



Rising incidence and clinical impact of kidney cancer in China and worldwide: a call for targeted prevention, early diagnosis, and equitable treatment

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Background: Kidney cancer is an increasing global public health challenge, with its incidence rising due to aging populations, lifestyle transitions, and advances in diagnostic technologies. However, this growth is unevenly distributed across regions, driven by disparities in healthcare access, socioeconomic conditions, and lifestyle factors. In China, kidney cancer incidence and mortality have escalated significantly, fueled by an aging population, urbanization, and higher prevalence of risk factors such as smoking and hypertension. Rural areas face disproportionately late-stage diagnoses due to healthcare inequities. Globally, notable gender differences persist, as men consistently exhibit higher rates of both incidence and mortality in comparison to women. This study aimed to analyze kidney cancer trends and risk factor contributions in China and globally from 1990 to 2021 to inform targeted public health strategies.

Methods: This study utilized data from the Global Burden of Disease (GBD) 2021 database to explore trends in kidney cancer between 1990 and 2021. Critical indicators, including age-standardized rates (ASRs) for incidence, prevalence, mortality, and disability-adjusted life years (DALYs), were examined using Joinpoint regression to uncover temporal patterns and demographic distinctions. Data stratification by age, gender, and region was performed, with advanced modeling approaches such as Disease Modeling-Meta-Regression (DisMod-MR) and Cause of Death Ensemble model (CODEm) employed to standardize outcomes and mitigate reporting inconsistencies.

Results: From 1990 to 2021, kidney cancer in China exhibited substantial increases in incidence, prevalence, and mortality rates. The age-standardized incidence rate (ASIR) grew from 1.794 to 3.319 per 100,000, while the prevalence rate rose from 7.191 to 17.754 per 100,000. Mortality rates experienced a moderate rise, with the age-standardized mortality rate (ASMR) increasing from 1.14 to 1.246 per 100,000. Although DALYs rose significantly, the age-standardized DALY rate (ASDR) displayed a marginal decline, dropping from 35.838 to 34.176 per 100,000. In China, contributions of smoking and high body mass index (BMI) to kidney cancer mortality and DALYs increased, while occupational exposure to trichloroethylene remained stable; globally, high BMI rose to become the leading risk factor, surpassing smoking, which declined. On a global scale, incidence and prevalence of kidney cancer steadily climbed, while mortality and DALY rates exhibited slight decreases, attributable to improvements in early diagnosis and treatment strategies. Gender disparities persisted, with men consistently showing higher rates across all metrics compared to women.

Conclusions: Over 30 years, kidney cancer burden has risen sharply with regional, demographic, and

gender disparities. China needs to reduce urban-rural gaps and improve early diagnosis. Globally, limited care access persists in low-income areas. Rising high BMI calls for metabolic interventions. Public health must ensure equitable care and targeted prevention to combat this burden.

Keywords: Kidney cancer; incidence; prevalence; mortality; disability-adjusted life years (DALYs)

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Introduction

Kidney cancer is a growing global public health concern, with its incidence rising due to aging populations, lifestyle changes, and advancements in diagnostic technologies (1,2). However, this increase is uneven across regions, as disparities in healthcare access, socioeconomic conditions, and lifestyle factors influence trends (3). While high-income

countries have benefited from earlier detection through advanced imaging techniques like computed tomography (CT) and magnetic resonance imaging (MRI), low- and middle-income countries (LMICs) face challenges in early diagnosis, leading to late-stage detection and poorer survival rates (4). Kidney cancer is also underreported in resource-limited regions, further complicating global assessments.

In China, kidney cancer incidence and mortality have risen significantly in recent years (5). Historically lower than in Western countries, this increase is linked to an aging population, urbanization, and lifestyle shifts, including higher rates of smoking and hypertension (6). Additionally, rising obesity prevalence, reflected by high body mass index (BMI), and occupational exposure to chemicals such as trichloroethylene have emerged as notable risk factors contributing to this trend (7,8). Improved diagnostic capabilities, particularly in urban areas, have contributed to more diagnoses. However, rural regions still face healthcare disparities, resulting in late-stage diagnoses and elevated mortality rates (9).

Gender disparities in kidney cancer are notable globally, with men having a higher incidence than women, a trend observed in China as well (10). Men, especially those aged 60 years and older, are more likely to develop kidney cancer, but the reasons for this gender gap are not fully understood. While genetic, environmental, and hormonal factors may contribute, behavioral risk factors such as higher smoking rates and occupational exposures to nephrotoxic agents like trichloroethylene among men likely play significant roles (11,12). Recent studies suggest that sex-specific molecular pathways and differential responses to therapies may play a role, and further research is needed to identify the underlying causes (13,14).

The Global Burden of Disease (GBD) database provides valuable data on kidney cancer trends, including incidence, prevalence, mortality, and DALYs (15,16). Using GBD 2021 data, this study examines kidney cancer trends in

Highlight box

Key findings

- This study reveals a significant increase in kidney cancer incidence, prevalence, and mortality in China from 1990 to 2021, with the age-standardized incidence rate nearly doubling. Disability-adjusted life years (DALYs) also increased, though age-standardized DALY rates slightly declined. Globally, incidence and prevalence rose steadily, while mortality and DALYs rates decreased modestly. Risk factor patterns shifted, with high body mass index (BMI) becoming the leading contributor to kidney cancer burden worldwide, surpassing smoking. In China, smoking and high BMI contributions increased, while occupational exposure remained unchanged. Men exhibited consistently higher rates across all kidney cancer indicators compared to women.

What is known and what is new?

- Kidney cancer incidence and mortality have been rising worldwide, influenced by aging, lifestyle factors, and diagnostic advances. Gender disparities and regional differences are well documented.
- This study provides the latest comprehensive analysis of trends in kidney cancer burden and risk factors in China and globally over three decades, highlighting shifting risk factor contributions and demographic patterns using standardized data from the Global Burden of Disease study.

What is the implication, and what should change now?

- Targeted public health interventions are urgently needed, especially addressing high BMI and smoking cessation, to curb kidney cancer growth. Efforts to improve early detection and equitable healthcare access in rural China should be prioritized. Globally, strategies must adapt to evolving risk profiles to reduce the kidney cancer burden effectively.

China and compares them with global patterns from 1990 to 2021. By employing Joinpoint regression analysis, it identifies temporal trends, demographic influences, and regional disparities in kidney cancer burden. Furthermore, this study investigates the contributions of modifiable risk factors-smoking, high BMI, and occupational exposure to trichloroethylene-to kidney cancer mortality and DALYs, assessing their evolving impact over the study period. By analyzing three decades of kidney cancer trends, this study aimed to identify high-risk populations and regions, evaluate current healthcare strategies, and propose improvements in prevention and treatment. The findings will offer critical insights to inform public health policies and guide future research, ultimately contributing to better outcomes for kidney cancer patients worldwide. We present this article in accordance with the STROBE reporting checklist (available at <https://tau.amegroups.com/article/view/10.21037/tau-2024-750/rc>).

Methods

Data source

This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. This study utilizes data from the GBD 2021 database (<https://vizhub.healthdata.org/gbd-results/>), which provides comprehensive and consistent estimates of health metrics, including incidence, prevalence, mortality, and DALYs for kidney cancer across different regions, time periods, and demographic groups. The GBD database compiles information from diverse sources, such as national cancer registries, cohort studies, health surveys, and vital registration systems, offering comprehensive and reliable insights into global kidney cancer trends. This study concentrated on analyzing data for China alongside global trends from 1990 to 2021. In addition to the kidney cancer burden indicators, this study also investigates modifiable risk factors associated with kidney cancer, including smoking, occupational exposure to trichloroethylene, and high BMI. The time trends in the contribution of each risk factor to kidney cancer-related mortality and disability-adjusted life years (DALYs) were analyzed for the period 1990–2021. The proportions of mortality and DALYs attributed to each risk factor were examined and compared across the study period to assess changes over time.

Study design

A comparative analysis of kidney cancer burden in China and globally was performed, utilizing age-standardized rates (ASRs) for incidence, prevalence, mortality, and DALYs. Joinpoint regression was applied to evaluate temporal trends, enabling the detection of notable trend changes and the estimation of annual percentage change (APC) throughout the study period.

Statistical analysis

Joinpoint regression analysis was applied to examine temporal changes in kidney cancer burden. This approach fits multiple line segments to the data, enabling the identification of periods with distinct trends. APC was computed for each period, with the significance of trend variations tested using the standard error of APC estimates. Additionally, the time trends in the proportion of kidney cancer mortality and DALYs attributed to these risk factors were analyzed. Analyses were conducted using Joinpoint software (version 4.9.0.0), and statistical significance was defined at a 0.05 threshold. ASRs were utilized to adjust for variations in population age structures across time and regions. ASRs for incidence, prevalence, mortality, and DALYs were derived based on the World Health Organization's standard population. These metrics allowed for unbiased comparisons of kidney cancer burden between China and global datasets, eliminating potential distortions caused by age distribution differences. Calculation of burden metrics: the burden of kidney cancer was assessed through four key metrics: incidence: the number of new cases of kidney cancer diagnosed annually per 100,000 population. Prevalence: the total number of existing kidney cancer cases per 100,000 population. Mortality: the number of deaths from kidney cancer annually per 100,000 population. DALYs: a composite measure of years of life lost due to premature mortality and years lived with disability due to kidney cancer. Data stratification: data were stratified by age, gender, and geographic region to explore potential disparities in kidney cancer burden. Age groups were categorized into 0–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85–89, 90–94, and 95+ years to examine how trends varied across different stages of life. Gender-specific analyses were also performed to assess potential differences

Table 1 All-age cases, age-standardized incidence, prevalence, mortality, and DALYs rates, and corresponding AAPC of kidney cancer in China and worldwide (1990 and 2021)

Location	Measure	1990		2021		1990 to 2021 AAPC (95% CI)
		All-ages cases (95% CI)	Age-standardized rates per 100,000 people (95% CI)	All-ages cases (95% CI)	Age-standardized rates per 100,000 people (95% CI)	
China	Incidence	16,232 (14,234, 18,286)	1.794 (1.579, 2.01)	65,799 (53,687, 79,742)	3.319 (2.725, 3.982)	1.9843 (1.7149, 2.2545)
	Prevalence	74,591 (65,951, 84,201)	7.191 (6.341, 8.133)	344,280 (281,003, 418,674)	17.754 (14.626, 21.286)	2.9524 (2.5205, 3.3862)
	Deaths	9,051 (7,938, 10,170)	1.14 (1.002, 1.276)	24,867 (20,361, 29,828)	1.246 (1.029, 1.484)	0.2168 (−0.1122, 0.5469)
	DALYs	346,829 (305,043, 394,194)	35.838 (31.714, 40.665)	663,805 (543,632, 798,730)	34.176 (28.292, 40.771)	−0.2817 (−0.4524, −0.1106)
Global	Incidence	159,774 (154,831, 163,926)	3.886 (3.755, 3.989)	387,829 (365,360, 406,635)	4.524 (4.261, 4.747)	0.4875 (0.4177, 0.5574)
	Prevalence	751,618 (728,246, 770,633)	17.256 (16.758, 17.667)	1,961,211 (1,861,777, 2,051,838)	22.695 (21.54, 23.758)	0.8913 (0.785, 0.9978)
	Deaths	77,421 (74,807, 79,691)	1.994 (1.912, 2.059)	161,195 (150,318, 169,348)	1.912 (1.777, 2.011)	−0.1335 (−0.2249, −0.0421)
	DALYs	2,291,995 (2,190,460, 2,385,798)	53.017 (50.961, 54.933)	4,016,362 (3,806,832, 4,246,783)	47.327 (44.756, 50.075)	−0.3652 (−0.448, −0.2823)

AAPC, average annual percentage change; CI, confidence interval; DALYs, disability-adjusted life years.

in kidney cancer burden between men and women.

Modeling and estimation

To estimate the kidney cancer burden, the GBD team employs advanced statistical models, including Disease Modeling-Meta-Regression (DisMod-MR) and Cause of Death Ensemble model (CODEm), to synthesize and standardize data across multiple sources. These models account for discrepancies in reporting and provide robust estimates for countries with incomplete or unreliable data. DisMod-MR is a Bayesian meta-regression tool that harmonizes epidemiological data on incidence, prevalence, and mortality (17). CODEm, a cause of death ensemble model, integrates multiple regression techniques and covariates to estimate the cause-specific mortality rates (18).

Results

Escalating kidney cancer burden in China: trends in incidence, prevalence, mortality, and disability (1990–2021)

As illustrated in *Table 1*, the burden of kidney cancer in

China exhibited a marked increase between 1990 and 2021. In 1990, there were an estimated 16,232 new cases [95% confidence interval (CI): 14,234 to 18,286], yielding an age-standardized incidence rate (ASIR) of 1.794 per 100,000 (95% CI: 1.579 to 2.01). By 2021, the number of new cases had risen substantially to 65,799 (95% CI: 53,687 to 79,742), with an ASIR of 3.319 per 100,000 (95% CI: 2.725 to 3.982). The average annual percentage change (AAPC) for incidence between 1990 and 2019 was 1.9843 (95% CI: 1.7149 to 2.2545), reflecting a consistent upward trend. Prevalence data demonstrated a similarly pronounced increase. Total prevalent cases rose from 74,591 (95% CI: 65,951 to 84,201) in 1990 to 344,280 (95% CI: 281,003 to 418,674) in 2021, while the age-standardized prevalence rate (ASPR) increased from 7.191 per 100,000 (95% CI: 6.341 to 8.133) to 17.754 per 100,000 (95% CI: 14.626 to 21.286). The AAPC for prevalence was 2.9524 (95% CI: 2.5205 to 3.3862), indicating a marked and sustained rise in the overall disease burden. In contrast, although the total number of kidney cancer-related deaths in China also increased—from 9,051 (95% CI: 7,938 to 10,170) in 1990 to 24,867 (95% CI: 20,361 to 29,828) in 2021—the

corresponding ASMR rose more modestly, from 1.14 per 100,000 (95% CI: 1.002 to 1.276) to 1.246 per 100,000 (95% CI: 1.029 to 1.484). The AAPC for mortality was 0.2168 (95% CI: -0.1122 to 0.5469), suggesting a relatively slower rate of increase in mortality compared to incidence and prevalence. The DALYs attributable to kidney cancer also escalated, increasing from 346,829 (95% CI: 305,043 to 394,194) in 1990 to 663,805 (95% CI: 543,632 to 798,730) in 2021. However, the age-standardized DALY rate (ASDR) declined slightly from 35.838 per 100,000 (95% CI: 31.714 to 40.665) in 1990 to 34.176 per 100,000 (95% CI: 28.292 to 40.771) in 2021. The AAPC for DALYs was -0.2817 (95% CI: -0.4524 to -0.1106), indicating a modest decrease in DALY burden relative to population growth and changes in age structure. Overall, these results emphasize the increasing kidney cancer burden in China over the past three decades and stress the need for improved prevention measures, early diagnosis, and treatment strategies to tackle this escalating public health issue.

Global trends in kidney cancer: rising incidence and prevalence amidst declining mortality and disability rates (1990–2021)

Table 1 also illustrates the global trends in the burden of kidney cancer. The worldwide incidence increased from 159,774 cases (95% CI: 154,831 to 163,926) in 1990 to 387,829 cases (95% CI: 365,360 to 406,635) in 2021. Correspondingly, the ASIR rose from 3.886 per 100,000 (95% CI: 3.755 to 3.989) in 1990 to 4.524 per 100,000 (95% CI: 4.261 to 4.747) in 2021, with an AAPC of 0.4875 (95% CI: 0.4177 to 0.5574). The total number of prevalent cases increased from 751,618 (95% CI: 728,246 to 770,633) in 1990 to 1,961,211 (95% CI: 1,861,777 to 2,051,838) in 2021. Concurrently, the ASPR rose from 17.256 per 100,000 (95% CI: 16.758 to 17.667) in 1990 to 22.695 per 100,000 (95% CI: 21.54 to 23.758) in 2021, reflecting an AAPC of 0.8913 (95% CI: 0.785 to 0.9978). Global mortality also increased over the study period, with the number of deaths growing from 77,421 (95% CI: 74,807 to 79,691) in 1990 to 161,195 (95% CI: 150,318 to 169,348) in 2021. However, the ASMR decreased slightly from 1.994 per 100,000 (95% CI: 1.912 to 2.059) in 1990 to 1.912 per 100,000 (95% CI: 1.777 to 2.011) in 2021, yielding an AAPC of -0.1335 (95% CI: -0.2249 to -0.0421). In terms of DALYs, the global burden from kidney cancer rose from 2,291,995 (95% CI: 2,190,460 to 2,385,798) in 1990 to 4,016,362 (95% CI: 3,806,832 to 4,246,783) in

2021. Despite this increase, the age-standardized DALY rate declined from 53.017 per 100,000 (95% CI: 50.961 to 54.933) in 1990 to 47.327 per 100,000 (95% CI: 44.756 to 50.075) in 2021, with an AAPC of -0.3652 (95% CI: -0.448 to -0.2823). Overall, these data indicate a modest but steady reduction in the global age-standardized burden of kidney cancer over the past three decades.

Temporal patterns in kidney cancer epidemiology: insights from Joinpoint regression analysis (1990–2021)

The Joinpoint regression analysis of kidney cancer trends from 1990 to 2021, depicted in Figures 1,2, reveals noteworthy fluctuations in ASIR, ASPR, ASMR, and ASDR in both China and worldwide. In China, the ASIR exhibited marked increases during the periods 1997–2004, 2004–2011, and 2016–2021, while the ASPR followed a similar pattern of elevation between 1998–2002, 2002–2009, and 2009–2021, interspersed with intervals of non-significant changes. Specifically, the ASIR rose significantly from 1997 to 2004 (APC =4.56), and the ASPR increased notably during 1998–2002 (APC =7.07) and 2002–2009 (APC =4.44), all with P values <0.05. In contrast, ASMR declined from 1990 to 1997 (APC =-1.21) but then underwent significant increases from 1997 to 2002 (APC =3.33) and continued a gradual upward trend from 2014 to 2021. Concurrently, ASDR decreased during the early 1990s and again from 2003 to 2021, except for a brief increase between 1997 and 2003. Globally, similar patterns emerged. The ASIR increased between 1990 and 1995 (APC =1.89) but showed a notable decrease from 2015 to 2021 (APC =-0.84). The ASPR increased from 1990 to 2010, then declined sharply after 2015. The ASMR showed early increases (1990–1994), but subsequently declined significantly from 2003 to 2021, paralleled by a downward trend in ASDR beginning in 1994. Taken together, these findings underscore both regional and global shifts in the epidemiology of kidney cancer, as reflected by changing incidence, prevalence, mortality, and disability rates over the past three decades.

Contrasting trends in kidney cancer burden: a comparative study of China and global data (1990–2021)

The trends in the burden of kidney cancer from 1990 to 2021 revealed contrasting patterns in China compared to global observations across the ASIR, ASMR, ASPR, and ASDR (Figure 3). In China, the ASIR demonstrated

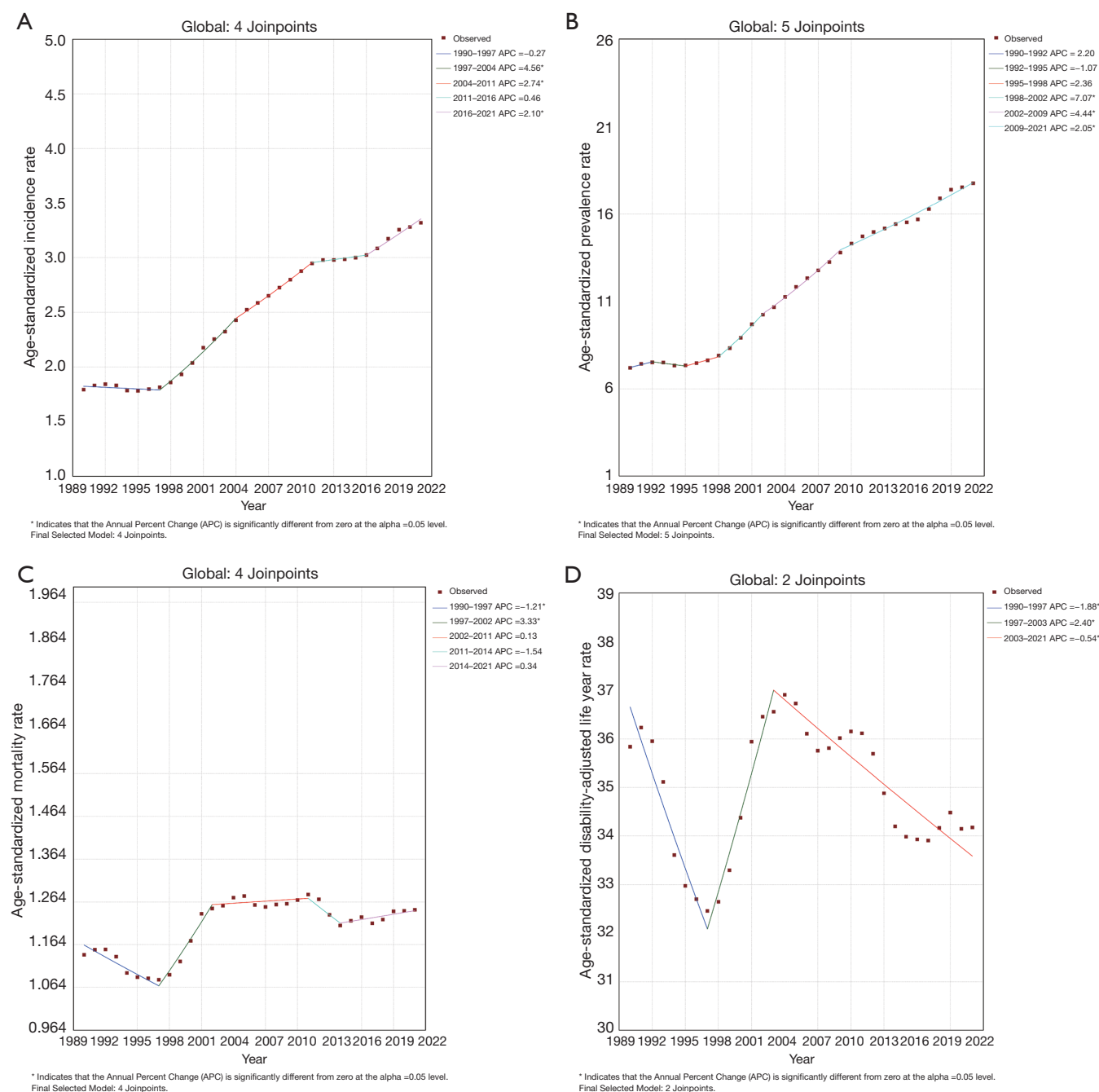


Figure 1 Trends in ASRs of incidence, prevalence, mortality, and disability-adjusted life years in China (1990–2021) based on Joinpoint regression analysis. (A) ASIR. (B) ASPR. (C) ASMR. (D) ASDR. APC, annual percentage change; ASDR, age-standardized DALY rate; ASIR, age-standardized incidence rate; ASMR, age-standardized mortality rate; ASR, age-standardized rates; ASPR, age-standardized prevalence rate.

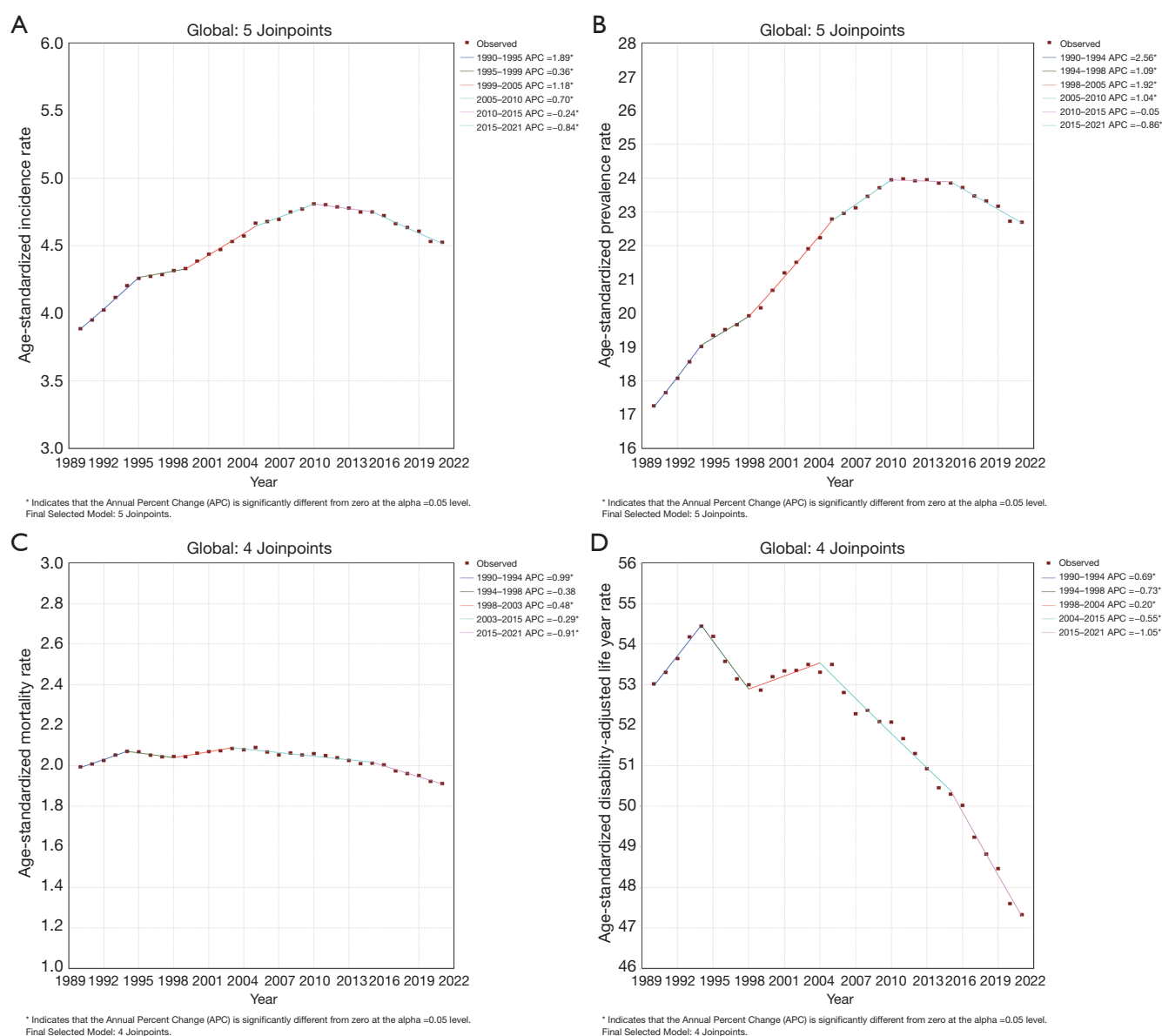


Figure 2 Global trends in age-standardized incidence, prevalence, mortality, and disability-adjusted life years rates (1990–2021) based on Joinpoint regression analysis. (A) ASIR. (B) ASPR. (C) ASMR. (D) ASDR. APC, annual percentage change; ASDR, age-standardized DALY rate; ASIR, age-standardized incidence rate; ASMR, age-standardized mortality rate; ASPR, age-standardized prevalence rate.

a gradual and steady increase over the three decades, indicating a rising incidence of kidney cancer. Concurrently, the ASMR exhibited a moderate yet consistent upward trend, reflecting an increase in kidney cancer-related mortality. The ASPR saw the most significant rise, nearly doubling during this period, which suggests a growing number of individuals living with kidney cancer. In contrast, the DALYs rate remained relatively stable with minor

fluctuations, maintaining a higher burden compared to other measures but showing no significant decrease over time. Globally, the ASIR followed a similar slow upward trend, mirroring the patterns observed in China. The ASMR remained relatively stable with only slight increases, indicating some progress in managing kidney cancer mortality on a global scale. The ASPR showed a clear increase from 1990 to 2010, followed by stabilization post-

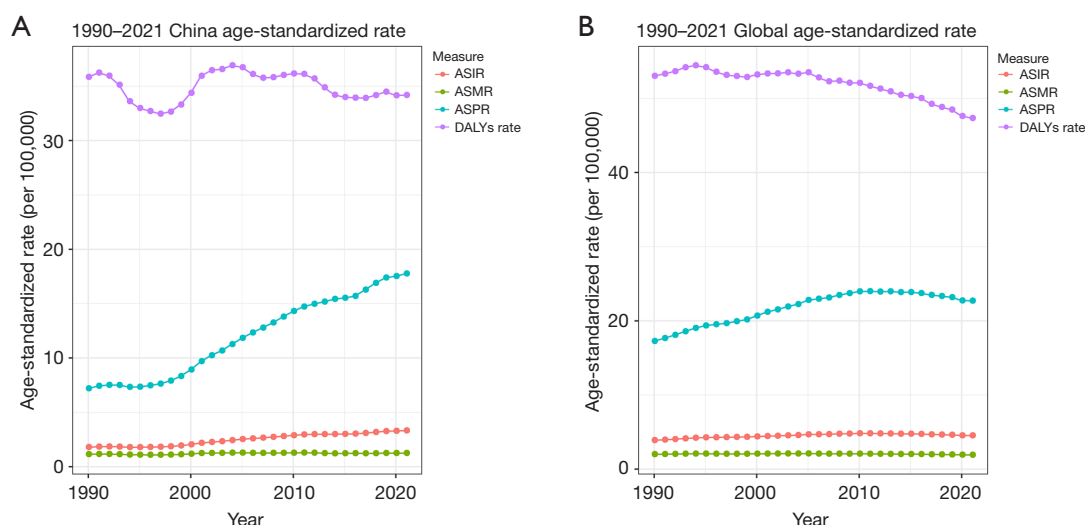


Figure 3 Comparative trends of ASR incidence, prevalence, mortality, and DALYs rates of kidney cancer in China and worldwide (1990–2021). (A) Trends in China. (B) Global trends. ASIR, age-standardized incidence rate; ASMR, age-standardized mortality rate; ASR, age-standardized rates; ASPR, age-standardized prevalence rate; DALYs, disability-adjusted life years.

2010. However, the global DALYs rate exhibited a gradual decline, which contrasts with the stable trend observed in China. This decline suggests improvements in disease management and treatment outcomes worldwide, although the global DALYs burden remains substantial.

Trends and age-specific burden of kidney cancer in China and globally from 1990 to 2021: incidence, prevalence, mortality, and DALYs

The kidney cancer burden in China grew significantly from 1990 to 2021, with marked differences observed across age groups and metrics, including incidence, prevalence, mortality, and DALYs (Figure 4). In 1990, both the number of new cases and crude incidence rates were low across all age groups, gradually rising from ages 40–44 years and peaking at 70–74 years. By 2021, incidence numbers and rates had surged across all age brackets, particularly among individuals aged 55–84 years, with the highest rates in the 75–79 years age group. For prevalence, kidney cancer cases in 1990 were minimal but increased slightly with age, reaching a peak in the 65–69 years group. By 2021, prevalence had risen sharply across all age groups, with the greatest burden recorded in the 65–74 years age range. The crude prevalence rate also markedly increased in older populations, highlighting a significant rise in disease burden over three decades. Mortality trends mirrored those of incidence and prevalence. In 1990, kidney cancer-

related deaths were primarily concentrated among older individuals, with the highest mortality observed in the 70–74 years age group. By 2021, both mortality numbers and crude death rates had risen significantly across all age groups, with the greatest burden in those aged 75–79 years. For DALYs, the burden in 1990 was focused on younger populations (0–14 years) and older adults (70+ years). By 2021, DALYs increased sharply across all age groups, with individuals aged 55–79 years contributing the most. The peak DALY burden was recorded in the 70–74 years age group, highlighting the growing impact of kidney cancer on overall health and quality of life. Globally, the burden of kidney cancer rose significantly across all age groups from 1990 to 2021, as shown by metrics including incidence, prevalence, mortality, and DALYs (Figure 5). In 1990, new kidney cancer cases were relatively low, gradually increasing with age and peaking at 70–74 years. By 2021, incidence numbers had risen dramatically across all age categories, particularly among individuals aged 55–79 years, with the highest incidence recorded in the 75–79 years age group. The crude incidence rate per 100,000 also grew substantially in older populations, indicating a major global shift in disease burden over three decades. For prevalence, kidney cancer cases in 1990 were mainly concentrated in older age groups, increasing slightly after age 50 years and peaking in the 65–69 years age group. By 2021, prevalence had grown significantly across all age groups, with the greatest burden observed among individuals aged 65–74 years. The crude

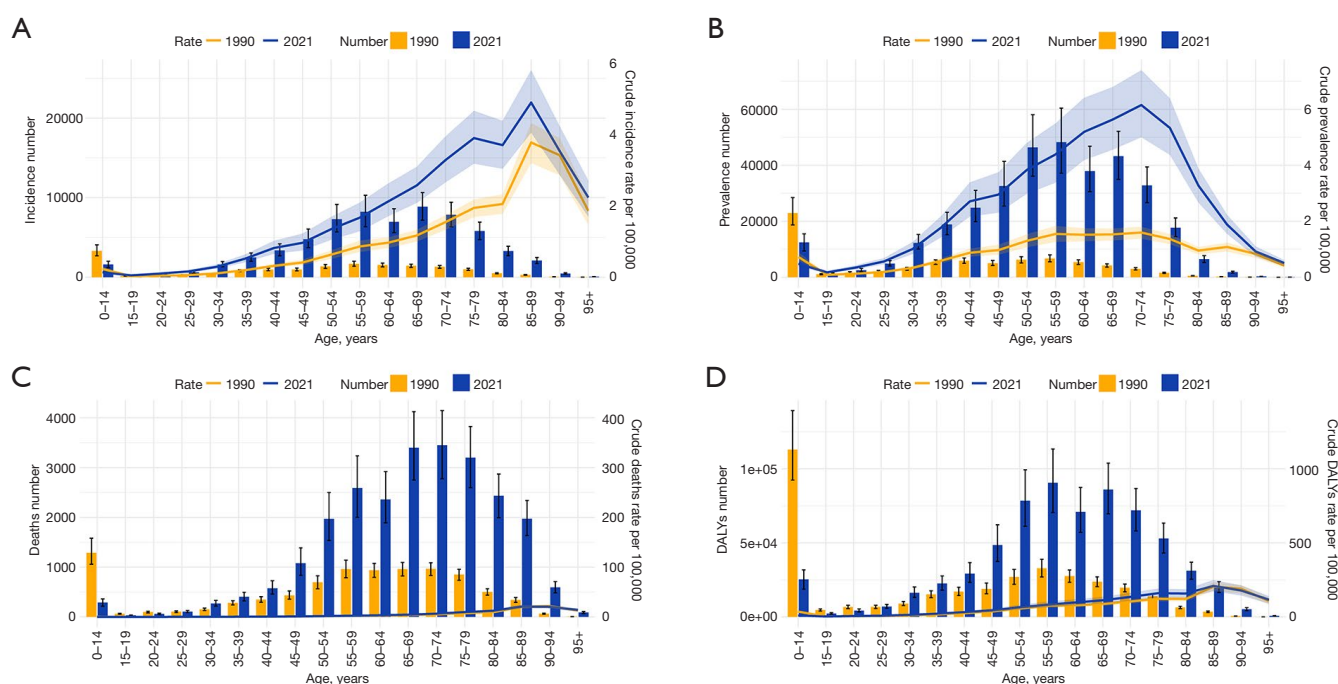


Figure 4 Comparison of incidence, prevalence, mortality, and DALYs of kidney cancer by age in China, 1990 and 2021. (A) Incidence. (B) Prevalence. (C) Mortality. (D) DALYs. DALYs, disability-adjusted life years.

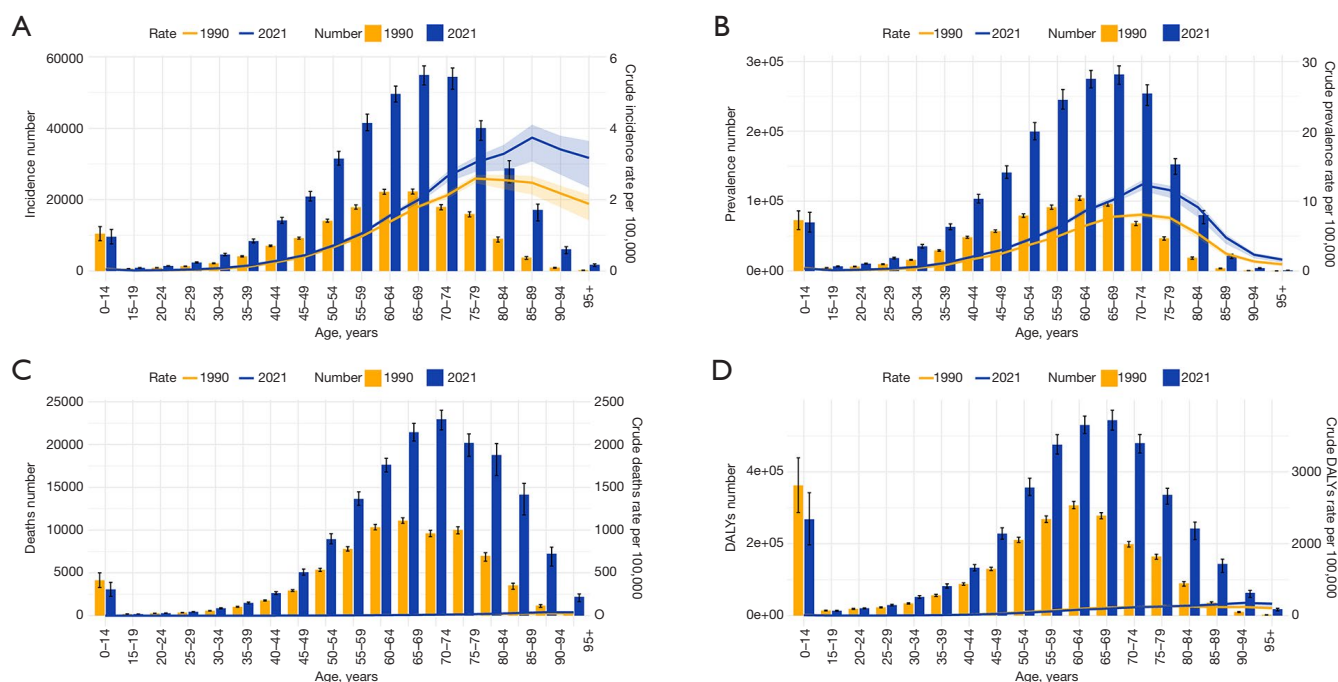


Figure 5 Comparison of incidence, prevalence, mortality, and DALYs of kidney cancer by age worldwide, 1990 and 2021. (A) Incidence. (B) Prevalence. (C) Mortality. (D) DALYs. DALYs, disability-adjusted life years.

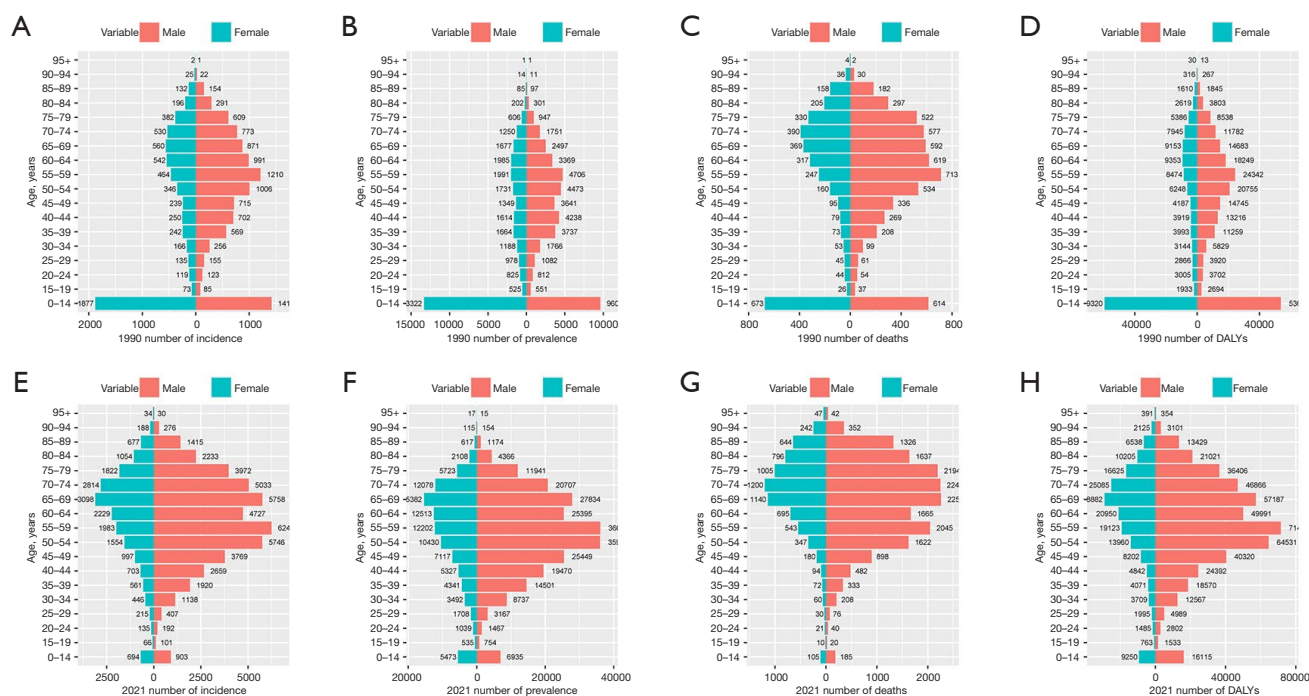


Figure 6 Comparison of age and sex distribution of kidney cancer in terms of incidence, prevalence, mortality, and DALYs in China, 1990 and 2021. (A) Incidence in 1990. (B) Prevalence in 1990. (C) Mortality in 1990. (D) DALYs in 1990. (E) Incidence in 2021. (F) Prevalence in 2021. (G) Mortality in 2021. (H) DALYs in 2021. DALYs, disability-adjusted life years.

prevalence rate also rose markedly, particularly among those aged 55–79 years, reflecting an increasing number of people living with kidney cancer worldwide. Mortality trends followed a similar pattern. In 1990, deaths and crude death rates were low but progressively increased with age, peaking in the 70–74 years age group. By 2021, mortality numbers had risen sharply, especially among individuals aged 55–84 years, with the highest burden observed in the 75–79 years age group. This significant rise in mortality underscores the growing global impact of kidney cancer, particularly among aging populations. For DALYs, the global burden in 1990 was concentrated among younger populations (0–14 years) and older adults (70+ years) but remained relatively low overall. By 2021, DALYs had escalated dramatically across all age groups, with individuals aged 55–79 years bearing the most substantial burden. The peak DALY burden shifted to the 65–74 years age group, illustrating the severe health and productivity losses caused by kidney cancer globally.

Gender disparities in the burden of kidney cancer in China and globally (1990–2021): trends in incidence, prevalence, mortality, and DALYs

Significant gender disparities in incidence, prevalence, mortality, and DALYs were observed in the burden of kidney cancer in China for both 1990 and 2021 (Figure 6). In 1990, the incidence of kidney cancer was markedly higher in males compared to females, with the disparity widening with increasing age. The incidence peaked in the 70–74 years age group for both genders; however, males bore a substantially higher burden. Prevalence followed a similar pattern, with males predominating across all age groups, particularly within the 55–74 years age range. Mortality and DALYs were also concentrated in older age groups, with males experiencing significantly higher numbers of deaths and DALYs, peaking in the 65–79 years age range. By 2021, the burden of kidney cancer had sharply increased for both genders across all metrics, especially among individuals aged 55–84 years. Males continued to exhibit a higher

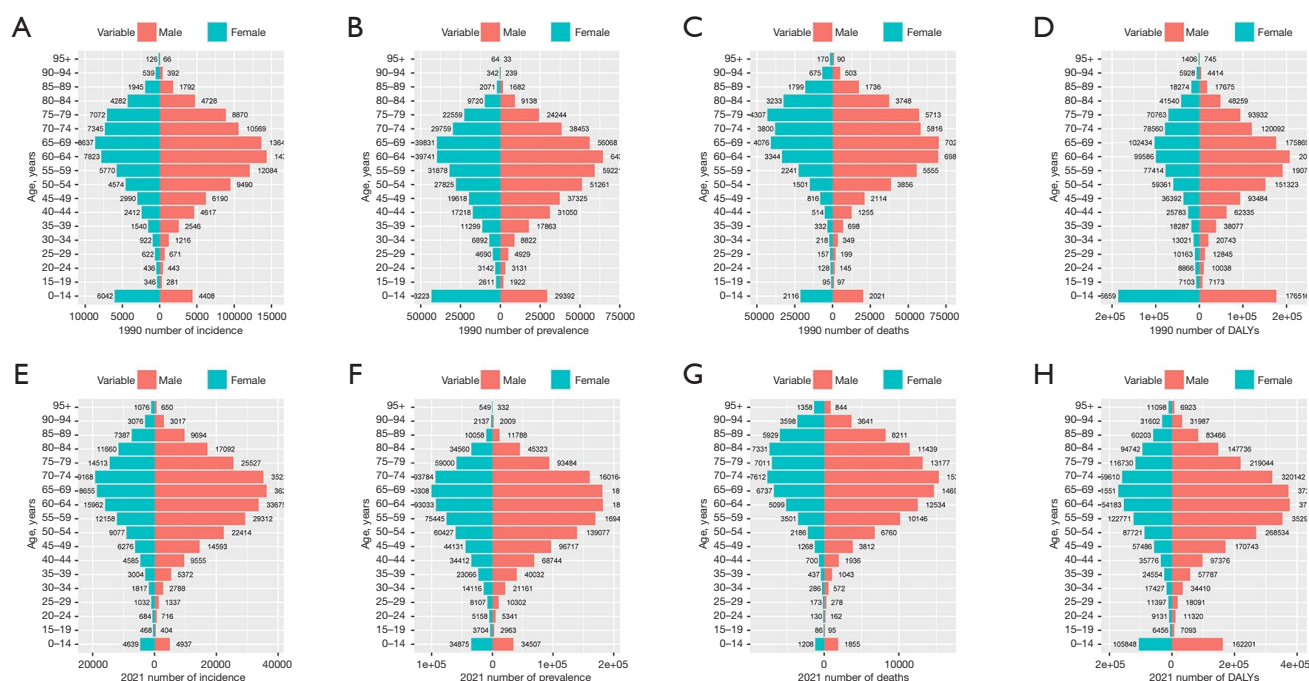


Figure 7 Comparison of age and sex distribution of kidney cancer in terms of incidence, prevalence, mortality, and DALYs worldwide in 1990 and 2021. (A) Incidence in 1990. (B) Prevalence in 1990. (C) Mortality in 1990. (D) DALYs in 1990. (E) Incidence in 2021. (F) Prevalence in 2021. (G) Mortality in 2021. (H) DALYs in 2021. DALYs, disability-adjusted life years.

burden compared to females. Incidence numbers nearly doubled, peaking in the 70–74 years age group for males, while females experienced a lower yet substantial increase. Prevalence increased significantly across all age groups, with males maintaining dominance, particularly within the 65–79 years age range. Mortality demonstrated a similar pattern, with deaths rising markedly in the 75–84 years age range, where the gender gap further widened. DALYs followed the same trajectory, showing the highest burden in the 70–74 years age group for males, highlighting their disproportionate burden compared to females. Globally, kidney cancer burden in 1990 and 2021 showed notable gender disparities in incidence, prevalence, mortality, and DALYs, with males consistently bearing a higher burden than females across all age groups (*Figure 7*). In 1990, the global incidence of kidney cancer was relatively low but exhibited a clear male predominance across all age groups. The incidence peaked in the 70–74 years age group for both genders, with males having nearly twice the incidence rate compared to females. Prevalence followed a similar trend, with males showing higher prevalence, particularly within the 65–79 years age range. Mortality rates also revealed clear disparities, with male deaths concentrated

among older populations (65–79 years), whereas females demonstrated a comparatively lower burden. DALYs mirrored these trends, with males experiencing significantly higher values across all age groups, especially peaking in the 70–74 years age group. By 2021, the global burden of kidney cancer had increased dramatically in both genders, with males continuing to exhibit disproportionately higher values across all metrics. Incidence numbers rose sharply, particularly among individuals aged 55–84 years, with the highest incidence observed in the 70–74 years age group for males. Prevalence also increased significantly, with the most substantial burden occurring within the 65–79 years age range, where male prevalence far exceeded that of females. Mortality patterns reflected these increases, with deaths concentrated among individuals aged 75–84 years, where male mortality remained significantly higher. DALYs followed a similar trajectory, with males experiencing the highest burden within the 65–79 years age groups.

Gender-based comparison of kidney cancer burden and ASRs in China and globally (1990–2021)

The burden of kidney cancer in China between 1990 and

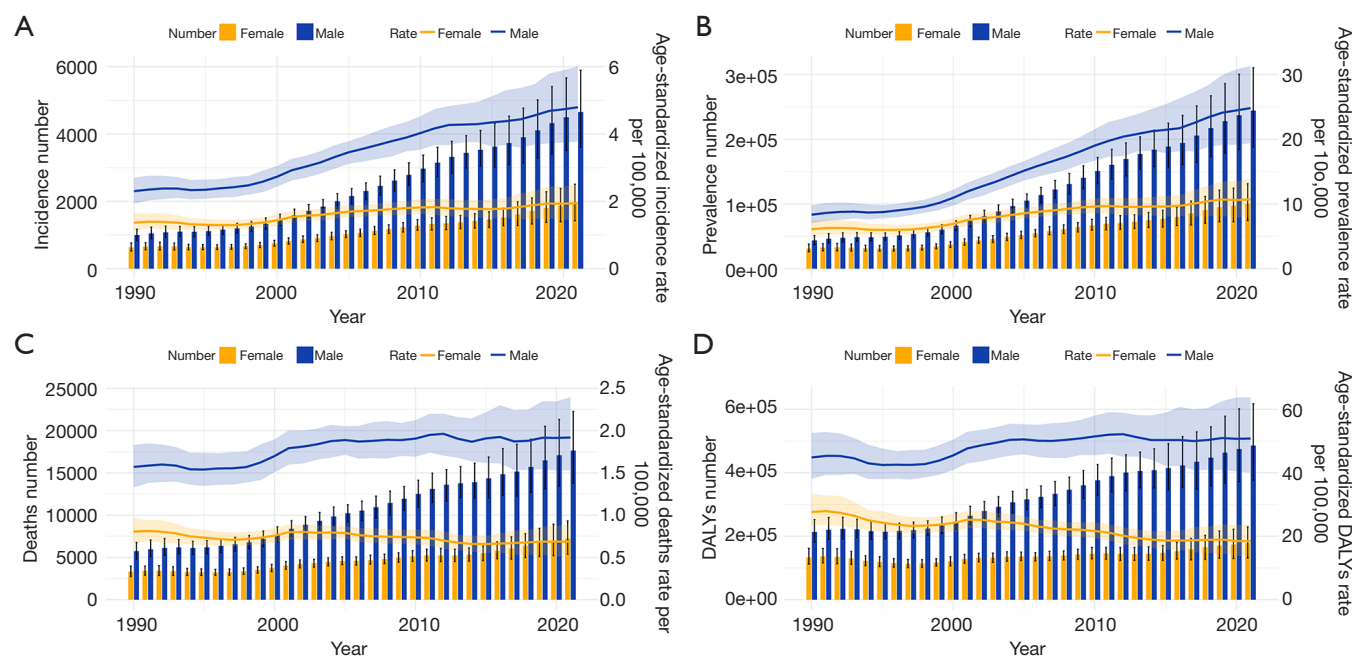


Figure 8 Trends in total cases and age-standardized rates of incidence, prevalence, mortality, and DALYs for kidney cancer in men and women in China (1990–2021). (A) Incidence of kidney cancer. (B) Prevalence of kidney cancer. (C) Mortality of kidney cancer. (D) DALYs of kidney cancer. DALYs, disability-adjusted life years.

2021 demonstrated significant gender disparities across key epidemiological indicators, including incidence, prevalence, mortality, and DALYs. Across all metrics and time points, males consistently showed higher values than females, with the gap widening over three decades (*Figure 8*). The total number of new cases and ASIR of kidney cancer steadily increased for both genders over the study period. However, males showed a consistently higher incidence burden compared to females. The ASIR for males rose more sharply after 2000, reaching approximately 6 per 100,000 by 2021, while females remained below 3 per 100,000. These trends highlight a disproportionate increase in incidence rates among males. The prevalence of kidney cancer also rose markedly for both genders. Males demonstrated a significantly higher burden, with the ASPR increasing from approximately 10 per 100,000 in 1990 to 30 per 100,000 by 2021. In contrast, females experienced a slower rise, with the ASPR stabilizing at around 15 per 100,000. This widening gap in prevalence underscores the growing disease burden among males over the study period. Trends in mortality revealed similar gender disparities. Both the total number of deaths and the ASMR increased steadily for males and females. However, males experienced a consistently higher mortality burden. By 2021, the ASMR for males reached

nearly 2 per 100,000, while females remained below 1 per 100,000, highlighting persistent gender differences in mortality outcomes. The number of DALYs and the ASDR also showed an increasing trend from 1990 to 2021, with males bearing a significantly higher burden. The ASDR for males rose sharply after 2000, reaching approximately 60 per 100,000 by 2021, whereas females remained below 40 per 100,000. This difference reflects the greater impact of kidney cancer on mortality and health loss among males compared to females. Globally, kidney cancer exhibited a consistent upward trend in incidence, prevalence, mortality, and DALYs between 1990 and 2021. As observed in China, males experienced significantly higher burdens across all metrics, with persistent and widening gender disparities (*Figure 9*). Worldwide, the number of new kidney cancer cases increased steadily for both genders over the study period. Males consistently exhibited higher incidence rates than females, with the global ASIR for males surpassing 20 per 100,000 by 2021, nearly double that of females, whose ASIR remained below 10 per 100,000. The global prevalence of kidney cancer also increased substantially for both genders, with males experiencing a significantly higher burden. The ASPR for males rose continuously, reaching approximately 100 per 100,000 by 2021, while females

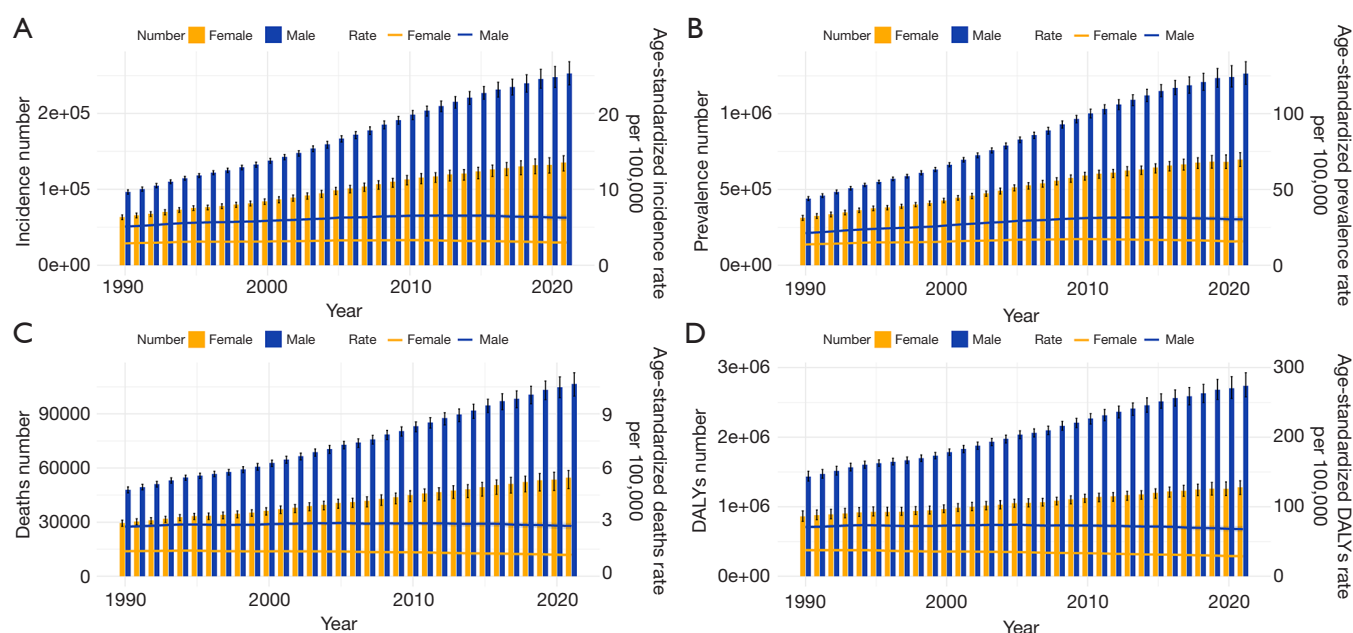


Figure 9 Global trends in total cases and age-standardized rates of incidence, prevalence, mortality, and DALYs for kidney cancer in men and women (1990–2021). (A) Incidence of kidney cancer. (B) Prevalence of kidney cancer. (C) Mortality of kidney cancer. (D) DALYs of kidney cancer. DALYs, disability-adjusted life years.

stabilized at around 50 per 100,000, further widening the gender gap over time. Global mortality data revealed similar disparities. The number of deaths and the ASMR for kidney cancer increased for both genders, with males consistently exhibiting higher mortality rates. By 2021, the ASMR for males approached 10 per 100,000, while females remained below 5 per 100,000, reflecting persistent gender differences in mortality outcomes. The global burden of DALYs due to kidney cancer increased steadily over the three decades. By 2021, the ASDR for males approached 300 per 100,000, nearly double that of females, whose rate remained below 150 per 100,000. These trends emphasize the greater health loss and mortality burden associated with kidney cancer among males globally.

Comparison of kidney cancer risk factor trends in China and globally (1990–2021)

As shown in *Figure 10*, for China, from 1990 to 2021, the contributions of smoking and high BMI to kidney cancer mortality and DALYs have shown an upward trend, while the impact of occupational exposure to trichloroethylene has remained relatively stable. Globally, kidney cancer mortality and DALYs attributable to high BMI have steadily

increased, reflecting a persistent growth in the association between obesity and kidney cancer risk, whereas the contributions of smoking to kidney cancer mortality and DALYs have exhibited a gradual decline, and the impact of occupational exposure to trichloroethylene on kidney cancer has remained relatively constant. In summary, obesity has surpassed smoking as the leading risk factor for kidney cancer, highlighting the critical importance of metabolic health management.

Discussion

This study offers a detailed analysis of kidney cancer burden trends in China and globally from 1990 to 2021, highlighting key temporal, demographic, and geographic patterns. Utilizing data from the GBD database, significant increases were identified in incidence, prevalence, mortality, and DALYs related to kidney cancer. In China, the burden has grown more rapidly compared to the global average. These results emphasize the escalating public health challenge of kidney cancer and pinpoint critical areas for focused interventions and resource allocation.

The sharp increase in kidney cancer burden in China, reflected by the consistent growth in ASIR and ASPR, is

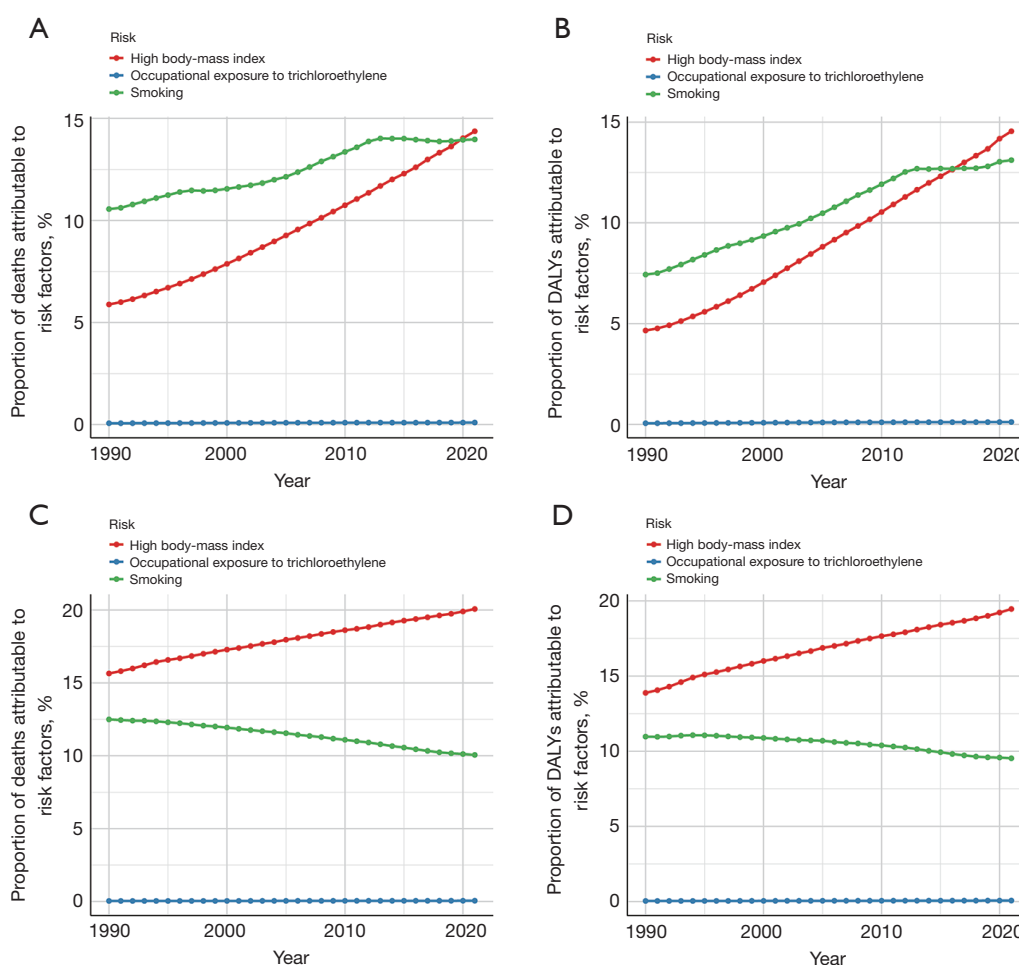


Figure 10 The kidney cancer deaths and DALYs attributable to risk factors from 1990 to 2021, in China and global. (A) The kidney cancer deaths attributable to risk factors from 1990 to 2021 in China. (B) The kidney cancer DALYs attributable to risk factors from 1990 to 2021 in China. (C) The kidney cancer deaths attributable to risk factors from 1990 to 2021 in global. (D) The kidney cancer DALYs attributable to risk factors from 1990 to 2021 in global. DALYs, disability-adjusted life years.

linked to multiple factors (19). Key contributors include population aging, urbanization, and the prevalence of lifestyle-related risks such as smoking, hypertension, and obesity (20–22). Our analysis further reveals that from 1990 to 2021, the contributions of smoking and high BMI to kidney cancer mortality and DALYs in China have significantly increased, reflecting the growing influence of these modifiable risk factors. In contrast, the contribution of occupational exposure to trichloroethylene has remained stable over this period, suggesting a limited role in driving the observed burden increase. Improved diagnostic capabilities, particularly in urban areas, have also contributed to increased detection rates (23). However, this improvement in diagnosis has not been evenly distributed

across regions, with rural areas continuing to experience healthcare disparities that delay diagnosis and result in poorer outcomes (24). These results underscore the pressing need for equitable healthcare initiatives to address disparities and enhance access to early detection and treatment in underserved regions.

Globally, the kidney cancer burden has also increased over the past three decades, though at a slower rate than in China. Notably, while global ASIR and ASPR have shown moderate increases, ASMR and ASDR have either stabilized or declined. This suggests progress in early detection, treatment modalities, and disease management in high-income countries. For instance, advances in imaging technologies and the introduction of targeted therapies

and immune checkpoint inhibitors have likely contributed to improved survival outcomes globally (25-27). However, these benefits have not been uniformly distributed, as LMICs continue to face barriers to accessing advanced diagnostic and therapeutic options, leading to higher mortality rates in these regions.

The study reveals a persistent and widening gender disparity in kidney cancer burden, with males consistently experiencing higher incidence, prevalence, mortality, and DALY rates than females. This trend is evident both in China and worldwide. While biological factors such as hormonal differences and genetic predispositions may partly explain this disparity, behavioral and environmental factors, including higher smoking rates and occupational exposures among men, are likely significant contributors (22,28,29). Addressing these disparities will require gender-specific prevention and intervention strategies, such as targeted smoking cessation programs and workplace safety regulations (30).

The burden of kidney cancer disproportionately affects older populations, with peak incidence, prevalence, and mortality observed in individuals aged 65–79 years. This demographic trend emphasizes the importance of integrating cancer screening and management into geriatric care frameworks. In China, the rising burden among older adults poses additional challenges for the healthcare system, which must address the complex needs of an aging population. Globally, the observed decline in DALY rates among younger age groups suggests that early intervention strategies have been effective; however, sustaining these gains will require ongoing investment in public health initiatives and healthcare infrastructure. The study's findings carry important implications for public health policy and resource distribution.

Future research should focus on identifying modifiable risk factors, exploring the genetic and environmental determinants of kidney cancer, and evaluating the cost-effectiveness of various prevention and treatment strategies. Additionally, longitudinal studies are needed to assess the long-term impact of emerging therapies and public health interventions on kidney cancer outcomes.

While this study provides valuable insights into kidney cancer trends, it is not without limitations. The reliance on GBD data, which synthesizes estimates from diverse sources, may introduce variability and limit the precision of results in regions with incomplete or unreliable data. Additionally, the study does not account for certain risk factors, such as dietary habits, physical activity levels, and

environmental exposures, which may influence kidney cancer trends. Furthermore, the GBD database primarily focuses on epidemiological characteristics and lacks clinical data on treatment strategies or disease staging, restricting our ability to evaluate their influence on the observed burden trends. Future research should integrate these variables to offer a deeper insight into the disease burden.

Conclusions

This study emphasizes the rising kidney cancer burden in China and globally over the past three decades, revealing notable disparities in trends by region, gender, and age group. The results highlight the critical need for targeted prevention, early diagnosis, and equitable access to advanced treatments, especially in LMICs and underserved populations. Tackling these issues through public health initiatives can reduce the growing impact of kidney cancer and improve patient outcomes worldwide.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at <https://tau.amegroups.com/article/view/10.21037/tau-2024-750/rc>

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was

conducted in accordance with the Declaration of Helsinki and its subsequent amendments.

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