Variations and Trends in Health Burden of Visual Impairment Due to Cataract: A Global Analysis

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PURPOSE. To evaluate the global trends in health burden of people visually impaired from cataract in terms of disability-adjusted life years (DALY) and its correlations with national levels of socioeconomic development.

METHODS. Global, regional, and national DALY numbers, crude rate, and age-standardized rate of cataract vision loss by age and sex were obtained from the database of the Global Burden of Disease Study 2015. The human development index, per capita gross domestic product, and other country-level data were derived from international open databases. Regression analysis was used to assess the correlations between age-standardized DALY rate and socioeconomic variables.

RESULTS. The global DALY numbers of cataract vision loss increased by 89.42%, from 2048.18 (95%CI: 2766.07–5232.43) thousands in 1990 to 3879.74 (95% CI: 237.17–394.4) and crude rate 38.29 (95%CI: 35.35–41.23) after adjusting for age and country (all P < 0.001). The age-standardized DALY rate was higher in countries with low human development index (HDI), with 91.03 (95%CI: 73.04–108.75) for low HDI, 81.67 (95%CI: 53.24–108.82) for medium HDI, 55.89 (95% CI: 36.87–69.63) for high HDI, and 17.10 (95% CI: 13.91–26.84) for very high HDI countries (P < 0.01), respectively. The national age-standardized DALY rates in 2015 were negatively associated with both HDI (R² = 0.489, P < 0.001) and per capita gross domestic product (R² = 0.351, P < 0.001). Stepwise multiple regression showed that HDI was significantly correlated with national age-standardized DALY rates in 2015 after adjusting for other confounding factors (P < 0.001).

CONCLUSIONS. The global health burden of vision loss due to cataract increased between 1990 and 2015 despite considerable efforts from the World Health Organization and VISION 2020 initiatives.

Keywords: cataract, health burden, QALY, socioeconomic, global, human development index, gross domestic product

Cataract has caused worldwide >50% vision loss, including 33.4% blind people and 18.4% people with moderate-to-severe visual impairment.1 Globally, 10.8 million were blind and 35.1 million people were visually impaired from cataract in 2010.1,2 Along with the aging population and extended life expectancy, the number of people with cataract is expected to increase continuously. Cataract can be cured by surgery, which ranks as the most cost-effective intervention with 4500% financial return on investment.3,4 Cataract surgery leads to huge socioeconomic benefits and improvement in well-being and quality of life. Cataract remains a concern for public health, especially in low- and middle-income countries. A total of $5735 million investment was estimated to be required for eliminating blindness due to cataract between 2010 and 2020.5

Apart from the prevalence data, the health burden of a disease is also informative for policymakers. The health burden of disease can be quantified by the disability-adjusted life years (DALY), which is defined as the sum of years of healthy life loss caused by premature death or disability. DALY reflects the gap between the actual health status and the normative situation. One DALY means 1 lost year of healthy life owing to the disease. DALY combines both the prevalence of a disease and its impact on mortality and morbidity. The advantage of DALY lies in its aggregative nature, which enables comparisons of different diseases and injuries across time and regions. The most recent estimation demonstrated that vision loss was the third largest impairment in DALY after anemia and hearing loss.6,7 Of all vision-threatening disorders, cataract was the second leading cause of disability and accounted for 3.9 million DALYs, after refraction and accommodation disorders.6,7 Thus, cataract remains a public health concern.

The World Health Assembly endorsed disease burden, cataract surgical rate/coverage, and human resources as the national indicator for monitoring eye services.8 In our previous study, we evaluated the changes of cataract surgical rate in each country in the last decade and revealed a close association between cataract surgical rate and country per capita gross domestic product.9 Although it is also valuable for policy making and program planning, knowledge of the health burden of cataract was not adequate. The aim of this study was to evaluate the time trends of the global health burden of cataract...
vision loss and its distribution across age, sex, and national levels of socioeconomic development.

**METHODS**

**Global Burden of Visual Impairment Caused by Cataract**

The data on DALY owing to cataract vision loss were obtained from the open database of the Global Burden of Disease 2015 Study (http://ghdx.healthdata.org/gbd-results-tool; in the public domain), which provided a particular means to estimate the disease burden of 315 diseases and injuries in 196 countries/territories from 1990 to 2015. The DALY is defined as the sum of years of life lost and years lost due to disability resulting from cataract vision loss. The methodology of the Global Burden of Disease 2015 Study has been detailed in previous publications. In brief, the DALYs of cataract vision loss in a country were obtained in four steps. (1) The overall prevalence of presenting vision loss was modeled; visual impairment was defined in accordance with the guidance of the World Health Organization (WHO), and the cases were constrained to vision loss caused by any type of cataract with the minimum age of 20 years. (2) The prevalence of presenting vision loss caused by uncorrected refractory errors was estimated. (3) The prevalence of cataract vision loss was calculated. (4) The DALYs were obtained by the following algorithm: DALY number = (Number of deaths × Standard life expectancy at age of death in years) + (Number of prevalent cases × Disability weight). The crude DALY rate was calculated by adjusting for population size (per 100,000 population), and the age-standardized DALY rate was obtained by further adjusting for population size and structure (per 100,000 population).

The following data were used for statistical analysis: (1) the global DALY number, crude rate, age-standardized rate in 1990, 1995, 2000, 2005, 2010, and 2015; (2) the age- and sex-specific DALY numbers and crude rate in individual countries/territories in 2015; (3) the WHO regional DALY numbers, crude rate, and age-standardized DALY rate in 2015; (4) national age-standardized DALY rate in 2015.

**Country-Level Indicators**

The exposure factors were the country-level demographic, socioeconomic, and environmental indicators derived from the following well-known open databases. The open database of the World Bank (http://data.worldbank.org; in the public domain) was used to obtain the per capita gross domestic product of individual countries in 2015 by the purchasing power parity method in constant 2011 international dollars. The United Nations Development Programme (http://hdr.undp.org/en/data; in the public domain) was used to obtain the national levels of human development index (HDI), which is a composite measure of social and economic achievement. HDI has four components: life expectancy index, mean years of schooling index, expected years of schooling index, and income index. HDI ranges from 0 to 1, with higher value indicating higher socioeconomic level, and countries were classified into four socioeconomic groups: low (HDI < 0.550), medium (0.550-0.699), high (0.700-0.799), and very high (0.800 or greater) HDI. The average daily level of ambient ultraviolet radiation, average annual concentration of fine particulate matter (PM2.5), cellular phone subscribers per 100 people, age-standardized mean systolic blood pressure, mean body mass index, and percent urbanization rate in a country were obtained from the WHO Global Health Observatory data repository (http://apps.who.int/gho/data/node. imr; in the public domain). The annual PM2.5 concentration is a common measure of air pollution, which is defined as the mean annual concentration of fine suspended particles < 2.5 μm in diameter in a country.

**Statistical Analysis**

All statistical analyses were performed by using STATA 12.0SE (Stata Corp, College Station, TX, USA). The outcomes included the geographic, sex, and time distribution of DALY of cataract vision loss, as well as the influence of socioeconomic indicators on DALY of cataract vision loss. The Wilcoxon signed rank test was used to compare the sex differences in DALY number and crude rate for each age group. The multilevel mixed-effects linear model was used to evaluate the influence of sex on overall DALY number and crude rate. Comparisons of age-standardized DALY rate among four HDI-based countries groups were assessed by Kruskal-Wallis test, followed by Mann-Whitney–Wilcoxon test for two-group comparisons. Scatter plots were constructed to explore the relationship between national age-standardized DALY rate and country-level variables. Linear regression analysis was used to explore the influence of country-level indicators on the national age-standardized DALY rate in 2015. Multiple linear regression modeling was fitted using the stepwise backward approach with significance level set at 0.05. A P < 0.05 was considered statistically significant.

**RESULTS**

**Changes of Health Burden Over the Last 25 Years**

The DALY number of cataract vision loss increased by 89.42%, from 2048.18 (95% CI [confidence interval]: 1457.60–2761.80) thousands in 1990 to 3879.74 (95% CI: 2766.07–5232.43) thousands in 2015 (Fig. 1A). During the same period, the crude DALY rate increased by 36.28%, from 38.62 (95% CI: 27.49–52.08) to 52.63 (95% CI: 37.53–70.99) (Fig. 1B). After removing the influence of population size and structure, cataract burden in terms of age-standardized DALY rate increased before 2005, and then decreased to the 1990s level. The global age-standardized DALY rate in 1990 and 2015 was 60.28 (95% CI: 43.01–81.01) and 60.35 (95% CI: 43.14–81.21), respectively (Fig. 1C).

**Global Health Burden of Cataract Vision Loss by Age and Sex**

Figure 2 shows the sex differences of global DALY numbers and crude rate for each age group in 2015. The two sexes showed a similar trend of global DALY by age, slowly increasing before 50 years of age and sharply increasing after 50 years of age (Fig. 2). Wilcoxon signed rank tests showed significant sex disparities in national DALY numbers and crude rate for each age group (all P < 0.01). Multilevel mixed modeling confirmed that females had higher DALY numbers, 315.85 (95% CI: 237.17–394.4), and crude rate, 38.29 (95% CI: 35.35–41.23), after adjusting for age and country.

**Global Health Burden of Cataract Vision Loss by WHO Regions**

Figure 3 maps the distribution of health burden of cataract vision loss in 2015. As expected, the countries with largest populations had the highest DALY numbers (Fig. 3A). After controlling for population size, the DALY rate was highest in India and lowest in high-income countries (Fig. 3B). After
controlling for population size and structure, India, Africa, and South American countries had the heaviest burden of cataract (Fig. 3C). Looking at the health burden in each of the WHO Regions, DALY numbers were highest in Southeast Asia, followed by the Western Pacific Region (Fig. 4A). Southeast Asia also has the highest DALY crude rate, followed by the Eastern Mediterranean Region (Fig. 4B). The age-standardized DALY rate was highest in Southeast Asia, followed by Eastern Mediterranean, Africa, Western Pacific, and America, with the lowest rate in Europe. The age-standardized DALY rates in Southeast Asia, the Eastern Mediterranean, and Africa were higher than that at the global average level (Fig. 4C).

**Health Burden of Cataract Vision Loss and Socioeconomic Factors**

Age-standardized DALY rate differed significantly among countries with different HDI ($P < 0.001$) (Fig. 5A). The mean value of age-standardized DALY rate was 91.03 (95% CI: 73.04–108.75) for low HDI, 81.67 (95% CI: 53.24–108.82) for medium HDI, 55.89 (95% CI: 36.87–69.63) for high HDI, and 17.10 (95% CI: 13.91–26.84) for very high HDI countries, respectively. Linear regression analysis revealed that HDI was negatively correlated with age-standardized DALY rate ($R^2 = 0.489$, $P < 0.001$; Fig. 5B). In further analysis of the four components of HDI, expected years of schooling was identified as the most influential indicator, which accounted for 55.6% of global variations in age-standardized DALY rates (Table 1). Similarly, the age-standardized DALY rate was negatively associated with per capita gross domestic product ($R^2 = 0.351$, $P < 0.001$).

The daily ultraviolet radiation, annual PM2.5 concentration, urbanization rate, percent cellular subscribers, mean body mass index, and systolic blood pressure also were found to be significantly associated with the age-standardized DALY rate (Fig. 6). Stepwise multiple regression analyses were conducted to eliminate colinearity (Table 2). When the composite HDI
was used, three factors (HDI, daily ultraviolet radiation, and average annual PM2.5) were included in the model, which accounted for 62.7% of global variations in age-standardized DALY rate. When the four components of HDI were used, three indicators (mean years of schooling index, daily ultraviolet radiation, and average annual PM2.5) were significant, and the model could explain 63.4% of global variations in age-standardized DALY rate.

DISCUSSION

This study provides an overview of the global pattern of the health burden of cataract vision loss by year, age, sex, region, and socioeconomic levels. From 1990 to 2015, the DALY number of cataract vision loss increased by 89.42%. The age-standardized DALY rate increased before 2005 and then decreased slowly to the 1990s level. The health burden of cataract increased rapidly in people over 50 years of age. Females had a higher health burden compared to males at the same age. The health burden of cataract vision loss is closely associated with socioeconomic factors, even after adjusting for demographic and environmental factors.

Although prevalence data and DALY could not be compared directly, both types of information have implications for understanding the situation of cataract vision loss. It was estimated that the prevalence of cataract vision loss was decreasing during the period between 1990 and 2010 in all countries, with the exception of eastern Sub-Saharan Africa. From 1990 to 2010, the number of people with cataract blindness was reduced by 11.4%, and the percentage of blindness due to cataract decreased from 38.6% to 33.4%. This may be associated with global action such as VISION 2020, which set cataract as a priority, and national programs such as the China Million Cataract Surgeries Program. However, the

**TABLE 1.** Linear Regression Analysis of the Relationship Between National Health Burden of Cataract and Socioeconomic Variables

<table>
<thead>
<tr>
<th>Age-Standardized DALY Rate</th>
<th>Coefficient (95%CI)</th>
<th>P Value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDI</td>
<td>-165.9 (-190.8, -141.1)</td>
<td>&lt;0.001</td>
<td>0.489</td>
</tr>
<tr>
<td>Life expectancy index</td>
<td>-2.7 (-3.2, -2.2)</td>
<td>&lt;0.001</td>
<td>0.389</td>
</tr>
<tr>
<td>Mean years of schooling index</td>
<td>-8.6 (-10.0, -7.2)</td>
<td>&lt;0.001</td>
<td>0.459</td>
</tr>
<tr>
<td>Expected years of schooling index</td>
<td>-8.8 (-10.0, -7.7)</td>
<td>&lt;0.001</td>
<td>0.556</td>
</tr>
<tr>
<td>Income index</td>
<td>-17.4 (-21.2, -13.7)</td>
<td>&lt;0.001</td>
<td>0.320</td>
</tr>
<tr>
<td>Per capita GDP, log scale</td>
<td>-17.8 (-21.6, -14.1)</td>
<td>&lt;0.001</td>
<td>0.331</td>
</tr>
</tbody>
</table>

GDP, gross domestic product.
improvement in prevalence did not mean a lesser health burden of this condition, as our study demonstrates. The DALY number increased continuously, which may be due to the population growth and elongation of life expectancy. As shown earlier, the DALY was closely associated with population number and life expectancy. In the past 25 years, population and life expectancy increased by approximately 30% and 16%\textsuperscript{13}. The life expectancy factor contributed to 38.9% of the variation in age-standardized DALY rate across countries (Table 1). However, the educational factor was more influential and accounted for 55.6% of global variations in age-standardized DALY rate. Therefore, regarding the observation that the health burden of cataract blindness increased during the past decade, it is unlikely that it changed if one considers the changes in life expectancy.

The outcomes and potential complications of cataract surgery were also key components of blind prevention projects. The outcomes in low-income countries are very low.
compared to those in high-income countries. There are several possible causes of poor outcomes of cataract surgery in low-income countries: (1) problems of biometry and availability of intraocular lenses fitted for each patient; (2) postoperative opacification of the capsular bag without YAG laser access; (3) poor surgical techniques; (4) endophthalmitis related to the lack of sterile conditions; and (5) other classic complications (retinal detachment, cystoid macular edema, and so on). For example, it was reported that 0.39% of patients experienced retinal detachment after cataract surgery in Denmark, while the risk was 0.47% for patients in China.

These findings reinforced sustained demands for allocating resources to cataract services and monitoring the quality of cataract surgery. We observed a disproportionate distribution of the health burden of cataract. A previous study demonstrated that cataract ranked as the most unevenly distributed eye disorder in 2004, with higher DALYs in low- and middle-income countries. The World Health Survey in 70 countries showed that the prevalence of vision difficulty in low-income countries was two times higher than that in high-income countries. Among the 21 Super Regions, the prevalence of cataract blindness was highest in Oceania, followed by South and Southeast Asia, and the lowest in high-income countries.

Consistent with previous studies, the present study observed an unevenly distributed health burden of cataract. The levels of health burden in Southeast Asia, the Eastern Mediterranean, and Africa were higher than the global level; addressing this should be a priority in future programs.

The national HDI level was independently correlated with the health burden of cataract vision loss, with higher age-standardized DALY rates in lower HDI countries. HDI reflects the quality of wealth, which has become a standard indicator for comparisons of socioeconomic development across coun-

![FIGURE 5. Relationship between health burden of cataract vision loss and national levels of socioeconomic development. (A) Health burden differed among different HDI categories. (B) Health burden was inversely associated with HDI. The blue line represents fitted line.](Downloaded From: http://arvojournals.org/ on 01/17/2018)

![FIGURE 6. Relationship between health burden of cataract vision loss and country-level demographic and environmental factors. (A) Average daily ultraviolet radiation, (B) average annual concentration of PM2.5 in a country, (C) urbanization rate, (D) cellular subscribers per 100 people, (E) mean body mass index, (F) mean systolic blood pressure.](Downloaded From: http://arvojournals.org/ on 01/17/2018)
Table 2. Stepwise Multiple Regression Analysis of the Relationship Between National Health Burden of Cataract and Country-Level Variables

<table>
<thead>
<tr>
<th>Age-Standardized DAILY Rate</th>
<th>Coefficient (95%CI)</th>
<th>P Value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1*</td>
<td></td>
<td></td>
<td>0.627</td>
</tr>
<tr>
<td>HDI</td>
<td>-88.1 (-117.3, -58.8)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Daily ultraviolet radiation, J/m²</td>
<td>0.010 (0.007, 0.013)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Average PM2.5, μg/m³</td>
<td>0.5 (0.3, 0.7)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Model 2†</td>
<td></td>
<td></td>
<td>0.634</td>
</tr>
<tr>
<td>Mean years of schooling index</td>
<td>-5.2 (-6.9, -3.5)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Daily ultraviolet radiation, J/m²</td>
<td>0.009 (0.005, 0.012)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Average PM2.5, μg/m³</td>
<td>0.3 (0.1, 0.5)</td>
<td>0.003</td>
<td></td>
</tr>
</tbody>
</table>

HDI, human development index (combinative indicator for social and economic development).
* Model 1 was fitted with the inclusion of HDI and other country-level indicators.
† Model 2 was fitted with the inclusion of HDI components and other country-level indicators.

The economy may be implicated as one possible determinant of output and quality of cataract surgery. The number of ophthalmologists per million people varied with socioeconomic development, with higher concentration in regions with higher HDI and per capita gross domestic product. Generally, the preoperative visual acuity with regard to cataract surgery was associated with increasing HDI and per capita income. The cost was the main barrier to utilization of cataract surgery in some developing countries. Reduction of the cost effectively increased the cataract surgical rate in southern China by 160%. More free or low-price surgeries are needed to reduce the health burden of cataract vision loss. The educational factor was found to be the most prominent HDI component. It was previously reported that increased knowledge was associated with accepting cataract surgery, whereas cost and transportation were not. This may be explained by the following reasons. First, high education usually means better knowledge of cataract. Willingness to pay for cataract surgery has been reported to increase with knowledge of cataract. Secondly, higher education leads to a higher possibility of a steady occupation, as well as higher income and coverage by medical insurance, enabling the cost of cataract surgery to be more affordable. Even in the United States, annual use of eye services was significantly associated with levels of educational attainment after adjusting for other factors. A randomized controlled trial demonstrated that educational interventions can successfully increase the uptake of cataract surgery.

Sex differences in the health burden of cataract vision loss were significant for each age group. One possible explanation is that females have a higher incidence of cataract and longer life expectancy. Another explanation may be related to sex inequality in relation to utilization of cataract surgery. Evidence suggests that females are less likely to access eye health, especially in developing countries. Though 60% of cataract blindness was in females, males had 1.39 times odds of uptake of cataract surgery compared to women. Being female usually was related to a higher rate of illiteracy, especially among the elderly, and less control of finances compared to men, which prevented opportunities for operations. For children with bilateral cataract, access to surgery for girls was also lower than for boys in low-income countries. After adjusting for other factors, being female was found to be associated with poor uncorrected visual acuity (P = 0.04) and corrected visual acuity (P = 0.03) post cataract surgery. Closing sex disparities in cataract surgical services would be beneficial with regard to improving the health burden of cataract.

This study has limitations. First, the accuracy of health burden information suffered from the limitations of the data sources. For example, statistical assumptions may introduce bias. Second, the analytic unit was at the national level rather than the district level, which may introduce the ecologic fallacy. Significant variations in development levels and disease burden may exist within a country. Finally, subgroup analyses by culture and health system factors were not performed, as corresponding data for these fields were unavailable. Notwithstanding the above limitations, the findings of this study could serve as an impetus for continued efforts toward eliminating cataract blindness.

To conclude and in summary, the global health burden of vision loss related to cataract increased between 1990 and 2015 despite considerable efforts in the form of the WHO and VISION 2020 initiatives. Older age, being female, less education, and poor socioeconomic status were associated with a higher burden of cataract vision loss. These findings can raise awareness of the disease burden of cataract and could serve as impetus for continued efforts toward eliminating cataract blindness.

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