# Global Estimates on the Number of People Blind or Visually Impaired by Diabetic Retinopathy: A Meta-analysis From 1990 to 2010

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## OBJECTIVE

**To estimate global and regional trends from 1990 to 2010 of the prevalence and number of persons visually impaired specifically by diabetic retinopathy (DR), as a complication of the precipitous trends in global diabetes, is fundamental for health planning purposes.**

## RESEARCH DESIGN AND METHODS

**The meta-analysis of published population studies from 1990 to 2012 for the Global Burden of Disease Study 2010 (GBD) yielded estimated global regional trends in DR among other causes of moderate and severe vision impairment (MSVI; presenting visual acuity <6/18, ≥3/60) and blindness (presenting visual acuity <3/60).**

## RESULTS

**Globally in 2010, out of overall 32.4 million blind and 191 million visually impaired people, 0.8 million were blind and 3.7 million were visually impaired because of DR, with an alarming increase of 27% and 64%, respectively, spanning the two decades from 1990 to 2010. DR accounted for 2.6% of all blindness in 2010 and 1.9% of all MSVI worldwide, increasing from 2.1% and 1.3%, respectively, in 1990. These figures were lower in regions with younger populations (<2% in East and Southeast Asia and Oceania) than in high-income regions (North America, Western Europe, and Australasia) with relatively aging populations (>4%).**

## CONCLUSIONS

**The number of persons with visual impairment due to DR worldwide is rising and represents an increasing proportion of all blindness/MSVI causes. Age-standardized prevalence of DR-related blindness/MSVI was higher in sub-Saharan Africa and South Asia. One out of 39 blind people had blindness due to DR, and 1 out of 52 visually impaired people had visual impairment due to DR.**


Data on the prevalence of visual impairment and blindness, its causes, and its changes over time is of high importance for public health issues. On the basis of previous large-scale population-based studies and meta-analyses, diabetic retinopathy (DR) has been recognized as one of the most common and important causes for visual impairment and blindness (1–19). These studies in general showed that DR was the leading cause of blindness globally among working-aged adults and therefore has a significant socioeconomic impact (20–22). Although timely treatment of DR can reduce the risk of visual loss by 60%, the proportion of blindness due to DR

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ranged from 3 to 7% in the Southeast Asia and Western Pacific regions and was as high as 15–17% in developed regions such as the Americas and Europe (23).

A previous meta-analysis (21) summarizing 35 studies with more than 20,000 patients with diabetes estimated a prevalence of any DR of 34.6%, of diabetic macular edema of 6.8%, and of vision-threating DR of 10.2% within the diabetes population. The prevalence estimates of any DR and vision-threatening DR varied with ethnicity and were highest in African Americans and lowest in Asians. By extrapolating these prevalence rates to the 2010 world diabetes population, Yau et al. (21) estimated that ~93 million people had some DR and 28 million people had sight-threatening stages of DR. However, this meta-analysis did not address the prevalence of visual impairment and blindness due to DR and thus the impact of DR on the general population. No previous studies assessed changes in the prevalence of DR-related blindness from 1990 to 2010 or the number of people functionally affected applying the same methodology across all time periods.

We therefore conducted the present meta-analysis of all available population-based studies performed worldwide within the last two decades as part of the Global Burden of Disease Study 2010 (GBD) to estimate the number of people affected by blindness and visual impairment. The global prevalence, causes, and regional estimates have been reported previously (24,25). Because the numbers of persons living with diabetes and DR have triggered a global public health response, we believe that it is imperative to present the figures we estimated specifically for blindness and visual impairment due to DR in the present analysis. Along with the global and regional figures, we offer the temporal trends from 1990 to 2010; we examine regional differences in the prevalence of DR-related blindness and moderate and severe vision impairment (MSVI); and we consider the implications of how the number of people with DR-related blindness and visual impairment compares with the number of people with blindness and visual impairment due to other eye diseases.

## RESEARCH DESIGN AND METHODS

The GBD methodology is detailed elsewhere (24–26). Herein we shall only review the methodology pertinent to the present analysis of the prevalence of visual impairment due to DR. A systemic literature review yielded 14,908 relevant articles published between 1980 and 2012 primarily identified by searching Medline, Embase, and the World Health Organization (WHO) library information system. (The full search strategy is included in Supplementary Appendix 1.) Of those, 243 population-based studies were analyzed after review by an expert panel of ophthalmologists, optometrists, and ophthalmic epidemiologists. The search terms applied included "blindness," "visual impairment," "population," "eye," "survey," and a list of ocular disorders (24,25). Additionally, personal communication with principal investigators identified in the literature search provided additional unpublished data sources (24,25).

In the GBD, blindness was defined as presenting visual acuity $<3/60$ and MSVI as presenting visual acuity $<6/18$, $\geq 3/60$. Population-based studies that reported prevalence of visual impairment and blindness disaggregated by cause (128 studies) provided the basic data to calculate the proportion of blindness and MSVI due to DR (20 studies) in addition to other causes such as cataract, age-related macular degeneration, glaucoma, trachoma, or undercorrection of refractive error (24). Ten of the 21 (47.6%) GBD regions (27) were represented with data on DR-related blindness/MSVI (Australasia, Central and Western Europe, North America, Caribbean, Tropical Latin America, Oceania, and South, East, and Southeast Asia). On a country level, studies were available for 14 out of 191 countries.

Trends in causes of vision impairment were calculated by age in 5-year increments, sex, and GBD region. We additionally performed an analysis of uncertainties. The statistical analysis included the data identification and accessibility; the estimation of fractions for each cause stratified by the severity of vision impairment, sex, age, and region; and the application of cause fractions to the prevalence of all-cause presenting vision impairment (24). The statistical analysis applied the DisMod-MR (https://github.com/ihmeuw/dismod_mr) model to calculate the fraction of vision impairment due to DR and the other causes mentioned above (24). The DisMod-MR is a negative binomial regression model including the following elements: covariates that predict variation in the true proportion of vision impairment from each disease (e.g., year); fixed effects that adjust for definitional differences (e.g., whether the causes of presenting vs. best-corrected vision impairment were reported); a hierarchical model structure that fits random intercepts in individual countries derived from the data observed in the country, in its region, and in other regions on the basis of the availability and consistency of country- and region-specific data; age-specific fixed effects allowing for a nonlinear age pattern; and a fixed effect for data on males. The fraction of blindness and visual impairment due to DR resulted from fitting one DisMod-MR model using three covariates: an indicator variable describing whether the data were for blindness or for MSVI, an indicator variable describing whether the data were based on presenting visual acuity or best-corrected visual acuity measurements, and a country-level covariate reflecting health systems access. Two sets of predictions for DR were generated, one for best-corrected blindness and one for best-corrected MSVI. Age-standardized prevalence represented the WHO reference population (28). The generation of numbers of people with vision impairment and blindness due to DR reflects each region's population size and age structure (24,25).

## RESULTS

Our overall estimates suggest that 32.4 million people were blind and 191 million people were visually impaired worldwide in 2010 (24). Of these, 833,690 people were blind and 3.7 million were visually impaired because of DR (Table 1). Data for 1990 are presented in Supplementary Appendix 2. From 1990 to 2010, the number of people with blindness due to DR increased by ~176,000 or 27% and the number with visual impairment due to DR increased by 1.4 million or 64% (Table 1 and Supplementary Appendix 2). In 2010, South Asia was home to 35% of those with blindness due to DR (294,811) and 40% of those with visual impairment due to DR (1.5 million) (Table 1, Supplementary Appendix 2, and Figs. 1 and 2). Of those aged 50 years and older, the number of people with blindness due to DR increased from 574,000 in 1990 to 731,000 in 2010 and the number of people with DR-related visual impairment increased from 1,858,000 in 1990 to 3,074,000 in 2010.

**Table 1—Number of people (mean [95% UI]) with blindness (presenting visual acuity <3/60) or MSVI (presenting visual acuity <6/18, ≥3/60) due to DR, the age-standardized prevalence (%) in people aged ≥50 years (mean [95% UI]), and the percentage of all blindness or MSVI attributed to DR (95% UI) in 21 world regions in 2010**

| | | Blindness due to DR | | | MSVI due to DR | | |
|---|---|---|---|---|---|---|---|
| World region | 2010 total population ('000s) | Number of people ('000s) with blindness in 2010 | Age-standardized prevalence of blindness in people aged ≥50 years in 2010 | Percentage of all blindness in 2010 | Number of people ('000s) with MSVI in 2010 | Age-standardized prevalence of MSVI in people aged ≥50 years in 2010 | Percentage of MSVI in 2010 |
| World | 6,890,000 | 834 (703, 1,102) | 0.05 (0.04, 0.07) | 2.6 (2.2, 3.4) | 3,714 (3,128, 5,471) | 0.22 (0.18, 0.31) | 1.9 (1.6, 2.7) |
| Asia Pacific, high income | 169,000 | 15 (8, 31) | 0.02 (0.01, 0.03) | 4.3 (2.6, 7.1) | 61 (38, 226) | 0.07 (0.04, 0.26) | 3.1 (2.0, 5.4) |
| Asia, Central | 68,800 | 5 (4, 10) | 0.04 (0.02, 0.06) | 4.0 (2.9, 6.0) | 33 (21, 73) | 0.21 (0.13, 0.48) | 2.8 (2.1, 4.6) |
| Asia, East | 1,190,000 | 58 (32, 111) | 0.02 (0.01, 0.03) | 1.1 (0.61, 2.0) | 279 (153, 567) | 0.07 (0.04, 0.15) | 0.84 (0.49, 1.6) |
| Asia, South | 1,120,000 | 295 (167, 514) | 0.12 (0.07, 0.21) | 2.8 (1.7, 4.8) | 1,450 (864, 2,873) | 0.51 (0.29, 0.96) | 2.1 (1.2, 3.7) |
| Asia, Southeast | 460,000 | 499 (35, 76) | 0.12 (0.03, 0.07) | 1.4 (1.1, 2.1) | 223 (154, 427) | 0.19 (0.13, 0.36) | 1.2 (0.91, 1.9) |
| Australasia | 20,500 | 2 (0.9, 5) | 0.02 (0.01, 0.05) | 4.3 (2.5, 7.7) | 13 (5, 42) | 0.14 (0.06, 0.42) | 2.9 (1.8, 5.9) |
| Caribbean | 34,300 | 5 (3, 8) | 0.05 (0.03, 0.08) | 2.3 (1.7, 3.4) | 24 (15, 42) | 0.24 (0.14, 0.41) | 2.0 (1.5, 3.2) |
| Europe, Central | 122,000 | 12 (8, 27) | 0.03 (0.02, 0.06) | 3.7 (2.8, 5.5) | 84 (49, 174) | 0.18 (0.10, 0.36) | 2.5 (1.8, 4.0) |
| Europe, Eastern | 222,000 | 24 (11, 48) | 0.03 (0.01, 0.06) | 4.0 (2.5, 6.9) | 166 (65, 371) | 0.21 (0.08, 0.47) | 2.8 (1.8, 5.2) |
| Europe, Western | 381,000 | 40 (28, 68) | 0.02 (0.01, 0.03) | 4.2 (3.4, 5.9) | 225 (153, 426) | 0.12 (0.08, 0.22) | 3.0 (2.4, 4.5) |
| Latin America, Andean | 38,600 | 5 (3, 9) | 0.05 (0.03, 0.09) | 2.5 (1.6, 4.2) | 31 (18, 55) | 0.32 (0.19, 0.55) | 2.2 (1.5, 3.8) |
| Latin America, Central | 166,000 | 23 (16, 38) | 0.06 (0.04, 0.09) | 2.5 (1.9, 3.7) | 109 (74, 192) | 0.25 (0.17, 0.44) | 2.1 (1.6, 3.5) |
| Latin America, Southern | 48,900 | 12 (8, 26) | 0.07 (0.04, 0.14) | 5.5 (3.6, 9.1) | 64 (37, 139) | 0.36 (0.21, 0.77) | 4.0 (2.6, 6.8) |
| Latin America, Tropical | 154,000 | 23 (12, 51) | 0.05 (0.03, 0.12) | 2.9 (1.9, 4.6) | 108 (62, 204) | 0.24 (0.14, 0.45) | 2.2 (1.4, 3.6) |
| North Africa/Middle East | 301,000 | 108 (76, 165) | 0.16 (0.11, 0.25) | 3.5 (2.8, 5.0) | 334 (233, 567) | 0.44 (0.31, 0.75) | 2.4 (1.8, 3.9) |
| North America, high income | 281,000 | 19 (10, 34) | 0.01 (0.01, 0.03) | 3.9 (2.7, 6.4) | 86 (56, 195) | 0.07 (0.04, 0.15) | 2.8 (1.9, 4.7) |
| Oceania | 5,814 | 0.4 (0.2, 0.9) | 0.05 (0.02, 0.09) | 1.4 (0.91, 2.4) | 3 (2, 6) | 0.26 (0.13, 0.47) | 1.2 (0.77, 2.3) |
| Sub-Saharan Africa, Central | 53,400 | 8 (4, 23) | 0.10 (0.05, 0.25) | 3.0 (2.0, 5.2) | 33 (18, 82) | 0.33 (0.18, 0.80) | 2.3 (1.6, 4.0) |
| Sub-Saharan Africa, East | 208,000 | 50 (35, 76) | 0.14 (0.10, 0.20) | 2.4 (1.9, 3.4) | 128 (92, 204) | 0.31 (0.21, 0.49) | 1.8 (1.4, 2.6) |
| Sub-Saharan Africa, South | 52,600 | 10 (5, 20) | 0.10 (0.05, 0.20) | 3.4 (2.1, 5.8) | 24 (14, 55) | 0.22 (0.12, 0.50) | 2.5 (1.6, 4.6) |
| Sub-Saharan Africa, West | 201,000 | 66 (44, 107) | 0.19 (0.12, 0.31) | 3.1 (2.4, 4.9) | 193 (125, 249) | 0.50 (0.32, 0.92) | 2.7 (1.9, 4.5) |

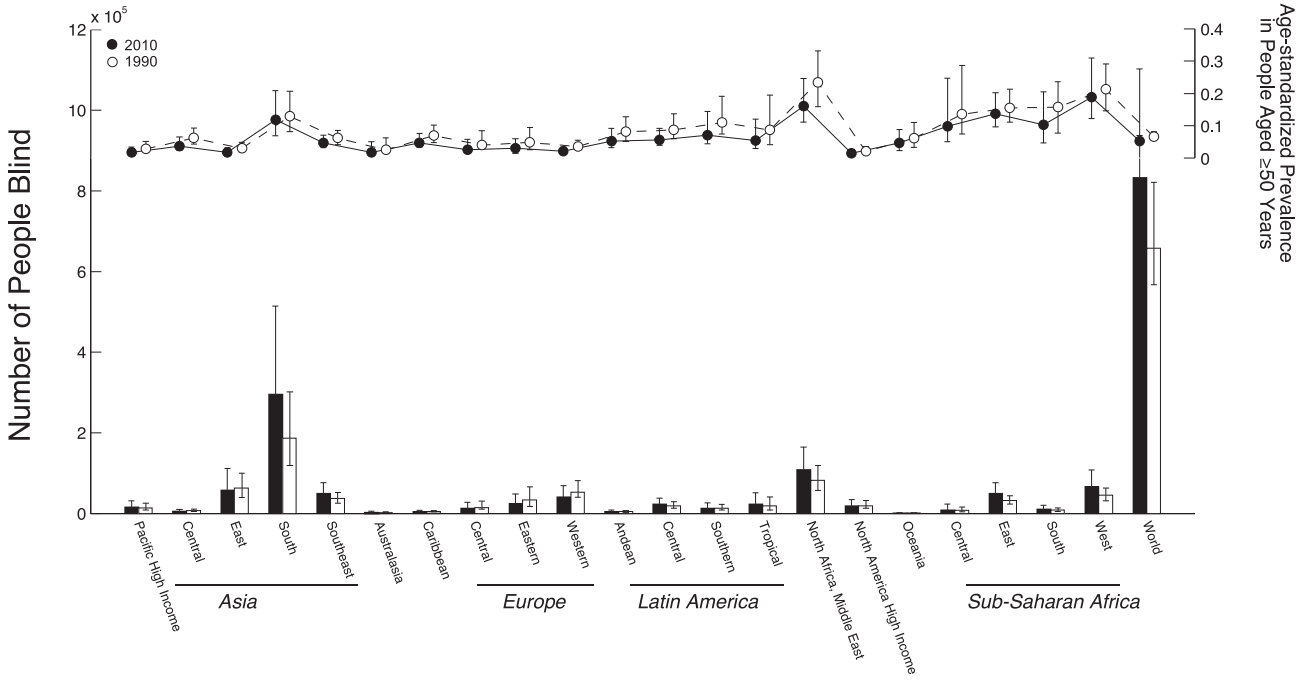


**Figure 1—**Number of people with blindness due to DR in 1990 and 2010 by world region of all ages and the age-standardized prevalence in 1990 and 2010 by world region of those aged ≥50 years (95% UI).

DR caused 2.6% of all cases with blindness worldwide in 2010 and 1.9% of all cases for MSVI (Table 1). The percentage of blindness caused by DR varied regionally from <2% in East and Southeast Asia and Oceania to ≥5.5% in Southern Latin America (Table 1). World regions with older populations such as the high-income regions, Southern Latin America, and Eastern and Western Europe, as compared with regions with relatively younger populations, showed a higher percentage of blindness caused by DR (Table 1).

Compared with 1990, of all global blindness causes, the percentage caused by DR increased from 2.1 to 2.6% in 2010, and of global MSVI causes, the

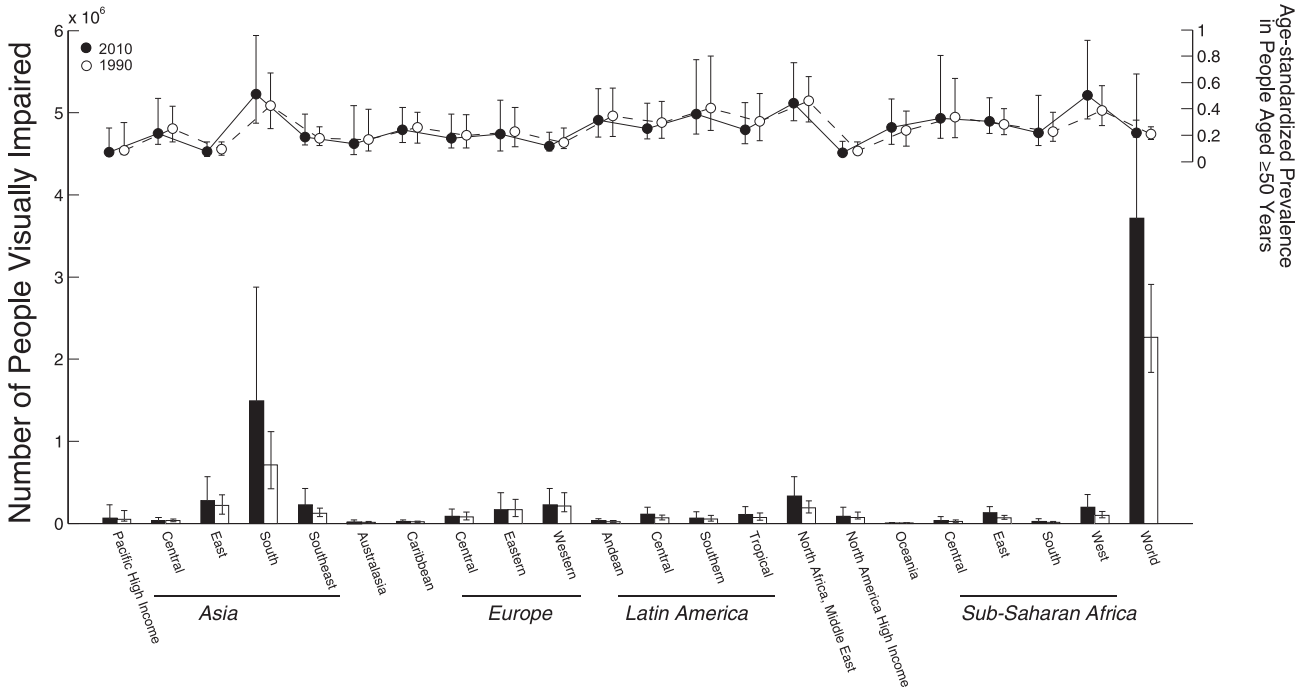


**Figure 2—**Number of people with MSVI due to DR in 1990 and 2010 by world region of all ages and the age-standardized prevalence in 1990 and 2010 by world region of those aged ≥50 years (95% UI).

percentage caused by DR increased from 1.3 to 1.9% in 2010 (Table 1 and Supplementary Appendix 2). The increase in the percentage of global blindness caused by DR from 1990 to 2010 took place in all world regions except those higher-income regions of Asia Pacific, Australasia, Western Europe, and North America where a slight decrease occurred (Table 1 and Supplementary Appendix 2).

Age-standardized prevalence of DR-related blindness and MSVI in those aged ≥50 years was relatively unchanged worldwide. Age-standardized prevalence of blindness due to DR changed to 0.0518% (95% uncertainty interval [UI] 0.0440, 0.0690) in adults aged ≥50 years in 2010 from 0.0652% (95% UI 0.0565, 0.0812) in 1990. Age-standardized prevalence of MSVI due to DR changed to 0.2185% (95% UI 0.1843, 0.3135) in 2010 from 0.2093% (95% UI 0.1689, 0.2635) in 1990 (Table 1, Supplementary Appendix 2, and Figs. 1 and 2).

On a regional basis, in 2010, the age-standardized prevalence of blindness related to DR in those aged ≥50 years was highest in West sub-Saharan Africa (0.1889%) and North Africa/Middle East (0.1599%), followed by East sub-Saharan Africa (0.1366%), and 0.1% or less in all other regions (Table 1). In 2010, the age-standardized prevalence of MSVI due to DR in those aged ≥50 years was highest in South Asia (0.5112%), West sub-Saharan Africa (0.5002%), and North Africa/Middle East (1.0%) and lowest in the high-income regions such as North America (Table 1).

## CONCLUSIONS

DR ranks as the fifth most common cause of global blindness and of global MSVI (25). Regardless of the relatively low percentage of <3% of all global blindness and MSVI being caused by DR, this analysis estimates that, in 2010, 1 out of every 39 blind people had blindness due to DR and 1 out of every 52 people had visual impairment due to DR. In adults aged ≥50 years, the global age-standardized prevalence in 2010 was 0.05% for DR-related blindness and 0.22% for DR-related MSVI. The prevalence of any DR has been previously reported in a number of population-based studies (1–23). However, few addressed the prevalence of DR-related blindness at the global level. Within the period from 1990 to 2010, the age-standardized prevalence of DR-related blindness and MSVI did not markedly change as a global mean. This is in contrast to the global decrease in the age-standardized prevalence of cataract, undercorrected refractive error, and trachoma (24,25). Our study demonstrated regional differences such as the increase in age-standardized prevalence observed in sub-Saharan regions and how the highest age-standardized prevalence of DR-related blindness and MSVI was in the regions of North Africa/Middle East, sub-Saharan Africa, and South Asia and the lowest prevalence was in the high-income regions. Similar interregional findings were reported in a recent meta-analysis (21) where prevalence estimates of any DR and of vision-threatening DR were highest in African Americans and lowest in Asians.

We propose that the phenomenon of an increase in numbers of people with vision loss due to DR with a relatively unchanged age-standardized prevalence of vision loss due to DR from 1990 to 2010 globally can be attributed to the increasing population and average age in most regions coupled with falling death rates (27).

Our data suggest that the percentage of blindness and MSVI attributable to DR was lower in low-income regions with younger populations than in high-income regions with older populations. There are several reasons that may explain this observation. First, low-income societies may have a higher percentage of unoperated cataract or undercorrected refractive error–related blindness and MSVI (25), which is probably related to access to visual and ocular health services. Therefore, the proportional increase in blindness and MSVI attributable to DR may be rising because of the decreasing proportion attributable to cataract (25) as a result of the increasing availability of cataract surgery in many parts of the world (29) during the past decade. Improved visualization of the fundus afforded by cataract surgery should also improve the detection of DR. The increase in the percentage of global blindness caused by DR within the last two decades took place in all world regions except Western Europe and high-income North America where there was a slight decrease. This decrease may reflect the effect of intensified prevention and treatment of DR possibly in part due to the introduction of intravitreal injections of steroids and anti-VEGF (vascular endothelial growth factor) drugs (30,31).

Second, in regions with poor medical infrastructure, patients with diabetes may not live long enough to experience DR (32). This reduces the number of patients with diabetes, and, furthermore, it reduces the number of patients with DR-related vision loss. Studies in the literature have reported that the prevalence of severe DR decreased from 1990 to 2010 (21) while the prevalence of diabetes simultaneously increased (27), which implies a reduction in the prevalence of severe DR per person with diabetes. This paradox is even more remarkable if one takes into account that duration of diabetes is one of the most important risk factors for the development of DR and for the development of severe DR. For example, in Central India (19) the prevalence of DR within the diabetes population was 5%, which was considerably lower than the global prevalence of 34.6%. In that rural population in Central India, the prevalence of diabetes in 2006/2008 decreased after the age of 60 years, and the prevalence of DR was exceptionally low compared with populations in industrialized countries. Differences between regions in the screening and management of DR and diabetes, socioeconomic factors, medical infrastructure, ethnic differences, and variation in genetic susceptibility for DR may also explain some of these differences (22). Interestingly, the age-standardized prevalence of DR-related blindness and MSVI were as low in South Asia as in high-income regions, despite marked regional differences in socioeconomic levels and medical infrastructure.

Third, as in the case of Central India described above (19), younger populations may have a lower prevalence of diabetes (33). If we apply our prevalence results to the number of people with diabetes reported by Danaei et al. (34), ~350 million, our figures would suggest that ~0.2% (or 834,000 people) of the 350 million were blind because of DR and that 1.1% (or 3.7 million individuals) of the 350 million with diabetes were visually impaired because of DR. These

percentages are much lower than the aforementioned figure of 35% of all patients with diabetes having any form of DR as reported in the meta-analysis by Yau et al. (21) in 2012. In that meta-analysis, the prevalence of vision-threatening DR, defined as the presence of proliferative DR or diabetic macular edema, was 10.2%. Assuming that the data in the meta-analysis of our study are also valid, our data indicate that about 10% of the individuals with vision-threatening DR experience a marked reduction in visual acuity to levels of visual impairment and that ~2% of them become bilaterally blind.

Therefore, considering further economic development in rural regions, improvements in medical infrastructure, the general global demographic transition to elderly populations, and the association between increasing economic development and obesity, we project the increase in the proportion of DR-related blindness and MSVI to continue to rise in the future. These findings can be used to develop strategies for preserving the vision of adults with diabetes, and several of these are advanced in Table 2.

Several limitations of our study should be mentioned. First, as also noted in our previous publications on the global prevalence of vision loss (24,25), a major limitation was that most country-years were without data or only had subnational data. Second, some data sources did not report prevalence by age. To use these data, we imputed age-specific cause fractions, assuming that the age pattern of visually impaired in the study represented the modeled age pattern of visually impaired in the country where the study was conducted (24,25). Third, recommended WHO surveillance protocol dictated that population-based studies reported one cause as the principal cause for an individual examined in that particular study in order to arrive at the causal prevalence. When there were multiple disorders contributing equally to visual loss, only the ''most readily curable'' or the ''most easily preventable'' was recorded (35). This approach has the potential to underestimate the impact of DR when the patient presented with cataract and underestimate the burden of cataract when patients also had an uncorrected refractive error (36). Fourth, some studies reporting population blindness had a relatively small sample size, with a relatively small proportion of visual impairment attributed to DR. The DisMod-MR model, however, took into account power estimates so that studies with small sample sizes influenced the estimates less than studies with large sample sizes. For this reason, the uncertainty intervals of cause-specific prevalence estimates are relatively large.

Strengths of this study design as compared with previous meta-analytical literature reviews (37) included the amount of population-based data accessed and used, analysis of trends in the causes of vision impairment and blindness, incorporation of nonlinear age trends and accounting for data that were not reported by age, and systematic quantitative analysis and reporting of uncertainty.

Global estimates of the prevalence and number of persons with visual impairment specifically caused by DR as a complication of the precipitous trends in global diabetes are fundamental data for health planning purposes. Although DR is estimated to affect nearly 100 million people globally and nearly 30 million have vision-threatening stages of disease, our data suggest that less than 1 million are currently blind and 4 million visually impaired. The current global strategy of prioritizing more treatable eye diseases such as cataract and uncorrected refractive error may reduce avoidable blindness in more people and may be more successful, cost efficient, and safe; however, it is imperative to plan for a greater share of blindness and visual impairment due to DR and to develop strategies (Table 2) to prevent DR and subsequent vision loss.

**Table 2—Strategies for preserving the vision of adults with diabetes**

| |
|---|
| Development of evidence-based, cost-effective strategies to screen for DR |
| Improve control of systemic risk factors (e.g., glucose and blood pressure) among persons with diabetes |
| Increase health education and awareness of the risk of visual loss from DR |
| Intensified prevention and treatment of DR through the introduction of laser treatments, intravitreal injections of steroids, and anti-VEGF drugs (20,38) |
| Reduction of differences between regions in the screening and management of diabetes and DR, socioeconomic factors, and medical infrastructure |

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**Author Contributions.** J.L.L., R.R.A.B., J.B.J., K.N., K.P., H.P., and T.Y.W. researched the data. R.R.A.B., S.R.F., and R.A.W. conducted the statistical analysis. J.L.L., R.R.A.B., J.B.J., and T.Y.W. wrote the manuscript. J.L.L., J.B.J., T.Y.W., S.R., and H.R.T. edited the manuscript, and all authors reviewed the manuscript. R.R.A.B. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
**Prior Presentation.** Parts of this study were presented in abstract form at the Association for Research in Vision and Ophthalmology 2014 Annual Meeting, Orlando, FL, 4–8 May 2014. The detailed methods and some of the results have been published within the context of an analysis of all causes of global blindness and visual impairment in the appendix of Bourne et al. (25).

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