



• Global Eye Health and Epidemiology Selection •

doi: 10.12419/es25030602

View this article at: <https://dx.doi.org/10.12419/es25030602>

Global pattern, trend, and cross-country inequality of blindness and vision impairment: an analysis of the Global Burden of Disease Study 2021

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HIGHLIGHTS

- Global blindness and vision impairment (BVI) have continued to rise from 1990 to 2021, with widening disparities across regions, sexes, and socioeconomic levels. The burden is highest in low-SDI settings and disproportionately affects women, particularly in South Asia.
- Using Global Burden of Disease 2021 data, we applied age–sex stratified, multi-scale analyses across 204 countries and 21 regions. Temporal trends were quantified with estimated annual percentage change (EAPC), integrating prevalence, DALYs, and SDI correlations.
- Findings call for targeted interventions in low- and middle-income countries, prioritizing women and vulnerable populations. Integrating eye care into universal health coverage is essential to reduce inequities and improve global vision health.

Received date: 2025-03-11; Revised date: 2025-05-21; Accepted date: 2025-07-08; Published online: 2025-09-20

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Full Text

Abstract: **Background:** Blindness and vision impairment (BVI) continue to pose significant global public health challenges, disproportionately impacting vulnerable populations and further widening socioeconomic disparities. This study conducts a comprehensive evaluation of the global burden of BVI and the socioeconomic inequalities in its distribution from 1990 to 2021, aiming to provide insights for targeted intervention strategies. **Methods:** Using data from Global Burden of Disease 2021, this study performed a multiscale analysis of BVI burden, examining patterns at the global, regional and national levels. We quantified the disease burden using disability-adjusted life years DALY and prevalence rates. Temporal trends were analyzed by calculating estimated annual percentage changes (EAPC). Stratified assessments were carried out by sex and age group across 21 regions and 204 countries. The study also included comparative analyses of six major eye conditions and evaluated their associations with socio-demographic index (SDI). **Results:** Globally, the age-standardized prevalence of BVI increased from 12,453.52 per million (95% UI: 10,287.58-15,226.09) in 1990 to 15,784.33 per million (12,761.44-19,502.32) in 2021, with an EAPC of 1.09% (95% UI: 0.97-1.20). During this period, global DALYs attributable to BVI increased by 37.7%. Disease trends exhibited significant divergence, with near vision loss showing the steepest increase (EAPC: 1.47%), while the prevalence of glaucoma declined (EAPC: -0.73%). Geographic disparities were pronounced, with substantial improvements observed in Equatorial Guinea (EAPC: -1.75) and worsening burdens in Benin (+0.54). Disease distribution demonstrated strong regional clustering, with near vision loss being predominant in Sub-Saharan Africa (64.47%) and East Asia (50.97%), while cataract was the most common condition in Oceania (33.86%). Females consistently bore a higher burden, particularly in South Asia (646.3 vs 563.2 DALYs). Moreover, we identified a strong inverse correlation between SDI and BVI burden ($P=-0.772$ for DALYs). **Conclusions:** This study highlights the severe global burden of BVI and the significant cross-country inequality, particularly in low- and middle-income countries. It emphasizes the urgent need for targeted interventions and the integration of eye care into universal health policies to promote global health equity in the post-pandemic era.

Keywords: Global Burden of Disease; blindness; visual impairment; disability-adjusted life years; cross-country inequality

Cite this article as: Guo X, Chen ZF, Xiong K, Yao JW, Huang ZX, Gong X, Huang JQ, Huang WY, Liu T, Huang WM. Global pattern, trend, and cross-country inequality of blindness and vision impairment: an analysis of the Global Burden of Disease Study 2021. *Eye Science*, 2025, 2(3): 211-221. doi: 10.12419/es25030602.

INTRODUCTION

Blindness and vision impairment (BVI) impact approximately 2.2 billion people across the globe, imposing a considerable burden on individuals, their households, communities, and societies as a whole.^[1-2] The World Report on Vision 2023 points out that the effects of BVI are particularly severe in low- and middle-income countries. These cross-country disparities not only diminish individuals' quality of life and life expectancy but also impede progress towards achieving several sustainable development goals.^[3-4] Recently, the World Health Organization's directive to incorporate eye

care into the framework of universal health coverage has highlighted the necessity for a thorough assessment of national disparities in the burden of BVI and an explanation of the root causes behind these disparities.

The persistent regional disparities in eye health warrant scholarly focus, especially amid emerging global challenges. While countries with medium and low Socio-Demographic Index (SDI) levels had managed to achieve notable reductions in blindness rates by 2019, newly emerging risk factors—particularly the widespread use of digital devices—pose a threat to reversing these trends.^[5] Excessive screen time, which has become a defining feature of modern work, education, and leisure

activities, has been associated with digital eye strain, the progression of myopia, and dry eye syndrome.^[6-7] Moreover, the aging of the global population—with one-third of the world's population projected to be over 60 years old by 2030—combines with sedentary lifestyles and reduced time spent outdoors, further increasing the risks for age-related eye diseases.^[8] These evolving trends highlight the urgent need for up-to-date epidemiological data.^[9]

The objective of this study is to offer fresh insights into global disparities in major BVI by utilizing data from the Global Burden of Disease 2021 (GBD). This research aims to estimate the disease burden of BVI at global, regional, and national scales. Furthermore, we analyzed disability-adjusted life years (DALYs) for 204 countries and territories, with the data segmented by age group and sex from 1990 to 2021. Additionally, we investigated the influence of SDI on DALY values.

METHOD

Data sources

This study conducts a secondary analysis of data from the Global Burden of Disease (GBD) 2021 study. It assesses health losses attributable to 369 diseases and injuries across 204 countries and territories, with the data stratified by age and sex.^[10] The GBD employs a comprehensive meta-regression framework for data analysis, presenting a variety of interconnected indicators that collectively offer a detailed evaluation of disease burden.^[11] These indicators encompass prevalence and DALYs. The latter quantifies the overall disease burden by representing the number of years of healthy life lost due to illness. Specifically, DALYs gauge the disparity between an individual's current health status and an ideal health status, in which the individual attains life expectancy without experiencing disease or disability.

To evaluate the burden of BVI, we extracted prevalence estimates along with their 95% uncertainty intervals (UIs), with a particular focus on conditions classified under the GBD etiological code B.10.1. The analysis encompassed data on the prevalence and DALYs for conditions including glaucoma, cataract, age-related macular degeneration (AMD), uncorrected refractive disorders (URD), near vision loss, and other types of vision loss. These data were stratified by age group and sex across various regions for the period from

1990 to 2021. The information was obtained from the Global Health Data Exchange for the GBD 2021 study (<https://ghdx.healthdata.org/gbd-2021>). Additionally, SDI was used as a comprehensive indicator of a country's or region's development status. It combines data on per capita income, educational attainment, and fertility rates into a single value ranging from 0 to 1, with higher values indicating greater levels of development.^[12]

Data analysis

This study covered three geographical scales, namely global, regional, and national levels, and incorporated several key methodological elements. First, we computed multiple burden metrics, including total DALYs per 100,000 population, crude DALY rates, and age-standardized DALY rates. Additionally, we used the estimated annual percentage change (EAPC) to analyze trends in VI. This was done by fitting linear regression models to the natural logarithm of ASRs, where the slope coefficient (β) indicates the annual trend. An upward trend was identified when both the EAPC value and the lower bound of its 95% CI were greater than 0. Conversely, a downward trend was determined when both values were less than 0 for both prevalence and DALY metrics. We conducted comprehensive descriptive analyses by stratifying the data in detail according to sex (male/female), 5-year age groups, and geographical regions (national and GBD regional levels). To examine disease-specific burden patterns, we employed multiple visualization techniques: choropleth maps were used to show the national-level distributions of both standardized and non-standardized DALY rates and prevalence; grouped bar charts were utilized to compare disease prevalence and DALY proportions across 21 GBD regions; horizontal stacked bar charts illustrated gender-specific DALY rates for BVI and major eye diseases by region in 2021; and scatter plots analyzed the relationship between age-standardized DALY rates and SDI values across 204 countries and territories. All statistical analyses and visualizations were carried out using JD_GBDR_V2.06.1, R software (version 4.2.2; R Foundation for Statistical Computing), and Python 3.6, with the aid of key libraries such as pandas and matplotlib.pyplot for data manipulation and graphical representation. The multi-platform approach ensured robust computation of burden metrics and facilitated sophisticated geospatial and temporal visualizations.

RESULTS

Overview of BVI burdens

The age-standardized prevalence of BVI rose from 12,453.52 (95% UI: 10,287.58-15,226.09) per million in 1990 to 15,784.33 (95%UI: 12,761.44-19,502.32) per million in 2021, with an EAPC of 1.09% (95% CI: 0.97%-1.20%) (Table 1). Correspondingly, the DALYs rate for BVI increased by 37.7% over the same period. In 1990, it was 268.4 (184.0-381.4) per 100,000 population, and in 2021, it reached 369.6 (95%UI: 241.2-543.9) per 100,000 population (Figure 1, Supplementary Table 1). There was a modest annual increase in the DALYs rate, with an EAPC of 0.14% (95% CI: 0.08%-0.19%) (Supplementary Table 2). Age-standardized DALYs showed a more gradual increase, rising by 0.2% increase (Supplementary Table 1). When examining disease-specific trends, divergent patterns emerged. Near vision loss exhibited the most significant increase in prevalence, with an EAPC of 1.47%. In contrast, the prevalence of glaucoma declined significantly, with an EAPC of -0.73% (Figure 2). Other conditions, such as AMD and refraction disorders, showed slight decreases in prevalence (Table 1). The maps of DALY rates and prevalence rates

indicated similar geographical distributions between 1990 and 2021 (Supplementary Figure 1).

Regional variations in disease prevalence

Global analyses uncovered distinct geographical patterns in the burden of vision impairment (Figure 2). Supplementary Table 3-4 display the age-standardized DALY rates across 21 regions and 204 countries/territories. Among them, Equatorial Guinea (EAPC: -1.75, 95% CI: -1.84 to -1.65) and Saudi Arabia (EAPC: -1.66, 95% CI: -1.71 to -1.61) demonstrated the most significant declines in BVI DALY rates from 1990 to 2021. In contrast, Côte d'Ivoire (EAPC: +0.62) and Benin (EAPC: +0.54) experienced the largest increases (Supplementary Table 5). The distribution of disease showed strong regional clustering. Near vision loss accounted for 64.47% of cases in Central Sub-Saharan Africa and 50.97% in East Asia. Cataract was responsible for 33.86% of burden in Oceania and 28.25% in South Asia. Uncorrected refractive disorders (URD) made up 31.71% of cases in Southern Latin America and 28.69% in North Africa/Middle East. Other types of vision loss constituted 21.46% of cases in the Caribbean and 21.17% in Eastern Europe. Glaucoma (6.63%) and AMD (7.24%)

Table 1 Age-standardized prevalence rates for BVI and different eye diseases from 1990 to 2021

	Age-standardized prevalence rates				
	1990 (million)	2019 (million)	2021 (million)	EAPC (1990-2021)	EAPC (2019-2021)
BVI	12,453.52 (10,287.58-15,226.09)	15,558.7 (12,578.24-19,253.26)	15,784.33 (12,761.44-19,502.32)	1.09 (0.97-1.20)	0.72 (-0.50-1.96)
Cataract	1,145.05 (1,022.69-1,278.12)	1,173.18 (1,039.68-1,323.84)	1,181.01 (1,044.47-1,334.29)	0.21 (0.12-0.31)	0.33 (-0.75-1.43)
Glaucoma	116.29 (100.81-136.3)	94.15 (81.14-110.29)	90.12 (77.78-105.49)	-0.73 (-0.78--0.69)	-2.16 (-3.25--1.06)
AMD	99.5 (83.16-118.04)	94.25 (78.43-114.5)	94 (78.32-114.42)	-0.26 (-0.31--0.22)	-0.13 (-2.47-2.26)
Near vision loss	9,788.66 (7,371.64-12,888.27)	13,157.06 (9,949.15-17,190.03)	13,436.18 (10,223.45-17,585.84)	1.47 (1.32-1.62)	1.06 (-0.55-2.68)
Refraction disorders	2,053.56 (1,835.31-2,275.8)	1,937.25 (1,729.93-2,152.53)	1,919.66 (1,715.24-2,135.28)	-0.24 (-0.27--0.21)	-0.46 (-0.97-0.06)
Other vision loss	507.89 (452.94-568.05)	459.49 (407.44-516.66)	454.75 (402.01-511.73)	-0.39 (-0.42--0.36)	-0.52 (-1.2-0.18)

BVI, blindness and vision loss; AMD, age-related macular degeneration, EAPC, estimated annual percentage change.

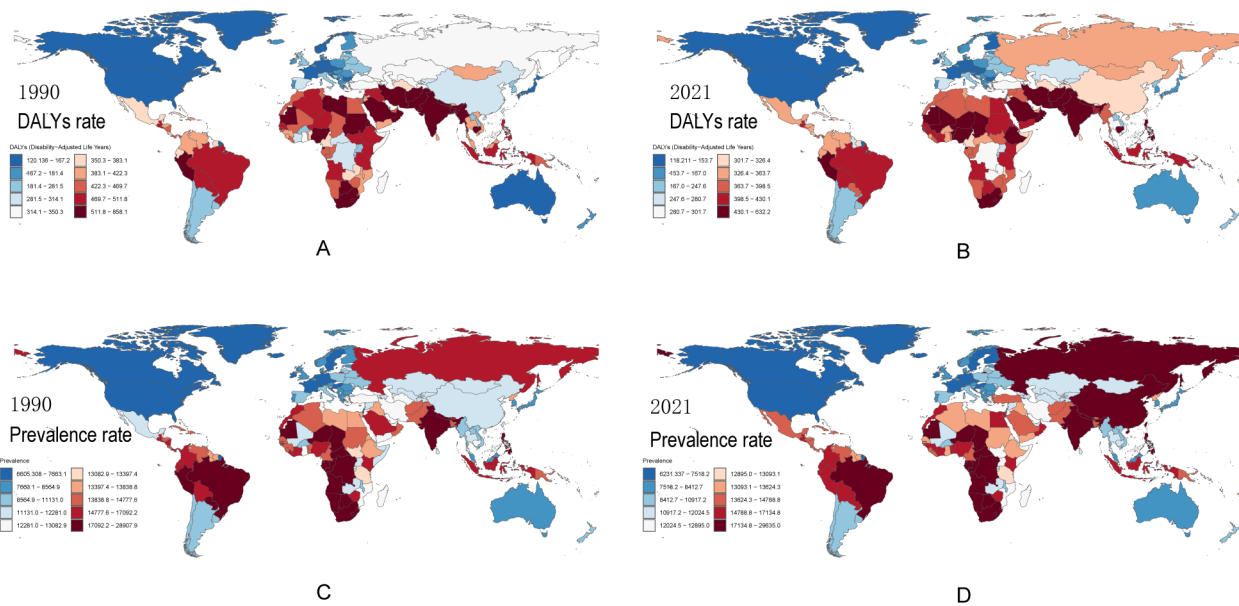


Figure 1 Maps about age-standardized DALYs rates and age-standardized prevalence rates for BVI in 1990 and 2021

exhibited focal prevalence in High-income Asia Pacific and Western Europe, respectively (Supplementary Figure 2, Supplementary Table 7-8).

Disease burden across gender and age group

Figure 3 illustrates the age-stratified trends in DALYs due to vision impairment from 1990 to 2021. The results reveal significant differences across age groups: the group 95 years and above showed a consistent downward trend in DALYs, whereas the cohort aged 45-50 years exhibited a pronounced upward trend. Distinct patterns of fluctuation were noted in both under 5 years old and young adults aged 20-24 years. On a global scale, females bore a higher BVI burden than males, especially in South Asia, where the DALY rate for females was 646.3 (95% CI:436.7-920.8) compared to 563.2 (95% CI:377.1-807.9) for males. Similar disparities were observed in Southern Sub-Saharan Africa (females:485.6 [305.6-746.6]; males: 462.8 [294.7-706.4]). In contrast, High-income North America had the lowest BVI DALY rates (139.5 [86.9-217.7]). There were some notable exceptions to these general trends. For instance, cataract was more prevalent among males in Andean/Central Latin America, and glaucoma consistently showed a male-predominant pattern. AMD was predominantly male only in Southern Latin America, with a DALY rate

of 3.0 (95% CI:1.9-4.2) for males compared to 2.6 (95% CI:1.7-3.7) for females (Supplementary Table 9-10, Supplementary Figure 3).

SDI and BVI burdens correlation

Figure 4 reveals a robust inverse relationship between SDI and the burden of vision impairment. Specifically, when considering age-standardized DALYs, the Spearman's rank correlation coefficient is $P=-0.772$, and for prevalence, $P=-0.599$. Regions with a high SDI demonstrated significantly lower DALYs rates. For example, High-income North America had a DALY rate of 134.1 (95% CI:83.8-206.9), and High-income Asia Pacific had a rate of 156.0 (95% CI:97.1-239.0). In contrast, low-SDI regions, such as South Asia, had a much higher DALY rate of 605.3 (95% CI:407.0-862.3). This pattern of a higher burden in low-SDI areas was also evident at the national level. Low-SDI countries like India (632.2 [421.0-912.8]) and Pakistan (589.4 [427.1-802.3]) carried a burden that was 3-5 times greater than that of high-SDI nations. For instance, Sweden had a DALY rate of 118.2 (95% CI: 71.5-187.7), and Canada had a rate of 126.3 (95% CI:78.5-194.4). Analyses focusing on specific diseases further confirmed consistent presence of socioeconomic gradients in vision impairment burden (Supplementary Table 11-12, Supplementary Figure 4).

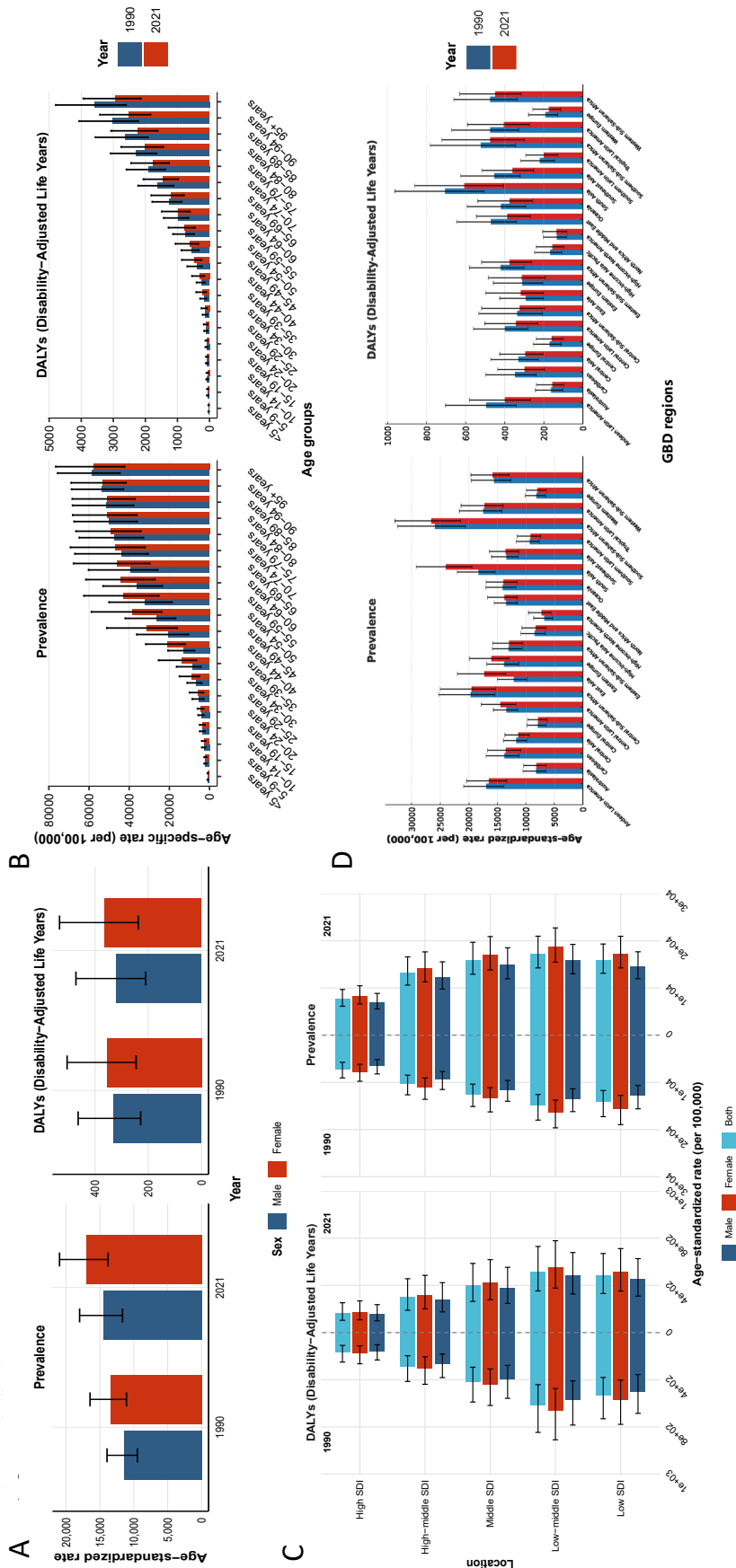


Figure 2 Sub-group analysis of the global burden of blindness and vision loss, 1990 vs 2021
 (A) Sex-specific age-standardized rates (per 100,000 people) of prevalence and disability-adjusted life-years (DALYs) in 1990 and 2021, (B) age-specific rates (per 100,000 people) of prevalence and DALYs across 5-year age groups in 1990 and 2021, (C) age-standardized rates (per 100,000 people) of prevalence and DALYs by Socio-demographic Index (SDI) quintile for males, females, and both sexes in 1990 and 2021, and (D) age-standardized rates (per 100,000 people) of prevalence and DALYs by Global Burden of Disease (GBD) super-regions in 1990 and 2021. Error bars represent 95% uncertainty intervals.

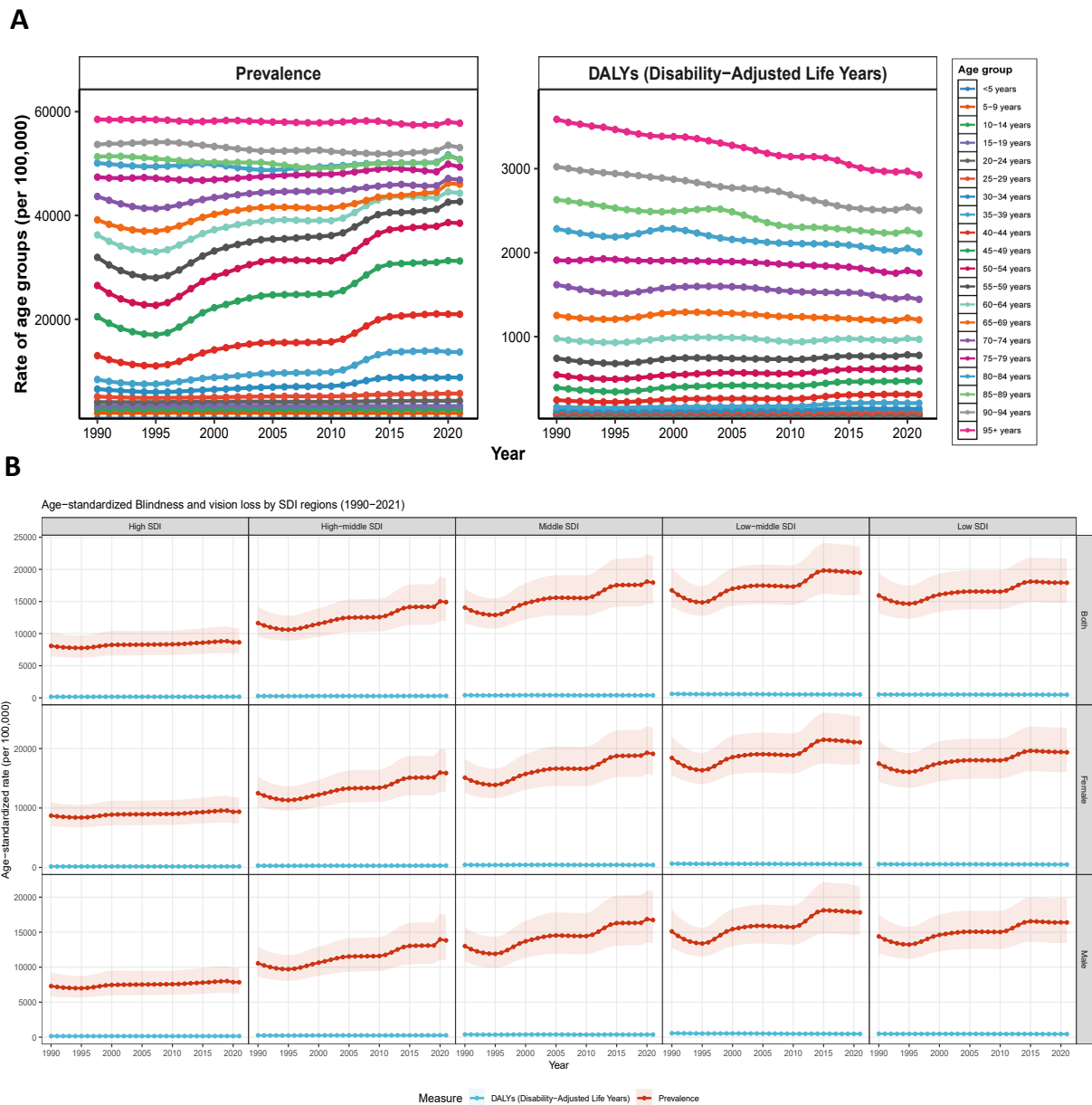


Figure 3 Temporal trends and socio-demographic disparities in blindness and vision loss globally, 1990-2021
 (A) Age-specific annual prevalence and DALY rates, (B) Age-standardized prevalence and DALY rates by SDI quintile and sex.

DISCUSSION

This study provides an updated perspective on global inequality, revealing that the global burden of disease associated with blindness and visual impairment is escalating on an annual basis. There remain substantial disparities in eye health. The overall DALY rate for BVI increased from 1990 to 2021. A regional analysis indicates that South Asia has a significantly higher age-

standardized DALY rate for BVI, while high-income North America has the lowest. Moreover, in the economic correlation analysis concerning the overall burden of eye health a trend of first increasing and then decreasing with the SDI value was observed. These persistent regional inequalities highlight the urgent necessity for eye care programs, policies, research, and practices. These initiatives should not only focus on addressing regional equity but also develop interventions that explicitly

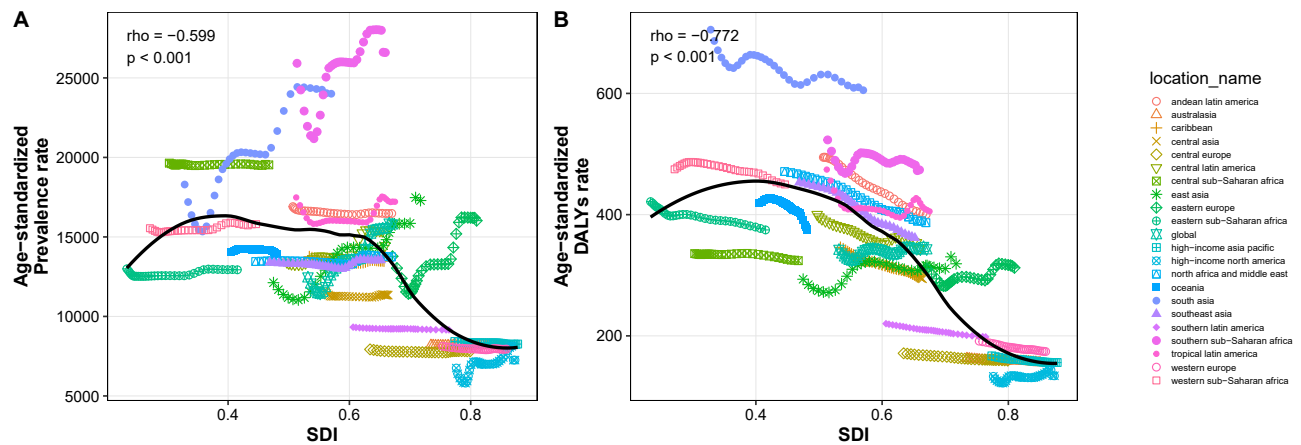


Figure 4 Inverse relationship between Socio-demographic Index (SDI) and the burden of blindness and vision loss by Global Burden of Disease (GBD) super-regions, 1990 – 2021

(A) SDI versus age-standardized prevalence rate (per 100,000) of blindness and vision loss (Spearman $P = -0.599$, $P < 0.001$), (B) SDI versus age-standardized DALY rate (per 100,000) of blindness and vision loss (Spearman $P = -0.772$, $P < 0.001$)

model the relationships, collaborations, and practices required to reduce the BVI burden. Such interventions should be based on data-driven insights from different regions.^[13]

This study enhances the analysis of regional inequalities in the burden of blindness and BVI by integrating data from 2021 and introducing the EAPC metric. In contrast, previous studies exclusively relied on absolute changes for their assessments. The long-term over the period from 1990 to 2021 (EAPC=1.09) substantiates the ongoing increase in BVI burden. This result is in line with prior findings but offers a more precise quantification⁵. Notably, our pioneering calculation of short-term EAPC for the period 2019-2021(EAPC=0.72) suggests a potential stabilization of the BVI burden. However, given the wide confidence interval, a cautious interpretation is warranted due to possible data fluctuations that can occur over such a short time span. Moreover, significant regional disparities continue to exist. When examining age-standardized data, it becomes evident that the overall BVI burden is higher in South Asia and Eastern Sub-Saharan Africa, while it is lower in high-income Asia-Pacific and high-income North America. In light of these findings, future public health policies and eye health interventions should give top priority to addressing regional income-related inequalities in eye health. Additionally, efforts should focus on developing higher-quality and more targeted interventions for BVI.

This finding highlights the potential of well-crafted health policies to effectively alleviate regional disease burdens. Specifically, near-vision loss was found to be notably widespread in Eastern Sub-Saharan Africa, whereas cataracts posed a more significant problem in South Asia. These conditions have a profound impact on the health and quality of life of affected populations.^[14-15] However, the ability to tackle these issues in Eastern Sub-Saharan Africa is severely hampered by limitations in research time, funding, and the availability of relevant skills.^[16] This high disease burden in this region is further compounded by a scarcity of healthcare resources and a substantial shortage of refractive services.^[17] This situation underscores the urgent need for improvements in human resources and service delivery.^[18] As a result, there is an immediate need for regional interventions. These interventions should include strengthened governmental oversight, clinical regulation of refraction and eyewear dispensing, and the introduction of standardized training programs for refractive care.^[19-20] Such measures are designed to address existing disparities and enhance eye health in these regions. By giving priority to these targeted interventions, it is feasible to reduce the significant burden of near vision loss and cataracts. This, in turn, ultimately improve the quality of life and health outcomes for affected populations in the regions with the highest needs.^[21]

It is crucial to take into account the impact of economic factors on disease burden, as emphasized in

the current study. The study revealed that countries with higher SDI values generally exhibited lower levels of disease burden. Notably, countries with moderate and low-moderate SDIs have been especially successful in reducing the burden of BVI. This reduction can be ascribed to the rapid development of these nations and the effective implementation of universal eye care programs, which have received support from the World Health Organization (WHO) over the past few decades. For instance, all 193 WHO Member States have officially pledged to invest in eye care. The vast majority of them have set up VISION 2020 committees and formulated national eye care plans.^[22] In Zambia, the Eye Health Strategic Plan 2012-2015 has outlined five key goals.^[23] In Nepal, collaboration among professionals from the governmental, nongovernmental, and private sectors has facilitated the delivery of eye care services.^[24] Moreover, the SDI analysis indicated that age-standardized DALY rates were most severe in India and Pakistan. This finding underscores critical areas where interventions are urgently needed to address disparities in visual health.

The SDI analysis disclosed that India and Pakistan had the highest age-standardized DALY rates for BVI. In India, this high disease burden is mainly attributed to the fact that disadvantaged and marginalized groups are more prone to visual impairments or blindness and have limited access to eye care service.^[25-26] Moreover, it is alarming that over 90% of glaucoma cases in India remain undiagnosed.^[27] Given India's large and rapidly aging population,^[28] it is of utmost importance to strengthen public health policies focused on blindness prevention and improving access to the diagnosis and treatment of BVI. To tackle these challenges, we suggest implementing policies aimed at enhancing the capacity for early detection and treatment of ocular diseases. Strengthening eye health education and the prevention of blindness and vision loss should also be integral parts of these initiatives. Such strategic improvements are vital for reducing the substantial disease burden and enhancing overall public health outcomes in the region. In Pakistan, where the eye care system lacks cohesion and is notably decentralized,^[29] adopting a structured approach to developing an eye care pathway is crucial for improving the effectiveness and sustainability of services. We recommend implementing a step-by-step strategy to establish a comprehensive framework for eye care, using scientifically validated tools such as the WHO Eye Care Situation Analysis Tool. This tool provides a

solid framework covering six key areas: leadership and governance, financing, health workforce, service delivery, access to essential medicines, and health information systems. By systematically addressing these components, Pakistan can upgrade its eye care infrastructure, ensuring better health outcomes and more efficient service delivery throughout the country.

We used the latest GBD 2021 data to carry out a detailed evaluation of regional inequalities at the local, national, and global scales. This all-encompassing analysis is intended to provide insights for public health policy by drawing attention to disparities that require targeted interventions. However, these data are subject to several limitations. Firstly, there may be structural flaws in the data. These include inconsistencies in the criteria used for including patients with blinding eye diseases, as well as differences in diagnostic rates and treatment approaches across various countries and regions. Secondly, the influence of other biases, especially those associated with socioeconomic conditions, cannot be ignored. These biases could substantially impact regional disparities in the burden of blinding eye diseases. Furthermore, the data analysis methods and statistical models used might have limitations in fully explaining regional differences in disease burden. For instance, they may not adequately consider potential confounding factors and interaction effects that could sway the results. It is crucial that these complex concepts be consistently and properly taken into account throughout the research process.^[30]

CONCLUSION

This study concludes that the overall burden of BVI continues to be severe, with a disproportionate share of this burden falling on low- and middle-income countries. From the perspective of regional inequalities, the obstacles to implementing the “Universal eye health: a global action plan” are clearly apparent. There is an urgent imperative to tackle these widespread and long-standing health disparities, especially those that impact vulnerable groups such as women, the elderly, and individuals living in under-resourced regions. Efforts should be focused on countries and regions with a high BVI burden, aiming to improve access to health services. Additionally, it is essential to lay a solid foundation for policy development, ensuring that eye care becomes an integral part of universal health coverage.

Abbreviations and Acronyms:

BVI = Blindness and vision impairment; VI = vision impairment; GBD = Global Burden of Disease; SDI = Socio-demographic index; DALYs = disability-adjusted life years; EAPC = estimated annual percentage changes; UIs = uncertainty intervals; AMD = age-related macular degeneration; URD = uncorrected refractive disorders

Correction Notice

None

Acknowledgement

We sincerely thank the team at the Institute for Health Metrics and Evaluation (IHME) for the Global Burden of Disease (GBD) study data.

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- (VI) Manuscript writing: All authors
- (VII) Final approval of manuscript: All authors

Funding

This study was supported by grants from the National Natural Science Foundation of China (82000901, 82171084).

Conflict of Interests

None of the authors has any conflicts of interest to disclose. All authors have declared in the completed the ICMJE uniform disclosure form.

Patient Consent for Publication

None

Ethical Statement

None

Provenance and Peer Review

This article was a standard submission to our journal. The article has undergone peer review with our anonymous review system.

Data Sharing Statement

None

Open Access Statement

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Supplementary data

Please visit <https://journal.gzzoc.com/es/Stage/ArticleShow.aspx?AID=5796> for detailed information.

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