Global burden of vision impairment due to age-related macular degeneration, 1990–2021, with forecasts to 2050: a systematic analysis for the global burden of disease study 2021

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Summary

Background Age-related macular degeneration (AMD) is a growing public health concern worldwide, as one of the leading causes of vision impairment. We aimed to estimate global, national, and region-specific prevalence and disability-adjusted life-years (DALYs) along with tobacco as a modifiable risk factor to aid public policy addressing AMD.

Methods Data on AMD were extracted from the Global Burden of Disease, Injuries, and Risk Factor Study 2021 database in 204 countries and territories, 1990–2021. Vision impairment was defined and categorised by severity as follows: moderate to severe vision loss (visual acuity from <6/18 to 3/60) and blindness (visual acuity <3/60 or a visual field <10 degrees around central fixation). The burden of vision impairment attributable to AMD was subsequently estimated. These estimates were further stratified by geographical region, age, year, sex, Healthcare Access and Quality (HAQ) Index, and Socio-demographic Index (SDI) levels. Additionally, the effect of tobacco use, a modifiable risk factor, on the burden of AMD was analysed, and projections of AMD burden were estimated through to 2050. These projections also included scenario modelling to assess the potential effects of tobacco elimination.

Findings Globally, the number of individuals with vision impairment due to AMD more than doubled, rising from 3·64 million (95% uncertainty inverval [UI] 3·04–4·35) in 1990 to 8·06 million (6·71–9·82) in 2021. Similarly, DALYs increased by 91% over the same period, from 0·30 million (95% UI 0·21–0·42) to 0·58 million (0·40–0·80). By contrast, age-standardised prevalence and DALY rates declined, with prevalence rates decreasing by 5·53% (99·50 per 100 000 of the population [95% UI 83·16–118·04] in 1990 to 94·00 [78·32–114·42] in 2021) and DALY rates dropping by 19·09% (8·38 [5·70–11·53] to 6·78 [4·70–9·32]). These rates showed a consistent decrease in higher SDI quintiles, reflecting the negative correlation between HAQ Index and AMD burden. A general downward trend was observed from 1990 to 2021, with the largest age-standardised reduction occurring in the low-middle SDI quintile. The global contribution of tobacco to age-standardised DALYs decreased by 20%, declining from 12·45% (95% UI 7·73–17·37) in 1990 to 9·96% (6·12–14·06) in 2021. By 2050, the number of individuals affected by AMD is projected to increase from 3·40 million males (95% UI 2·81–4·17) in 2021 to 9·02 million (5·72–14·20) and from 4·66 million females (3·88–5·65) to 12·32 million (8·88–17·08). Eliminating tobacco use could reduce these numbers to 8·17 million males (5·59–11·92) and 11·15 million females (8·58–14·48) in 2050.

Interpretation While the total prevalence and DALYs due to AMD have steadily increased from 1990 to 2021, age-standardised prevalence and DALY rates have declined, probably reflecting the effect of population ageing and growth. The consistent decrease in age-standardised rates with higher SDI levels highlights the crucial role of health-care resources and public policies in mitigating AMD-related vision impairment. The downward trend observed from 1990 to 2021 might also be partially attributed to the reduced effect of tobacco as a modifiable risk factor, with declines in tobacco use seen globally and across all SDI quintiles. The burden of vision impairment due to AMD is projected to increase to about 21·34 million in 2050. However, effective tobacco regulation has the potential to substantially reduce AMD-related vision impairment, particularly in lower SDI quintiles where health-care resources are limited.

Funding Gates Foundation.

Introduction

Age-related macular degeneration (AMD) is a degenerative disease that occurs with ageing, with symptoms ranging from asymptomatic to vision impairment, and further progressing to blindness.[1] AMD, the third leading cause of vision impairment,[2] is known to

increase the risk of depression by 15%.[3] Moreover, vision impairment due to AMD contributes to increased all-cause mortality[4] and diminishes quality of life,[5] while also exerting a national impact on productivity decline.[6] Given its potential effect on individual health and broader societal outcomes, it is imperative to accurately estimate

Research in context

Evidence before this study

The growing and ageing population worldwide has led to the increased attention to the burden of age-related macular degeneration (AMD). We conducted a comprehensive search of PubMed and MEDLINE on May 1, 2024, without language restrictions, covering studies published from database inception up to Nov 30, 2024, using the terms ("age-related macular degeneration" AND "prevalence" OR "DALYs"). The 2014 meta-analysis by Wong and colleagues estimated the overall prevalence of AMD without addressing the specific prevalence of vision impairment caused by AMD, nor did it provide data at the country or regional level. Other studies have focused on the burden of AMD in specific regions, often restricted to high-income countries. Additionally, while the Global Burden of Disease, Injuries, and Risk Factors Study (GBD) 2019 Blindness and Vision Impairment Collaborators presented the prevalence of vision impairment due to AMD, they did not include data related to disability-adjusted life-years (DALYs). Previous investigations categorised tobacco as an established risk factor, whereas our study undertook a comprehensive analysis of tobacco's effect as a modifiable risk factor on DALYs. Consequently, to our knowledge no other study has fully explored the burden of AMD from both demographic and geographical perspectives.

Added value of this study

This study assessed the prevalence and DALYs associated with vision impairment caused by AMD across 204 countries and territories from 1990 to 2021, using robust data from the GBD 2021. Globally, vision impairment due to AMD affected 8·06 million (95% uncertainty interval 6·71–9·82) individuals in 2021. This study further analysed the burden by

incorporating demographic factors, the Healthcare Access and Quality Index, and the Socio-demographic Index (SDI) to provide the burden in depth. Tobacco use, an established risk–outcome pair for AMD, was included as a contributing risk factor to the burden of AMD-related vision impairment. The findings suggest that tobacco regulation may have contributed to reducing DALYs associated with AMD. Projections indicate that the number of affected individuals will rise to 21·34 million by 2050; however, eliminating tobacco use could reduce this burden by approximately 19·32 million, emphasising the importance of targeted tobacco control measures.

Implications of all the available evidence

Despite the overall declining trend in the prevalence and DALYs of vision impairment due to AMD, it remains a significant burden, particularly for females, older age groups, and lower SDI quintiles. Given the unequal distribution of medical resources across SDI groups, there is a requirement for alternative strategies beyond novel treatments such as anti-vascular endothelial growth factors, including a focus on controlling risk factors associated with AMD-related vision impairment. The findings of this study suggest that tobacco regulation could be an effective strategy for reducing the burden of AMD, with projections indicating that such interventions would be particularly beneficial in the future, especially in lower SDI quintiles. Furthermore, tailored interventions for different SDI quintiles, including cost-effective medical treatments and dietary improvements, would help address the burden of AMD. Future studies should focus on identifying additional risk factors for AMD and developing effective policies and interventions to reduce disparities in the burden of AMD across SDI groups.

the extent of AMD's effect within societies undergoing population growth and ageing worldwide.

Previous research on the global burden of AMD, primarily systematic reviews, has highlighted the heterogeneity of data.[7] Many previous studies estimating AMD prevalence have focused on specific regions or high-income countries,[8] making it challenging to assess the burden of AMD in low-income to middle-income countries (LMICs). Furthermore, given the restricted access to treatment in LMICs,[9] the burden of AMD is notably disproportionate on a global scale, underscoring the need for further research including such regions for a comprehensive global analysis.

The influence of specific risk factors on AMD remains contentious. While the detrimental effects of tobacco and the potential benefits of antioxidant intake are relatively established,[10] the association with other factors vary across studies and is subject to ongoing debate. Nevertheless, despite the well documented global impact of tobacco on AMD, there is a notable gap in the literature concerning the analysis of tobacco's contribution to disability-adjusted life-years (DALYs) based on geographical location and

Socio-demographic Index (SDI; a measure that captures income per capita, education, and fertility).

AMD should be addressed as a paramount global public health concern owing to its prominence as a leading cause of irreversible vision impairment on a global scale.[11] This study aimed to estimate the prevalence and DALYs of AMD from 1990 to 2021, stratified by age, sex, location, and SDI levels, while also quantifying the burden attributable to tobacco use. Additionally, the study sought to provide deeper insights into the global burden of AMD by projecting trends through to 2050 and analysing the potential effect of eliminating tobacco as a risk factor, using data from the Global Burden of Disease, Injuries, and Risk Factors Study (GBD) 2021.

This manuscript was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.[12,13]

Methods
Overview
The GBD 2021 integrates an extensive and expanding array of data sources, encompassing surveys, censuses,

vital statistics, and other health-related databases. These diverse datasets were harnessed to estimate morbidity, illness, injury, and attributable risk across 204 countries and territories from 1990 to 2021.[12,13] Incidence, prevalence, years lived with disability (YLDs), and DALYs were calculated for the period spanning 1990 to 2021.[12,13] The 2021 GBD methodologies have been meticulously developed and improved upon over several iterations, benefiting from the rigorous research conducted in preceding iterations of the GBD studies.[14] This study adheres to the GATHER reporting guidelines. Further details on methods are outlined in appendix 1 and appendix 2.

Input data and case definition

Data preparation was conducted through a systematic review by the Vision Loss Expert Group (VLEG) of population-based studies on vision impairment and blindness, supplemented by grey literature sources. Eligible studies were combined with data from the Rapid Assessment of Avoidable Blindness (RAAB) studies, the US National Health and Nutrition Examination Survey, and the WHO Study on Global Ageing and Adult Health, with support from the GBD collaborators.

The VLEG commissioned the York Health Economics Consortium (York, UK) to perform a comprehensive literature review using databases such as Embase, SciELO, PubMed, MEDLINE, WHOLIS, and Open Grey. Titles and abstracts were screened, and quality assessments were conducted by regional VLEG committees to make final inclusion decisions. The detailed search keywords and methodology are described in a previous GBD study.[15] Additional data included 5-year age-disaggregated RAAB surveys obtained from the RAAB repository. Population-representative data, primarily from national and subnational cross-sectional surveys, were used for modelling cause-specific vision impairment. RAAB surveys, which focus on individuals 50 years and older, were crucial for data collection in LMIC regions, ensuring a comprehensive and reliable analysis (appendix 1 pp 11–13). The methodology for RAAB surveys is detailed in a previous study.[16]

Studies were included based on the following two criteria: first, visual acuity had to be measured using a test chart compatible with the Snellen scale, and second, the sample needed to be representative of the general population. Studies relying on self-reported vision loss were excluded. Vision impairment was categorised according to the ICD 11th edition, which defines three severity levels: moderate vision loss (visual acuity ≥6/60 and <6/18), severe vision loss (visual acuity ≥3/60 and <6/60), and blindness (visual acuity <3/60 or a visual field of less than 10° around central fixation). The definition of AMD pertains to the age-related deterioration of the macula, the central portion of the retina responsible for central vision, resulting in central vision loss (appendix 1 pp 10–11).

Data preparation and processing

First, raw data were separated into datasets encompassing the GBD-defined vision loss envelopes for all-cause moderate and severe vision impairment, as well as blindness. A mixed-effects meta-regression tool, developed by the Institute for Health Metrics and Evaluation and known as MR-BRT (Meta Regression–Bayesian, Regularised, Trimmed), was used to adjust non-reference data to align with the reference definition of presenting vision data within the WHO severity categories. MR-BRT is specifically designed to account for between-study heterogeneity as part of uncertainty adjustments and to trim outlier input data, thereby improving the reliability of the estimates. This adjustment process was applied to data from studies that did not use RAAB methods. Data collected using the RAAB methodology were further adjusted to align with comprehensive surveys to act as the reference definitions using the same adjustment factors applied to all-cause moderate and severe vision impairment and blindness (appendix 1 pp 13–16). This approach was adopted because a substantially larger volume of data was available for all-cause moderate vision impairment, severe vision impairment, and blindness compared with data for individual specific causes. This allowed for the development of more data-rich models, ensuring robust estimates across these categories. The methodological details are presented in previous studies.[15,17]

Disease Modelling Meta-Regression 2.1 estimation

In the GBD 2021 the estimation of non-fatal impairment due to macular degeneration was conducted using the Disease Modelling Meta-Regression 2.1 (DisMod-MR 2.1) model, a Bayesian mixed-effects meta-regression tool designed for non-fatal disease modelling. This method, described in detail elsewhere,[13] employs a compartmental model with age integration to ensure consistency across all disease parameters using differential equations with appropriate boundary conditions (appendix 1 pp 17–19). For vision-related diseases such as macular degeneration, which do not have a fatal component, DisMod-MR 2.1 focuses exclusively on estimating prevalence. The model incorporates an offset log-normal approach with fixed effects for location-specific covariates and random effects to account for variations across locations. Input data from all locations are integrated into a mixed-effects non-linear model to produce a global estimate of disease burden. The outputs of this global model (including global fit, fixed effects, and random effects) are cascaded as priors to generate estimates for GBD super-regions, regions, countries, and subnational areas within 21 countries. This hierarchical cascade approach ensures consistency across all geographical levels.

Modelling and post processing

The estimation of YLDs for macular degeneration followed a structured approach using DisMod-MR 2.1 and

accounted for location-specific covariates with fixed effects and variations across locations through random effects. After using DisMod-MR 2.1 to generate prevalence estimates for vision loss severity categories, these estimates were used to calculate YLDs by multiplying prevalence with corresponding disability weights, which measure the degree of health impairment on a 0 to 1 scale (0 for perfect health to 1 for death-equivalent health loss). Uncertainty was quantified using 500 comorbidity-corrected YLDs and disability weight samples, assuming no correlation between the two, with 95% uncertainty intervals (UIs) determined from the resulting distribution. This hierarchical approach ensured robust, location-specific estimates of YLDs, incorporating the latest prevalence data and disability weights while adjusting for comorbidity. Further detail is provided in appendix 1 (pp 20–24).

Forecasting model for 2050

The final estimates for GBD 2021 cover the years 1990 to 2021. Prevalence for non-fatal conditions, where mortality was not observed, was primarily modelled using linear mixed-effects models to directly estimate prevalence. For forecasting, a generalised ensemble modelling approach was applied, incorporating 12 distinct submodels based on two primary strategies: the annualised rate of change and a two-stage spline model using the MR-BRT. Each submodel employed six recency-weighting parameters (Ω), ranging from 0 to 2·5, with higher values assigning greater weight to more recent data. The ensemble model's performance was evaluated using root-mean-square error. Additionally, population attributable fractions were incorporated to account for the influence of risk factors, enabling forecasts for global, sex-specific scenarios under two different versions. Further methodological details are provided in appendix 1 (pp 26–35).

Risk factors

The GBD 2021 introduced several advancements in estimating risk exposure levels, relative risks, and attributable burdens compared with previous GBDs. For 211 risk–outcome pairs, the burden-of-proof risk function analysis was used to address unexplained heterogeneity across studies in the input data, providing a more conservative interpretation of risk–outcome associations. To facilitate the interpretation and comparison of burden-of-proof risk function metrics across risk factors, summary risk–outcome scores were calculated and mapped to a star rating system (ranging from one star to five stars) to summarise the strength of evidence for these associations. These updates incorporated findings from new or revised systematic reviews conducted since 2019. Overall, the GBD 2021 risk factor analysis used data from 54 561 distinct sources to generate epidemiological estimates for 88 risk factors and 631 associated risk–outcome pairs. Risk factors were classified within a hierarchical structure comprising four levels, with level one categorised into environmental and occupational, behavioural, and metabolic risks. Each risk factor was further subdivided into more specific categories at subsequent levels.

For macular degeneration, tobacco use—classified as a level one behavioural risk and level two specific risk—was the only risk factor that met the inclusion criteria for analysis. Tobacco remained a validated risk factor for AMD in both GBD 2019 and GBD 2021, despite the introduction of more rigorous and updated evaluation methodologies. Other potential risk factors for AMD did not meet the GBD inclusion thresholds, highlighting the need for further research to better establish their relevance. The assessment of all risk–outcome pairs followed stringent criteria established by the GBD collaborators, with continual updates to ensure consistency with emerging scientific evidence. Comprehensive methodological details regarding these evaluations are provided in appendix 1 (pp 36–42).

Healthcare Access and Quality Index

This study examines health-care access and quality for AMD within defined age groups, based on the Organisation for Economic Co-operation and Development definition of the working-age population (age 15–64 years) and Nolte and McKee's avoidable mortality age limit of 74 years.[18] The Healthcare Access and Quality (HAQ) Index quantifies health-care performance on a scale from 0 to 100, where 0 represents the lowest observed performance and 100 the highest performance. The Index standardises the effects of cause-specific factors and risk exposures through an average weighting system to allow meaningful comparisons across age groups, years, and countries.[19] Separate HAQ Index estimates were calculated for each country, year, and age group. Additionally, the study assessed convergence trends between high-SDI countries and those in lower SDI quintiles to evaluate progress in improving health-care access and quality over time. Further methodological details are provided in appendix 1 (pp 42–45).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Global burden of vision impairment due to AMD

163 RAAB surveys and 107 non-RAAB studies were used to estimate vision impairment attributable to AMD. The distribution of these studies by country, categorised as RAAB and non-RAAB studies, is presented in appendix 1 (pp 11–13). The age-standardised prevalence and DALY rates of AMD at the regional level are illustrated in figure 1; the table presents the AMD rates for 1990, 2021, and the annual percentage change.

In 2021, the western sub-Saharan Africa region showed the highest age-standardised prevalence rate (229·48 [95% UI 185·45 to 281·21] per 100 000 of the population), followed by the North Africa and Middle East region (177·95 [144·80 to 218·13]), and the east Asia region (121·81 [100·23 to 148·40]). The western sub-Saharan Africa region also showed the highest age-standardised DALY rate (14·73 [95% UI 10·43 to 20·56] per 100 000 of the population), followed by the North Africa and Middle East region (14·04 [9·60 to 9·61]) and eastern sub-Saharan Africa (11·11 [7·39 to 15·78]; figure 1 and table). Globally, age-standardised prevalence rates decreased by 5·53% (−8·84 to −2·23) from 1990 (99·50 [83·16 to 118·04]) to 2021 (94·00 [78·32 to 114·42]), while age-standardised DALY rates decreased by 19·09% (−22·56 to −15·42) over the same period (8·38 [5·70 to 11·53] in 1990 to 6·78 [4·70 to 9·32] in 2021; table). Regionally, an increase in age-standardised prevalence rates compared with 1990 was observed only in central sub-Saharan Africa and southern sub-Saharan Africa, with increases of 5·42% and 9·13%, respectively. However, no rise in age-standardised DALY rates compared to 1990 was noted in any region (table).

In 2021, the number of cases was highest in the east Asia region (2·68 million [95% UI 2·21–3·30]), followed by the south Asia region (1·58 million [1·29–1·96]), and the western Europe region (0·94 million [0·79–1·11]; appendix 1 pp 52–53). The numbers of DALYs were also highest in the east Asia region (0·15 million [0·11–0·21]), followed by the south Asia region (0·11 million [0·08–0·16]), and the western Europe region (0·09 million [0·06–0·13]; appendix 1 pp 54–55). Globally, the number of individuals with vision impairment due to AMD more than doubled, rising from 3·64 million (95% UI 3·04–4·35) in 1990 to 8·06 million (6·71–9·82) in 2021 (appendix 1 pp 56–58). Similarly, the number of DALYs increased by 91% during the same
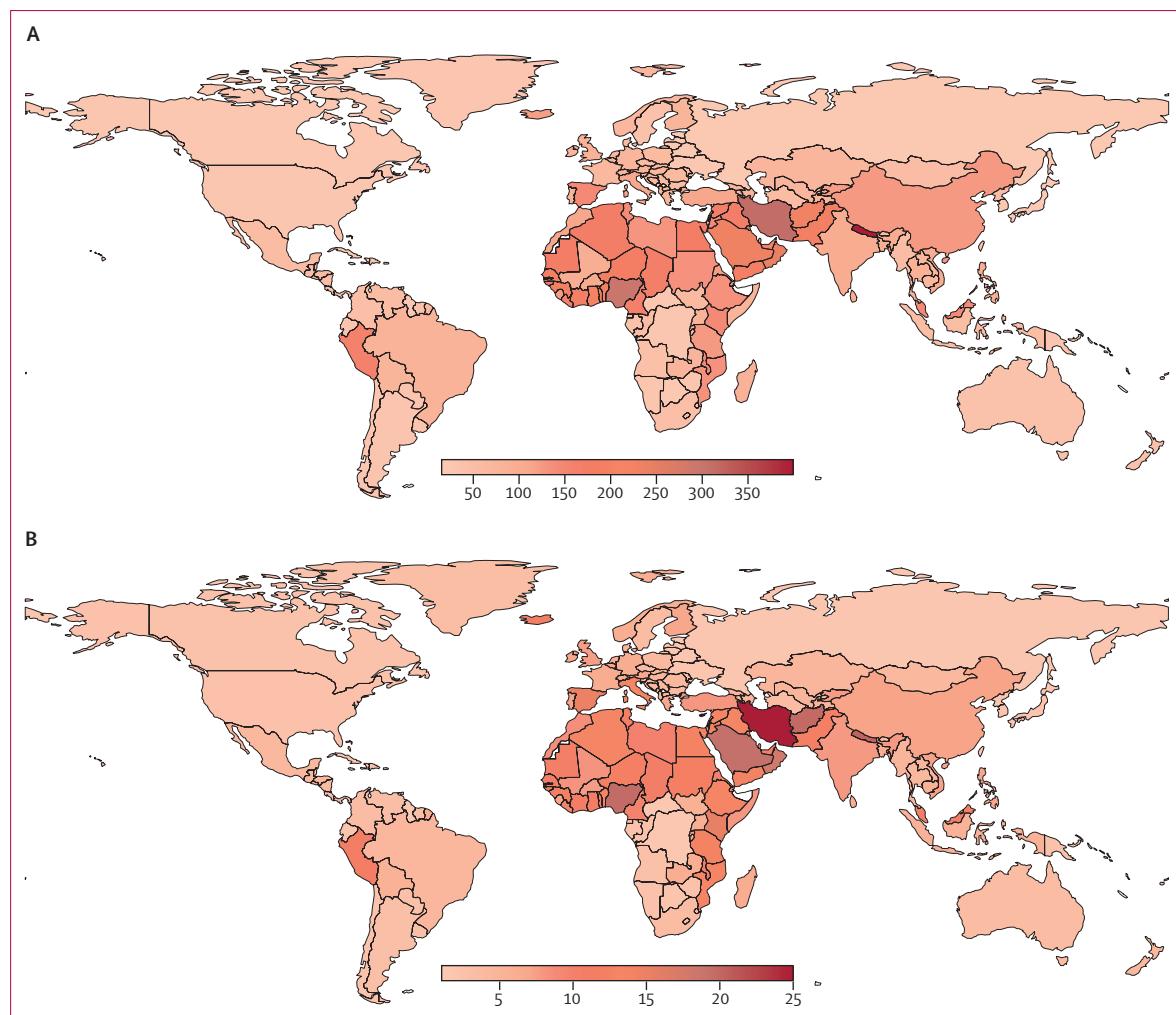
Figure 1: **Global distribution of age-related macular degeneration in both sexes, 2021**
Age-standardised prevalence (A) and DALY rate (B) per 100 000 of the population, 2021. DALY=disability-adjusted life-year.

	Prevalence			DALYs		
	1990 (95% UI)	2021 (95% UI)	Annual percentage change between 1990 and 2021, % (95% UI)	1990 (95% UI)	2021 (95% UI)	Annual percentage change between 1990 and 2021, % (95% UI)
Global	99·50 (83·16 to 118·04)	94·00 (78·32 to 114·42)	−5·53% (−8·84 to −2·23)	8·38 (5·70 to 11·53)	6·78 (4·70 to 9·32)	−19·09% (−22·56 to −15·42)
Sex						
Male	92·23 (76·87 to 110·83)	87·10 (71·99 to 106·29)	−5·56% (−8·82 to −2·45)	7·37 (5·01 to 10·24)	6·01 (4·15 to 8·29)	−18·48% (−22·13 to −14·71)
Female	104·34 (87·50 to 123·10)	99·53 (82·98 to 120·72)	−4·62% (−8·05 to −1·13)	9·04 (6·16 to 12·45)	7·38 (5·11 to 10·12)	−18·40% (−21·97 to −14·49)
SDI regions						
Low SDI	144·70 (120·56 to 171·58)	139·92 (114·54 to 171·01)	−3·31% (−7·20 to 1·30)	11·90 (8·19 to 16·58)	10·08 (6·91 to 13·86)	−15·31% (−19·41 to −10·62)
Low-middle SDI	138·32 (114·13 to 165·93)	104·67 (85·46 to 127·94)	−24·32% (−27·12 to −21·46)	11·43 (7·79 to 16·04)	7·64 (5·28 to 10·75)	−33·21% (−36·41 to −30·04)
Middle SDI	114·58 (94·89 to 138·84)	107·56 (88·68 to 131·24)	−6·13% (−9·27 to −3·19)	8·65 (5·85 to 12·13)	7·26 (5·00 to 9·96)	−16·09% (−19·70 to −12·03)
High-middle SDI	100·42 (84·93 to 118·77)	104·55 (87·88 to 126·60)	4·11% (−0·84 to 9·36)	8·65 (5·88 to 11·82)	7·40 (5·15 to 10·14)	−14·47% (−19·11 to −9·26)
High SDI	56·98 (47·61 to 67·51)	48·43 (40·55 to 57·77)	−15·01% (−17·78 to −12·16)	5·48 (3·68 to 7·35)	4·08 (2·76 to 5·49)	−25·57% (−28·63 to −22·40)
Central Europe, eastern Europe, and central Asia						
Central Asia	77·20 (61·54 to 96·52)	74·59 (59·75 to 93·95)	−3·38% (−6·78 to −0·32)	5·16 (3·56 to 7·16)	4·76 (3·25 to 6·70)	−7·68% (−13·47 to −2·20)
Central Europe	64·32 (52·90 to 77·73)	60·30 (49·02 to 74·97)	−6·25% (−9·45 to −3·41)	4·72 (3·22 to 6·53)	4·03 (2·77 to 5·61)	−14·63% (−18·78 to −9·96)
Eastern Europe	27·07 (22·15 to 32·65)	24·51 (20·03 to 29·61)	−9·46% (−12·21 to −6·73)	2·35 (1·54 to 3·27)	1·93 (1·28 to 2·69)	−17·84% (−22·39 to −12·56)
High-income regions						
Australasia	44·46 (36·72 to 52·45)	37·76 (30·65 to 44·98)	−15·05% (−20·13 to −9·71)	4·83 (3·16 to 6·86)	3·73 (2·43 to 5·22)	−22·76% (−30·65 to −13·96)
High-income Asia Pacific	23·69 (19·74 to 28·57)	20·57 (17·16 to 24·97)	−13·19% (−16·41 to −10·20)	2·51 (1·60 to 3·50)	1·99 (1·31 to 2·76)	−20·67% (−24·92 to −16·21)
High-income North America	29·77 (24·90 to 35·14)	27·30 (22·77 to 32·60)	−8·30% (−10·33 to −6·31)	3·01 (2·03 to 4·16)	2·58 (1·77 to 3·52)	−14·25% (−17·55 to −10·55)
Southern Latin America	38·04 (30·42 to 46·34)	32·32 (25·89 to 39·45)	−15·02% (−19·86 to −10·40)	3·74 (2·39 to 5·25)	2·79 (1·82 to 3·85)	−25·33% (−32·51 to −16·55)
Western Europe	107·40 (89·61 to 126·02)	85·55 (71·62 to 101·13)	−20·34% (−23·14 to −17·36)	11·76 (7·83 to 15·93)	8·49 (5·68 to 11·35)	−27·79% (−30·72 to −24·34)
Latin America and Caribbean						
Andean Latin America	118·47 (95·50 to 146·51)	113·60 (92·60 to 140·13)	−4·11% (−10·89 to 2·98)	9·28 (6·33 to 12·97)	7·92 (5·46 to 11·00)	−14·64% (−23·03 to −6·01)
Caribbean	26·10 (20·88 to 32·83)	23·58 (18·71 to 29·36)	−9·64% (−12·98 to −5·47)	2·22 (1·44 to 3·10)	1·78 (1·17 to 2·50)	−19·89% (−27·19 to −12·30)
Central Latin America	57·92 (47·41 to 70·66)	50·91 (41·44 to 63·41)	−12·11% (−15·43 to −8·78)	4·97 (3·41 to 6·89)	3·84 (2·61 to 5·29)	−22·67% (−26·98 to −18·19)
Tropical Latin America	81·43 (67·39 to 98·71)	80·30 (65·95 to 98·34)	−1·40% (−4·85 to 2·39)	4·85 (3·41 to 6·64)	4·44 (3·13 to 6·09)	−14·25% (−17·55 to −10·55)
North Africa and Middle East	186·36 (151·99 to 221·21)	177·95 (144·80 to 218·13)	−4·51% (−8·91 to −0·44)	16·73 (11·36 to 23·55)	14·04 (9·60 to 19·61)	−16·07% (−19·90 to −11·63)

(Table continues on next page)

period, from 0·30 million (95% UI 0·21–0·42) in 1990 to 0·58 million (0·40–0·80) in 2021 (appendix 1 pp 59–60).

Moderate to severe vision loss and blindness due to AMD
The total prevalence of vision impairment due to AMD, categorised by moderate vision loss, severe vision loss, and blindness, showed notable increases between 1990 and 2021. Cases of moderate vision loss rose from 2·13 million (95% UI 1·64–2·76) in 1990 to 5·39 million (4·18–7·00) in 2021, severe vision loss increased from 0·39 million (0·28–0·51) to 0·79 million (0·58–1·03), and blindness rose from 1·12 million (0·84–1·47) to 1·88 million (1·41–2·46). By contrast, age-standardised rates revealed varying trends. Per 100 000

	Prevalence			DALYs		
	1990 (95% UI)	2021 (95% UI)	Annual percentage change between 1990 and 2021, % (95% UI)	1990 (95% UI)	2021 (95% UI)	Annual percentage change between 1990 and 2021, % (95% UI)
(Continued from previous page)						
South Asia	157·88 (129·30 to 191·03)	113·88 (93·23 to 139·40)	–27·87% (–31·04 to –24·81)	13·12 (8·83 to 18·69)	8·23 (5·67 to 11·51)	–37·31% (–40·84 to –33·44)
Southeast Asia, east Asia, and Oceania						
East Asia	118·72 (97·65 to 144·26)	121·81 (100·23 to 148·40)	2·60% (–0·72 to 6·14)	7·23 (5·10 to 10·02)	7·04 (4·89 to 9·69)	–2·61% (–6·41 to 2·09)
Oceania	37·83 (30·17 to 46·91)	32·84 (26·10 to 41·15)	–13·20% (–17·48 to –8·77)	3·70 (2·41 to 5·36)	2·87 (1·88 to 4·10)	–22·53% (–29·92 to –14·25)
Southeast Asia	96·28 (79·45 to 114·03)	77·01 (63·35 to 92·62)	–20·02% (–24·94 to –14·78)	8·51 (5·57 to 12·16)	5·82 (3·92 to 8·26)	–31·58% (–35·77 to –26·81)
Sub-Saharan Africa						
Central sub-Saharan Africa	31·73 (25·32 to 39·93)	33·45 (26·83 to 42·30)	5·42% (0·89 to 10·36)	2·00 (1·32 to 2·81)	2·02 (1·36 to 2·89)	1·30% (–7·94 to 11·68)
Eastern sub-Saharan Africa	129·97 (106·45 to 152·97)	116·04 (94·08 to 138·20)	–10·72% (–15·06 to –5·54)	14·52 (9·78 to 20·28)	11·11 (7·39 to 15·78)	–23·52% (–27·30 to –19·29)
Southern sub-Saharan Africa	40·87 (33·37 to 50·23)	44·60 (36·73 to 54·69)	9·13% (6·25 to 12·20)	3·19 (2·12 to 4·50)	3·28 (2·21 to 4·59)	2·67% (–2·42 to 7·83)
Western sub-Saharan Africa	226·01 (185·74 to 273·72)	229·48 (185·45 to 281·21)	1·54% (–2·31 to 5·45)	15·46 (11·10 to 21·22)	14·73 (10·43 to 20·56)	–16·07% (–19·90 to –11·63)

DALYs=disability-adjusted life-years. SDI=Socio-demographic Index. UI=uncertainty interval.

Table: Global age-standardised rates per 100 000 of the population and annual percentage change of prevalence and DALYs for age-related macular degeneration, 1990–2021

of the population, age-standardised rates increased for moderate vision loss (56·98 [95% UI 44·40–72·90] in 1990 to 62·46 [48·59–80·76] in 2021), but declined for severe vision loss and blindness (10·49 [7·68–13·55] to 9·22 [6·81–11·84] and 32·02 [24·57–41·51] to 22·32 [16·81–29·05], respectively) over the same period (appendix 1 pp 61–63).

The number of YLDs also increased across all categories. YLDs from moderate vision loss rose from 0·06 million (95% UI 0·04–0·10) in 1990 to 0·16 million (0·09–0·26) in 2021; YLDs from severe vision loss rose from 0·07 million (0·04–0·10) to 0·14 million (0·09–0·21); and YLDs from blindness rose from 0·20 million (0·12–0·30) to 0·34 million (0·20–0·50). Age-standardised rates per 100 000 of the population showed a different pattern, with moderate vision loss rates increasing slightly (1·71 [0·97–2·75] in 1990 to 1·88 [1·07–3·01] in 2021), while rates for severe vision loss and blindness declined (1·84 [1·18–2·79] to 1·62 [1·03–2·44] and 5·74 [3·48–8·52] to 4·00 [2·43–5·93], respectively; appendix 1 pp 64–65).

Burden of vision impairment due to AMD according to age and sex

The results of the subgroup analysis are shown in figure 2 and appendix 1 (pp 66–67). Across all age groups and measures, females exhibited a higher burden of AMD than males.

In 2021, the prevalence in females was higher in both number and rate, with 4·66 million cases (95% UI 3·88–5·65) with a rate of 118·46 per 100 000 of the population (95% UI 98·73–143·71). In contrast, males had 3·40 million cases (2·81–4·17) and a rate of 85·86 per 100 000 of the population (70·93–105·25). Similarly, females showed higher DALY counts and rates, with 3·35 million cases (2·39–4·74) with a rate of 8·78 per 100 000 of the population (95% UI 6·09–12·05). For males, the DALY count was 2·33 million DALYs (1·60–3·23), and the rate was 5·87 per 100 000 of the population (4·04–8·16). The highest prevalence and DALY counts were observed in the age 65–69 years group, with 1·55 million cases (95% UI 1·18–2·03) and 1·02 million DALYs (0·07–1·48), respectively. An increasing trend in prevalence and DALY rates was noted with advancing age for both sexes (figure 2; appendix 1 pp 66–67).

Burden of vision impairment due to AMD according to SDI and correlation with the HAQ Index

Total counts of prevalence and DALYs, stratified by SDI quintiles from 1990 to 2021, are presented in appendix 1 (pp 68–75). In 2021, the highest prevalence of AMD and highest DALYs were observed in the high-middle SDI quintile (2·10 million cases [95% UI 1·76–2·56] and 0·15 million [0·10–0·20], respectively).

Despite the higher total counts in the high-middle SDI quintile, age-standardised prevalence and DALY rates tended to decrease with higher SDI quintiles. In 2021, age-standardised prevalence rates were highest in the low SDI quintile (139·92 per 100 000 of the population [95% UI 114·54–171·01]). Low-middle SDI, middle SDI,
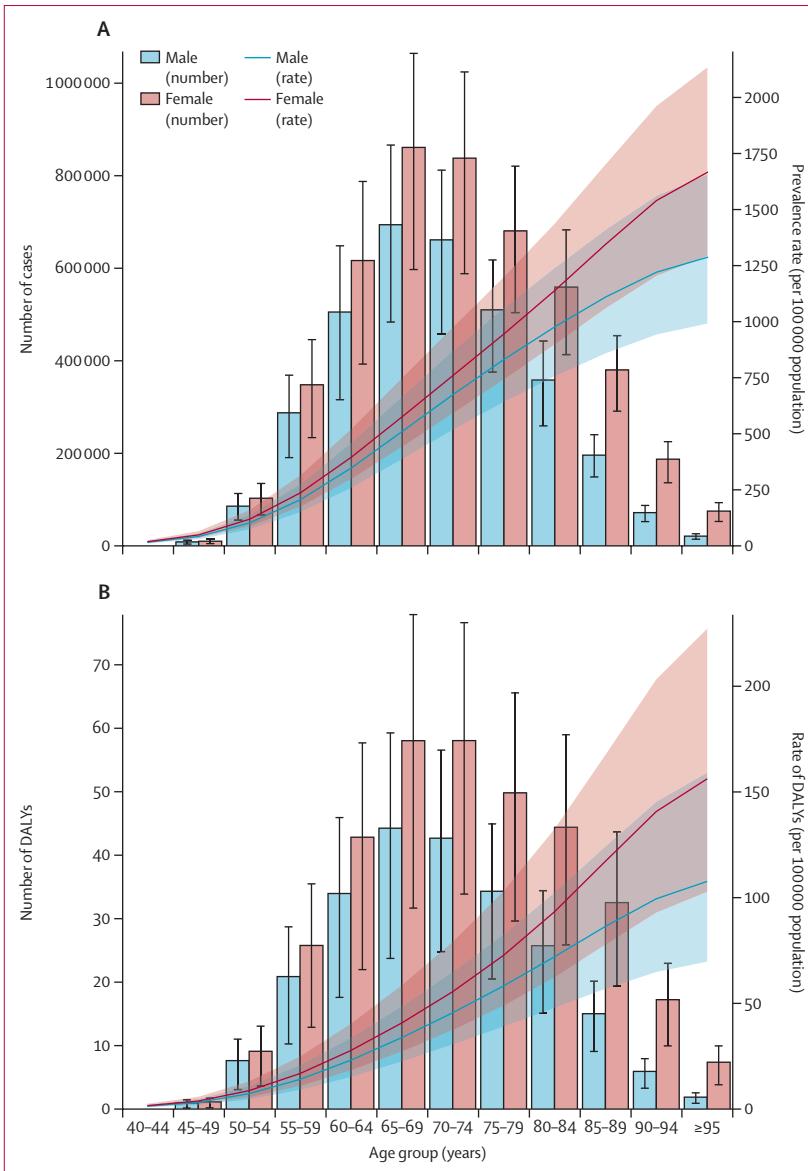
Figure 2: Rate per 100 000 of the population of prevalence (A) and DALYs (B) from age-related macular degeneration at the global level by age group and sex, 2021
Shaded regions indicate 95% uncertainty intervals. DALYs=disability-adjusted life-years.

and high-middle SDI exhibited similar rates (104·67 [85·46–127·94], 107·56 [88·68–131·24], and 104·55 [87·88–126·60], respectively). The high SDI quintile showed the lowest prevalence rate of 48·43 (40·55–57·77; figure 3A; appendix 1 pp 72–73). A similar pattern was observed for age-standardised DALY rates. The low SDI quintile had a highest rate of 10·08 per 100 000 of the population (95% UI 6·91–13·86), while the high SDI quintile had the lowest rate (4·08 [2·76–5·49]). Rates for low-middle, middle, and high-middle SDI quintiles were 7·64 (5·28–10·75), 7·26 (5·00–9·96), and 7·40 (5·15–10·14), respectively (figure 3B and appendix 1 pp 74–75).

From 1990 to 2021, age-standardised prevalence and DALY rates exhibited a general downward trend across all SDI quintiles. The largest prevalence decrease occurred in the low-middle SDI quintile (138·32 per 100 000 of the population [95% UI 114·13–165·93] in 1990 to 104·67 [85·46–127·94] in 2021). Decreases were also observed in the high SDI quintile (56·98 [47·61–67·51] to 48·43 [40·55–57·77]), the middle SDI quintile (114·58 [94·89–138·84] to 107·56 [88·68–131·24]), the low-middle SDI quintile (138·32 [114·13–165·93] to 104·67 [85·46–127·94]), and the low SDI quintile (144·70 [120·56–171·58] to 139·92 [114·54–171·01]). By contrast, the high-middle SDI quintile showed a slight increase (100·42 [84·93–118·77] to 104·55 [87·88–126·60]; figure 3A; appendix 1 pp 74–75). The largest decrease in age-standardised DALY rates occurred in the low-middle SDI quintile (11·43 per 100 000 of the population [95% UI 7·79–16·04] in 1990 to 7·64 [5·28–10·75] in 2021). Decreases were also observed in the high SDI quintile (5·48 [3·68–7·35] to 4·08 [2·76–5·49]), high-middle SDI quintile (8·65 [5·88–11·82] to 7·40 [5·15–10·14]), middle SDI quintile (8·65 [5·85–12·13] to 7·26 [5·00–9·96]), and low SDI quintile (11·90 [8·19–16·58] to 10·08 [6·91–13·86]; figure 3B; appendix 1 pp 79–80).

Appendix 1 (p 49) illustrates the negative correlation between prevalence rates, DALY rates, and the HAQ Index. Specifically, the analysis reveals a negative correlation between prevalence rates and the HAQ Index (r –0·217, p<0·001). Additionally, DALY rates are negatively correlated with the HAQ Index (r –0·179, p=0·011).

Burden of vision impairment due to AMD attributable to tobacco

In 2021, the total number of DALYs attributable to tobacco was 0·06 million (95% UI 0·03–0·10). Males were estimated to have 0·05 million (0·03–0·07) DALYs attributable to tobacco, or 18·72% (95% UI 11·69–26·02) of all AMD DALYs in males, whereas females were estimated to have 0·01 million (0·01–0·02) DALYs attributable to tobacco, or 3·89% (95% UI 2·20–5·83) of all DALYs from AMD in females in 2021 (appendix 1 pp 76–79).

A downward trend of attribution of tobacco to age-standardised DALYs is observed in all SDI levels. Globally, the percentages of DALYs attributable to tobacco decreased 20·03% from 12·45% (95% UI 7·73–17·37) in 1990 to 9·96% (6·12–14·06) in 2021. Specifically, the effect of tobacco on DALYs decreased across all SDI levels: 13·62% (95% UI 8·10–19·55) in 1990 to 10·00% (5·80–14·63) in 2021 for the high SDI quintile, 13·07% (8·14–17·97) to 11·81% (7·38–16·38) for the high-middle SDI quintile, 12·85% (8·14–17·57) to 10·03% (6·24–14·02) for the middle SDI quintile, 11·92% (7·40–16·44) to 9·24% (5·67–13·17) for the low-middle SDI quintile, and 7·84% (4·74–10·96) to 6·01% (3·56–8.60) for the low SDI quintile (figure 4; appendix 1 pp 76–79).
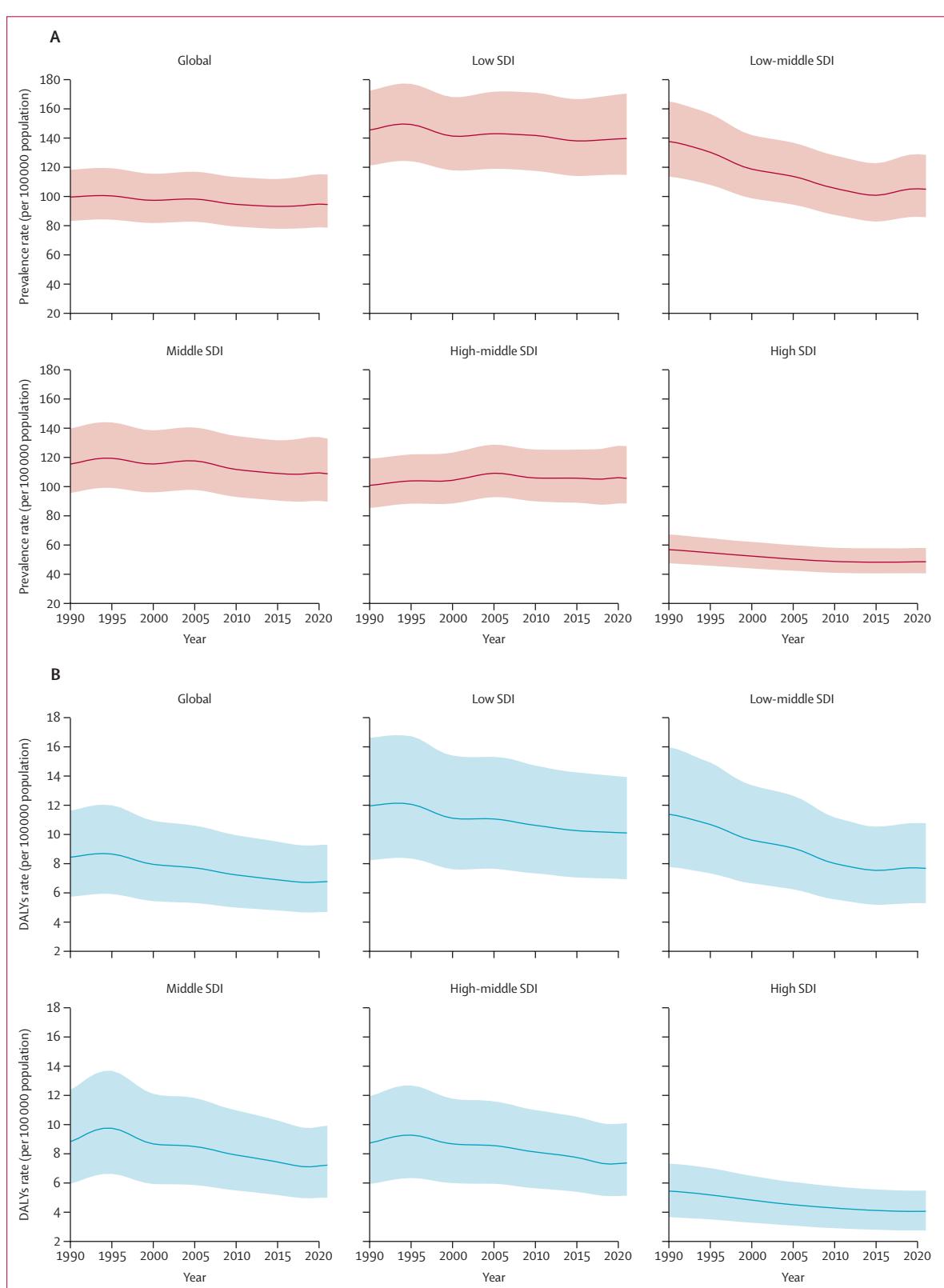
Figure 3: Age-standardised prevalence rate (A) and DALYs (B) per 100 000 of the population from age-related macular degeneration for both sexes by SDI, 2021
Shaded regions indicate 95% uncertainty intervals. DALYs=disability-adjusted life-years. SDI=Socio-demographic Index.
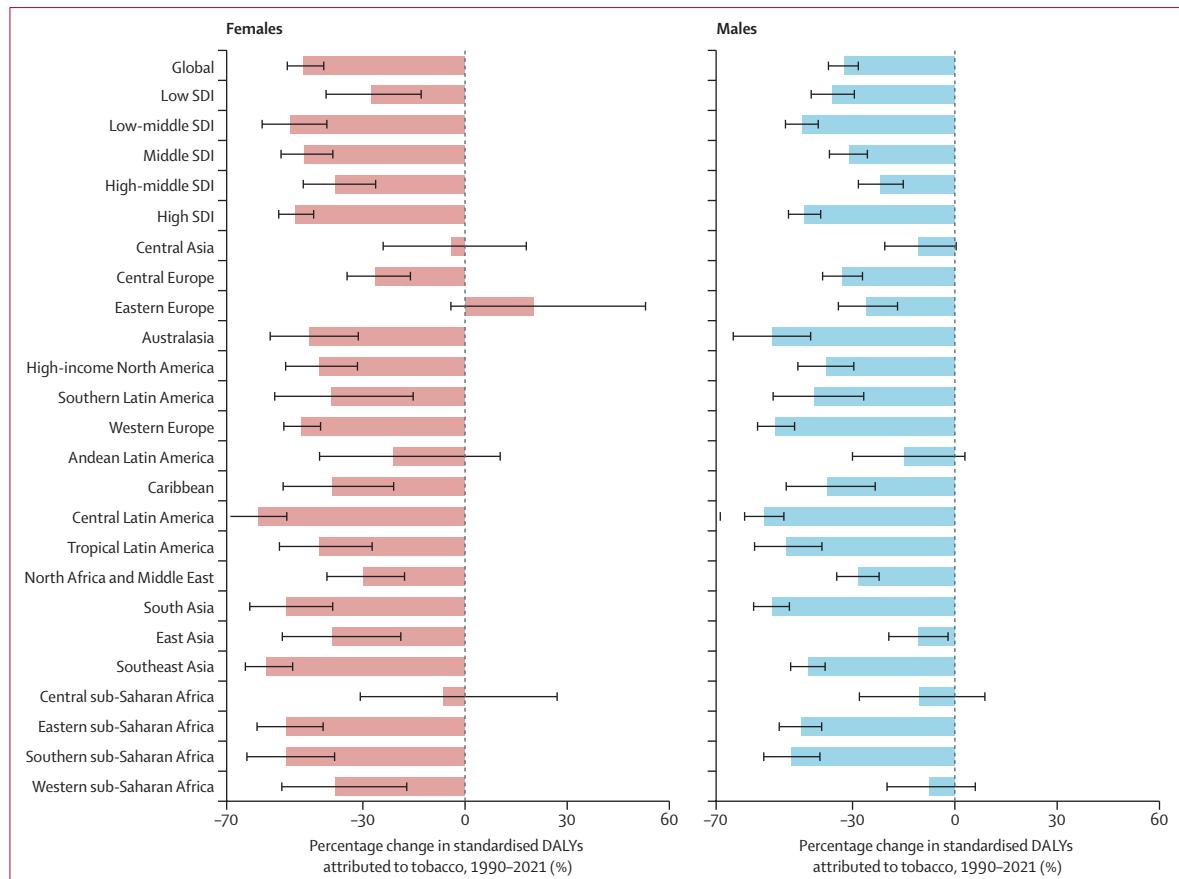
Figure 4: Percentage change in age-standardised DALYs attributed to tobacco as a risk factor from age-related macular degeneration by the SDI groups and regions, 1990–2021
Error bars indicate 95% uncertainty intervals. DALYs=disability-adjusted life-years. SDI=Socio-demographic Index.

Forecasting the burden of vision impairment due to AMD until 2050

The forecasted burden of vision impairment due to AMD is presented in figure 5 and appendix 1 (pp 80–83). In 2021, the number of individuals affected was estimated at 3·40 million males (95% UI 2·81–4·17) and 4·66 million females (3·88–5·65). These numbers are projected to increase substantially in the coming decades. By 2030, the burden is expected to rise to 5·82 million for males (3·69–9·16) and 7·54 for million females (5·44–10·46); the burden is forecasted to increase again to reach 7·43 million males (4·71–11·69) and 9·95 million females (7·17–13·80) by 2040. By 2050, the burden is projected to increase further to 9·02 million males (5·72–14·20) and 12·32 million females (8·88–17·08; figure 5A, B; appendix 1 pp 80–83) to a total of 21·34 million cases globally.

If the risk of tobacco use is eliminated, a substantial reduction in the burden of vision impairment due to AMD is expected for both sexes, with an overall reduction in 2050 of approximately 19·32 million. For males, the burden is projected to decrease as follows: in 2030, from 5·82 million (95% UI 3·69–9·16) to 5·27 million

(3·61–7·70); in 2040, from 7·43 million (4·71–11·69) to 6·73 million (4·60–9·82); and in 2050, from 9·02 million (5·72–14·20) to 8·17 million (5·59–11·92; figure 5C, D; appendix 1 pp 80–83). For females, similar reductions are expected: in 2030, from 7·54 million (95% UI 5·44–10·46) to 6·84 million (5·26–8·88); in 2040, from 9·95 million (7·17–13·80) to 9·01 million (6·94–11·71); and in 2050, from 12·32 million (8·88–17·08) to 11·15 million (8·58–14·48; figure 5E, F; appendix 1 pp 80–83). Corresponding rates per 100 000 of the population also display decreases when tobacco use is eliminated (appendix 1 pp 80–83).

Discussion
Key findings
This study provides a comprehensive assessment of the global, regional, and national burden of vision impairment due to AMD, using estimates from GBD 2021. The total numbers, prevalence, and DALYs have increased since 1990, with a particularly notable rise in the east Asia region. This increase is probably driven by population growth and ageing, considering that age-standardised prevalence and DALY rates have shown a downward trend
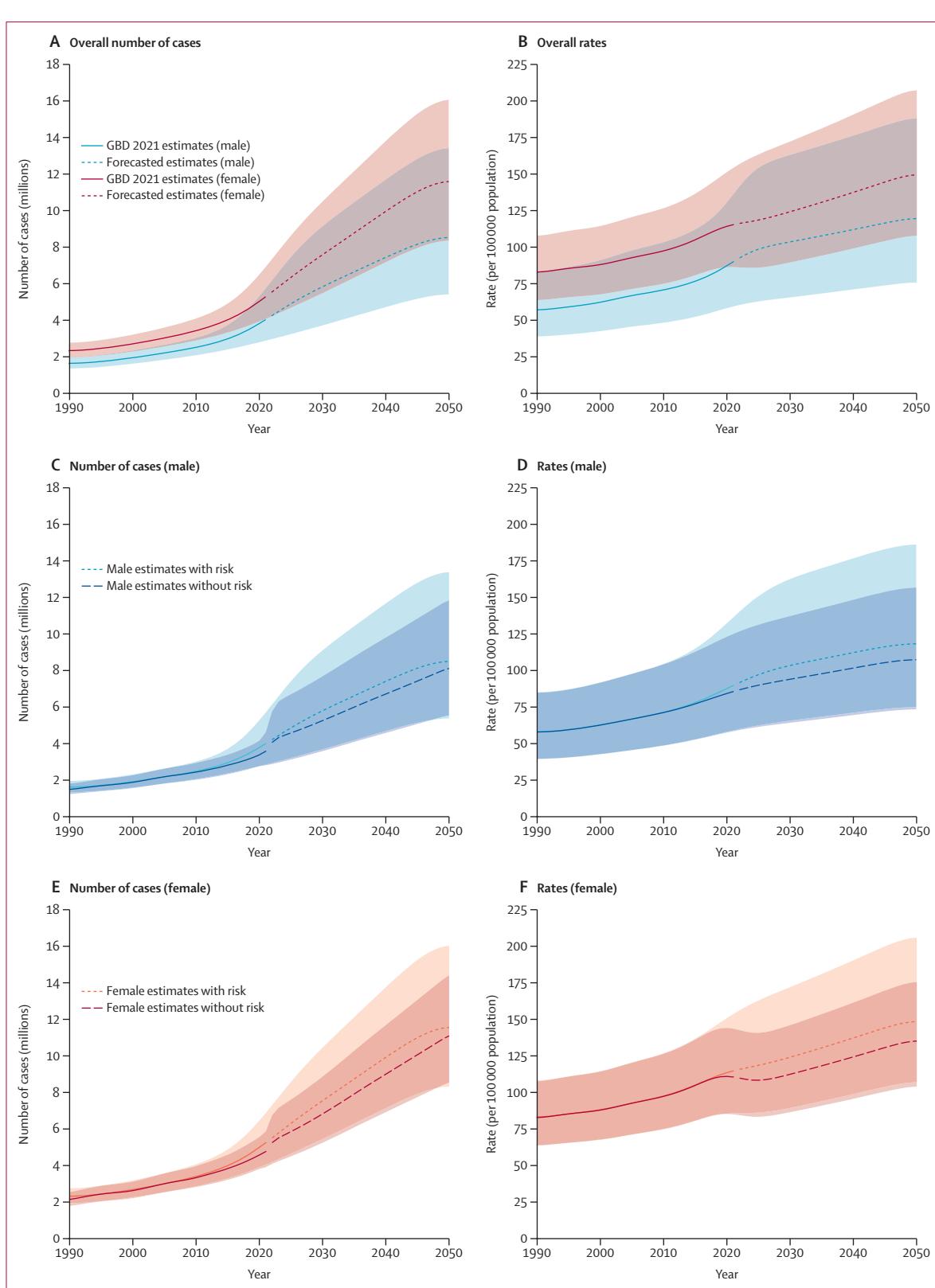
Figure 5: **Forecasted prevalent cases and rates per 100 000 of the population of age-related macular degeneration by sex, comparing estimates with and without risk factor, all ages, 1990–2050** Number of cases and rates overall (A,B), for males (C,D), and for females (E,F). The shaded regions represent 95% uncertainty intervals, while the dashed line marks the forecast period beginning in 2022. The risk factor for this disease in this study is smoking.

(–5·53% and –19·09%, respectively) compared with 1990. Subgroup analysis revealed that females consistently had higher rates than males for all measures across all age groups. A negative correlation was observed between HAQ Index and prevalence and DALY rates, with higher SDI quintiles associated with lower rates. This relationship underscores the crucial role of health-care access and quality in mitigating the burden of AMD, and highlights disparities in health-care resources as a major contributor to the unequal global burden. Furthermore, a consistent downward trend in age-standardised prevalence and DALY rates has been observed across all SDI levels from 1990 to 2021. This decline might be partly explained by the reduction of DALYs attributable to tobacco use by 20·03% globally over the same period. Lastly, projections of AMD-related vision impairment through to 2050 indicate a continuous increase in its global burden. However, the forecasts also highlight the potential for substantial reductions through effective tobacco regulation, particularly in lower SDI regions.

Plausible underlying mechanism

AMD is a multifactorial disease characterised by a complex interplay between ageing, environmental risk factors, and genetic susceptibility.[20] Among these factors, ageing is the most prominent risk factor.[21,22] A discernible increase in prevalence rates with advancing age was observed, in line with the findings from Wong and colleagues' 2014 systemic review and meta-analysis that projected burden of AMD up to 2040.[7]

Distinctive findings in this study, compared to previous research and meta-analyses, include differences in the number of individuals affected by AMD. Unlike the review by Wong and colleagues, which estimated the total number of AMD cases without focusing on individuals with vision impairment,[7] this study specifically examined individuals with vision impairment due to AMD. Consequently, while Wong and colleagues estimated approximately 196 million people would be affected by AMD globally in 2020,[7] this study estimates approximately 8 million individuals with vision impairment caused by AMD in 2021. Recent data from the USA, which estimated that 1·49 million out of 18·34 million patients with AMD have vision-threatening late stage, correspond closely to this study's finding.[23]

Additionally, females exhibited higher prevalence and DALY rates than males in this study. There are reports indicating that hormonal differences might be associated with the progression of AMD.[24] Nevertheless, there is ongoing debate regarding the role of oestrogen, with some studies suggesting that oestrogen could have a protective effect against AMD due to its antioxidative and anti-inflammatory signalling cascades.[25,26] There are reports indicating the onset of exudative AMD is associated with the use of either endogenous or exogenous oestrogen.[27] Consequently, further investigation is necessary to conclusively clarify the effects of oestrogen on AMD.

An analysis of age-standardised DALY rates spanning the period from 1990 to 2021 revealed a consistent decline across all countries, excluding countries in central and southern sub-Saharan Africa. Additionally, a discernible global downward trend in age-standardised DALY rates was evident in all SDI quintiles. This reduction in DALY rates can be attributed to several factors. First, the implementation of the WHO Vision 2020 Act,[28] which mandates the training of adequate numbers of eye care providers at all levels and the establishment of essential infrastructure and technology, has probably played a pivotal role.[29] Vision 2020 has been instrumental in advocacy efforts by securing sufficient resources and the commitment to achieve its objectives.[29,30] Additionally, the emergence of novel medical resources such as anti-vascular endothelial growth factor (anti-VEGF) agents (eg, ranibizumab, aflibercept, faricimab, brolucizumab, and bevacizumab)[9,17] and ongoing research on treatments for non-exudative AMD, particularly geographic atrophy (eg, pegcetacoplan and avacincaptad pegol),[31] might have contributed to the decline in DALY rates. Furthermore, advancements in diagnostic technologies, particularly the widespread adoption of optical coherence tomography for both detection and treatment monitoring, have significantly improved accuracy in diagnosis and treatment selection.[9] However, given the substantial cost burden of anti-VEGF and disparities in medical resource allocation across different SDI quintiles, contribution of optical coherence tomography to the decrease in DALYs should not be overemphasised.[30,32] The global decline in tobacco use might have a more important role in decreasing age-standardised DALY rates across SDI quintiles.[33] Furthermore, improvements in HAQ Index across all SDI quintiles,[30] along with the heightened attention to personal health and education levels, probably contributed to the observed decline in age-standardised DALY rates.[34]

Clinical and policy implications

Ageing is intrinsic and an unmodifiable element, yet is the strongest risk factor in AMD.[35] Among modifiable risk factors, tobacco use is the most established, with previous research indicating a global three-fold increase in risk of AMD due to smoking.[9] Males were more significantly affected by tobacco than females across all regions in 2021 (18·72% [95% UI 11·69–26·02] for males vs 3·89% [2·20–5·83] for females). This disparity could be attributed to the substantial difference in smoking prevalence between sexes, with male prevalence notably higher in 2015 (25·0% in males vs 5·4% in females).[33] Surprisingly, a consistent decrease in the effect of tobacco on DALYs from 1990 to 2021 was observed across all SDI levels, potentially due to global efforts such as the implementation of the WHO Framework Convention on Tobacco Control, which have led to a decline in tobacco prevalence worldwide.[36] The effect of tobacco on DALYs in the low-middle SDI quintile decreased notably in 2021

from 1990, with the reduction in age-standardised DALY rates being the highest, at 33·21%. This implies that in countries with limited resources, such as medical facilities, reducing the influence of tobacco could lead to a decrease in DALYs. Indeed, evidence suggests that strengthening tobacco control measures, including taxation policies, could further reduce prevalence.[36] Targeting the reduction of modifiable risk factors is an essential strategy for preventing AMD. Thus, considering such evidence could be pivotal in future efforts to address AMD, particularly for lower SDI quintiles.

Although anti-VEGF treatments are known to be effective against the exudative form of AMD,[37] given that the majority of patients with AMD have the non-exudative form, it is essential to develop treatments and preventive measures specifically targeting non-exudative AMD.[17] As evidenced by the negative correlation between the HAQ Index and both prevalence and DALY rates, increased health-care resources are associated with a reduced burden of vision impairment due to AMD. However, access to costly treatments such as anti-VEGF therapies could be less accessible in low-income countries.[32] Additionally, the progression of AMD from early to late stages and the implementation of visual restoration strategies, such as retinal pigment epithelium allograft transplantation, might also vary based on the level of medical resources in each country.[9] To address the disproportionate burden of AMD globally, research on cost-effective treatment methods tailored to different SDI levels is essential. For instance, exploring the use of off-label bevacizumab might help reduce costs.[34] Additionally, a high dietary intake of lutein and zeaxanthin might help reduce the risk of late AMD in lower SDI quintiles.[10] Furthermore, prioritising service development for vulnerable groups in LMICs and implementing strategies to slow AMD progression could substantially reduce the global burden of AMD,[9] and future studies should emphasise this focus.

Strengths and limitations

Although our study benefited from a robust dataset comprised of national and regional levels, the present study is subject to several notable limitations. First, as this study used data from the GBD 2021, low data availability from certain countries, regions, and years cannot be overlooked. Consequently, due to this scarcity of data, descriptive statistics necessitated reliance on predictive modelling using covariates, potentially leading to less precise inferences compared with those for regions with more robust data. Second, an important limitation of our study is the absence of fundus photography data in certain regions, which are typically used for diagnosing AMD.[10] This deficiency limits our understanding of whether the exudative or non-exudative form of AMD is responsible for the vision impairment. The availability of such data would facilitate distinguishing between these forms, allowing us to estimate the effect of anti-VEGF treatments on reducing DALYs. Moreover, analysing the effects of non-exudative AMD separately could provide valuable insights on the burden of vision impairment due to AMD, considering the limited treatment options and their potentially large influence on DALYs.[17] Third, while this study provides data on the prevalence and DALYs of vision impairment due to AMD, there is a possibility that the burden of vision impairment due to AMD may have been underestimated, owing to the heterogeneous nature of AMD diagnostic classification. Fourth, the risk analysis focused solely on smoking as a risk factor, overlooking emerging risk factors such as low physical activity and lipid profiles.[9] Incorporating various risk factors could have enabled the assessment of each factor's contribution to DALYs, thereby aiding addressing AMD on a global scale. Lastly, the effect of genetic susceptibility on AMD was not investigated, particularly regarding ethnicity. While prevalence rates tend to be higher among groups of European ancestry,[7] our study, constrained by geographical data alone, did not reflect this aspect.

Despite these limitations, this study offers several strengths and novel contributions to the literature. Unlike previous global estimation studies,[7] our study used robust GBD data to analyse both prevalence and DALYs, providing a more comprehensive understanding of AMD's burden. AMD, as a lifelong disability, has become an increasingly important public health concern due to increased longevity, contributing significantly to vision impairment, particularly in high-income countries.[2] Thus, investigating DALYs rather than cross-sectional prevalence offers a more meaningful assessment of the effect of AMD on population health over time and informs strategies to mitigate the burden. Additionally, this study analysed the role of tobacco as a modifiable risk factor,[9] quantifying the use of tobacco's contribution to DALYs across different SDI levels and observing a clear downward trend. These findings underscore the importance of addressing tobacco use to reduce AMD's global burden effectively. Furthermore, by forecasting the burden of vision impairment due to AMD through to 2050, and comparing scenarios with and without the effect of tobacco, our analysis highlights the potential for significant reductions in AMD-related vision impairment through targeted tobacco regulation.

Conclusion

Vision impairment due to AMD remains a substantial global burden, affecting approximately 8 million individuals in 2021, with projections indicating an increase to 21·34 million by 2050. This study highlights the role of improved health-care access and reduced tobacco impact in lowering age-standardised DALY rates, particularly in lower SDI quintiles where resources are limited. Introducing cost-effective treatments and diagnostics, especially in LMICs, alongside tobacco regulation, could significantly reduce the global burden of AMD-related vision impairment.

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Please see appendix 3 (pp 13–16) for more detailed information about individual author contributions to the research, divided into the following categories: managing the overall research enterprise; writing the first draft of the manuscript; primary responsibility for applying analytical methods to produce estimates; primary responsibility for seeking, cataloguing, extracting, or cleaning data; designing or coding figures and tables; providing data or critical feedback on data sources; developing methods or computational machinery; providing critical feedback on methods or results; drafting the manuscript or revising it critically for important intellectual content; and managing the estimation or publications process. Members of the core research team for this topic area had full access to the underlying data used to generate estimates presented in this study (Ali H Mokdad, Jae Il Shin, and Dong Keon Yon). Yi Deun Jeong, Seoyoung Park, and Min Seo Kim contributed equally as first authors. Dong Keon Yon is the corresponding author. Jae Il Shin and Dong Keon Yon contributed equally. All authors had full access to the study data and had final responsibility for the decision to submit for publication. The corresponding author had full access to the data in the study and had final responsibility for the decision to submit for publication.

References

1 Fleckenstein M, Schmitz-Valckenberg S, Chakravarthy U. Age-related macular degeneration: a review. *JAMA* 2024; **331**: 147–57.

2 Burton MJ, Ramke J, Marques AP, et al. The *Lancet Global Health* Commission on global eye health: vision beyond 2020. *Lancet Glob Health* 2021; **9**: e489–551.

3 Hwang S, Kang SW, Kim SJ, et al. Impact of age-related macular degeneration and related visual disability on the risk of depression: a nationwide cohort study. *Ophthalmology* 2023; **130**: 615–23.

4 Ehrlich JR, Ramke J, Macleod D, et al. Association between vision impairment and mortality: a systematic review and meta-analysis. *Lancet Glob Health* 2021; **9**: e418–30.

5 Assi L, Chamseddine F, Ibrahim P, et al. A global assessment of eye health and quality of life: a systematic review of systematic reviews. *JAMA Ophthalmol* 2021; **139**: 526–41.

6 Marques AP, Ramke J, Cairns J, et al. Global economic productivity losses from vision impairment and blindness. *EClinicalMedicine* 2021; **35**: 100852.

7 Wong WL, Su X, Li X, et al. Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. *Lancet Glob Health* 2014; **2**: e106–16.

8 Xu T, Wang B, Liu H, et al. Prevalence and causes of vision loss in China from 1990 to 2019: findings from the Global Burden of Disease Study 2019. *Lancet Public Health* 2020; **5**: e682–91.

9 Guymer RH, Campbell TG. Age-related macular degeneration. *Lancet* 2023; **401**: 1459–72.

10 Mitchell P, Liew G, Gopinath B, Wong TY. Age-related macular degeneration. *Lancet* 2018; **392**: 1147–59.

11 Vision Loss Expert Group of the Global Burden of Disease Study. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. *Lancet Glob Health* 2017; **5**: e1221–34.

12 GBD 2021 Causes of Death Collaborators. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet* 2024; **403**: 2100–32.

13 GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet* 2024; **403**: 2133–61.

14 GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020; **396**: 1204–22.

15 GBD 2019 Blindness and Vision Impairment Collaborators, and the Vision Loss Expert Group of the Global Burden of Disease Study. Trends in prevalence of blindness and distance and near vision impairment over 30 years: an analysis for the Global Burden of Disease Study. *Lancet Glob Health* 2021; **9**: e130–43.

16 McCormick I, Butcher R, Ramke J, et al. The Rapid Assessment of Avoidable Blindness survey: review of the methodology and protocol for the seventh version (RAAB7). *Wellcome Open Res* 2024; **9**: 133.

17 GBD 2019 Blindness and Vision Impairment Collaborators, and the Vision Loss Expert Group of the Global Burden of Disease Study. Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of avoidable blindness in relation to VISION 2020: the Right to Sight: an analysis for the Global Burden of Disease Study. *Lancet Glob Health* 2021; **9**: e144–60.

18 Nolte E, McKee M. Measuring the health of nations: analysis of mortality amenable to health care. *BMJ* 2003; **327**: 1129.

19 GBD 2019 Healthcare Access and Quality Collaborators. Assessing performance of the Healthcare Access and Quality Index, overall and by select age groups, for 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet Glob Health* 2022; **10**: e1715–43.

20 Fleckenstein M, Keenan TDL, Guymer RH, et al. Age-related macular degeneration. *Nat Rev Dis Primers* 2021; **7**: 31.

21 Thomas CJ, Mirza RG, Gill MK. Age-related macular degeneration. *Med Clin North Am* 2021; **105**: 473–91.

22 Velez-Montoya R, Oliver SC, Olson JL, Fine SL, Quiroz-Mercado H, Mandava N. Current knowledge and trends in age-related macular degeneration: genetics, epidemiology, and prevention. *Retina* 2014; **34**: 423–41.

23 Rein DB, Wittenborn JS, Burke-Conte Z, et al. Prevalence of age-related macular degeneration in the US in 2019. *JAMA Ophthalmol* 2022; **140**: 1202–08.

24 Heesterbeek TJ, Lorés-Motta L, Hoyng CB, Lechanteur YTE, den Hollander AI. Risk factors for progression of age-related macular degeneration. *Ophthalmic Physiol Opt* 2020; **40**: 140–70.

25 Kaarniranta K, Machalińska A, Veréb Z, Salminen A, Petrovski G, Kauppinen A. Estrogen signalling in the pathogenesis of age-related macular degeneration. *Curr Eye Res* 2015; **40**: 226–33.

26 Fraser-Bell S, Wu J, Klein R, Azen SP, Varma R. Smoking, alcohol intake, estrogen use, and age-related macular degeneration in Latinos: the Los Angeles Latino Eye Study. *Am J Ophthalmol* 2006; **141**: 79–87.

27 Hwang S, Kang SW, Han J, et al. Female reproductive factors and the risk of exudative age-related macular degeneration: a nationwide cohort study. *Retina* 2021; **41**: 2088–97.

28 Bourne RRA. Vision 2020: where are we? *Curr Opin Ophthalmol* 2020; **31**: 81–84.

29 Pizzarello L, Abiose A, Ffytche T, et al. Vision 2020: The Right to Sight: a global initiative to eliminate avoidable blindness. *Arch Ophthalmol* 2004; **122**: 615–20.

30 GBD 2019 Healthcare Access and Quality Collaborators. Assessing performance of the Healthcare Access and Quality Index, overall and by select age groups, for 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet Glob Health* 2022; **10**: e1715–43.

31 Girgis S, Lee LR. Treatment of dry age-related macular degeneration: a review. *Clin Exp Ophthalmol* 2023; **51**: 835–52.

32 Parikh R, Pirakitikulr N, Chhablani J, Sakurada Y, Singh RP, Modi YS. A multinational comparison of anti-vascular endothelial growth factor use: the United States, the United Kingdom, and Asia-Pacific. *Ophthalmol Retina* 2019; **3**: 16–26.

33 GBD 2015 Tobacco Collaborators. Smoking prevalence and attributable disease burden in 195 countries and territories, 1990–2015: a systematic analysis from the Global Burden of Disease Study 2015. *Lancet* 2017; **389**: 1885–906.

34 Xu X, Wu J, Yu X, Tang Y, Tang X, Shentu X. Regional differences in the global burden of age-related macular degeneration. *BMC Public Health* 2020; **20**: 410.

35 Apte RS. Age-related macular degeneration. *N Engl J Med* 2021; **385**: 539–47.

36 Bialous S, Da Costa E Silva VL. Where next for the WHO Framework Convention on Tobacco Control? *Tob Control* 2022; **31**: 183–86.

37 Rao P, Lum F, Wood K, et al. Real-world vision in age-related macular degeneration patients treated with single anti-VEGF drug type for 1 year in the IRIS Registry. *Ophthalmology* 2018; **125**: 522–28.