

An Epidemiological Analysis Based on the Global Burden of Disease Study 2021

Harbord Kelada*

Unit of Environmental Cancer Epidemiology,
International Agency for Research on
Cancer, Lyon, France

Abstract

Chronic kidney disease (CKD) remains a major contributor to global morbidity, mortality, and healthcare expenditure, with its impact increasing alongside demographic and epidemiological transitions. Understanding long-term changes in disease burden across different geographic and socioeconomic settings is essential for informing effective prevention and healthcare policies. This study examined temporal trends and geographic variations in the global burden of CKD between 1990 and 2021 using comprehensive estimates from the Global Burden of Disease (GBD) 2021 study.

Keywords: Chronic Kidney Disease; Epidemiological trends; Disability-adjusted life years; Global health disparities.

*Corresponding author:

Harbord Kelada, Unit of Environmental
Cancer Epidemiology, International Agency
for Research on Cancer, Lyon, France.
E-mail: harbord_kelada@iarc.fr

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Global Epidemiological Trends in Chronic Kidney Disease (1990–2021)

Chronic kidney disease (CKD) has emerged as one of the fastest-growing non-communicable diseases worldwide, placing a substantial burden on healthcare systems and affected populations. Between 1990 and 2021, the number of individuals living with CKD increased considerably due to demographic transitions, urbanization, and the rising prevalence of metabolic disorders such as diabetes mellitus, hypertension, and obesity. Although advances in healthcare have improved disease recognition and management in many countries, the overall incidence, prevalence, mortality, and disability-adjusted life years (DALYs) attributable to CKD have continued to rise. Population aging has played a central role in this trend because declining renal function is closely associated with advancing age. In addition, improvements in survival among patients with chronic diseases have increased the number of individuals living long enough to develop kidney dysfunction [1,2]. These long-term epidemiological changes demonstrate that CKD has evolved

into a major global public health challenge requiring coordinated prevention strategies, early diagnosis, and effective long-term management [3].

Geographic Variations and Socioeconomic Disparities in CKD Burden

The distribution of CKD burden varies substantially across countries and regions owing to differences in socioeconomic development, healthcare accessibility, environmental exposures, and lifestyle-related risk factors. High-income regions generally demonstrate greater diagnostic capacity and access to renal replacement therapy, yet they continue to experience increasing mortality and DALY rates because of aging populations and the coexistence of multiple chronic diseases. Conversely, many low- and middle-income countries experience disproportionately higher disease burden because of limited screening programs, delayed diagnosis, shortages of nephrology specialists, and

inadequate healthcare infrastructure. The relationship between CKD burden and the Socio-Demographic Index (SDI) is complex and nonlinear, reflecting diverse stages of epidemiological transition. Countries undergoing rapid economic development often face increasing CKD incidence driven by urbanization and lifestyle changes (Table 1), whereas resource-limited settings continue to struggle with preventable causes and restricted treatment availability. These regional differences highlight the importance of tailoring healthcare policies according to local demographic and socioeconomic conditions [4].

Indicator	1990	2021	Percentage Change (%)
Prevalent Cases (millions)	442.8	674.0	52.2
Incident Cases (millions)	12.6	19.9	58.1
Deaths (millions)	0.86	1.53	77.9
DALYs (millions)	28.7	44.5	55.1
Age-standardized Incidence Rate	100.0*	121.6*	+21.6
Age-standardized Mortality Rate	100.0*	128.9*	+28.9
Age-standardized DALY Rate	100.0*	112.1*	+12.1

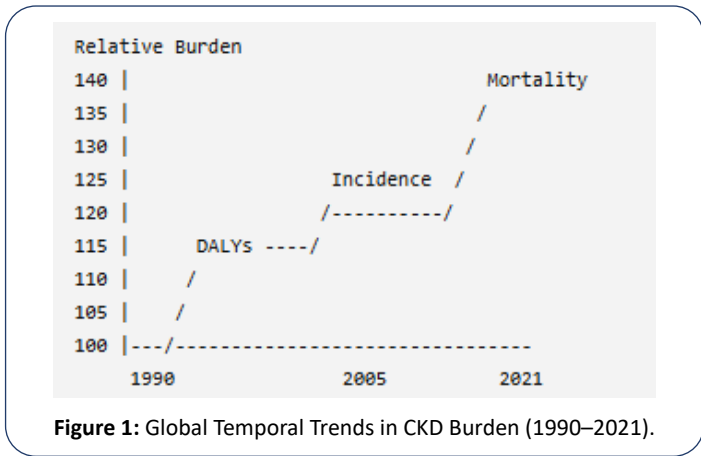
Table 1: Global Burden of Chronic Kidney Disease in 1990 and 2021.

Demographic Characteristics and Major Drivers of CKD Burden

Age, sex, and population dynamics significantly influence the global burden of CKD. The disease predominantly affects older adults because physiological declines in kidney function are accelerated by chronic metabolic and cardiovascular disorders. Women generally exhibit a higher prevalence of CKD, while men frequently experience faster disease progression and higher mortality due to differences in biological susceptibility (Figure 1), health behaviors, and associated comorbidities. Decomposition analyses indicate that population growth and population aging account for most of the observed increase in CKD cases worldwide, while epidemiological changes—including rising diabetes prevalence, hypertension, obesity, and unhealthy dietary patterns—further amplify disease burden. Environmental risk factors, including air pollution, occupational exposures, and climate-related health impacts, have also emerged as important contributors in several regions. Together, these demographic and epidemiological factors emphasize the need for preventive interventions targeting modifiable risk factors throughout the lifespan [5].

Public Health Implications and Healthcare System Challenges

The growing burden of CKD presents substantial clinical, economic, and societal challenges. Patients with CKD often require lifelong monitoring, complex pharmacological management, and, in advanced stages, costly renal replacement therapies such as dialysis or kidney transplantation. Healthcare expenditures



continue to increase as the prevalence of advanced CKD rises, particularly in countries with aging populations. Early detection through routine screening of high-risk individuals—including those with diabetes, hypertension, cardiovascular disease (Table 2), and family history of kidney disease—offers an effective strategy for slowing disease progression and reducing long-term healthcare costs. Integration of CKD management into primary healthcare systems, improved access to essential medications, patient education, and multidisciplinary care models can significantly improve clinical outcomes. Furthermore, strengthening national surveillance systems and expanding equitable healthcare access remain essential for reducing disparities between high- and low-resource settings [6-10].

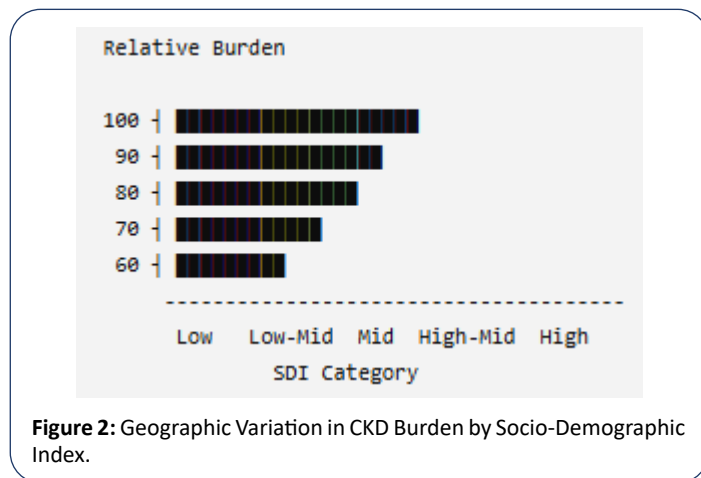
Factor	Contribution to Increase (%)	Public Health Implication
Population Growth	54.75	Increased absolute number of CKD cases worldwide
Population Aging	26.71	Greater disease burden among older adults
Epidemiological Changes	18.54	Rising diabetes, hypertension, obesity, and metabolic disorders
Healthcare Accessibility	Region-dependent	Influences early diagnosis and disease management
Socioeconomic Development	Variable	Determines screening coverage and treatment availability

Table 2: Principal Drivers of Increasing CKD Burden.

Future Perspectives for Reducing the Global Burden of CKD

Addressing the increasing global burden of CKD requires coordinated efforts involving healthcare providers, policymakers, researchers, and public health organizations. Future strategies should prioritize precision prevention through early identification of high-risk populations, implementation of evidence-based clinical guidelines, and wider adoption of digital health technologies for disease monitoring and patient engagement. Advances in biomarkers, artificial intelligence (Figure 2), genomic medicine,

and predictive risk modeling have the potential to improve early diagnosis and individualized treatment approaches. Expanding universal access to preventive services, nephrology care, and renal replacement therapy will be particularly important in low- and middle-income countries where healthcare inequalities remain substantial. International collaboration in epidemiological surveillance and health policy development will facilitate more effective allocation of healthcare resources and strengthen global responses to CKD. Continued investment in prevention, research, and equitable healthcare delivery is essential for mitigating the long-term clinical and economic consequences of chronic kidney disease worldwide [11].



A population-level epidemiological analysis was conducted using GBD 2021 estimates for CKD prevalence, incidence, mortality, disability-adjusted life years (DALYs), and corresponding age-standardized rates across global, regional, and national settings from 1990 to 2021. Temporal changes were evaluated using Estimated Annual Percentage Change (EAPC) and Joinpoint regression models. Decomposition analysis was performed to quantify the relative contributions of population growth, population aging, and epidemiological shifts to changes in CKD burden. Relationships between the Socio-Demographic Index (SDI) and disease burden were further explored to assess socioeconomic disparities [12].

The analysis demonstrated a sustained increase in the worldwide burden of CKD throughout the study period. By 2021, hundreds of millions of individuals were living with CKD, accompanied by substantial increases in incident cases, deaths, and DALYs compared with 1990. Age-standardized incidence, mortality, and DALY rates exhibited significant upward trends over the three decades. Marked regional heterogeneity was observed, with high-SDI regions experiencing the greatest increases in mortality-related outcomes despite stronger healthcare systems, whereas several low-SDI regions continued to shoulder a disproportionately high overall burden [13,14]. The association between SDI and CKD burden was nonlinear, indicating varying epidemiological trajectories across different levels of socioeconomic development. Population expansion and demographic aging accounted for most of the observed increase in CKD burden, while epidemiological changes contributed to regional differences in disease patterns.

Conclusion

The concluding section should summarize the principal findings of the review, emphasizing that retinal and choroidal vascular permeability alterations are important manifestations of systemic microvascular dysfunction in chronic kidney disease. It should reinforce the value of comprehensive ophthalmic assessment as part of routine CKD care and highlight future opportunities for integrating ocular biomarkers into clinical decision-making to improve patient outcomes.

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