 also indicate that, from 1990 to 2021, the global age-standardized incidence and prevalence rates of kidney cancer have significantly increased, while the age-standardized mortality rate (ASMR) and age-standardized DALY rate (ASDR) have significantly decreased, exhibiting notable geographic, age, and gender variations.[16] High BMI in the elderly has emerged as a critical health risk factor, yet research investigating its association with kidney cancer remains scarce.

Physiological changes in the elderly pose unique challenges in both the onset and treatment of cancer. Thus, studying the impact of high BMI on the burden of kidney cancer in this population holds significant clinical relevance. This study aims to leverage data from GBD 2021 to conduct an in-depth analysis of the global burden of kidney cancer among individuals aged 60 and above with high BMI. By quantifying the DALY rates, mortality, and associated burdens of kidney cancer in this population, the study seeks to elucidate the relationship between high BMI and kidney cancer, assess differences across regions and genders, and explore the regional characteristics of the kidney cancer burden attributable to high BMI. The findings of this study will provide a scientific basis for developing more effective public health strategies and interventions, particularly in preventing obesity-related kidney cancer in the elderly and reducing associated mortality, thereby offering significant practical value.

Data Sources and Methods

Data Sources and Study Design

This study utilized data from the Global Burden of Disease Study 2021 (GBD 2021) database (https://ghdx.healthdata.org/gbd-2021), which provides comprehensive estimates for 204 countries and territories, 371 diseases and injuries, and 88 risk factors.[13,17] We selected the following parameters: "Risk factor" for GBD Estimate, "DALYs" and "Deaths" for Measure, "Number" and "Rate" for Metric, "High body-mass index" for Risk, and "Kidney cancer" for Cause. The study population comprised adults aged 60 years and above, with a time span from 1990 to 2021.

Disease Definition and Classification

According to the GBD 2021, diseases and injuries are typically categorized into four main levels. Kidney cancer is classified under the first level of non-communicable diseases, the second level of neoplasms, and the third level of specific cancers. In the International Classification of Diseases (ICD)-10, kidney cancer is primarily coded as C64, while in ICD-11, it is coded as 2C90.[18]

Health Inequality Analysis

To investigate health inequalities in the global disease burden, we employed the Slope Index of Inequality (SII) and the Concentration Index. The SII measures absolute inequality in health variables across socioeconomic groups, representing the health difference between the lowest and highest socioeconomic status groups. The Concentration Index quantifies the degree of inequality in health variables across socioeconomic groups, ranging from −1 to 1, with 0 indicating perfect equality.

Decomposition Analysis

To further explore factors contributing to global disease burden disparities, we conducted decomposition analysis. This method allows for the disaggregation of overall health differences into contributions from various factors, such as population growth, population aging, and epidemiological changes.

Socio-Demographic Index

The Socio-demographic Index (SDI), developed by GBD researchers, is a composite indicator of development status closely related to health outcomes. We applied LOESS smoothing to visualize trends and performed Spearman correlation tests to quantify the relationship between SDI and disease burden indicators.

BAPC Model Construction

The Bayesian Age-Period-Cohort (BAPC) prediction model is a statistical method based on a Bayesian framework that combines age, period, and birth cohort effects to predict future trends in disease incidence, mortality, or other health indicators. We used the INLA framework within the BAPC package to forecast disease burden from 2022 to 2040.

Statistical Analysis

All data processing, statistical analyses, and visualizations were performed using R version 4.4.1. We utilized the following packages: dplyr, tidyr, stringr, and arrow for data manipulation and analysis; ggplot2, ggmap, rgdal, RColorBrewer, patchwork, and ggrepel for data visualization; rgdal for geospatial analysis; and stats for statistical analysis.

Results

Global Burden of Kidney Cancer Attributable to High BMI in Adults Aged 60 and Older, 1990-2021

Between 1990 and 2021, there was a significant global increase in the burden of kidney cancer attributable to high BMI among adults aged 60 and older. By 2021, DALYs due to high-BMI-related kidney cancer reached 494,094 cases (95% UI: 199,428 to 797,780), representing a 165.82% increase from 1990 (Table 1). Similarly, deaths rose to 25,331 cases (95% UI: 10,114 to 41,151), marking a 186.39% increase since1990 (Table S1).In terms of age-standardized rates (ASRs), the ASDR in 2021 was 45.55 (95% UI: 18.35 to 73.59) per 100,000 population, reflecting a 19.18% increase from 1990, with an estimated annual percent change (EAPC) of 0.51 (95% CI: 0.44 to 0.58). Concurrently, the ASMR reached 2.39 (95% UI: 0.95 to 3.89) per 100,000 population, a 24.48% rise since 1990, with an EAPC of 0.68 (95% CI: 0.60 to 0.75). Notably, among individuals aged 60 and older with high BMI, males experienced a significantly higher burden of kidney cancer compared to females (Tables 1, S1 and Figures 1, 2). Both genders saw increases in DALYs, deaths, ASDR, ASMR, and their respective EAPCs from 1990 to 2021. However, while males exhibited a steady linear increase in ASDR and ASMR over the 32-year period, females experienced slight fluctuations during the same timeframe.

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Table 1 Global, SDI-Based, and Regional Trends in DALY Numbers and Rates for Kidney Cancer Attributable to High BMI Among Adults Aged 60 and Older, for Both Sexes Combined, Males, and Females, 1990–2021

Location	Sex	DALY Cases			DALY Rates			
		1990_Numbers (95% UI)	2021_Numbers (95% UI)	Percentage Change in Case (%)	1990_Per100000 (95% UI)	2021_Per100000 (95% UI)	Percentage Change in ASRs (%)	EAPC (95% CI)
Global	Both	185873 (72,925,302,520)	494,094 (199,428,797,780)	165.82	38.22 (14.95,62.27)	45.55 (18.35,73.59)	19.18	0.51 (0.44 to 0.58)
Global	Male	106159 (41,251,173,415)	311,042 (125,435,503,981)	193.00	48.75 (18.89,79.63)	62.62 (25.18,101.61)	28.45	0.79 (0.72 to 0.87)
Global	Female	79713 (31,348,129,775)	183,052 (73,395,292,970)	129.64	29.8 (11.69,48.55)	31.15 (12.49,49.86)	4.53	0.02 (−0.05 to 0.09)
Low SDI	Both	1167 (441,1897)	4981 (1748,8417)	326.82	4.34 (1.63,7.06)	8.55 (3,14.45)	97.00	2.25 (2.12 to 2.37)
Low SDI	Male	651 (245,1091)	2970 (1026,5128)	356.22	4.76 (1.79,8)	10.51 (3.63,18.11)	120.80	2.56 (2.46 to 2.67)
Low SDI	Female	517 (194,884)	2011 (735,3475)	288.97	3.92 (1.47,6.69)	6.72 (2.45,11.62)	71.43	1.87 (1.71 to 2.04)
Low-middle SDI	Both	3673 (1412,5912)	23,043 (9115,37,297)	527.36	5.18 (1.98,8.34)	13.22 (5.21,21.46)	155.21	3.26 (3.19 to 3.33)
Low-middle SDI	Male	1999 (756,3239)	13,699 (5447,22,259)	585.29	5.57 (2.1,9.01)	16.53 (6.55,26.93)	196.77	3.78 (3.69 to 3.86)
Low-middle SDI	Female	1674 (654,2701)	9344 (3626,15,050)	458.18	4.79 (1.86,7.75)	10.25 (3.97,16.54)	113.99	2.65 (2.53 to 2.78)
Middle SDI	Both	12631 (4897,20,528)	76,669 (31,165,126,617)	506.99	10.44 (4.03,16.98)	23.03 (9.34,38.07)	120.59	2.57 (2.53 to 2.62)
Middle SDI	Male	7118 (2717,11,618)	47,254 (19,469,78,544)	563.87	12.45 (4.74,20.34)	30.35 (12.46,50.57)	143.78	2.97 (2.9 to 3.04)
Middle SDI	Female	5513 (2141,9006)	29,415 (11,909,47,901)	433.56	8.69 (3.37,14.23)	16.68 (6.74,27.19)	91.94	2.02 (1.98 to 2.06)
High-middle SDI	Both	60492 (23,832,99,046)	161,034 (64,579,259,729)	166.21	47.19 (18.53,77.28)	62.62 (25.08,101.07)	32.70	0.81 (0.69 to 0.93)
High-middle SDI	Male	32429 (12,610,53,183)	98,080 (39,311,159,772)	202.45	60.76 (23.54,99.5)	85.83 (34.32,140.07)	41.26	1.02 (0.89 to 1.15)
High-middle SDI	Female	28063 (11,216,45,984)	62,954 (25,508,99,759)	124.33	37.82 (15.08,62.01)	44.05 (17.86,69.76)	16.47	0.36 (0.26 to 0.47)
High SDI	Both	107537 (42,096,176,180)	227,564 (92,357,365,597)	111.61	74.42 (29.14,121.93)	82.16 (33.46,131.69)	10.40	0.28 (0.18 to 0.38)
High SDI	Male	63742 (24,903,104,558)	148,540 (60,348,237,985)	133.03	105.16 (41.03,172.5)	118.53 (48.15,189.75)	12.71	0.38 (0.29 to 0.48)
High SDI	Female	43795 (17,082,71,589)	79,024 (31,504,127,348)	80.44	51.83 (20.28,84.63)	51.12 (20.57,81.97)	−1.37	−0.15 (−0.27 to −0.03)
High-income Asia Pacific	Both	4215 (1603,6896)	15,567 (5822,25,641)	269.32	16.51 (6.27,27.01)	24.92 (9.33,40.86)	50.94	1.25 (1.06 to 1.43)
High-income Asia Pacific	Male	2631 (1008,4338)	10,240 (3853,16,857)	289.21	24.31 (9.3,40.11)	37.68 (14.12,62.05)	55.00	1.37 (1.2 to 1.54)
High-income Asia Pacific	Female	1584 (589,2605)	5328 (1929,9002)	236.36	10.73 (3.99,17.66)	14.05 (5.14,23.57)	30.94	0.69 (0.47 to 0.91)
High-income North America	Both	41568 (16,505,67,691)	92,325 (38,217,143,670)	122.11	89.99 (35.76,146.44)	104.01 (43.07,161.74)	15.58	0.37 (0.14 to 0.59)
High-income North America	Male	24839 (9854,40,682)	61,877 (25,622,96,164)	149.11	125.94 (49.94,206.36)	152.98 (63.25,237.93)	21.47	0.58 (0.36 to 0.8)
High-income North America	Female	16730 (6645,27,234)	30,448 (12,457,47,405)	82.00	62.53 (24.91,101.53)	62.4 (25.62,96.8)	−0.21	−0.21 (−0.44 to 0.03)
Western Europe	Both	61172 (23,882,99,582)	108,780 (42,762,178,136)	77.83	80.3 (31.39,130.75)	88.81 (35.08,145.07)	10.60	0.34 (0.28 to 0.41)
Western Europe	Male	36527 (14,130,59,604)	70,932 (28,123,115,944)	94.19	116.6 (45.06,190.3)	129.69 (51.52,211.73)	11.23	0.38 (0.31 to 0.44)
Western Europe	Female	24645 (9572,40,078)	37,848 (14,725,61,951)	53.57	54.36 (21.21,88.39)	54.33 (21.35,88.38)	−0.06	−0.01 (−0.07 to 0.06)
Australasia	Both	2344 (892,3930)	6158 (2483,10,081)	162.71	75.12 (28.55,126.09)	86.47 (34.9,141.18)	15.11	0.35 (0.23 to 0.47)
Australasia	Male	1350 (510,2305)	4248 (1724,6993)	214.67	97.13 (36.66,165.71)	127.78 (51.85,210.07)	31.56	0.82 (0.74 to 0.9)
Australasia	Female	994 (378,1684)	1910 (758,3161)	92.15	57.37 (21.74,97.23)	49.58 (19.72,81.69)	−13.58	−0.61 (−0.84 to −0.37)
Andean Latin America	Both	773 (301,1316)	3825 (1588,6502)	394.83	32.05 (12.47,54.56)	52.93 (21.95,90.02)	65.15	1.53 (1.38 to 1.68)
Andean Latin America	Male	357 (138,609)	2184 (896,3837)	511.76	30.59 (11.83,52.27)	63.57 (26.03,111.76)	107.81	2.53 (2.4 to 2.67)
Andean Latin America	Female	416 (161,724)	1641 (667,2914)	294.47	33.47 (12.94,58.23)	43.3 (17.61,76.91)	29.37	0.44 (0.07 to 0.81)
Tropical Latin America	Both	2795 (1084,4649)	17,304 (6793,28,614)	519.11	25.25 (9.77,42.07)	53.45 (20.95,88.42)	111.68	2.55 (2.47 to 2.63)
Tropical Latin America	Male	1545 (593,2626)	10,630 (4118,17,714)	588.03	29.96 (11.48,51.04)	73.95 (28.57,123.23)	146.83	3.15 (3.04 to 3.25)

Tropical Latin America	Female	1250 (491,2078)	6674 (2651,10,907)	433.92	21.18 (8.28,35.29)	37.12 (14.74,60.66)	75.26	1.8 (1.68 to 1.92)
Central Latin America	Both	3711 (1455,6072)	22,171 (9368,35,683)	497.44	38.02 (14.89,62.25)	71.16 (30.03,114.62)	87.16	1.95 (1.88 to 2.02)
Central Latin America	Male	1896 (727,3150)	13,342 (5643,21,759)	603.69	40.34 (15.45,67.04)	93.41 (39.42,152.44)	131.56	2.69 (2.63 to 2.76)
Central Latin America	Female	1814 (727,2943)	8829 (3711,14,212)	386.71	35.87 (14.34,58.34)	52.32 (21.97,84.27)	45.86	1.08 (0.98 to 1.18)
Southern Latin America	Both	5388 (2110,8949)	16,116 (6464,25,934)	199.11	89.78 (35.11,149.22)	143.83 (57.73,231.32)	60.20	1.73 (1.55 to 1.92)
Southern Latin America	Male	3105 (1174,5362)	10,738 (4273,17,627)	245.83	116.57 (44.1,201.16)	217.08 (86.37,356.53)	86.22	2.1 (1.84 to 2.37)
Southern Latin America	Female	2283 (879,3802)	5378 (2120,8698)	135.57	68 (26.17,113.29)	85.45 (33.74,137.93)	25.66	1.09 (0.99 to 1.2)
Caribbean	Both	722 (282,1187)	2531 (1009,4165)	250.55	22.32 (8.72,36.7)	37.75 (15.05,62.12)	69.13	1.87 (1.78 to 1.95)
Caribbean	Male	393 (154,640)	1552 (608,2596)	294.91	25.17 (9.83,40.99)	49.65 (19.45,83.1)	97.26	2.39 (2.26 to 2.53)
Caribbean	Female	329 (125,547)	979 (388,1624)	197.57	19.65 (7.48,32.73)	27.31 (10.82,45.25)	38.98	1.19 (1.08 to 1.31)
Central Europe	Both	18207 (7215,29,840)	40,101 (16,400,65,291)	120.25	91.51 (36.24,150.1)	132.8 (54.37,216.13)	45.12	1.19 (1.04 to 1.33)
Central Europe	Male	10836 (4260,17,792)	24,750 (10,045,40,394)	128.41	129.79 (50.85,213.23)	192.68 (78.14,314.8)	48.46	1.32 (1.15 to 1.49)
Central Europe	Female	7371 (2959,12,059)	15,351 (6395,24,883)	108.26	64.02 (25.69,104.86)	87.21 (36.5,141.16)	36.22	0.87 (0.74 to 1)
Eastern Europe	Both	27637 (10,826,44,809)	60,373 (24,452,96,228)	118.45	73.25 (28.66,118.64)	124.18 (50.32,197.91)	69.53	1.63 (1.45 to 1.81)
Eastern Europe	Male	12733 (4815,20,789)	33,561 (13,439,55,171)	163.57	101.74 (38.47,166.22)	183.92 (73.41,302.15)	80.77	1.87 (1.69 to 2.05)
Eastern Europe	Female	14905 (5970,24,250)	26,812 (10,875,41,910)	79.89	59.71 (23.9,97.11)	87.9 (35.68,137.36)	47.21	1.15 (0.97 to 1.33)
Central Asia	Both	2184 (865,3554)	6125 (2425,10,068)	180.45	37.28 (14.74,60.82)	59.61 (23.62,98.07)	59.90	1.4 (1.19 to 1.62)
Central Asia	Male	975 (372,1654)	3676 (1420,6187)	277.03	42.61 (16.1,72.44)	82.28 (31.8,138.57)	93.10	2.27 (1.99 to 2.56)
Central Asia	Female	1208 (488,1994)	2448 (1013,3936)	102.65	33.8 (13.6,55.83)	42.55 (17.58,68.56)	25.89	0.35 (0.17 to 0.53)
North Africa and Middle East	Both	3729 (1426,6102)	20,377 (8588,32,999)	446.45	18.99 (7.23,31.15)	39.15 (16.39,63.52)	106.16	2.4 (2.35 to 2.46)
North Africa and Middle East	Male	2274 (853,3742)	13,614 (5810,22,873)	498.68	22.76 (8.45,37.63)	51.84 (21.99,87.39)	127.77	2.65 (2.59 to 2.72)
North Africa and Middle East	Female	1456 (562,2499)	6763 (2769,10,749)	364.49	15.14 (5.82,26.07)	26.41 (10.75,42.19)	74.44	1.97 (1.83 to 2.12)
South Asia	Both	1486 (555,2506)	12,631 (4643,20,962)	750.00	2.24 (0.83,3.78)	6.93 (2.55,11.52)	209.38	3.71 (3.66 to 3.77)
South Asia	Male	1018 (380,1737)	7920 (2923,13,398)	678.00	2.95 (1.1,5.03)	8.95 (3.3,15.18)	203.39	3.58 (3.5 to 3.67)
South Asia	Female	469 (166,854)	4711 (1696,8166)	904.48	1.47 (0.52,2.67)	5.03 (1.82,8.75)	242.18	4.2 (4.14 to 4.26)
Southeast Asia	Both	1323 (493,2182)	8328 (3125,13,940)	529.48	4.39 (1.63,7.26)	10.18 (3.81,17.08)	131.89	2.44 (2.27 to 2.62)
Southeast Asia	Male	782 (291,1320)	4840 (1837,8238)	518.93	5.57 (2.07,9.42)	12.75 (4.83,21.72)	128.90	2.42 (2.25 to 2.58)
Southeast Asia	Female	540 (196,912)	3488 (1288,6046)	545.93	3.37 (1.22,5.7)	7.99 (2.94,13.89)	137.09	2.47 (2.27 to 2.67)
East Asia	Both	6885 (2691,11,534)	52,792 (19,757,90,410)	666.77	6.9 (2.69,11.56)	19.04 (7.13,32.65)	175.94	3.49 (3.29 to 3.69)
East Asia	Male	3920 (1490,6602)	31,971 (12,027,56,701)	715.59	8.69 (3.3,14.6)	24.96 (9.39,44.24)	187.23	3.64 (3.44 to 3.83)
East Asia	Female	2965 (1123,5078)	20,821 (8077,36,624)	602.23	5.57 (2.11,9.56)	14.17 (5.49,24.93)	154.40	3.19 (2.99 to 3.4)
Oceania	Both	16 (5,28)	54 (20,97)	237.50	4.86 (1.67,8.65)	6.76 (2.44,11.96)	39.09	1.06 (0.97 to 1.14)
Oceania	Male	13 (4,24)	46 (16,85)	253.85	8.03 (2.67,14.62)	11.05 (3.89,20.14)	37.61	0.99 (0.86 to 1.12)
Oceania	Female	2 (1,4)	8 (3,13)	300.00	1.59 (0.61,2.8)	2.18 (0.87,3.7)	37.11	1.05 (0.83 to 1.27)
Western Sub-Saharan Africa	Both	489 (176,823)	2585 (959,4282)	428.63	4.71 (1.69,7.94)	11.88 (4.42,19.7)	152.23	3.22 (3.14 to 3.29)
Western Sub-Saharan Africa	Male	294 (100,519)	1570 (602,2672)	434.01	5.69 (1.95,10.09)	15.5 (5.92,26.45)	172.41	3.46 (3.38 to 3.53)
Western Sub-Saharan Africa	Female	195 (71,335)	1015 (358,1745)	420.51	3.77 (1.38,6.52)	8.66 (3.06,14.9)	129.71	2.91 (2.81 to 3)
Eastern Sub-Saharan Africa	Both	599 (223,985)	2794 (959,4870)	366.44	6.8 (2.52,11.19)	14.73 (5.04,25.61)	116.62	2.53 (2.42 to 2.65)
Eastern Sub-Saharan Africa	Male	305 (110,521)	1433 (475,2539)	369.84	6.88 (2.49,11.77)	16.05 (5.32,28.37)	133.28	2.7 (2.61 to 2.79)

(*Continued*)

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Table 1 (Continued).

Location	Sex	DALY Cases			DALY Rates			
		1990_Numbers (95% UI)	2021_Numbers (95% UI)	Percentage Change in Case (%)	1990_Per100000 (95% UI)	2021_Per100000 (95% UI)	Percentage Change in ASRs (%)	EAPC (95% CI)
Eastern Sub-Saharan Africa	Female	295 (107,512)	1361 (482,2475)	361.36	6.74 (2.45,11.66)	13.57 (4.79,24.6)	101.34	2.38 (2.23 to 2.53)
Central Sub-Saharan Africa	Both	124 (41,233)	657 (221,1307)	429.84	4.72 (1.54,9.03)	10.88 (3.59,21.88)	130.51	2.74 (2.48 to 3)
Central Sub-Saharan Africa	Male	85 (27,176)	490 (156,1027)	476.47	7.01 (2.15,14.65)	18.94 (5.85,40.12)	170.19	3.23 (3.01 to 3.45)
Central Sub-Saharan Africa	Female	38 (13,74)	166 (53,350)	336.84	2.69 (0.87,5.23)	4.91 (1.55,10.47)	82.53	1.96 (1.75 to 2.16)
Southern Sub-Saharan Africa	Both	506 (179,845)	2501 (978,3984)	394.27	15.97 (5.66,26.69)	36.54 (14.32,58.35)	128.80	2.94 (2.72 to 3.15)
Southern Sub-Saharan Africa	Male	281 (97,497)	1428 (543,2312)	408.19	21.15 (7.33,37.48)	52.2 (19.94,85.13)	146.81	3.12 (2.94 to 3.31)
Southern Sub-Saharan Africa	Female	225 (84,388)	1073 (428,1708)	376.89	12.29 (4.59,21.22)	26.38 (10.51,42.11)	114.65	2.78 (2.49 to 3.07)

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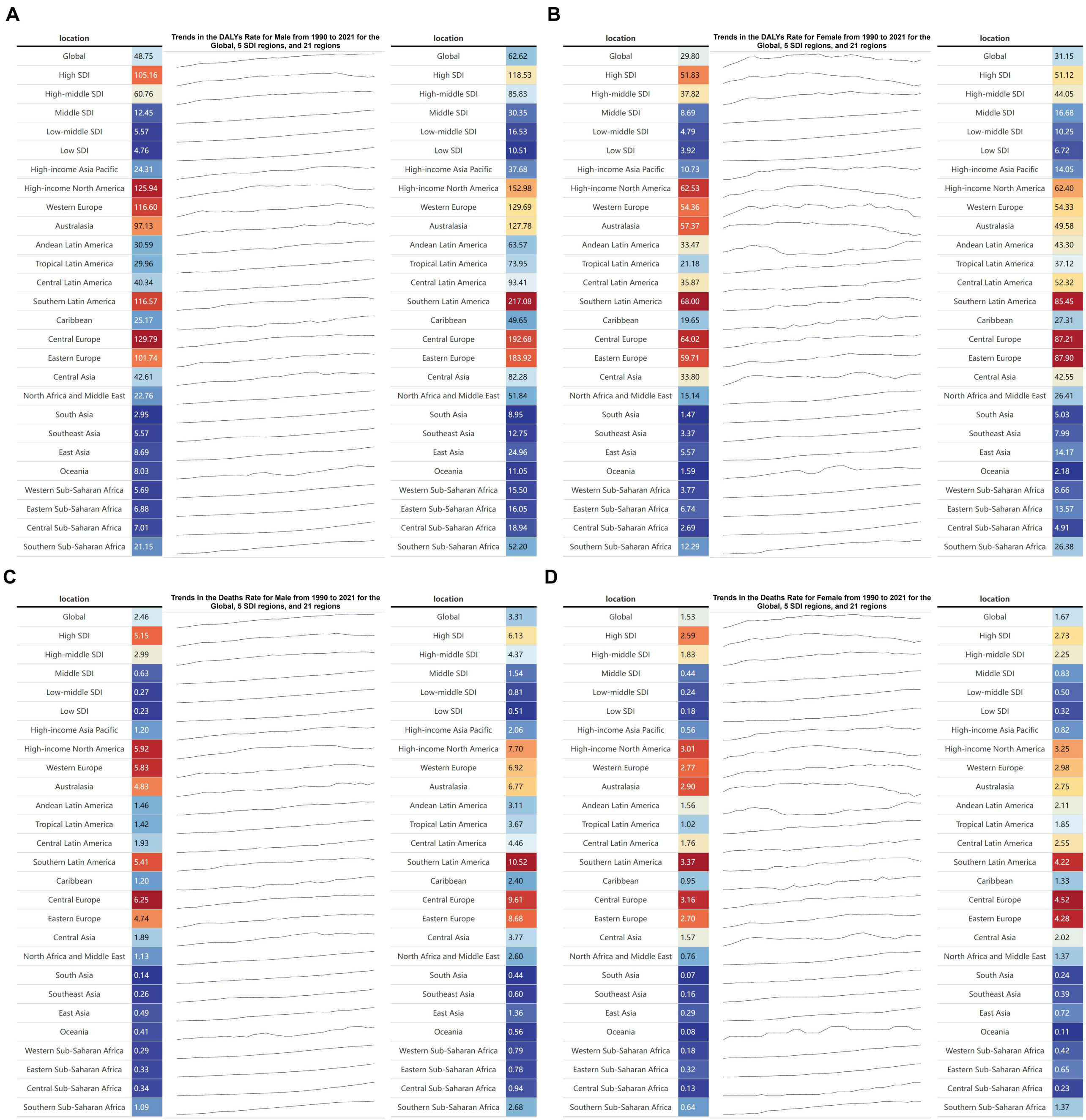

Figure 1 Trends in age-standardized DALY and death rates of kidney cancer attributable to high BMI in adults aged 60 and older, 1990–2021. (**A**) Age-standardized DALY rates for male globally, in 5 SDI regions, and 21 GBD regions; (**B**) Age-standardized DALY rates for female globally, in 5 SDI regions, and 21 GBD regions; (**C**) Age-standardized death rates for male globally, in 5 SDI regions, and 21 GBD regions; (**D**) Age-standardized death rates for female globally, in 5 SDI regions, and 21 GBD regions.

Socio-Demographic Disparities in the Burden of Kidney Cancer Attributable to High BMI Among Adults Aged 60 and Older, 1990-2021

Consistent with global trends, all five SDI regions exhibited an increasing burden of kidney cancer attributable to high BMI among adults aged 60 and older from 1990 to 2021, with the High SDI region being particularly prominent. In this region, DALYs reached 227,564 cases (95% UI: 92,357 to 365,597) in 2021, with an ASDR of 82.16 (95% UI: 33.46 to 131.69) per 100,000 population (Table 1). Deaths numbered 12,364 (95% UI: 4,933 to 20,012), with an ASMR of 4.24

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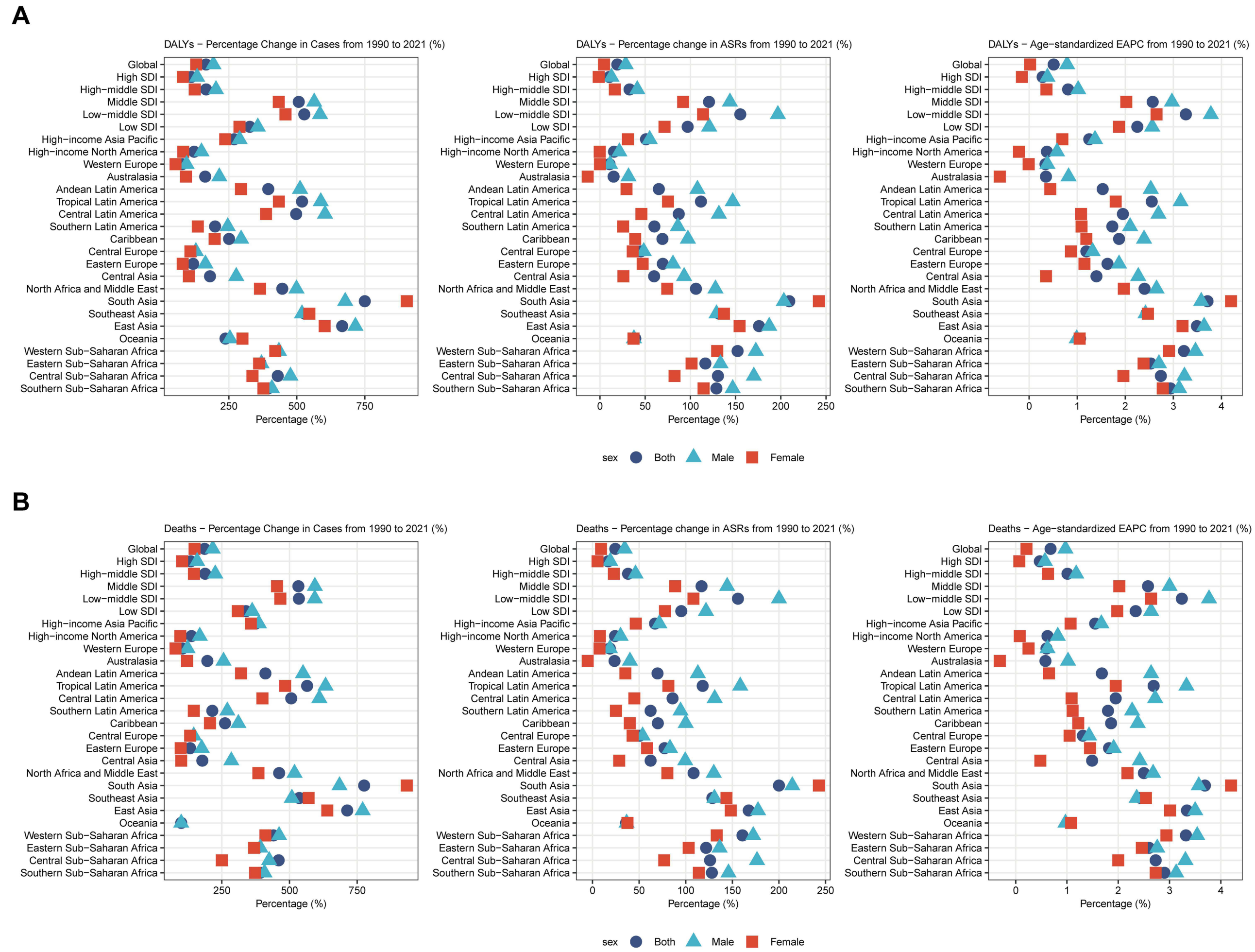

Figure 2 Changes in burden of kidney cancer attributable to high BMI in adults aged 60 and older, 1990–2021. (**A**) Percentage change in DALY numbers and age-standardized rates, and EAPC in age-standardized DALY rates for both sexes globally, in 5 SDI regions, and 21 GBD regions; (**B**) Percentage change in death numbers and age-standardized rates, and EAPC in age-standardized death rates for both sexes globally, in 5 SDI regions, and 21 GBD regions.

(95% UI: 1.70 to 6.84) per 100,000 population (Table S1). In contrast, the Low SDI region reported the lowest DALYs, deaths, ASDR, and ASMR. Over the 32-year period, the High SDI region experienced a 111.61% increase in DALYs, a 10.04% rise in ASDR, and a 16.80% uptick in ASMR, with EAPCs of 0.28 (95% CI: 0.18 to 0.38) and 0.47 (95% CI: 0.38 to 0.57) for ASDR and ASMR, respectively-the lowest among the five regions. Conversely, the Low-middle SDI region exhibited the highest growth rates, with DALYs increasing by 527.36%, ASDR by 155.21%, and ASMR by 156.00%. The EAPCs for ASDR and ASMR in this region were 3.26 (95% CI: 3.19 to 3.33) and 3.24 (95% CI: 3.17 to 3.31), respectively. Additionally, in all five SDI regions, males bore a higher burden of kidney cancer than females, with this disparity widening by 2021 (Tables 1, S1 and Figures 1, 2). Notably, the Middle and Low-middle SDI regions exhibited more pronounced gender differences in burden growth, with males experiencing greater increases. Despite the High SDI region maintaining the highest DALYs, deaths, ASDR, and ASMR, the Low-middle SDI region demonstrated the most substantial growth rates. The High SDI region had the lowest growth rates, particularly among females, where the ASDR decreased by 1.37% compared to 1990, with an EAPC of −0.15 (95% CI: −0.27 to −0.03).

Regional Disparities in the Burden of Kidney Cancer Attributable to High BMI Among Adults Aged 60 and Older, 1990-2021

Globally, across 21 geographical regions, the burden of kidney cancer attributable to high BMI among adults aged 60 and older has intensified, with increases observed in DALYs, death cases, and percentages of ASRs. The EAPCs for both ASDR and ASMR were consistently greater than zero (Tables 1, S1, and Figures 1–3). Among these regions, Western Europe had the highest number of DALYs and death cases, reaching 12,631 (95% UI: 4,643 to 20,962) and 578 (95% UI: 214 to 964) in 2021, respectively, significantly higher than other regions. However, from 1990 to 2021, the growth rates of DALYs and death cases in Western Europe were relatively low, at 77.83% and 104.45%, respectively. In contrast, South Asia had the highest growth rates, with increases of 750.00% and 775.76% in DALYs and death cases, respectively. In terms of ASRs, Southern Latin America had the highest ASDR and ASMR in 2021, at 143.83 (95% UI: 57.73 to 231.32) per 100,000 and 6.93 (95% UI: 2.76 to 11.25) per 100,000 population, respectively. Oceania and South Asia had the lowest ASDR and ASMR. However, South Asia exhibited the highest growth rates and EAPCs for both ASDR (209.38% growth, EAPC: 3.71(95% CI: 3.66 to 3.77)) and ASMR (200.00% growth, EAPC: 3.69 (95% CI: 3.62 to 3.75)). In contrast, Western Europe had the lowest growth rates and EAPCs, with ASDR increasing by 10.60% (EAPC: 0.38(95% CI: 0.316 to 0.44)) and ASMR by 18.59% (EAPC: 0.60(95% CI: 0.54 to 0.66)).

Notably, except for South Asia, Oceania, and Southeast Asia, males consistently bore a higher kidney cancer burden than females in all other regions. Among the 21 regions, the kidney cancer burden attributable to high BMI in males showed a clear linear upward trend over the past 32 years. In 2021, Western Europe had the highest number of DALYs and death cases in males, while Southern Latin America and Central Europe had the highest ASDR and ASMR. However, East Asia and South Asia faced more severe increases in the burden, with the highest growth rates and

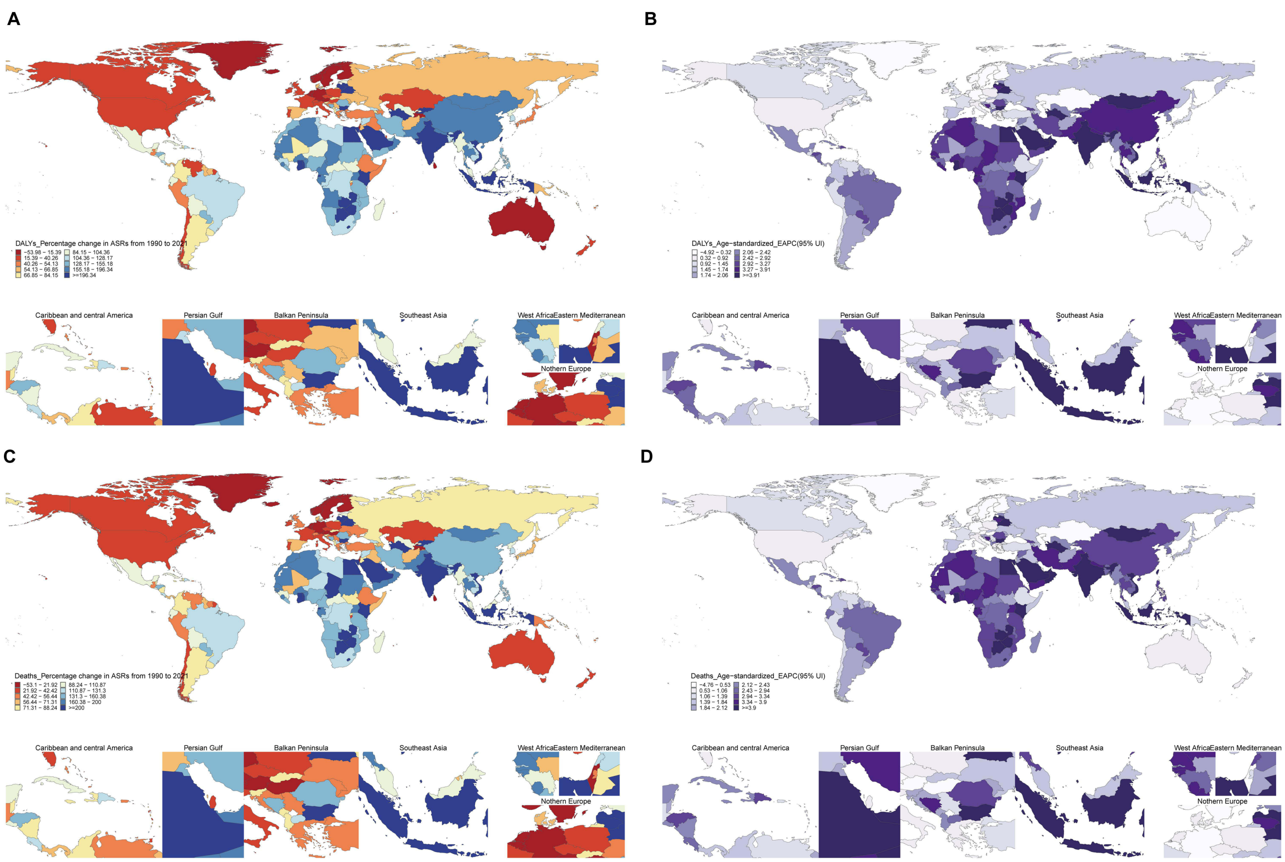

Figure 3 Global distribution of changes in burden of kidney cancer attributable to high BMI in adults aged 60 and older, 1990–2021. (**A**) Percentage change in age-standardized DALY rates for both sexes in 204 countries; (**B**) EAPC in age-standardized DALY rates for both sexes in 204 countries; (**C**) Percentage change in age-standardized death rates for both sexes in 204 countries; (**D**) EAPC in age-standardized death rates for both sexes in 204 countries.

EAPCs for DALYs, death cases, ASDR, and ASMR. Similarly, among females, Western Europe had the highest number of DALYs and death cases, while Central Europe and Southern Latin America had the highest ASDR and ASMR. South Asia and East Asia also had leading growth rates and EAPCs for DALYs, death cases, ASDR, and ASMR. Notably, Australasia, High-income North America, and Western Europe were the only regions where the ASDR and its EAPC in females were less than zero. Additionally, significant gender differences in the burden were observed in regions such as Andean Latin America, Central Sub-Saharan Africa, and Central Latin America.

National Disparities in Kidney Cancer Attributable to High BMI Among Adults Aged 60 and Older: A Global Analysis of 204 Countries from 1990 to 2021

At the national level, the United States of America had the highest number of DALYs cases attributable to high-BMI-related kidney cancer among adults aged 60 and older, reaching 83,803 (95% UI: 35,000 to 130,015) in 2021. In 1990, the United States was the only country with over 1,000 death cases, which increased to 4,256 (95%UI: 1,745 to 6,688) in 2021, representing a 132.19% growth. The United Arab Emirates, Ghana, and Equatorial Guinea had the highest growth rates in DALYs cases. Notably, Sweden was the only country with a decrease in DALYs cases, with a decline of 1.78%. Taiwan (Province of China), Zambia, and Thailand had the highest growth rates in death cases, at 1,318.18%, 1,000.00%, and 930.00%, respectively. In contrast, Sweden, Austria, and Norway had the lowest growth rates in death cases, at 14.29%, 27.91%, and 33.33%, respectively. In terms of ASRs, Czechia had the highest ASDR and ASMR. In 2021, Czechia's ASDR reached 201.06 (95% UI: 83.28 to 340.13) per 100,000 population, representing an 18.29% increase since 1990. Simultaneously, Czechia's ASMR surpassed 10 per 100,000, reaching 10.24 (95% UI: 4.21 to 17.42) per 100,000 population, an increase of 10.24%. However, Cabo Verde, Ghana, and Taiwan (Province of China) had the most prominent growth rates for both ASDR and ASMR. Cabo Verde, in particular, saw the most significant increase from 1990 to 2021, with ASDR growing by 3,717.46% (EAPC: 11.25(95% CI: 9.12 to 13.42)) and ASMR by 3,833.33% (EAPC: 11.47(95% CI: 9.33 to 13.66)). Not all countries exhibited increasing trends in ASDR, ASMR, and their EAPCs. Sri Lanka, Sweden, San Marino, and eight other countries had decreasing trends in ASDR and ASMR, with corresponding EAPCs less than zero. Sri Lanka had the largest decline, with ASMR decreasing by 53.98% (EAPC: −4.92(95% CI: −6.06 to −3.77)) and ASDR by 53.10% (EAPC: −4.76(95% CI: −5.86 to −3.65)) (Tables S2 and S3).

Age-Specific Trends in Global Burden of Kidney Cancer Attributable to High BMI: 1990-2021

Significant variations in the burden of kidney cancer attributable to high BMI were also observed across different age groups (Tables 2, and S4). Globally, the 60–64 years age group had the highest number of DALYs cases in 1990, but this burden extended to the 60–74 years age group by 2021. Similarly, the distribution of death cases also exhibited similar age patterns: the 65–69 years age group had the highest number of death cases in 1990, which expanded to include the age groups including 65–69, 70–74, and 75–79 years by 2021. Notably, the 95 years and older age group had the highest growth rates in DALYs and death cases over the past 32 years, at 876.08% and 884.33%, respectively. Additionally, this age group also had the highest ASDR and ASMR and their growth rates. In 2021, the global ASDR for this age group reached 61.61 (95% UI: 22.5 to 104.46) per 100,000 population, representing an 82.33% increase since 1990, while the ASMR reached 7.49 (95% UI: 2.74 to 12.68) per 100,000 population, an 83.87% increase. However, in terms of EAPCs for ASDR and ASMR, the 90–94 years age group was the most prominent, with EAPCs of 2.09 (95% CI: 2.00 to 2.19) and 2.09 (95% CI: 1.99 to 2.19), respectively.

Significant gender differences were also observed across different age groups. Except for the 80 years and older age group in 1990, males consistently had higher DALYs and death cases, as well as higher ASDR, ASMR, their growth rates, and EAPCs than females (Figures 4, 5 and Tables 2, S4). Among males, the 60–64 years age group had the highest number of DALYs cases, while among females, the 65–69 years age group had the highest number. The 60–69 years age group had the highest number of death cases in males in 1990, which shifted to the 65–74 age group by 2021. The 95 years and older age group had the highest growth rates in both DALYs and death cases, with males experiencing 1,071.02% and 1,079.93% growth, respectively, and females experiencing 787.84% and 796.01% growth, respectively.

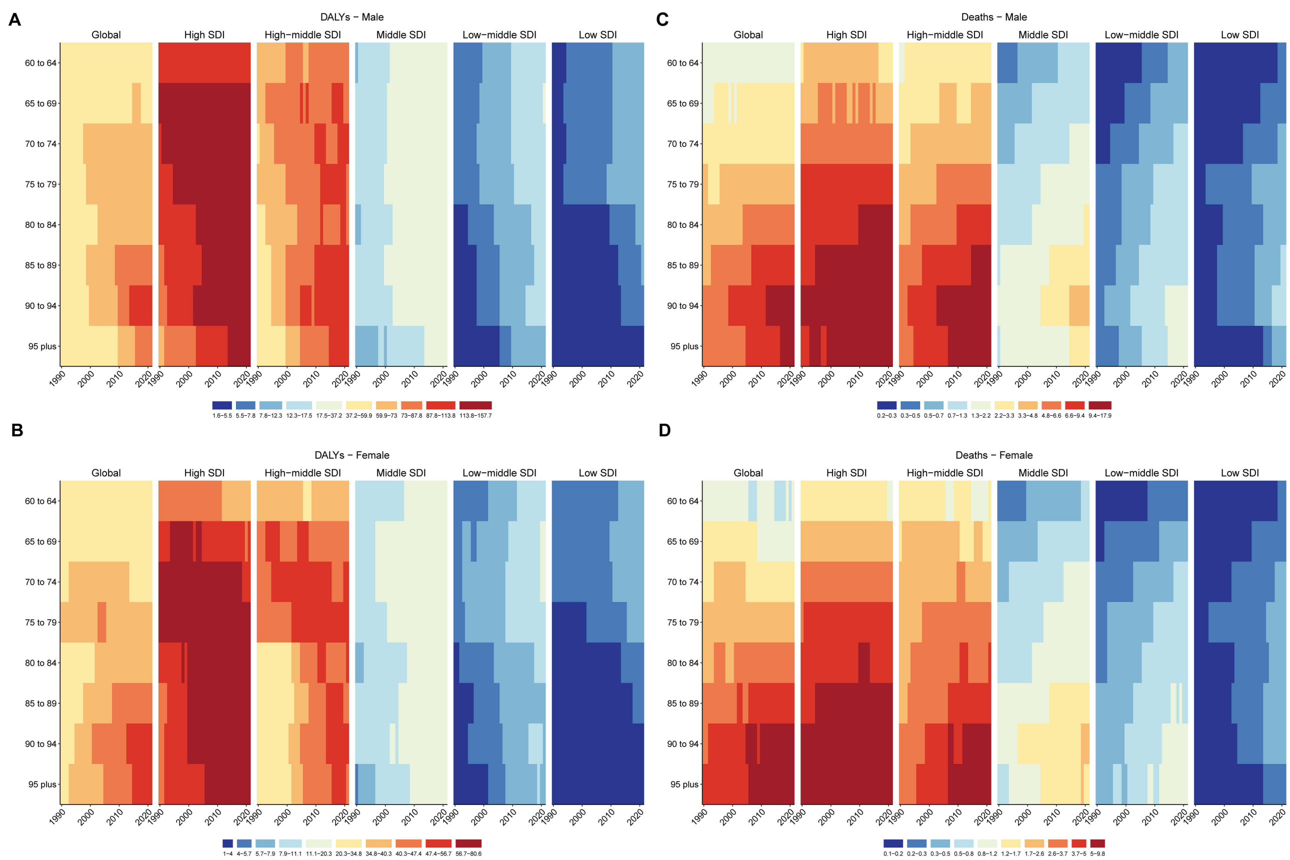

Figure 4 Age-specific burden of kidney cancer attributable to high BMI in adults aged 60 and older, 1990 and 2021. (**A**) Age-standardized DALY rates by 5-year age groups (60+ years) for males globally, in 5 SDI regions, and 21 GBD regions; (**B**) Age-standardized DALY rates by 5-year age groups (60+ years) for female globally, in 5 SDI regions, and 21 GBD regions; (**C**) Age-standardized death rates by 5-year age groups (60+ years) for males in 204 countries; (**D**) Age-standardized death rates by 5-year age groups (60+ years) for females in 204 countries.

From 1990 to 2021, both males and females exhibited an aging trend in the kidney cancer burden, with increases in DALYs, death cases, ASDR, and ASMR observed with age. However, males and females peaked at different ages, with males peaking in the 90–94 age group and females in the 95 years and older age group. Specifically, from 1990 to 2021, the ASDR in males aged 90–94 increased by 101.62%, with an EAPC of 2.54 (95% CI: 2.42 to 2.65), and the ASMR increased by 101.49%, with an EAPC of 2.53 (95% CI: 2.42 to 2.65). In females aged 95 years and older, the ASDR increased by 101.54%, with an EAPC of 2.39 (95% CI: 2.2 to 2.57), and the ASMR increased by 72.42%, with an EAPC of 1.80 (95% CI: 1.69 to 1.91). Notably, the EAPCs for ASDR and ASMR in females aged 60–74 were significantly negative.

Sociodemographic Index in Age-Specific Burden of Kidney Cancer Attributable to High BMI: A Global Analysis from 1990 to 2021

Across the five SDI regions, the High SDI region had the highest number of DALYs cases among individuals aged 65–69 years, while the other four regions had the highest number of DALYs cases among those aged 60–64 years (Tables 2 and S4). The Low SDI and Low-middle SDI regions had the highest number of death cases among those aged 60–64 years, but in the Middle SDI and High SDI regions, the age group with the highest number of death cases shifted over time, from 60–64 years in 1990 to 65–69 years in 2021. The High SDI region exhibited a trend towards higher age groups, with the peak shifting from 65–69 years in 1990 to older age groups in 2021. The 60–64 years age group also had the lowest growth rates in DALYs and death cases, particularly in the High SDI region, where DALYs cases increased by 60.04% and death cases by only 56.55% from 1990 to 2021. In contrast, the 95 years and older age group had the

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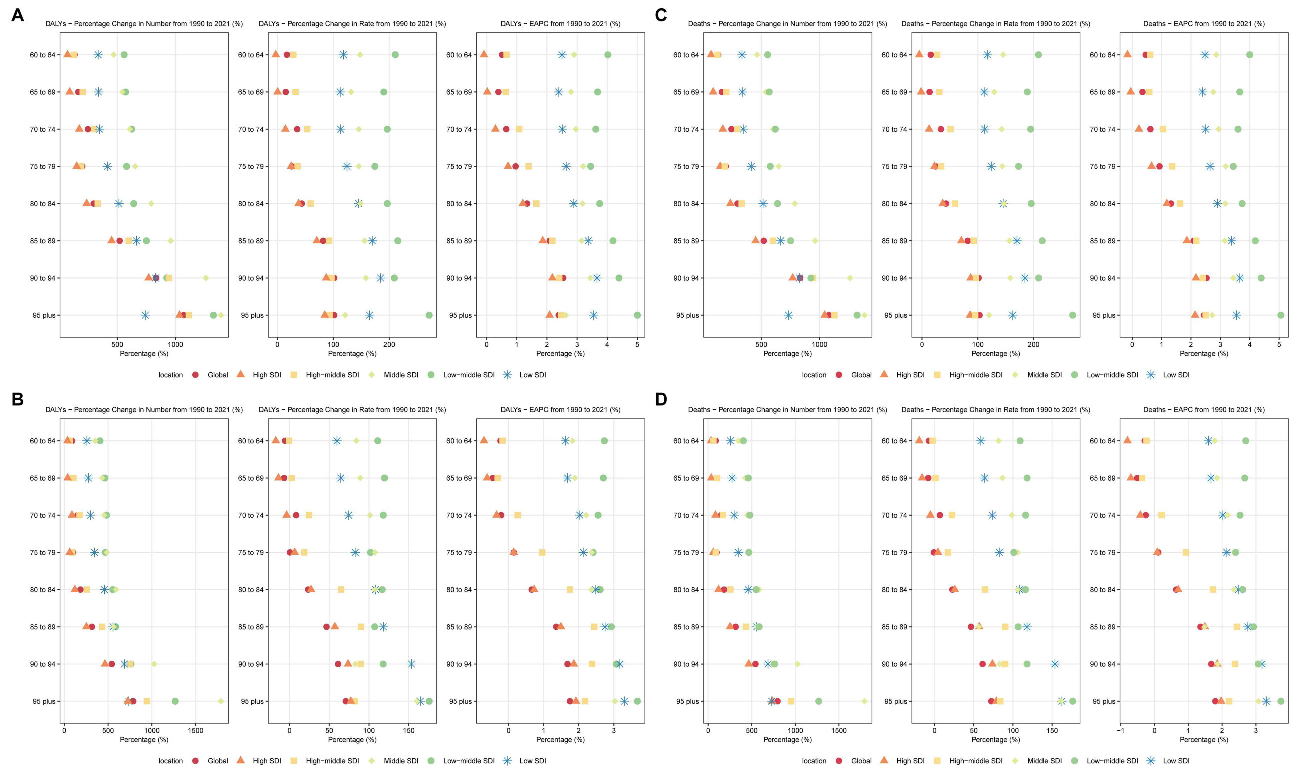

Figure 5 Changes in age-specific burden of kidney cancer attributable to high BMI in adults aged 60 and older, 1990–2021. (**A**) Percentage change in DALY numbers and age-standardized rates, and EAPC in age-standardized DALY rates by 5-year age groups (60+ years) for males globally, in 5 SDI regions, and 21 GBD regions; (**B**) Percentage change in DALY numbers and age-standardized rates, and EAPC in age-standardized DALY rates by 5-year age groups (60+ years) for females globally, in 5 SDI regions, and 21 GBD regions; (**C**) Percentage change in death numbers and age-standardized rates, and EAPC in age-standardized death rates by 5-year age groups (60+ years) for males in 204 countries; (**D**) Percentage change in death numbers and age-standardized rates, and EAPC in age-standardized death rates by 5-year age groups (60+ years) for females in 204 countries.

smallest number of DALYs and death cases but the highest growth rates, especially in the Middle SDI region, where DALYs cases increased by 1,593.54% and death cases by 1,591.82% from 1990 to 2021. With increasing SDI levels, ASDR and ASMR gradually increased. In 2021, the overall ASDR and ASMR in the High SDI region were higher than in other regions, with the 90–94 age group being the most prominent. Among the five regions, the Low-middle SDI region had the highest growth rates in ASDR and ASMR over the 32-year period, particularly in the 95 years and older age group, where ASDR increased by 210.51% (EAPC: 4.28 (95% CI: 4.05 to 4.51)) and ASMR by 210.26% (EAPC: 4.28 (95% CI: 4.05 to 4.51)). However, the growth rates in ASDR and ASMR were lowest in the 75–79 age group. Additionally, in the 60–69 years age group in the High SDI region, ASDR and ASMR exhibited a decreasing trend (EAPC < 0).

Males consistently bore a higher kidney cancer burden than females due to high BMI (Figures 4, 5 and Tables 2, S4). For both males and females, the burden of kidney cancer and mortality increased with increasing SDI levels and over time. In 2021, males and females aged 90–94 years in the High SDI and High-middle SDI regions had the highest ASDR and ASMR. However, the growth burden in these regions was gradually decreasing (EAPC < 0), particularly among males aged 60–65 years in the High SDI region, females aged 60–74 years in the High SDI region, and females aged 60–69 years in the High-middle SDI region. In contrast, although the Low SDI and Low-middle SDI regions had lower ASDR and ASMR, these rates increased over time. The Low-middle SDI region had the most dramatic increase in burden over the 32-year period, particularly among males and females aged 95 years and older, with males experiencing larger increases in ASDR and ASMR than females. Additionally, the burden of kidney cancer disability and mortality due to high BMI increased with age and became more pronounced with increasing age. Interestingly, the EAPCs for ASDR and ASMR exhibited an inverted U-shaped pattern with increasing SDI levels. The minimum EAPC values were

Table 2 Age-Specific Trends in DALY Numbers and Rates for Kidney Cancer Attributable to High BMI Among Adults Aged 60 and Older, by 5-year Age Groups, for Both Sexes Combined, Males, and Females, 1990–2021

Age (Years)	Sex	DALY Cases			DALY Rates			
		1990_Numbers (95% UI)	2021_Numbers (95% UI)	Percentage Change in Case (%)	1990_Per100000 (95% UI)	2021_Per100000 (95% UI)	Percentage Change in ASRs (%)	EAPC (95% CI)
Male	60 to 64	34,885.19 (13,638.86–57,139.77)	80,920.17 (32,760.59–128,808.07)	131.96	44.41 (17.36–72.75)	52.03 (21.06–82.82)	17.14	0.51 (0.43 to 0.59)
Female	60 to 64	20,330.20 (8272.62–32,634.92)	38,454.38 (15,726.96–60,053.61)	89.15	24.77 (10.08–39.77)	23.37 (9.56–36.5)	−5.65	−0.23 (−0.31 to −0.15)
Both	60 to 64	55,215.39 (22,073.62–89,064.77)	119,374.55 (48,532.21–189,477.04)	116.20	34.38 (13.74–55.45)	37.3 (15.16–59.2)	8.49	0.25 (0.18 to 0.32)
Male	65 to 69	29,367.39 (11,389.9–48,092.16)	77,606.64 (31,604.06–125,194.21)	164.26	51.22 (19.87–83.88)	58.87 (23.97–94.96)	14.92	0.39 (0.31 to 0.47)
Female	65 to 69	20,736.54 (8226.17–33,955.87)	41,986.85 (17,197.21–65,665.69)	102.48	31.29 (12.41–51.23)	29.16 (11.94–45.6)	−6.81	−0.45 (−0.55 to −0.36)
Both	65 to 69	50,103.93 (19,704.29–81,723.66)	119,593.49 (49,160.54–192,214.15)	138.69	40.53 (15.94–66.11)	43.36 (17.82–69.68)	6.96	0.1 (0.02 to 0.18)
Male	70 to 74	18,489.18 (7239.25–29,996.01)	64,123.8 (26,225.42–104,963.24)	246.82	49.15 (19.24–79.74)	66.52 (27.21–108.89)	35.35	0.65 (0.51 to 0.8)
Female	70 to 74	14,947.61 (5863.22–24,148.39)	37,664.64 (15,413.67–59,877.34)	151.98	31.77 (12.46–51.33)	34.41 (14.08–54.71)	8.30	−0.21 (−0.4 to −0.03)
Both	70 to 74	33,436.79 (13,099.61–54,314.21)	101,788.45 (41,932.99–165,325.36)	204.42	39.49 (15.47–64.15)	49.45 (20.37–80.32)	25.21	0.35 (0.19 to 0.51)
Male	75 to 79	13,903.08 (5430.95–22,601.45)	41,429.87 (16,728.23–67,591.87)	197.99	55.1 (21.52–89.57)	69.3 (27.98–113.05)	25.77	0.96 (0.81 to 1.11)
Female	75 to 79	13,021.59 (5101.97–21,436.49)	25,977.44 (10,512.07–42,250.63)	99.50	35.85 (14.05–59.02)	36.03 (14.58–58.6)	0.51	0.15 (−0.03 to 0.33)
Both	75 to 79	26,924.67 (10,532.92–44,171.18)	67,407.31 (27,280.52–108,970.73)	150.36	43.74 (17.11–71.76)	51.11 (20.69–82.63)	16.85	0.68 (0.52 to 0.84)
Male	80 to 84	6485.77 (2417.06–10,604.55)	25,711.5 (9989.9–42,119.53)	296.43	48.83 (18.2–79.83)	70.15 (27.26–114.92)	43.67	1.34 (1.18 to 1.49)
Female	80 to 84	6638.05 (2420.61–10,831.99)	18,898.34 (7144.25–31,278.78)	184.70	30.05 (10.96–49.03)	37.11 (14.03–61.41)	23.49	0.66 (0.47 to 0.85)
Both	80 to 84	13,123.82 (4907.91–21,507.48)	44,609.84 (17,005.95–73,187.97)	239.92	37.1 (13.87–60.8)	50.93 (19.42–83.56)	37.30	1.11 (0.95 to 1.28)
Male	85 to 89	2319.25 (871.2–3803.86)	14,374.5 (5534.19–23,882.51)	519.79	45.8 (17.2–75.11)	83.32 (32.08–138.43)	81.92	2.09 (1.94 to 2.24)
Female	85 to 89	2844.46 (1033.92–4754.43)	11,814.53 (4430.97–19,830.55)	315.35	28.31 (10.29–47.32)	41.5 (15.56–69.66)	46.58	1.36 (1.17 to 1.55)
Both	85 to 89	5163.71 (1910.05–8541.34)	26,189.03 (9965.15–43,465.01)	407.18	34.17 (12.64–56.52)	57.28 (21.8–95.06)	67.62	1.81 (1.65 to 1.97)
Male	90 to 94	602.14 (224.61–1000.32)	5620.38 (2132.03–9291.81)	833.41	47.83 (17.84–79.46)	96.43 (36.58–159.42)	101.62	2.54 (2.42 to 2.65)
Female	90 to 94	958.06 (345.07–1607)	6153.4 (2203.28–10,420.18)	542.28	31.66 (11.4–53.1)	51.02 (18.27–86.4)	61.16	1.68 (1.56 to 1.79)
Both	90 to 94	1560.20 (571.37–2616.1)	11,773.78 (4324.39–19,446.15)	654.63	36.41 (13.33–61.05)	65.81 (24.17–108.7)	80.76	2.09 (2 to 2.19)
Male	95 plus	107.21 (39.54–176.93)	1255.42 (460.37–2130.19)	1071.02	41.2 (15.2–67.99)	83.03 (30.45–140.88)	101.54	2.39 (2.2 to 2.57)
Female	95 plus	236.82 (84.57–405.59)	2102.6 (766.75–3593.56)	787.84	31.25 (11.16–53.52)	53.39 (19.47–91.25)	70.85	1.75 (1.64 to 1.87)
Both	95 plus	344.03 (124.74–581.09)	3358.01 (1226.26–5693.5)	876.08	33.79 (12.25–57.08)	61.61 (22.5–104.46)	82.33	2 (1.87 to 2.12)
Male	60 to 64	18,755.73 (7382.94–30,784.12)	32,138.28 (13,046.17–50,248.28)	71.35	99.28 (39.08–162.95)	96.41 (39.14–150.75)	−2.88	−0.09 (−0.2 to 0.03)
Female	60 to 64	9225.87 (3727.09–14,949.85)	12,642.81 (5262.72–20,078.65)	37.04	43.9 (17.74–71.14)	36.29 (15.11–57.64)	−17.33	−0.7 (−0.8 to −0.61)
Both	60 to 64	27,981.60 (11,179.73–45,974.04)	44,781.09 (18,358.53–70,488.13)	60.04	70.12 (28.01–115.2)	65.69 (26.93–103.4)	−6.31	−0.24 (−0.34 to −0.13)
Male	65 to 69	17,816.74 (6940.88–29,199.93)	33,814.55 (14,177.97–53,660.97)	89.79	115.86 (45.14–189.89)	116.39 (48.8–184.7)	0.45	0.02 (−0.07 to 0.12)
Female	65 to 69	10,862.51 (4298.43–17,832.99)	15,099.24 (6233.55–23,489)	39.00	55.51 (21.97–91.13)	47.83 (19.74–74.4)	−13.85	−0.61 (−0.73 to −0.5)
Both	65 to 69	28,679.24 (11,202.86–46,924.69)	48,913.79 (20,472.84–77,471.01)	70.55	82.07 (32.06–134.28)	80.68 (33.77–127.79)	−1.69	−0.1 (−0.21 to 0)
Male	70 to 74	11,763.20 (4646.32–19,131.02)	32,065.82 (13,325.29–51,712.86)	172.59	112.13 (44.29–182.36)	128.12 (53.24–206.62)	14.26	0.29 (0.16 to 0.41)
Female	70 to 74	8500.90 (3333.60–13,606.85)	15,949.53 (6536.22–25,444.45)	87.62	58.39 (22.9–93.46)	56.29 (23.07–89.81)	−3.59	−0.34 (−0.51 to −0.16)
Both	70 to 74	20,264.10 (7976.98–32,783.91)	48,015.35 (20,122.66–77,261.2)	136.95	80.9 (31.85–130.88)	89.98 (37.71–144.79)	11.23	0.19 (0.05 to 0.34)
Male	75 to 79	8968.92 (3531.96–14,881.46)	22,458.96 (9070.77–36,227.27)	150.41	110.4 (43.47–183.17)	137.52 (55.54–221.83)	24.57	0.71 (0.59 to 0.82)
Female	75 to 79	7845.27 (3065.52–12,939.34)	12,731.14 (5140.67–20,560.64)	62.28	60.13 (23.49–99.17)	64.03 (25.86–103.41)	6.50	0.15 (−0.02 to 0.31)
Both	75 to 79	16,814.19 (6600.04–27,652.72)	35,190.1 (14,297.86–56,846.12)	109.29	79.42 (31.17–130.61)	97.17 (39.48–156.98)	22.36	0.64 (0.51 to 0.78)

(*Continued*)

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Table 2 (Continued).

Age (Years)	Sex	DALY Cases			DALY Rates			
		1990_Numbers (95% UI)	**2021_Numbers (95% UI)**	**Percentage Change in Case (%)**	**1990_Per100000 (95% UI)**	**2021_Per100000 (95% UI)**	**Percentage Change in ASRs (%)**	**EAPC (95% CI)**
Male	80 to 84	4318.83 (1597.68–7074.17)	14,530.73 (5535.24–23,639.19)	236.45	92.84 (34.35–152.08)	128.2 (48.84–208.57)	38.09	1.2 (1.08 to 1.32)
Female	80 to 84	4439.31 (1608.54–7358.77)	9826.71 (3682.38–16,320.56)	121.36	49.44 (17.91–81.95)	62.84 (23.55–104.36)	27.10	0.73 (0.58 to 0.89)
Both	80 to 84	8758.13 (3278.83–14,479.08)	24,357.44 (9240.99–39,819.51)	178.11	64.25 (24.05–106.22)	90.31 (34.26–147.63)	40.55	1.18 (1.06 to 1.3)
Male	85 to 89	1601.74 (608.31–2630.14)	8822.86 (3411.16–14,601.34)	450.83	83.79 (31.82–137.58)	142.91 (55.25–236.5)	70.56	1.86 (1.75 to 1.98)
Female	85 to 89	1994.49 (716.4–3328.46)	7028.86 (2593.33–11,696.94)	252.41	43.33 (15.56–72.32)	68.08 (25.12–113.3)	57.11	1.49 (1.32 to 1.66)
Both	85 to 89	3596.23 (1327.92–5936.40)	15,851.71 (6038.05–26,201.38)	340.79	55.21 (20.38–91.13)	96.08 (36.6–158.81)	74.05	1.88 (1.76 to 2.01)
Male	90 to 94	436.02 (164.79–723.1)	3794.06 (1447.59–6355.45)	770.16	83.91 (31.71–139.16)	157.22 (59.99–263.36)	87.37	2.18 (2.09 to 2.26)
Female	90 to 94	733.54 (263.85–1240.20)	4148.01 (1480.25–7018.56)	465.48	45.45 (16.35–76.85)	78.96 (28.18–133.6)	73.72	1.86 (1.77 to 1.95)
Both	90 to 94	1169.56 (429.27–1964.28)	7942.08 (2913.59–13,266.49)	579.07	54.82 (20.12–92.07)	103.59 (38–173.04)	88.97	2.16 (2.1 to 2.23)
Male	95 plus	80.50 (30.01–134.39)	914.27 (334.18–1540.06)	1035.74	69.76 (26.01–116.46)	128.92 (47.12–217.16)	84.79	2.09 (1.93 to 2.25)
Female	95 plus	193.21 (68.74–332.54)	1598.1 (574.74–2739.68)	727.15	43.79 (15.58–75.38)	77.54 (27.89–132.93)	77.06	1.92 (1.77 to 2.07)
Both	95 plus	273.71 (100.06–464.51)	2512.37 (912.29–4243.22)	817.91	49.18 (17.98–83.46)	90.69 (32.93–153.17)	84.42	2.08 (1.92 to 2.23)
Male	60 to 64	12,503.51 (4863.51–20,610.32)	28,141.98 (11,378.81–45,552.75)	125.07	62.59 (24.35–103.18)	80.52 (32.56–130.34)	28.65	0.66 (0.53 to 0.79)
Female	60 to 64	8460.74 (3499.01–13,618.88)	13,835.34 (5715.33–21,419.26)	63.52	36.67 (15.17–59.03)	36.42 (15.05–56.39)	−0.68	−0.17 (−0.31 to −0.03)
Both	60 to 64	20,964.25 (8366.62–34,440.04)	41,977.32 (17,004.65–67,320.72)	100.23	48.7 (19.44–80.01)	57.56 (23.32–92.3)	18.18	0.38 (0.25 to 0.51)
Male	65 to 69	8771.07 (3444.78–14,388.09)	26,424.97 (10,652.02–42,482.25)	201.27	64.51 (25.34–105.82)	85.41 (34.43–137.31)	32.40	0.63 (0.43 to 0.82)
Female	65 to 69	7719.87 (3075.89–12,633.63)	15,673.57 (6587.96–24,455.28)	103.03	43.06 (17.16–70.47)	44.2 (18.58–68.96)	2.64	−0.31 (−0.49 to −0.13)
Both	65 to 69	16,490.94 (6542.6–26,796.72)	42,098.54 (17,141.99–67,009.33)	155.28	52.31 (20.75–85)	63.4 (25.81–100.91)	21.19	0.31 (0.12 to 0.49)
Male	70 to 74	4940.58 (1917.82–8010.75)	19,783.85 (8007.25–32,362.02)	300.44	58.72 (22.8–95.22)	90.07 (36.45–147.33)	53.38	1.08 (0.84 to 1.33)
Female	70 to 74	4953.64 (1976.46–8202.19)	13,557.36 (5513.6–21,383.77)	173.69	40.48 (16.15–67.02)	50.43 (20.51–79.54)	24.59	0.26 (0 to 0.53)
Both	70 to 74	9894.21 (3888.79–16,151.88)	33,341.21 (13,545.02–53,717.19)	236.98	47.91 (18.83–78.21)	68.25 (27.73–109.97)	42.46	0.8 (0.56 to 1.05)
Male	75 to 79	3821.01 (1498.95–6306.95)	11,055.81 (4395.5–18,165.86)	189.34	62.65 (24.58–103.41)	85.28 (33.9–140.12)	36.11	1.39 (1.18 to 1.6)
Female	75 to 79	4261.89 (1692.36–7105.52)	8094.29 (3239.87–13,012.57)	89.92	40.41 (16.05–67.37)	47.88 (19.17–76.98)	18.50	0.96 (0.75 to 1.18)
Both	75 to 79	8082.90 (3175.25–13,356.88)	19,150.1 (7653.16–31,208.38)	136.92	48.56 (19.08–80.25)	64.12 (25.62–104.49)	32.03	1.3 (1.09 to 1.51)
Male	80 to 84	1710.72 (634.14–2756.93)	7379.7 (2821.61–12,296.05)	331.38	55.02 (20.39–88.67)	87.71 (33.54–146.15)	59.43	1.65 (1.45 to 1.84)
Female	80 to 84	1802.19 (655.59–2970.87)	6431.98 (2431.37–10,490.85)	256.90	29.08 (10.58–47.93)	47.93 (18.12–78.18)	64.85	1.75 (1.52 to 1.98)
Both	80 to 84	3512.92 (1294.14–5740.19)	13,811.68 (5237.39–22,742.78)	293.17	37.74 (13.9–61.67)	63.26 (23.99–104.17)	67.62	1.84 (1.63 to 2.05)
Male	85 to 89	537.23 (197.59–875.01)	3748.83 (1461.78–6305.97)	597.80	49.62 (18.25–80.81)	95.39 (37.2–160.46)	92.27	2.18 (1.97 to 2.39)
Female	85 to 89	649.36 (238.73–1091.40)	3457.94 (1318.75–5769.04)	432.52	24.44 (8.99–41.08)	46.43 (17.71–77.46)	89.98	2.44 (2.23 to 2.64)
Both	85 to 89	1186.59 (434.32–1960.55)	7206.77 (2727.79–11,921.89)	507.35	31.73 (11.61–52.43)	63.34 (23.98–104.79)	99.64	2.46 (2.28 to 2.64)
Male	90 to 94	124.68 (46.21–202.02)	1301.44 (502.86–2201.7)	943.82	51.93 (19.24–84.14)	102.15 (39.47–172.82)	96.73	2.41 (2.16 to 2.65)
Female	90 to 94	178.95 (64.6–298.99)	1524.39 (558.02–2584.42)	751.84	25.93 (9.36–43.33)	49.21 (18.01–83.43)	89.77	2.38 (2.2 to 2.55)
Both	90 to 94	303.63 (109.97–504.65)	2825.83 (1036.57–4757.72)	830.67	32.64 (11.82–54.25)	64.64 (23.71–108.83)	98.03	2.49 (2.3 to 2.68)
Male	95 plus	20.03 (7.12–32.68)	243.44 (91–405.44)	1115.53	45.51 (16.18–74.26)	88.03 (32.9–146.6)	93.42	2.47 (2.26 to 2.67)
Female	95 plus	36.35 (13.38–62.74)	379.24 (142.9–643.99)	943.20	25.15 (9.25–43.4)	45.84 (17.27–77.84)	82.29	2.18 (2.01 to 2.36)
Both	95 plus	56.38 (20.42–94.78)	622.68 (232.48–1051.07)	1004.41	29.9 (10.83–50.26)	56.41 (21.06–95.22)	88.67	2.32 (2.15 to 2.5)

Male	60 to 64	244.57 (93.63–413.88)	1065.51 (371.31–1864.25)	335.67	5.01 (1.92–8.48)	10.94 (3.81–19.14)	118.21	2.5 (2.4 to 2.59)
Female	60 to 64	197.19 (76.61–338.91)	705.38 (259.51–1224.1)	257.71	4.43 (1.72–7.61)	7.07 (2.6–12.27)	59.71	1.62 (1.46 to 1.77)
Both	60 to 64	441.76 (172.09–719.44)	1770.89 (616.74–3022.51)	300.87	4.73 (1.84–7.71)	8.98 (3.13–15.33)	89.75	2.1 (1.98 to 2.22)
Male	65 to 69	186.64 (71.04–305.11)	817.5 (285.93–1418.77)	338.00	5.2 (1.98–8.51)	11.06 (3.87–19.19)	112.45	2.39 (2.29 to 2.5)
Female	65 to 69	152.41 (56.41–265.75)	571.93 (212.69–979.25)	275.26	4.53 (1.68–7.89)	7.44 (2.77–12.75)	64.47	1.68 (1.52 to 1.84)
Both	65 to 69	339.05 (129.11–552.17)	1389.42 (495.29–2348.66)	309.80	4.88 (1.86–7.94)	9.22 (3.29–15.58)	89.01	2.06 (1.93 to 2.19)
Male	70 to 74	122.34 (45.49–208.4)	546.16 (182.37–931.8)	346.44	5.07 (1.88–8.63)	10.79 (3.6–18.41)	113.00	2.51 (2.41 to 2.61)
Female	70 to 74	95.85 (34.2–161)	383.79 (134.23–660.67)	300.39	4.15 (1.48–6.96)	7.23 (2.53–12.45)	74.42	2.03 (1.87 to 2.18)
Both	70 to 74	218.19 (78.52–349.33)	929.95 (319.23–1549.07)	326.21	4.62 (1.66–7.39)	8.97 (3.08–14.94)	94.30	2.28 (2.16 to 2.4)
Male	75 to 79	68.56 (25.08–116.63)	352.69 (121.14–593.06)	414.39	5.08 (1.86–8.64)	11.39 (3.91–19.16)	124.41	2.64 (2.57 to 2.72)
Female	75 to 79	49.18 (19.05–81.16)	219.25 (81.89–378.37)	345.84	3.61 (1.4–5.96)	6.59 (2.46–11.38)	82.69	2.13 (1.95 to 2.32)
Both	75 to 79	117.74 (43.51–193.93)	571.94 (205.97–957.04)	385.76	4.34 (1.6–7.15)	8.91 (3.21–14.91)	105.25	2.41 (2.3 to 2.52)
Male	80 to 84	20.93 (7.47–34.73)	128.5 (44.92–217.05)	514.06	3.36 (1.2–5.58)	8.25 (2.88–13.94)	145.28	2.89 (2.78 to 3)
Female	80 to 84	16.08 (5.70–27.05)	89.86 (32.26–157.91)	458.98	2.38 (0.84–4)	4.95 (1.78–8.7)	108.34	2.47 (2.28 to 2.67)
Both	80 to 84	37 (13.05–59.22)	218.36 (76.34–365.45)	490.13	2.85 (1–4.56)	6.47 (2.26–10.83)	127.23	2.7 (2.56 to 2.83)
Male	85 to 89	6.14 (2.20–10.23)	46.96 (15.9–80.57)	664.95	2.95 (1.05–4.91)	7.95 (2.69–13.64)	169.76	3.37 (3.18 to 3.56)
Female	85 to 89	4.83 (1.69–8.20)	31.71 (11.17–58.07)	556.78	1.95 (0.69–3.32)	4.26 (1.5–7.8)	118.15	2.75 (2.5 to 3)
Both	85 to 89	10.97 (3.82–18.22)	78.67 (27.21–136.5)	617.34	2.41 (0.84–4)	5.89 (2.04–10.23)	144.77	3.1 (2.89 to 3.31)
Male	90 to 94	1.26 (0.45–2.14)	11.68 (4.04–20.03)	828.36	2.66 (0.95–4.52)	7.56 (2.62–12.96)	184.51	3.66 (3.33 to 3.99)
Female	90 to 94	1 (0.34–1.77)	7.88 (2.77–13.9)	686.99	1.52 (0.52–2.69)	3.86 (1.36–6.81)	153.58	3.17 (2.85 to 3.5)
Both	90 to 94	2.26 (0.79–3.77)	19.56 (6.81–33.13)	765.71	2 (0.7–3.33)	5.46 (1.9–9.24)	173.06	3.44 (3.13 to 3.75)
Male	95 plus	0.14 (0.05–0.25)	1.19 (0.39–2.21)	741.11	1.63 (0.53–2.89)	4.31 (1.43–8.01)	164.76	3.55 (3.02 to 4.08)
Female	95 plus	0.15 (0.05–0.28)	1.27 (0.45–2.41)	736.07	0.99 (0.32–1.83)	2.61 (0.92–4.97)	164.68	3.3 (2.97 to 3.64)
Both	95 plus	0.29 (0.10–0.52)	2.46 (0.85–4.49)	738.50	1.22 (0.41–2.15)	3.23 (1.11–5.9)	164.90	3.42 (3.03 to 3.82)
Male	60 to 64	726.15 (280.67–1179.3)	4783.65 (1955.67–7605.59)	558.76	5.55 (2.14–9.01)	17.23 (7.04–27.4)	210.67	4.02 (3.91 to 4.12)
Female	60 to 64	575.63 (226.8–916.43)	2923.96 (1118.27–4670.74)	407.96	4.71 (1.86–7.5)	9.94 (3.8–15.88)	111.05	2.73 (2.53 to 2.94)
Both	60 to 64	1301.79 (511.87–2093.9)	7707.61 (3080.47–12,167.74)	492.08	5.14 (2.02–8.27)	13.48 (5.39–21.29)	162.13	3.46 (3.34 to 3.58)
Male	65 to 69	556.19 (205.84–909.46)	3734 (1470.08–6145.62)	571.35	6.03 (2.23–9.86)	17.49 (6.89–28.79)	190.19	3.68 (3.6 to 3.76)
Female	65 to 69	456.56 (181.78–743.38)	2580.13 (1010.92–4142.81)	465.12	5.11 (2.03–8.31)	11.21 (4.39–18)	119.61	2.7 (2.51 to 2.89)
Both	65 to 69	1012.75 (387.51–1645.41)	6314.13 (2516.17–10,283.37)	523.46	5.57 (2.13–9.06)	14.23 (5.67–23.18)	155.37	3.23 (3.14 to 3.33)
Male	70 to 74	358.32 (136.26–581.56)	2594.86 (995.37–4256.73)	624.17	5.85 (2.22–9.49)	17.33 (6.65–28.43)	196.51	3.62 (3.55 to 3.68)
Female	70 to 74	321.39 (126.61–518.4)	1874.83 (750.66–2968.45)	483.35	5.22 (2.06–8.42)	11.38 (4.56–18.02)	118.01	2.55 (2.46 to 2.63)
Both	70 to 74	679.71 (259.87–1095.35)	4469.69 (1757.88–7333.81)	557.59	5.53 (2.11–8.91)	14.21 (5.59–23.32)	156.93	3.11 (3.08 to 3.15)
Male	75 to 79	226.29 (84.99–356.1)	1538.02 (628.25–2497.31)	579.66	6.01 (2.26–9.46)	16.49 (6.74–26.77)	174.23	3.45 (3.35 to 3.54)
Female	75 to 79	196.74 (75.67–316.45)	1119.89 (435.53–1843.48)	469.22	5.16 (1.98–8.29)	10.42 (4.05–17.15)	102.01	2.41 (2.34 to 2.48)
Both	75 to 79	423.04 (161.27–662.04)	2657.91 (1053.13–4320.05)	528.29	5.58 (2.13–8.74)	13.24 (5.24–21.52)	137.16	2.94 (2.88 to 3.01)
Male	80 to 84	90.58 (32.76–145.36)	671.12 (256.79–1116.99)	640.92	4.47 (1.62–7.18)	13.26 (5.07–22.07)	196.53	3.75 (3.64 to 3.86)
Female	80 to 84	81.43 (28.33–135.86)	531.98 (197.44–893.71)	553.26	3.81 (1.33–6.36)	8.26 (3.07–13.88)	116.74	2.61 (2.48 to 2.75)
Both	80 to 84	172.01 (61.35–279.32)	1203.09 (460.98–2028.5)	599.42	4.13 (1.47–6.71)	10.46 (4.01–17.64)	153.12	3.18 (3.06 to 3.3)

(*Continued*)

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Table 2 (Continued).

Age (Years)	Sex	DALY Cases			DALY Rates			
		1990_Numbers (95% UI)	2021_Numbers (95% UI)	Percentage Change in Case (%)	1990_Per100000 (95% UI)	2021_Per100000 (95% UI)	Percentage Change in ASRs (%)	EAPC (95% CI)
Male	85 to 89	31.92 (11.8–51.15)	271.5 (101.33–459.12)	750.55	4.05 (1.5–6.48)	12.76 (4.76–21.57)	215.24	4.19 (4.01 to 4.37)
Female	85 to 89	31.46 (11.25–53.11)	216.24 (77.6–364.82)	587.33	3.64 (1.3–6.14)	7.54 (2.71–12.72)	107.19	2.93 (2.75 to 3.11)
Both	85 to 89	63.38 (22.87–102.54)	487.74 (172.82–821.43)	669.54	3.83 (1.38–6.2)	9.76 (3.46–16.44)	154.65	3.54 (3.37 to 3.72)
Male	90 to 94	8.46 (3.06–13.84)	86.8 (32.99–145.83)	926.18	4.19 (1.51–6.85)	12.94 (4.92–21.73)	209.07	4.39 (4.18 to 4.6)
Female	90 to 94	8.68 (3.07–14.86)	74.85 (27.19–126.59)	762.29	3.63 (1.28–6.21)	7.9 (2.87–13.36)	117.90	3.07 (2.89 to 3.25)
Both	90 to 94	17.14 (5.95–28.18)	161.66 (58.47–271.89)	843.17	3.88 (1.35–6.38)	9.99 (3.61–16.8)	157.30	3.69 (3.52 to 3.86)
Male	95 plus	1.3 (0.45–2.2)	18.58 (6.76–32.07)	1327.68	3.06 (1.07–5.17)	11.38 (4.14–19.64)	271.29	5 (4.78 to 5.22)
Female	95 plus	1.63 (0.55–2.77)	22.28 (8.04–38.91)	1266.84	2.78 (0.94–4.74)	7.68 (2.77–13.41)	175.80	3.67 (3.39 to 3.96)
Both	95 plus	2.93 (1.04–4.93)	40.86 (14.92–70.43)	1293.85	2.9 (1.03–4.88)	9.01 (3.29–15.53)	210.51	4.22 (4 to 4.44)
Male	60 to 64	2579.04 (1000.77–4208.93)	14,666.61 (6107.42–23,697.58)	468.68	11.93 (4.63–19.47)	29.56 (12.31–47.76)	147.81	2.9 (2.81 to 2.99)
Female	60 to 64	1830.92 (714.09–2968.76)	8290.7 (3387.4–13,074.07)	352.82	8.63 (3.37–14)	15.89 (6.49–25.06)	84.11	1.82 (1.73 to 1.92)
Both	60 to 64	4409.96 (1752.12–7140.61)	22,957.3 (9460.42–37,525.4)	420.58	10.3 (4.09–16.67)	22.56 (9.29–36.87)	119.06	2.46 (2.38 to 2.53)
Male	65 to 69	1970.34 (740.3–3192.57)	12,679.3 (5303.4–21,057.27)	543.51	12.73 (4.78–20.63)	29.5 (12.34–48.99)	131.70	2.8 (2.7 to 2.89)
Female	65 to 69	1502.23 (584.09–2473.29)	7992.15 (3250.76–13,000.13)	432.02	9.16 (3.56–15.09)	17.32 (7.04–28.17)	88.95	1.89 (1.83 to 1.95)
Both	65 to 69	3472.56 (1337.21–5634.94)	20,671.46 (8426.49–34,096.89)	495.28	10.9 (4.2–17.68)	23.19 (9.45–38.25)	112.83	2.42 (2.36 to 2.48)
Male	70 to 74	1271.69 (491.7–2102.41)	9022.26 (3685–15,358.6)	609.47	12.55 (4.85–20.75)	30.81 (12.58–52.45)	145.46	2.96 (2.88 to 3.04)
Female	70 to 74	1050.18 (406.26–1706.63)	5831.54 (2408.04–9686.3)	455.29	8.96 (3.46–14.55)	18.03 (7.44–29.95)	101.30	2.21 (2.12 to 2.29)
Both	70 to 74	2321.87 (887.3–3783.82)	14,853.81 (6037.37–24,644.56)	539.73	10.62 (4.06–17.31)	24.1 (9.8–39.99)	126.89	2.66 (2.58 to 2.73)
Male	75 to 79	790.59 (296.17–1284.32)	5960.18 (2429.25–9924.45)	653.89	13.48 (5.05–21.9)	33.08 (13.48–55.09)	145.43	3.2 (3.11 to 3.28)
Female	75 to 79	643.44 (255.18–1042.91)	3766.44 (1530.23–6221.91)	485.36	8.57 (3.4–13.89)	17.79 (7.23–29.4)	107.58	2.37 (2.31 to 2.43)
Both	75 to 79	1434.03 (552.01–2339.04)	9726.62 (3967.24–15,978.79)	578.27	10.73 (4.13–17.49)	24.82 (10.13–40.78)	131.46	2.89 (2.83 to 2.95)
Male	80 to 84	332.19 (123.67–542.3)	2964.27 (1180.17–5113.45)	792.33	11.63 (4.33–18.98)	28.91 (11.51–49.88)	148.66	3.18 (3.09 to 3.27)
Female	80 to 84	286.88 (106.66–478.15)	1984.88 (754.81–3310.28)	591.89	7.04 (2.62–11.74)	14.63 (5.56–24.4)	107.71	2.36 (2.27 to 2.45)
Both	80 to 84	619.07 (230.34–1012.55)	4949.16 (1939.9–8397.51)	699.45	8.93 (3.32–14.61)	20.78 (8.14–35.25)	132.58	2.86 (2.78 to 2.95)
Male	85 to 89	138.29 (51.5–228.46)	1465.37 (568.81–2545.63)	959.63	12.98 (4.83–21.44)	33.21 (12.89–57.69)	155.84	3.15 (3.08 to 3.22)
Female	85 to 89	159.81 (60.13–268.23)	1059.99 (396.27–1772.16)	563.30	9.61 (3.62–16.13)	15.02 (5.62–25.12)	56.34	1.49 (1.35 to 1.63)
Both	85 to 89	298.1 (110.63–492.52)	2525.36 (959.75–4311)	747.16	10.93 (4.05–18.05)	22.02 (8.37–37.59)	101.55	2.36 (2.27 to 2.44)
Male	90 to 94	30.82 (11.17–50.2)	419.82 (166.01–717.88)	1261.95	12.42 (4.5–20.22)	32.06 (12.68–54.82)	158.18	3.44 (3.31 to 3.58)
Female	90 to 94	34.63 (12.88–59.26)	389.85 (144.54–665.9)	1025.79	8.37 (3.11–14.32)	15.31 (5.68–26.16)	82.97	1.87 (1.77 to 1.97)
Both	90 to 94	65.45 (24.02–107.89)	809.67 (308.99–1362.84)	1137.01	9.89 (3.63–16.3)	21 (8.01–35.35)	112.41	2.56 (2.47 to 2.65)
Male	95 plus	5.14 (1.89–8.32)	76.64 (28.46–129.09)	1392.42	10.39 (3.83–16.84)	22.98 (8.53–38.7)	121.14	2.63 (2.45 to 2.82)
Female	95 plus	5.26 (1.89–8.9)	99.44 (36.53–169.98)	1789.80	5.4 (1.94–9.14)	14.07 (5.17–24.05)	160.55	3.03 (2.82 to 3.25)
Both	95 plus	10.4 (3.76–16.96)	176.08 (64.84–300.19)	1593.54	7.08 (2.56–11.55)	16.92 (6.23–28.85)	139.09	2.81 (2.69 to 2.94)

observed in the 60–64 years age group in the High SDI region and the Low SDI region, but the maximum EAPC values for males were concentrated in the 75–79 years age group, and for females in the 85–89 years age group.

SDI and Disease Burden of Kidney Cancer Attributable to High BMI

Globally, ASDR and ASMR exhibited significant strong positive correlations with SDI levels ($r > 0.6$, $P < 0.05$) (Figure 6). However, they did not follow a simple linear pattern: with increasing SDI levels, ASDR and ASMR initially decreased slightly before rising sharply, then significantly decreased when SDI reached a middle-to-high level (around 0.75). Among the 204 countries, the correlations between ASDR, ASMR, and SDI levels were slightly lower than at the regional level, but the overall trends were consistent. Notably, when SDI was around 0.65, ASDR and ASMR reached a small peak and then accelerated. From a temporal perspective, the trends in ASDR and ASMR changed significantly with increasing global SDI levels. Before around 2011, global ASDR and ASMR were significantly higher than expected, but afterwards, they were lower than expected. Among the 21 regions, Southern Latin America, Central Europe, and Eastern Europe had ASDR and ASMR significantly higher than expected, while High-income Asia Pacific, East Asia, and Southeast Asia had lower-than-expected rates. At the national level, Czechia, Uruguay, and Slovak had significantly higher-than-expected ASDR and ASMR, while Viet Nam, Niger, and Timor-Leste had lower-than-expected rates.

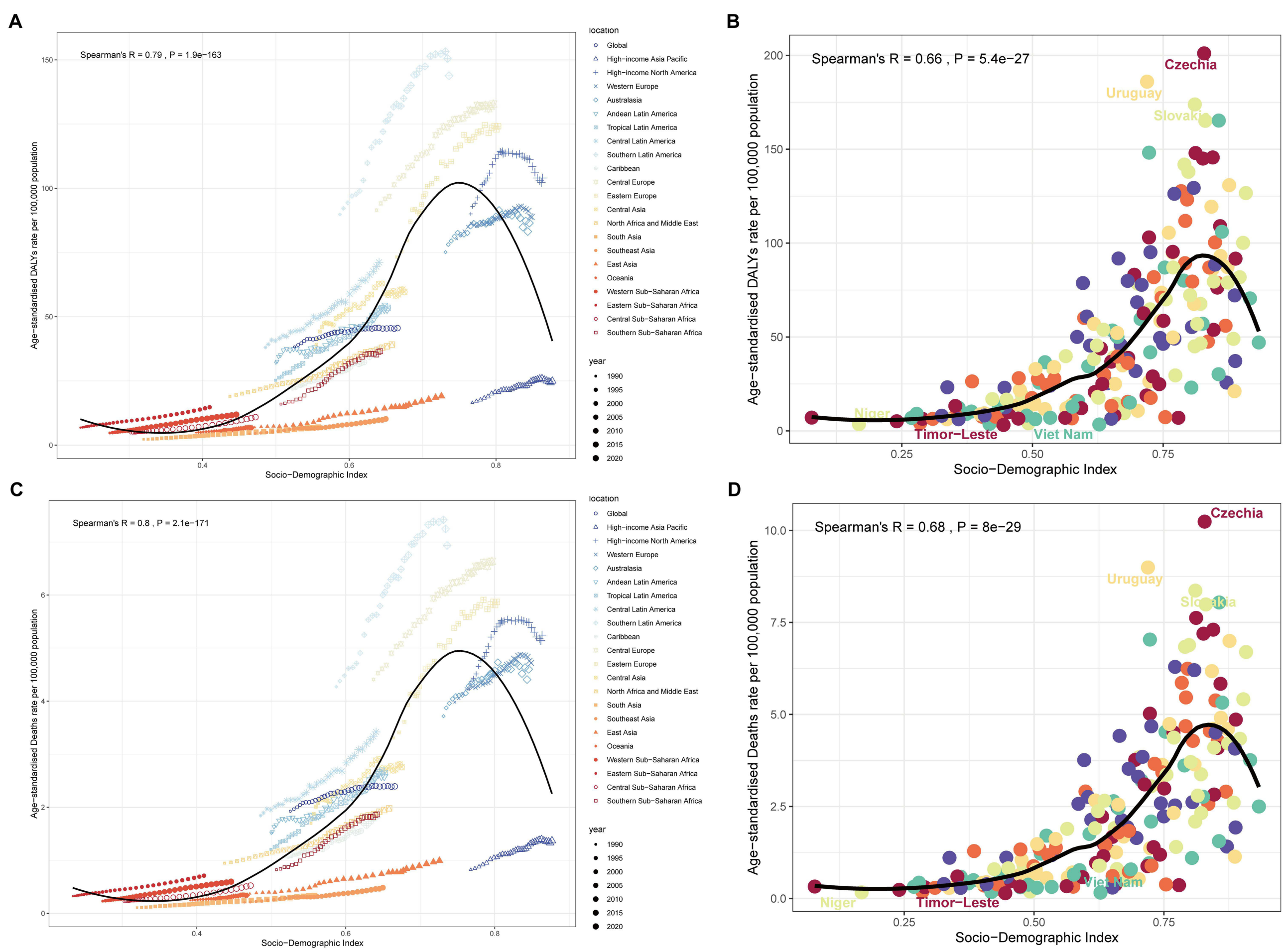

Figure 6 Correlation between burden of kidney cancer attributable to high BMI and socio-demographic index (SDI) in adults aged 60 and older, both sexes. (**A**) Correlation between age-standardized DALY rates and SDI for 21 GBD regions, 1990–2021; (**B**) Correlation between age-standardized DALY rates and SDI for 204 countries in 2021; (**C**) Correlation between age-standardized death rates and SDI for 21 GBD regions, 1990 −2021; (**D**) Correlation between age-standardized death rates and SDI for 204 countries in 2021.

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Health Inequalities in Kidney Cancer Attributable to High BMI Among Adults Aged 60 and Older

The health inequalities in the burden of kidney cancer attributable to high BMI among adults aged 60 years and older revealed a complex trend of increasing absolute inequality and decreasing relative inequality. The SII values for ASDR and ASMR were positive, indicating that regions with lower SDI levels had heavier disease burdens. From 1990 to 2021, the SII for ASDR increased from 72 to 84, suggesting an intensification of health inequalities (Figure 7A). Meanwhile, the concentration index for ASDR decreased from 0.45 (95% CI: 0.40 to 0.51) in 1990 to 0.35 (95% CI: 0.30 to 0.41) in 2021, with the corresponding curves located below the line of equality (Figure 7B). This indicated that the disability burden was still concentrated in High SDI regions but that the differences in distribution across SDI regions had decreased. ASMR exhibited similar changes, with the SII increasing from 4 in 1990 to 5 in 2021, and the concentration index decreasing from 0.47 (95% CI: 0.41 to 0.52) in 1990 to 0.38 (95% CI: 0.33 to 0.44) in 2021 (Figure 7C and D). These findings further suggested an expansion in the absolute gap in kidney cancer burden and a decrease in relative concentration.

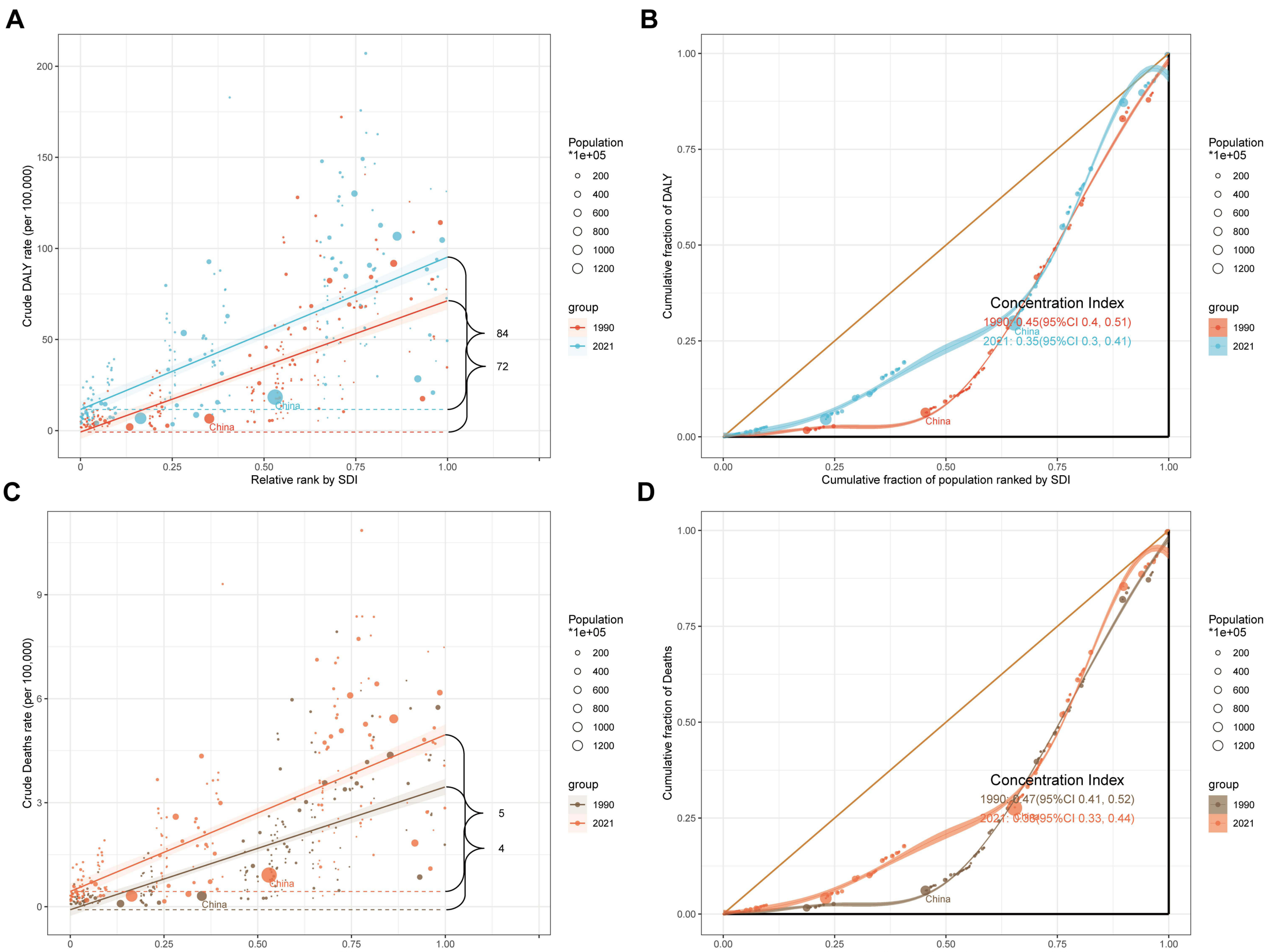

Figure 7 Health inequality analysis of kidney cancer burden attributable to high BMI in adults aged 60 and older, 1990–2021, both sexes. (**A**) Slope index of inequality for DALYs in 204 countries; (**B**) Concentration index for DALYs in 204 countries; (**C**) Slope index of inequality for deaths in 204 countries; (**D**) Concentration index for deaths in 204 countries.

Decomposition of Global, SDI-Based, and Gender-Specific Trends in Kidney Cancer Attributable to High BMI

Globally, the overall difference in DALYs was 308,221.92, and in deaths was 16,486.27, indicating an increase in the disability and mortality burden of kidney cancer attributable to high BMI among adults aged 60 and older (Figure 8 and Table S5). Population size changes contributed 75.46% and 81.65% to the difference in DALYs and deaths, respectively, and were the primary driving factors for burden growth. Epidemiological changes were the second most important factor, while the contribution of aging was relatively low. Among the different SDI regions, the overall difference in DALYs and deaths increased with increasing SDI levels. The High SDI region had the highest overall difference in DALYs (120,027.18) and deaths (7,103.4), far exceeding the Low SDI region. Population size changes were the main influencing factor for DALYs and deaths in all regions except the Low-middle SDI region. In particular, population size changes accounted for 84.34% of the overall difference in DALYs and 73.53% of the overall difference in deaths in the High SDI region. In the Low-middle SDI region, epidemiological changes replaced population size changes as the primary factor affecting DALYs and deaths, contributing 51.02% to DALYs and 50.01% to deaths. Aging increased the difference in deaths but had varying effects on DALYs across regions. In the High SDI region, aging increased difference of DALYs to 493.93 (0.41%), but in the other four regions, aging decreased DALYs, albeit with contribution rates of <-1.00%.

Globally, the overall difference in DALYs and deaths for males and females increased significantly, with males having approximately twice the difference of females. Population size changes were the primary driver of changes in DALYs and deaths for both genders globally, with a greater impact on females than males. Epidemiological changes had a greater impact on DALYs and deaths for males than females globally. Among different SDI regions and genders, the overall difference in DALYs and deaths increased positively, and with increasing SDI levels, the overall difference increased significantly, consistent with the overall trend. Population size changes remained the primary driver of changes

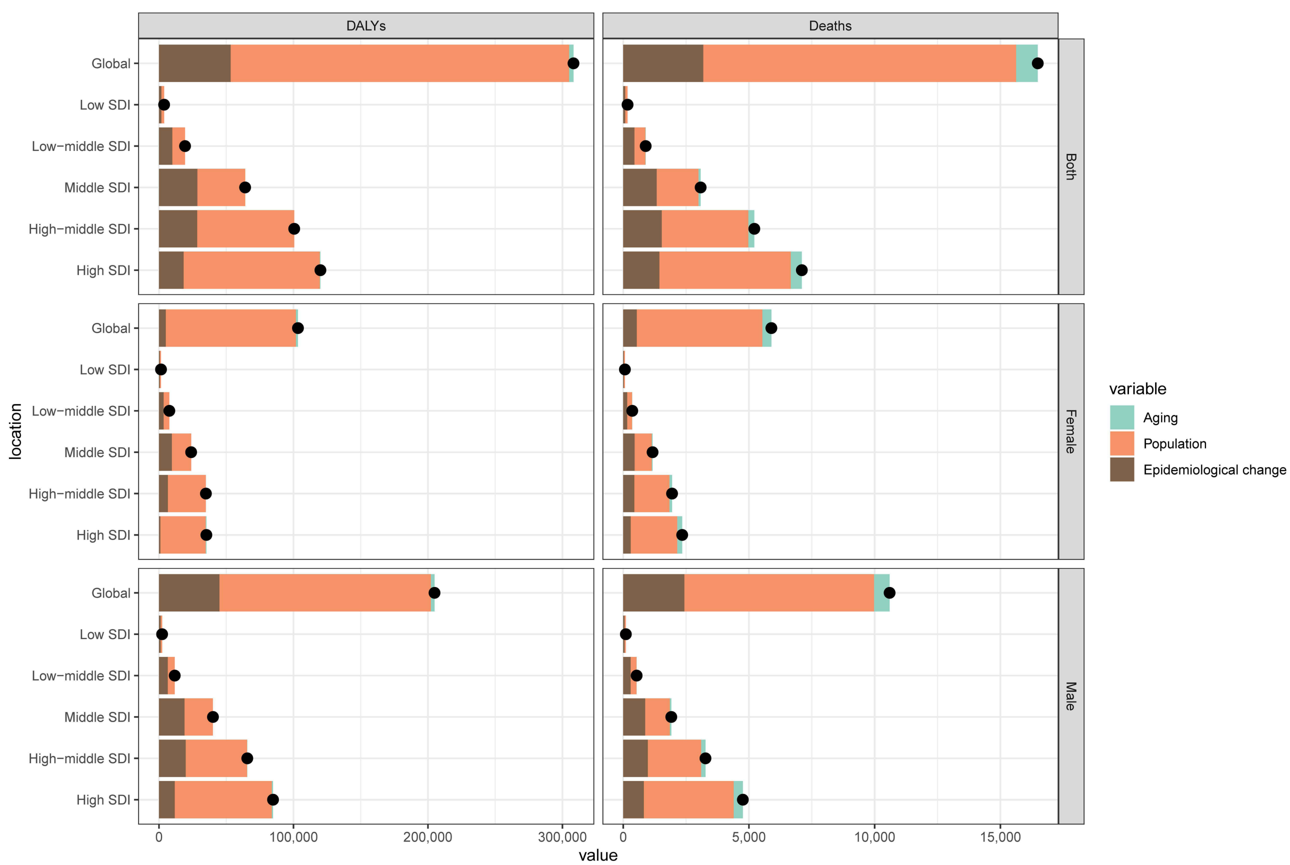

Figure 8 Decomposition analysis of kidney cancer burden attributable to high BMI for both sexes, males, and females globally, and 5 SDI regions.

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in DALYs and deaths for females across different SDI regions. In particular, in the High SDI region, population size changes increased DALYs for females to 33,712.54 (95.69% contribution). Epidemiological changes had a significant impact on the disease burden of females in regions with Middle SDI levels and below. This phenomenon was more pronounced among males: population size changes were the primary factor driving increases in DALYs and deaths for males in regions with Middle SDI levels and above, while epidemiological changes were the primary factor in regions with Low SDI and Low-middle SDI levels. Aging significantly increased deaths in the High SDI region, contributing to an increase difference to 97.64 deaths for females (8.43% contribution) and 364.01 deaths for males (7.65% contribution). However, aging also decreased DALYs for females in regions with Middle SDI levels and below and for males in the Low-middle SDI and Low SDI regions.

Projected Trends in Global Burden of Kidney Cancer Attributable to High BMI: 2022-2040 Using BAPC Algorithms

From 1990 to 2021, the global burden of kidney cancer attributable to high BMI among adults aged 60 and older, in terms of DALYs and deaths, continued to increase, despite relatively stable growth trends in ASDR and ASMR over the 32-year period (Figure 9). It is projected that from 2022 to 2040, global DALYs and deaths will further increase, with DALYs potentially increasing by approximately 410,000 and deaths reaching 48,400 by 2040 (Table S6). ASDR and

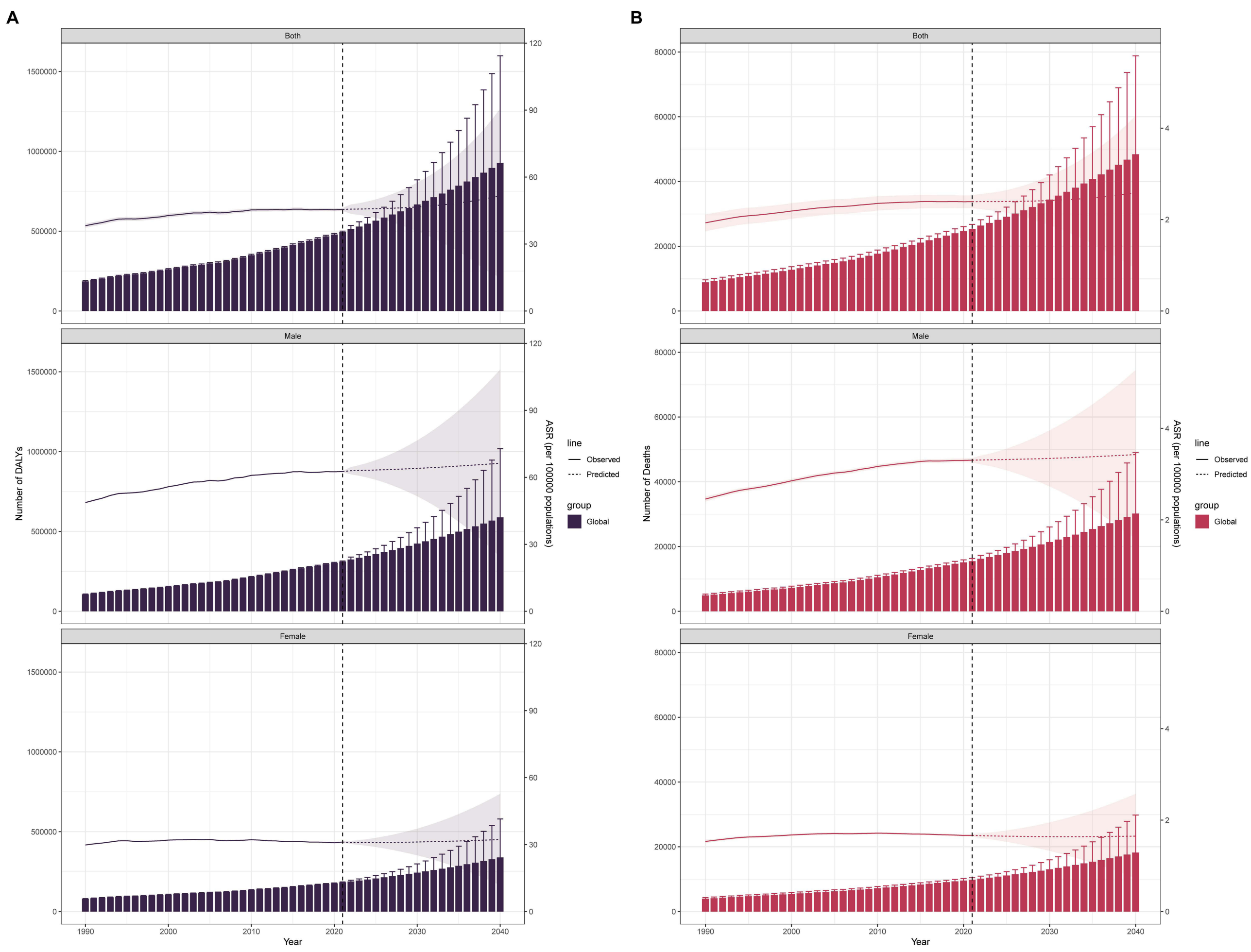

Figure 9 Projected global trends in DALY and death numbers and age-standardized rates for kidney cancer attributable to high BMI among adults aged 60 and older, both sexes combined, 2022–2040. (**A**) Projected global trends in DALY numbers and age-standardized rates for kidney cancer attributable to high BMI among adults aged 60 and older, both sexes combined, 2022–2040; (**B**) Projected global trends in death numbers and age-standardized rates for kidney cancer attributable to high BMI among adults aged 60 and older, both sexes combined, 2022–2040.

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ASMR are also expected to increase in the future, but at growth rates below 0.5%. For both genders, DALYs and deaths increased gradually from 1990 to 2021 and are projected to continue increasing from 2022 to 2040, with males experiencing greater growth rates than females (Figure 9 and Tables S7, S8). Specifically, by 2040, global male DALYs are expected to reach 588,320, and deaths to reach 30,168; female DALYs are expected to be 338,978, and deaths 18,232. Male ASDR and ASMR are significantly higher than the overall levels and exhibited a linear growth trend from 1990 to 2021, with further growth expected until 2040, although the growth trend will flatten. In contrast, female ASDR and ASMR exhibited a decreasing trend from 1990 to 2021. From 2022 to 2040, female ASDR is expected to increase from 30.96 per 100,000 to 32.26 per 100,000, while ASMR is expected to fluctuate around 1.65 per 100,000.

Discussion

Based on GBD 2019, compared to 1990, the global number of deaths (31,700) and DALYs (7,518,900) attributable to high BMI in 2019 increased by 183.1% and 164%, respectively.[19] Research has indicated that a high BMI is associated with an increased risk of kidney cancer, and a significant reduction in risk is observed when BMI is decreased by 10%, particularly among individuals aged over 50.[20] In 2017, there were 393,000 incident cases of kidney cancer globally, resulting in 138,500 deaths and 3.3 million DALYs, of which 18% of the DALYs were attributable to high BMI.[21] And in 2021, approximately 20.07% of deaths and 19.46% of DALYs due to kidney cancer globally were attributable to high BMI.[16] The incidence of kidney cancer is projected to continue rising in the future, driven by increasing known risk factors such as population aging, obesity, and hypertension, leading to a significant disease burden and economic costs, making kidney cancer a major health threat to the elderly.[7,22] Based on GBD 2021 data, this study quantified the incidence, mortality, and associated burden of kidney cancer among individuals aged 60 and older with high BMI, revealing the relationship between high BMI and kidney cancer, assessing its variations across different regions and genders, and exploring the regional characteristics of the burden attributable to high BMI. Our findings demonstrate a significant increase in the burden of kidney cancer DALYs and deaths due to high BMI among individuals aged 60 and older from 1990 to 2021, particularly in older age groups. This burden exhibits notable variations across different SDI levels, geographical locations, and genders, highlighting the crucial impact of high BMI on the kidney cancer burden in this population and providing a scientific basis for formulating more effective public health strategies and interventions.

The results of this study indicate that globally, the number of DALYs and deaths, as well as their ASRs, attributable to high BMI-related kidney cancer among individuals > 60 have significantly increased over the past 32 years. Zi et al,[16] based on GBD 2021, revealed the global burden of common urological diseases, with the ASDR and ASMR for kidney cancer exhibiting a declining trend. This discrepancy may be attributed to differences in the study populations. Population size changes are the primary driver of the increasing burden. From 1990 to 2021, the global population expanded, and the age structure continued to age, leading to an increase in the population base of the study population and consequently, an increase in the absolute number of kidney cancer patients.[13,23] However, the contribution of aging to the increasing disease burden is relatively low, potentially due to the fact that our study population is already in the aging stage. Additionally, with advancements in medical technology and improvements in public health conditions, the health status and life expectancy of the elderly have also improved,[13] which may further reduce the impact of aging on the increasing disease burden. Furthermore, from a pathological perspective, obesity influences cancer development through multiple pathways, such as insulin resistance, abnormalities in the IGF-I system and signaling, alterations in sex hormone biosynthesis and pathways, inflammation and oxidative stress, and pathophysiological changes in adipokines.[24] However, the "obesity paradox" reveals that overweight and obese patients are associated with improved specific survival rates in kidney cancer.[11] Research indicates that the tumor microenvironment of tumors and peritumoral adipose tissue differs based on BMI,[25] and high BMI exhibits a protective effect in older age groups.[12] This contributes to the relatively small contribution of aging to the burden of kidney cancer associated with high BMI among individuals aged 60 and older. Therefore, more comprehensive and individualized treatment strategies are needed for kidney cancer patients aged 60 and older with high BMI.

A significant strong positive correlation exists between the burden of kidney cancer attributable to high BMI among individuals aged 60 and older and SDI levels, consistent with previous studies.[16,26] High SDI regions exhibit higher absolute burdens, which is associated with more comprehensive disease monitoring, diagnosis, and reporting systems.[27]

In these regions, the population has higher education levels and health awareness, but these also lead to prolonged life expectancy, population growth, and aging issues.[28] Simultaneously, rapid modernization, urbanization, and industrialization in these high SDI regions have contributed to prominent obesity problems,[29] exacerbating the burden of kidney cancer due to high BMI among individuals aged 60 and older. Notably, when SDI reaches higher levels, ASDR and ASMR begin to decline, and the growth rates of ASDR and ASMR in high SDI regions are also lower. This may be attributed to the higher levels of medical resources, preventive measures, and health management systems in these regions.[30] In contrast, while medium and lower SDI regions currently have lower burden bases, the prevalence of obesity and related metabolic diseases is rapidly rising due to population changes, economic transitions, urbanization, and westernization of lifestyles. Additionally, due to economic constraints, access to medical resources is limited, leading to fewer opportunities for most patients to obtain healthcare services such as screenings and treatments.[4,22,31] Thus, epidemiological changes in these regions have also become an important driver of rapid burden growth. With the continued increase in the global population with high BMI, the prevention and management of kidney cancer will become more challenging.[32,33] Despite the implementation of a series of global public health interventions to improve the accessibility and quality of healthcare,[34] our study results indicate that health inequalities are still intensifying, influenced by multiple factors such as population growth, socioeconomic, and cultural environments.[35,36] Therefore, when formulating public health policies, regional differences and imbalances should be fully considered.

Numerous studies have elucidated significant geographical variations in the incidence and mortality of kidney cancer.[37] The penetration of urbanization and western dietary patterns in emerging economies has led to a sharp increase in high BMI-related diseases.[32] Meanwhile, environmental pollution, life stress, uneven distribution of medical resources, and racial differences have all influenced the DALY rates and mortality rates of kidney cancer due to high BMI among individuals aged 60 and older to varying degrees.[17,38,39] Among them, Western Europe, despite having relatively comprehensive healthcare systems, health education, and obesity prevention measures,[40] still ranks among the top regions globally in terms of disease burden. This may be related to factors such as the severe aging of the population, relatively sedentary lifestyles (eg, sedentary behavior, high-calorie diets), and socioeconomic stress.[41] In contrast, South Asia has experienced the most rapid growth in disease burden, which may be closely related to rapid economic growth, accelerated urbanization, and westernization of lifestyles.[32,42,43] Additionally, Southern Latin America has the highest ASDR and ASMR, which may be associated with its tropical and subtropical geographical climate, high-calorie and high-fat dietary habits, and socioeconomic conditions.[44,45] At the national level, high SDI countries such as the United States of America and Czechia have the highest burdens of kidney cancer due to high BMI among individuals aged 60 and older. This is closely related to their high obesity rates, unhealthy dietary habits, and lack of sufficient physical activity.[46,47] Meanwhile, some developing countries such as Ghana and Equatorial Guinea, despite initially having low kidney cancer burdens, have experienced rapid burden growth with economic development and lifestyle changes. In contrast, countries such as Sweden have shown a significant decline in disease burden, which is associated with a series of comprehensive health promotion policies, advanced healthcare systems, and active lifestyle changes.[5,48] Therefore, specific factors of different geographical locations should be fully considered to effectively control the burden of kidney cancer due to high BMI in the elderly population.

With the increasing global life expectancy, the aging of the global population is accelerating, with approximately two-thirds of the population aged 60 and older living in low- and middle-income countries, imposing a significant health and economic burden.[49] The results of this study show that different age groups exhibit significant variations in the burden of kidney cancer due to high BMI among individuals aged 60 and older, and these differences gradually intensify over time. With aging, human metabolism slows down, activity levels decrease, and adipose tissue relatively increases, leading to elevated BMI and subsequently increased cancer risk.[50] Additionally, the elderly may experience decreased cancer resistance due to weakened immune systems and accumulated chronic diseases, making the burden of kidney cancer even heavier.[51,52] Similarly, the increased risk of frailty in high BMI elderly patients may lead to reduced treatment efficacy.[53,54] With economic development, population expansion, and improvements in medical standards, the age group with the highest concentration of kidney cancer DALYs has expanded from 60–64 years to 60–74 years, and the age group with the highest concentration of deaths has expanded from 65–70 years to 65–79 years. This result not only reflects the low 5-year survival rate of kidney cancer but also the rapid socioeconomic, demographic, and medical transformations over the past 32 years. Notably, individuals aged 95 and older have experienced the highest growth rates in DALYs and death cases, as well as the highest ASDR, ASMR, and their growth rates, over the past 32 years. Aging may be the primary driver of this trend. Additionally, this population group, born earlier, has weaker health awareness and may not be aware of the occurrence of cancer or the harm of high BMI to human health.[55] Across different SDI regions, due to economic development, accelerated urbanization, and lifestyle changes, individuals of different age groups also exhibit varying burdens of kidney cancer, especially in underdeveloped regions. Therefore, special attention should be paid to the health management of the elderly population and raising awareness of the risks of high BMI and kidney cancer.

The disease burden of kidney cancer also exhibits significant sexual dimorphism, with the incidence and prevalence rates in males being almost twice those in females and even exceeding five times in some regions.[30] This study shows that globally, across different SDI regions, and across different age groups, males have significantly higher DALYs, death cases, ASDR, and ASMR than females. Due to biological differences, males and females exhibit significant differences in renal metabolism, leading to gender-dependent outcomes of kidney diseases.[56] Due to genomic and epigenetic differences, coupled with smoking, occupational hazards, and kidney diseases in males, the risk of kidney cancer in males is significantly higher than in females.[57] Additionally, gene expression involved in renal cancer tumor growth and immune response differs between males and females, thereby affecting their responses to tumor treatment.[58] Furthermore, females may be more inclined to maintain healthy dietary habits and moderate physical activity, which also helps reduce the risk of obesity and related diseases. Due to gender differences, males are diagnosed earlier than females due to the complexity and delay in female diagnosis.[57] It is also reflected in our age group analysis. Moreover, SDI levels also exhibit different disease burdens between males and females. In high-income countries, due to the intake of high-calorie and high-fat foods, lack of sufficient physical activity, and higher occupational stress, both males and females face similar high disease burdens. However, due to the sound healthcare system and economic support, the growth burden has gradually weakened in recent years. In contrast, in some economically underdeveloped regions, limited medical conditions and socio-cultural inequalities have exacerbated the growth of the disease burden. Notably, gender-related social and structural inequalities remain evident globally, although they have been weakened in high SDI regions. This has led to relatively fewer opportunities for females to access healthcare,[59] which may also result in an underestimation of the disease burden in females.

Differences in socioeconomic development levels, allocation of medical and health resources, implementation efforts of health education and health promotion strategies across regions with different SDI levels have led to inequalities in residents' access to health information and medical services. Additionally, individuals of different genders and age groups exhibit variations in lifestyles. It is projected that by 2040, the number of DALYs and deaths due to kidney cancer associated with high BMI among individuals aged 60 and older will further increase, reflecting the severe impact of kidney cancer on the health and quality of life of the elderly population. Nonetheless, the small increases in ASDR and ASMR may be attributed to advancements in medical technology and improvements in public health policies, enabling early detection and treatment of kidney cancer, thereby reducing the disability burden and mortality rate. Simultaneously, with increased emphasis on healthy lifestyles and the popularization of health education, the prevalence of high BMI may be controlled to some extent, slowing down the growth of the kidney cancer burden. However, among different genders, the future ASDR and ASMR in males will continue to increase, while those in females will fluctuate stably, highlighting the necessity of formulating targeted intervention strategies. To address the rising trend in the burden of kidney cancer due to high BMI among individuals aged 60 and older, the following strategies can be adopted to reduce the disease burden: I. Prioritize prevention: Strengthen the prevention of obesity and related metabolic diseases, promote healthy diets, regular exercise, and lifestyle interventions to reduce the occurrence of high BMI; II. Early screening and diagnosis: Establish effective kidney cancer screening mechanisms among the elderly population and incorporate BMI as a risk assessment indicator in routine physical examinations to facilitate early detection and timely treatment; III. Optimize resource allocation: Improve basic medical conditions and enhance detection and treatment capabilities in low SDI regions to narrow the health gap between developed and underdeveloped regions; IV. Personalized treatment: Formulate comprehensive treatment plans for elderly patients, especially those of advanced age, focusing on both weight management and physiological function and quality of life, avoiding a "one-size-fits-all" treatment model.

Limitations

Despite providing an in-depth analysis of the global burden of kidney cancer attributable to high BMI, this study has several limitations. Firstly, our study relies on existing statistical data and model predictions, which inherently possess limitations.[13,17] These limitations may affect the reliability of our results. Secondly, our study covers a substantial time span, during which medical advancements and improvements in statistical methods may have led to reporting biases across different countries and periods. Thirdly, while BMI is a widely used metric, it does not account for different obesity patterns. This means that BMI classification may not accurately reflect the impact of high BMI on cancer in specific populations.[60] Additionally, due to the limitations of the disease definitions provided by GBD and potential under-reporting or incomplete statistics in low-resource areas, the burden of kidney cancer attributable to high BMI among individuals aged 60 and older may be underestimated. Moreover, our study focuses on macro-level data from countries and regions, examining the burden of kidney cancer caused by high BMI in individuals aged 60 and older without considering the intricate interplay between individual-level factors such as BMI, lifestyle, and genetic background. The omission of these factors may compromise the accuracy of our findings. To address these limitations, future research should incorporate clinical and experimental data to delve deeper into the specific mechanisms by which high BMI influences kidney cancer and to evaluate the efficacy of various intervention strategies.

Conclusion

This study provides a comprehensive and in-depth analysis of the slowly increasing trend in the burden of kidney cancer attributable to high BMI among individuals aged 60 and older. Population size changes are the primary driver of this increasing burden. As SDI levels rise, the burden of kidney cancer exhibits a complex growth pattern, with notable health inequalities across regions. This underscores the need for global health policies to focus on reducing the burden of kidney cancer in low-income countries and regions. The interactive analysis between gender and SDI offers a new perspective for further exploring gender-specific intervention measures. It is projected that by 2040, the number of DALYs and deaths due to kidney cancer associated with high BMI will further increase, signifying the urgent need to formulate and implement targeted intervention measures to address the escalating obesity epidemic and its impact on kidney cancer, particularly in vulnerable populations and resource-limited environments, with the aim of reducing the global burden of kidney cancer.

Data Sharing Statement

The data used for the analyses in the study are publicly available at https://ghdx.healthdata.org/gbd-2021.

Ethics Approval and Consent to Participate

This study was exempt from ethical review by the Institutional Review Board of Chengdu Medical College, due to its reliance on publicly available, aggregated data from the GBD Study, which does not involve individual patient identifiers or direct human intervention, in accordance with Article 32 of the Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects (China, 2023).

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Disclosure

The authors declare no competing interests.

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