Global Prevalence of Vision Impairment and Blindness

Magnitude and Temporal Trends, 1990–2010

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Purpose: Vision impairment is a leading and largely preventable cause of disability worldwide. However, no study of global and regional trends in the prevalence of vision impairment has been carried out. We estimated the prevalence of vision impairment and its changes worldwide for the past 20 years.

Design: Systematic review.

Participants: A systematic review of published and unpublished population-based data on vision impairment and blindness from 1980 through 2012.

Methods: Hierarchical models were fitted fitted to estimate the prevalence of moderate and severe vision impairment (MSVI; defined as presenting visual acuity <6/18 but ≥3/60) and the prevalence of blindness (presenting visual acuity <3/60) by age, country, and year.

Main Outcome Measures: Trends in the prevalence of MSVI and blindness for the period 1990 through 2010.

Results: Globally, 32.4 million people (95% confidence interval [CI], 29.4–36.5 million people; 60% women) were blind in 2010, and 191 million people (95% CI, 174–230 million people; 57% women) had MSVI. The age-standardized prevalence of blindness in older adults (≥50 years) was more than 4% in Western Sub-Saharan Africa (6.0%; 95% CI, 4.6%–7.1%), Eastern Sub-Saharan Africa (5.7%; 95% CI, 4.4%–6.9%), South Asia (4.4%; 95% CI, 3.5%–5.1%), and North Africa and the Middle East (4.6%; 95% CI, 3.5%–5.8%), in contrast to high-income regions with blindness prevalences of ≤0.4% or less. The MSVI prevalence in older adults was highest in South Asia (23.6%; 95% CI, 19.4%–29.4%), Oceania (18.9%; 95% CI, 11.8%–23.7%), and Eastern and Western Sub-Saharan Africa and North Africa and the Middle East (95% CI, 15.9%–16.8%). The MSVI prevalence was less than 5% in all 4 high-income regions. The global age-standardized prevalence of blindness and MSVI for older adults decreased from 3.0% (95% CI, 2.7%–3.4%) worldwide in 1990 to 1.9% (95% CI, 1.7%–2.2%) in 2010 and from 14.3% (95% CI, 12.1%–16.2%) worldwide to 10.4% (95% CI, 9.5%–12.3%), respectively. When controlling for age, women's prevalence of blindness was greater than men's in all world regions. Because the global population has increased and aged between 1990 and 2010, the number of blind has increased by 0.6 million people (95% CI, −5.2 to 5.3 million people). The number with MSVI may have increased by 19 million people (95% CI, −8 to 72 million people) from 172 million people (95% CI, 142–198 million people) in 1990.

Conclusions: The age-standardized prevalence of blindness and MSVI has decreased in the past 20 years. However, because of population growth and the relative increase in older adults, the blind population has been stable and the population with MSVI may have increased.

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Vision impairment and age-related eye diseases affect economic and educational opportunities, reduce quality of life,[1] and increase the risk of death.[2,3] The World Health Organization estimated that vision loss caused 3.9% of the total global burden of disease measured as disability-adjusted life years in 2004.[4] A further update estimated that 39 million people were blind and 285 million were visually impaired in 2010.[5]

Estimating trends in the global burden of blindness and vision impairment is important for several reasons that include understanding areas of unmet need and the effects of interventions such as cataract surgery. Published estimates of vision impairment and blindness have combined the most recent data available for each world region without accounting for changes in vision impairment prevalence

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over time.[5–7] In addition, the most recent estimates did not estimate the prevalence of vision impairment by sex.[5]

Previously, we reported the methodology and the characteristics of studies included in the systematic review of published literature and some unpublished data from population-based studies that reported prevalence of blindness and vision impairment dating from 1980.[8] This was undertaken by the expert group convened for the Global Burden of Diseases, Injuries and Risk Factors (GBD) Study, which collated published data up to December 2008. We subsequently extended the review to include published data sources up to January 2012.[8] This work highlighted the uneven distribution of population-based data on the prevalence of vision impairment worldwide. The purpose of this study was to provide global estimates of the prevalence of presenting vision impairment and blindness and their trends using the prevalence data identified in our systematic review.

Methods

We estimated 1990 through 2010 trends in vision impairment prevalence and their uncertainties, by sex, for 190 countries in the 21 GBD subregions (Appendix A, Table A1, available at http://aaojournal.org).[9] We estimated the prevalence of 4 extended categories of vision impairment (Table 1; Appendix A, Text A1) and highlighted the prevalence of 2 core categories: blindness and the sum of moderate and severe vision impairment (MSVI). Vision impairment prevalence was based on presenting visual acuity. Our analysis was carried out in 5 steps: (1) data identification and access; (2) conversion of vision impairment data to 2 core levels (blindness and MSVI); (3) estimation of age-specific vision impairment prevalence when data were not reported by age; (4) selection and use of a statistical model to estimate the prevalence of blindness and MSVI by country, age, sex, and year; and (5) conversion from the prevalence of MSVI to the prevalence of severe, moderate, and mild vision impairment.

Data Identification, Access, and Extraction

We considered measured vision impairment data from epidemiologic studies identified in a systematic review. Bourne et al[8] reviewed the published literature and unpublished data that were identified by members of the expert group convened for the GBD Study, identifying 243 studies. After excluding 16 studies that did not report prevalence of distance vision impairment or used a definition of vision impairment for which we could not develop a method for inclusion and one study for which we did not have covariate data, 227 studies in 84 countries remained (Appendix A, Text A2; Table A2). Data on both presenting and best-corrected visual acuity were extracted and used.

Table 1. Levels of Visual Acuity Estimated in the Study[8]

Level	Presenting Visual Acuity* in the Better Eye
Mild vision impairment	<6/12 but 6/18 or better
Moderate vision impairment	<6/18 but 6/60 or better
Severe vision impairment	<6/60 but 3/60 or better
Blindness	<3/60 and/or a visual field of no more than 10° in radius around central fixation

*Snellen visual acuity or the equivalent calculated from published logarithm of the minimum angle of resolution values.

Conversion to Core Definitions of Visual Acuity

Not all prevalence data reported in the literature use the definitions of vision impairment selected for this study. To include prevalence data reported using other definitions of vision impairment, we developed logistic regressions to convert the prevalence of vision impairment using other severity thresholds to the core categories used in this analysis. We developed 4 regressions to convert 2 commonly used definitions of blindness (visual acuity <6/60 and visual acuity ≤6/60) to our definition of blindness, and we converted 2 commonly reported definitions of vision impairment (visual acuity <6/18 and visual acuity <6/12) to our definition of MSVI (further details are available in Appendix A, Text A3; see also Table A3 and Figs A1, A2, A3, and A4).

Conversion to Age-Specific Data

If data were reported by age, age-specific prevalence of vision impairment was used. In some cases, the prevalence of vision impairment was reported for a wide age group such as all ages or adults 50 years of age and older. We fitted 2 universal age patterns, 1 for the prevalence of blindness and 1 for the prevalence of MSVI, using study data that were available by age. We then applied the fitted age patterns to data that were available only by wide age group to calculate prevalence by 5-year age intervals. We did so by ensuring that the age-specific prevalence values summed to the reported wide age range prevalence when weighted by the country's population by age. Further details are available in Appendix A, Text A4.

Statistical Analysis of Vision Impairment Data

We fitted 2 hierarchical logistic regressions to estimate vision impairment prevalence over time by age group, sex, and country.[10,11] We fitted 1 model for the prevalence of blindness and 1 model for the prevalence of MSVI to reflect differences in geographic patterns and trends for the 2 levels of vision impairment. By using a hierarchical model, estimates of vision impairment were informed both by study data from the same country, if available, and by study data from other countries. The relative weight given to the data from the same country versus from other countries in the same region versus from countries in other regions was informed by the availability and consistency of the within-country data compared with the availability and consistency of data from different countries in the same region and with data from different regions. We summarize our model below and provide complete details in Appendix A, Text A5.

We used a model in which vision impairment levels in countries were modeled hierarchically to be nested in each of the 21 GBD subregions, which in turn were nested in 4 world regions (shown in Appendix A, Table A1). We modeled hierarchical linear trends over time, allowing for region-specific trends in the prevalence of vision impairment in 4 world regions. The difference in prevalence by sex likewise was modeled hierarchically in 4 world regions, which allows for differences in sex disparities in underlying risk of vision impairment or access to ophthalmologic care. Because vision impairment may not increase linearly by age, we modeled age as a 3-piece linear spline with knots at ages 40 years and 70 years.

Studies may vary more than indicated by their statistical uncertainty because of unmeasured design effects. In addition, subnational and community studies have larger variation than national studies. Our model includes study-specific error terms, which have a larger variance for subnational and community studies, thereby allowing national studies to have a greater influence on estimates. Studies carried out in urban or rural areas also may differ systematically from studies carried out in mixed populations. We included fixed effects for urban and rural studies for the blindness model; for the MSVI model, we found that these effects were not significant and therefore excluded them.

Some studies reported the prevalence of vision impairment after each subject was provided with the best-available correction. Others measured and reported the prevalence of vision impairment with subjects using any normally used visual aids (called presenting visual acuity), and still others reported both types of vision impairment. We accounted for this in our model by fitting a fixed effect for data recording presenting visual acuity. We allowed this difference to vary in the South Asia region, where the ratio of presenting and best-corrected visual acuity was larger than in other world regions.

We used time-varying covariates that reflect each country's development status to inform estimates. We evaluated 3 country-specific covariates for which a complete dataset for 190 countries from 1980 through 2011 was available: gross domestic product per capita,[12] mean years of adult education,[13] and a variable representing access to health care (Lancet 2011;377:969-70. [Webappendix p. 85]). To select the model that made the most accurate predictions for countries without data, we calculated the predictive validity of all combinations of the candidate covariates using cross-validation. Specifically, for each of 10 validation sets comprising a random set of 20% of countries with data, we fitted each candidate model to the remaining training set and used the resulting model to predict prevalences for each country-age-sex-severity group in the validation set. The differences between these predicted prevalences and the known but excluded prevalences were used to calculate the median relative error (Appendix B, Table B1, available at http://aaojournal.org). For both blindness and MSVI, the best performing model used only mean years of adult education and health care access as covariates.

We fitted our model with a maximum likelihood algorithm, as implemented in R version 2.14.1 with the lme4 package (available at: http://cran.r-project.org/web/packages/lme4/index.html and http://www.r-project.org/; accessed May 4, 2012). To generate estimates of uncertainty, we followed a bootstrap procedure. For each model (blindness and MSVI) we created 500 data sets by drawing vision impairment studies with replacement, such that each dataset had the same number of studies as the complete dataset. We then fitted each model 500 times, once for each resampled dataset. For countries with no data in the bootstrap sample, and thus without an estimate of the country-specific random effect, we randomly generated a country-specific effect using the observed standard deviation of country random effects in that bootstrap sample's fitted model (further details in Appendix A, Text A5). We then predicted blindness and MSVI prevalence for each country-sex-age-year unit using the predicted coefficients of the model fit with the full dataset and the 500 bootstrap models, predicting for presenting vision impairment in a mixed urban and rural population (Appendix A, Text A5). A graphical presentation of the model fits can be found in Appendix C (available at http://aaojournal.org).

Finally, we predicted the prevalence of severe, moderate, and mild vision impairment for the central estimate, for each draw, and for each country, year, age, and sex. We fitted logistic regressions to convert the prevalence of blindness and MSVI (further details are available in Appendix A, Text A5 and Figs A5, A6, and A7), naturally propagating uncertainty in the models of blindness and MSVI presented earlier. To obtain global and regional estimates, we combined the country predictions for the central estimate and each draw, age, and sex, weighting each country prediction by its population in the relevant age and sex category. We present uncertainty intervals in summary estimates as the 2.5th–97.5th percentiles of the distribution of draws.

We also calculated uncertainty around trends in vision impairment by creating (for each draw) age-standardized total vision impairment estimates for all ages and for ages 50 years and older for 1990 and 2010 and for all countries, regions, and the world. We calculated trends as the difference between the 1990 and the 2010 age-standardized prevalence. We present the 2.5th and 97.5th percentiles of the differences as the uncertainty interval for the time trend.

For presentation, we report age-standardized prevalences using the World Health Organization reference population.[14] We also calculated numbers of people with vision impairment, which reflected each region's population size, age structure, and vision impairment prevalence. Finally, we decomposed changes in population with vision impairment into growth in total population, change in population age and sex structure, and sex-specific disease rates, as described previously.[15]

Results

Global Estimates of the Burden of Vision Impairment in 2010

Globally, 32.4 million people (95% confidence interval [CI], 29.4–36.5 million people; 0.5% of the global population [95% CI, 0.4%–0.5% of the global population]) were blind in 2010, of whom 19.6 million (95% CI, 17.7–22.1 million; 60%) were women (Table 2, available at http://aaojournal.org). The largest number of blind people resided in South Asia (10.6 million; 95% CI, 8.4–12.5 million), followed by East Asia (5.2 million; 95% CI, 4.5–6.5 million), and Southeast Asia (3.5 million; 95% CI, 2.7–4.1 million). The prevalence of blindness varied from 0.1% (95% CI, 0.1%–0.2%) in the North America high-income region to 0.7% (95% CI, 0.5%–0.9%) in the North Africa and Middle East region (data by sex in Appendix B, Table B2).

An additional 191 million people (95% CI, 174–230 million people) had MSVI (2.8% of the global population; 95% CI, 2.5%–3.3% of the global population), of whom 109 million people (95% CI, 99–130 million people; 57%) were women. The largest number of visually impaired resided in South Asia (72 million; 95% CI, 58–93 million), followed by East Asia (33 million; 95% CI, 26–41 million) and Southeast Asia (18 million; 95% CI, 15–27 million). Of those with MSVI, 30 million people (95% CI, 1.4–157 million; 16%) had a severe vision impairment, and 161 million people (95% CI, 41–211 million) had a moderate vision impairment. The prevalence of MSVI varied from 0.9% (95% CI, 0.7%–1.6%) in the North America high-income region to 4.5% (95% CI, 3.6%–5.8%) in the South Asia region. We estimated mild vision impairment from MSVI prevalence, calculating that 155 million people (95% CI, 64–354 million people) worldwide had mild vision impairment in 2010.

The burden of vision impairment was greatest among those 50 years of age and older (Fig 1; Table 3 and Appendix B, Table B3). Within this age category were 84.6% of blind people and 77.5% of those with MSVI.

Interregional Disparities

The prevalence of vision impairment varied because of differences in regional age structures, and epidemiologic differences. To compare patterns and trends in the prevalence of vision impairment

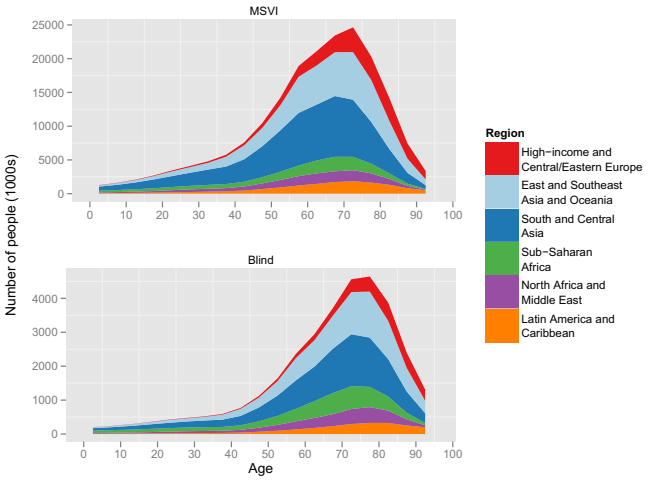

Figure 1. Graph showing the global population of blind persons and those with moderate and severe vision impairment by region and age. The 21 subregions used in this study (and listed in Table 1A) are combined into 6 groups.

without being confounded by the age structure, we calculated age-standardized prevalences. We focused on prevalence among adults 50 years and older (hereafter referred to as older adults) who experienced the largest burden of vision impairment.

The age-standardized prevalence of blindness and MSVI was far higher in some developing regions than in high-income regions (Fig 2; data by sex in Appendix B, Table B4). The prevalence of blindness among older adults was greater than 4% in 4 regions in 2010: Western Sub-Saharan Africa (6.0%; 95% CI, 4.6%−7.1%), Eastern Sub-Saharan Africa (5.7%; 95% CI, 4.4%−6.9%), South Asia (4.4%; 95% CI, 3.5%−5.1%), and North Africa and the Middle East (4.6%; 95% CI, 3.5%−5.8%). The blindness prevalence was lowest in high-income regions with figures of 0.4% or less. The prevalence of MSVI was highest in South Asia (23.6%; 95% CI, 19.4%−29.4%), Oceania (18.9%; 95% CI, 11.8%−23.7%), Western Sub-Saharan Africa (16.6%; 95% CI, 13.7%−21.0%), North Africa and the Middle East (16.8%; 95% CI, 14.1%−21.4%), and Eastern Sub-Saharan Africa (15.9%; 95% CI, 13.1%−19.6%). In a similar manner, the MSVI prevalence was lowest (<5%) in all 4 high-income regions, where it was 5 times lower than in South Asia. Although the age-standardized prevalences of adult blindness and MSVI were correlated with each other ($\rho = 0.82$), the blind made up a greater proportion of the visually impaired in Sub-Saharan Africa and in the North Africa and Middle East region than in other regions (Fig 3, available at http://aaojournal.org).

Sex Disparities

More women than men were visually impaired. When controlling for age, women's prevalence of blindness was greater than men's in all world regions (Fig 4). For blindness, the relative sex disparity was greatest in the high-income regions, with an adult age-standardized prevalence of blindness in women more than 1.5 times higher than the age-standardized prevalence of blindness in men. The sex disparity was lowest in the Sub-Saharan African regions, with blindness in women approximately 1.11 to 1.13 times greater than blindness in men, and the South Asia region, where adult blindness was 1.26 times greater in women. In all regions, the age-standardized adult prevalence of MSVI was 1.1 to 1.2 times greater in women than in men.

Distribution of Blindness and Vision Impairment by Country

The age-standardized prevalence of older adult blindness was highest in Yemen and 7 Sub-Saharan African countries: Niger, Mauritania, Mali, Chad, Somalia, Ethiopia, and Burkina Faso, all with prevalences of more than 8% (Appendix B, Table B5). The highest prevalence of MSVI was found in Egypt, Myanmar, and Afghanistan, 3 countries that had prevalences of 28% or more in their older adult population.

The most populated countries also have a large burden of blind and visually impaired people. More than half of the world's blind lived in 5 countries: India (8.3 million people; 95% CI, 6.6−9.7 million people), China (5.2 million people; 95% CI, 4.4−6.3 million people), Indonesia (1.5 million people; 95% CI, 0.9−1.8 million people), Pakistan (1.2 million people; 95% CI, 0.8−1.6 million people), and Nigeria (1.0 million people; 95% CI, 0.6−1.2 million people). Of the global population with MSVI, 31% lived in India and another 17% lived in China, followed by Pakistan and Indonesia.

Global Trends in Vision Impairment from 1990 through 2010

The global age-standardized prevalence of blindness among older adults decreased from 3.0% (95% CI, 2.7%−3.4%) in 1990 to 1.9% (95% CI, 1.7%−2.2%) in 2010, a decrease of 0.5% (95% CI, 0.4%−0.8%) per decade (Fig 2). During the same period, the global age-standardized prevalence of MSVI among older adults decreased from 14.3% (95% CI, 12.1%−16.2%) to 10.4% (95% CI, 9.5%−12.3%), a decrease of 2.0% (95% CI, 0.4%−2.8%) per decade.

We estimated a statistically significant decrease in the age-standardized prevalence of blindness and MSVI among older adults in all regions, with the largest absolute decreases in North

Table 3. Global Numbers Affected and Prevalence of Visual Impairment by Age and Sex, 2010

	Blind		Moderately and Severely Visually Impaired	
Age Range (yrs)	*Prevalence (%)*	*No. (Millions)*	*Prevalence (%)*	*No. (Millions)*
Males				
0−49	0.08 (0.07−0.09)	2.2 (1.9−2.5)	0.72 (0.63−0.91)	20 (18−26)
50−69	0.85 (0.74−0.97)	4.5 (3.9−5.1)	6.6 (5.9−7.9)	35 (31−42)
≥70	4.2 (3.7−4.8)	6.2 (5.5−7)	18.8 (17.0−22.0)	28 (25−33)
Females				
0−49	0.10 (0.09−0.12)	2.8 (2.4−3.2)	0.89 (0.78−1.1)	24 (21−30)
50−69	1.1 (1.0−1.3)	6.2 (5.5−7.1)	7.9 (7.2−9.5)	43 (39−52)
≥70	5.3 (4.8−6.0)	10.6 (9.6−12.1)	20.9 (19.1−24.6)	42 (38−49)

95% Confidence intervals are shown in parentheses.

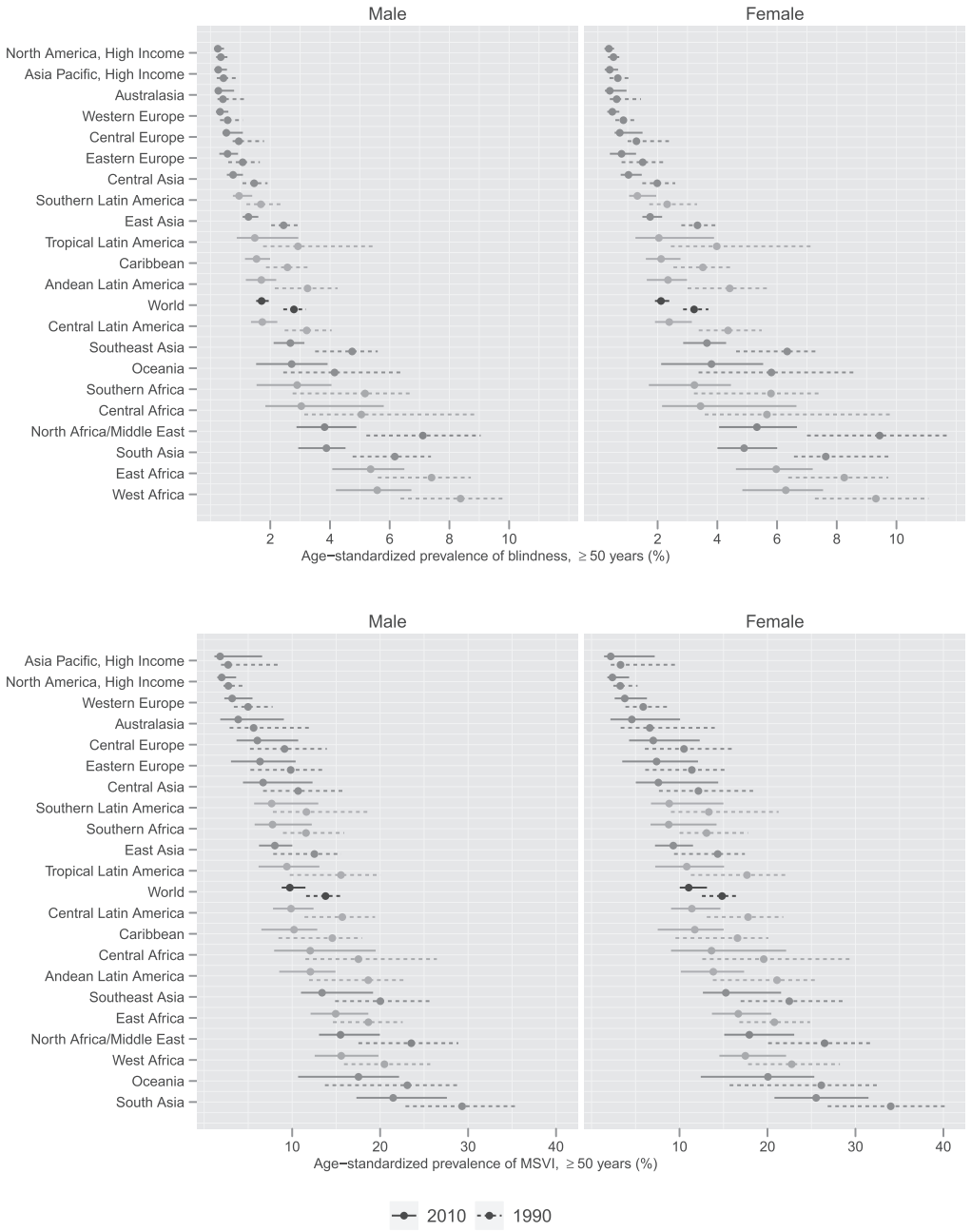

Figure 2. Graphs showing age-standardized prevalence of blindness and moderate and severe vision impairment (MSVI) by subregion and sex for 1990 and 2010.

Africa and the Middle East and in South Asia for MSVI (≥4.0% per decade) and in the same 2 regions plus Southeast Asia and the 4 Sub-Saharan African regions for blindness (all experienced declines of at least 1% per decade).

Because of increases in the proportion of older adults in the world population, the overall prevalence of blindness and MSVI has decreased less than adult age-standardized prevalences. In 1990, 0.6% (95% CI, 0.5%−0.7%) of the all-age global population was blind; this decreased to 0.5% (95% CI, 0.4%−0.5%) in 2010. Globally, 3.2% (95% CI, 2.7%−3.7%) of the population had MSVI in 1990, decreasing to 2.8% (95% CI, 2.5%−3.3%) in 2010. Because the global population has increased since 1990, the number of blind was stable at 31.8 million (95% CI, 28.2−36.8 million) in 1990 and 32.4 million (95% CI, 29.4−36.5 million) in 2010, a difference of 0.6 million (95% CI, −5.2 to 5.3 million; Table 4). The number with MSVI may have increased by 19 million people (95% CI, −8 to 72 million people) from 172 million people (95% CI, 142−198 million people) in 1990.

Discussion

We found that 32.4 million people worldwide were blind in 2010 and that 191 million people had MSVI, with the

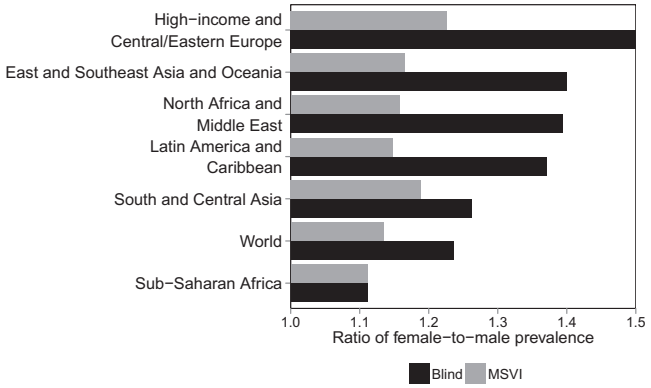

Figure 4. Bar graph showing the ratio of female-to-male age-standardized prevalence of blindness and of moderate and severe vision impairment (MSVI) by region in adults 50 years of age and older. The 21 subregions used in this study (and listed in Table A1) are combined into 6 groups.

largest number in South Asia, followed by East Asia and Southeast Asia. The global age-standardized prevalence of blindness and MSVI among adults 50 years of age and older decreased worldwide from 3.0% to 1.9% and from 14.3% to 10.4%, respectively; however, because of the rapid increase in the older adult population, the number of people blind and with MSVI did not decrease.

Our study follows previous meta-analyses of vision impairment data. Thylefors et al[16] summarized global data on blindness in 1995. Using data on best-corrected visual acuity, they estimated that there were 38 million blind people and a further 110 million people with low vision in 1990. They postulated an increase in the prevalence of blindness because of the increasing proportion of older adults in the global population. Seven years later, Resnikoff et al[7] performed a meta-analysis and reported global data on vision impairment in 2002. They estimated the number of people with vision impairment worldwide was in excess of 161 million, of whom approximately 37 million were blind. According to their study, the burden of vision impairment was not distributed uniformly throughout the world, with the least developed regions carrying the largest share. Vision impairment largely was confined to adults 50 years of age and older, and women had a significantly higher risk of having vision impairment than men. In the same year, Pascolini et al[17] performed a literature search and included 208 population-based studies on vision impairment from 68 countries. Based on these studies, Resnikoff et al[6] reported that an estimated 153 million people (95% CI, 123−184 million people) were visually impaired from uncorrected refractive errors in 2004. Finally, the prevalence of blindness and MSVI found in our study agrees with the recent analysis by Pascolini and Mariotti,[5] who performed a meta-analysis of recent data on vision impairment based on presenting visual acuity. Including surveys from 39 countries, Pascolini and Mariotti estimated that in 2010, 285 million people were visually impaired, of whom 39 million were blind. These figures are within our uncertainty range for most world regions. The main discrepancy is for China, where Pascolini and Mariotti estimated 8.2 million blind people and 67.2 million people with MSVI in 2010 versus our estimates of 5.4 million people (95% CI, 4.5−6.5 million people) and 32.4 million people (95% CI, 24.1−42.3 million people), respectively. Our estimates for China synthesize 23 subnational and local studies and 1 national study from 1987 (Appendix A, Table A2) and include an estimate of trends over time, whereas Pascolini and Mariotti based their estimates on 2 subnational studies, 1 representative of a rural area and 1 representative of an urban area.[18,19] Although there are many high-quality subnational studies of vision impairment prevalence in China, there is a risk that estimates are biased if studies are concentrated in areas with better access to treatment or higher socioeconomic status; a new nationally representative study of China would clarify the current prevalence of vision impairment and blindness.

In our study, we estimated the change in the prevalence of blindness and MSVI and found a decrease in both parameters. However, because of the worldwide demographic transition, with older adults growing in relative and absolute numbers in every country and region of the world, we estimated that the number of people with vision impairment, including blindness, has increased since 1990 (Table 4). This indicates that measures to reduce blindness and vision impairment were successful but were insufficient to counteract the demographic trends of the past 2 decades.

In all regions worldwide, women had a higher age-standardized prevalence of vision impairment and blindness than men. Interestingly, the relative sex difference was greatest in the high-income regions and lowest in the Sub-Saharan African regions. This finding is consistent with a meta-analysis of data published from 1980 to 1999: Abou-

Table 4. Global Trends in Numbers of People Blind or Visually Impaired between 1990 and 2010 and the Change Attributable to Population Growth, Population Ageing, and Change in Age-Specific Prevalence of Blindness or Visual Impairment

	Blind	Moderate and Severe Vision Impairment
No. of persons in 1990 (millions)	31.8	172.0
No. expected with 2010 population, 1990 population age structure, and 1990 prevalence (millions)	41.4	223.9
No. expected with 2010 population, 2010 population age structure, and 1990 prevalence (millions)	50.9	268.0
No. of persons in 2010 (millions)	32.4	191.0
Percentage change from 1990 because of population growth	30%	30%
Percentage change from 1990 because of population ageing	30%	26%
Percentage change from 1990 because of change in age-specific prevalence	−58%	−45%
Percentage change from 1990 to 2010	2%	11%

Gareeb et al[20] found that, after controlling for age, the odds ratio of blindness was highest in industrialized countries (1.63; 95% CI, 1.30−2.05) and lowest in Africa (1.41; 95% CI, 1.29−1.545). The authors hypothesized that a lower female-to-male ratio may be present in African regions affected by onchocerciasis. Other explanations for the observed geographical variations in sex difference may include factors such as accessibility or use of eye-care services, which are known to vary by culture and socioeconomic development.

Potential limitations of our study should be mentioned. First, the main limitation of our study is that many country-years remained without data or had only subnational data. Only a few national studies for all ages were available, whereas most surveys in the past 20 years were rapid assessments for ages 50 years and older.[8] In particular, there remains a dearth of information from certain regions such as high-income countries, Central and Eastern Europe, the Caribbean and Latin America, and Central Sub-Saharan Africa. The weaknesses in the available databases from these regions have led to increased uncertainty of the calculated prevalence of blindness and MSVI for these regions, reflected in their larger 95% CIs (Table 2, available at http://aaojournal.org). Second, some data sources did not report prevalence by age. To use these data, we imputed age-specific prevalence, assuming that the study participants' age distribution matched the population age pattern in the country where the study was carried out. Third, to use data on best-corrected vision impairment in our model, we estimated a fixed proportional relationship between best-corrected and presenting vision impairment. We allowed this parameter to vary in the South Asia region. Insofar as this relationship varies by population group outside of South Asia or over time, the inference we draw from studies reporting only best-corrected vision impairment (20% of studies; Appendix A, Table A2) would be affected. Fourth, some data sources used definitions of vision impairment that differed from those in this study or did not report blindness or MSVI. Conversion from alternate definitions to blindness and MSVI definitions used in this report allowed us to use more data sources but caused increased uncertainty. The strengths of our study included the large amount of population-based data accessed and used, analysis of trends in vision impairment by severity, systematic conversion of vision impairment prevalence data to standard definitions, incorporation of nonlinear age trends and accounting for data that were not reported by age, accounting for study representativeness such that our estimates used all available data but tracked data from nationally representative studies more closely, and systematic quantitative analysis and reporting of uncertainty. The large network of ophthalmologic researchers involved in identification and evaluation of data sources ensured that we were able to access unpublished materials and to reanalyze published studies, that all major studies of vision impairment were evaluated for inclusion in our dataset, and that low-quality studies were excluded from our analysis.

To improve the precision of the estimates and trends of the global prevalence of blindness and vision impairment, more nationally representative surveys of vision impairment prevalence are needed. These studies should follow strict epidemiologic principles applying the standardized definitions of vision impairment using presenting visual acuity as defined by the World Health Organization and, importantly, should report their results by age and sex. Data on children are particularly sparse; new methods for determining the prevalence of childhood blindness should be validated and expanded.[21,22] The prevalence of mild vision impairment and near vision impairment should be measured and reported to generate more accurate estimates of the total burden of vision impairment. Accurate national registries and increased surveillance of blindness and vision impairment are critical components that contribute to the information in national and subnational studies. Studies using rapid assessment methods can complement surveys using more comprehensive ophthalmic examinations.

In conclusion, in 2010, 191 million people had MSVI and 32.4 million people were blind worldwide. The prevalence of vision impairment, including blindness and MSVI, was highest in South Asia, East and West Sub-Saharan Africa, and North Africa and the Middle East. Women were affected more often by vision impairment and blindness compared with men, with the relative sex disparity being larger in high-income regions than in Sub-Saharan Africa. The prevalence of blindness and MSVI has been reduced markedly within the past 20 years, with greater reduction in absolute terms in low-income regions.

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