Original Article

The Association of Socioeconomic Status with the Burden of Cataract-related Blindness and the Effect of Ultraviolet Radiation Exposure: An Ecological Study*

DENG Yan[1], YANG Dan[1], YU Jia Ming[2], XU Jing Xian[2], HUA Hui[1], CHEN Ren Tong[1], WANG Nan[1], OU Feng Rong[3], LIU Ru Xi[4], WU Bo[5], and LIU Yang[1,#]

1. Department of Environmental Health, School of Public Health, China Medical University, Shenyang 110122, Liaoning, China; 2. Department of Ophthalmology, the Fourth Affiliated Hospital, China Medical University, Shenyang 110032, Liaoning, China; 3. Academic Affairs Office, China Medical University, Shenyang 110122, Liaoning, China; 4. Department of Immunology and Rheumatology, First Hospital, China Medical University, Shenyang 110001, Liaoning, China; 5. Department of Anal and Rectal Diseases, First Hospital, China Medical University, Shenyang 110001, Liaoning, China

Abstract

Objective To assess the association of socioeconomic status with the burden of cataract blindness in terms of year lived with disability (YLD) rates and to determine whether ultraviolet radiation (UVR) levels modify the effect of socioeconomic status on this health burden.

Methods National and subnational age-standardized YLD rates associated with cataract-related blindness were derived from the Global Burden of Disease (GBD) study 2017. The human development index (HDI) from the Human Development Report was used as a measure of socioeconomic status. Estimated ground-level UVR exposure was obtained from the Ozone Monitoring Instrument (OMI) dataset of the National Aeronautics and Space Administration (NASA).

Results Across 185 countries, socioeconomic status was inversely associated with the burden of cataract blindness. Countries with a very high HDI had an 84% lower age-standardized YLD rate [95% confidence interval (*CI*): 60%–93%, $P < 0.001$] than countries with a low HDI; for high-HDI countries, the proportion was 76% (95% *CI*: 53%–88%, $P < 0.001$), and for medium-HDI countries, the proportion was 48% (95% *CI*: 15%–68%, $P = 0.010$; P for trend < 0.001). The interaction analysis showed that UVR exposure played an interactive role in the association between socioeconomic status and cataract blindness burden (P value for interaction = 0.047).

Conclusion Long-term high-UVR exposure amplifies the association of poor socioeconomic status with the burden of cataract-related blindness. The findings emphasize the need for strengthening UVR exposure protection interventions in developing countries with high-UVR exposure.

Key words: Cataract; Blindness; Socioeconomic status; Ultraviolet rays; Global burden of disease

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#Correspondence should be addressed to LIU Yang, Professor, PhD, E-mail: yangliu@cmu.edu.cn, Tel/Fax: 86-13386885612.

Biographical note of the first author: DENG Yan, female, born in 1986, PhD, Candidate, majoring in environmental health.

INTRODUCTION

A series of efforts, such as including cataracts in most national plans for the prevention of visual impairment[1], have been made to improve cataract-related health services. However, cataracts remain a major public health problem[2]. In 2010, cataracts were responsible for 33.4% of global blindness and 18.4% of global moderate to severe vision impairment[2]. With the increasing life expectancy and rapidly aging population, the number of people with vision impairment due to cataracts is expected to increase continuously. The burden of cataracts can be quantified by disability adjusted life year (DALY) as the sum of year of life lost (YLL) and year lived with disability (YLD) for each location estimated by the Global Burden of Diseases (GBD), Injuries, and Risk Factors Study 2017[3]. The GBD study 2017 was the result of a global collaboration to examine data on 359 diseases and injuries in 195 countries and territories, and it revealed that the global DALYs for cataracts increased by 29.6% from 2007 to 2017, reaching 8,010 thousands[3].

Cataracts are the most unevenly distributed noncommunicable eye disease in the world, placing the greatest burden on middle- and low-income countries[4], which result from the combined effects of socioeconomic and environmental factors. From a socioeconomic perspective, previous studies have found that the health burden of cataract vision loss is correlated with socioeconomic status[5,6]. Cataracts can not only cause vision loss but also cause more serious blindness[1,2], which leading to an increased risk of death[7] and impaired quality of life[8]. We speculate that burden of cataract-related blindness is also correlated with socioeconomic status. From an environmental perspective, as it is well known, exposure to ultraviolet radiation (UVR) is one of the risk factors for cataract blindness, and the association of a higher cataract blindness burden with UVR has been documented in numerous reports[9-11]. A study concluded that the prevalence of cataracts increased at a rate of 3% for each degree of latitude to the south[12]. Therefore, UVR is a major factor leading to an uneven worldwide distribution of the cataract-related blindness burden, and it cannot be ignored. However, little evidence of evaluation of the effect of co-exposure to high-UVR and poor socioeconomic status on burden of cataract-related blindness.

We hypothesized that co-exposure on high-UVR and poor socioeconomic development jointly leads to the inequality in global cataract-related burden, with a stronger association of socioeconomic status with cataract-related burden in high-UVR countries than in countries of low UVR exposure. Therefore, in addition to evaluating the association of socioeconomic status and the burden of cataract-related blindness, we further explored the potential interaction effect between socioeconomic status and UVR exposure on the burden of cataract blindness in 185 countries and territories worldwide. Our study may be informative and helpful in achieving the aim proposed by the World Health Organization (WHO) Global Action Plan (GAP)[1] of eliminating blindness caused by cataracts.

METHODS

Study Design

This study involved all countries in the world, using both country-level and subnational-level data. In the country-level analysis, countries with data in the GBD study 2017 but not in the Human Development Report were excluded (Supplementary Table S1 available in www.besjournal.com). We also analyzed subnational-level data if subnational regions were included in the GBD study 2017 (Supplementary Table S2 available in www.besjournal.com). All variables used the latest values, except UVR exposure and gross domestic product (GDP) per capita (Supplementary Table S3 available in www.besjournal.com). Satellite-derived UVR exposure data were incomplete from June 1–14, 2016 and from May 12–16, 2017, so we used 2015 solar UVR data. The GDP per capita of Japan was available only in 2014.

Data Sources and Definitions

Global Burden of Cataract Blindness The GBD study 2017 provides YLD to quantify the burden of cataract blindness. Age-standardized YLD rates associated with blindness due to cataracts were analyzed. The data were derived from the open-access database of the Global Burden of Disease study 2017 (http://ghdx.healthdata.org/gbd-results-tool), which contains quantitative data on nonfatal health outcomes in terms of YLDs for a list of 354 GBD causes according to different severity splits in 195 countries[13]. The YLDs were estimated as the product of a prevalence estimate and a disability weight for the health states of each mutually exclusive sequela, adjusted for comorbidity[13]. Disability weights employed numbers on a scale from 0 to 1 that represented the severity of health loss associated with a single given health state. Regarding cataracts (International Classification of Diseases 10th Revision (ICD-10) codes H25-H26 and H28-H28.8), the disability weight was 0.187 (0.124–0.260) for blindness[13]. YLD rates were calculated by dividing the number of YLDs by the relevant population. The GBD study 2017 reference population was used to calculate the age-standardized YLD rate[14]. The following GBD study 2017 data concerning cataract blindness were collected as the outcome variables: (1) national age-standardized YLD rates owing to cataract blindness in 2017 and (2) subnational age-standardized YLD rates owing to cataract blindness in 2017. Because the GBD study data can be downloaded from an open access database, ethics approval and informed consent were not required for this study.

Human Development Index The human development index (HDI), as a regional socioeconomic indicator, is a composite measure of health, education, and income, measured by life expectancy at birth, mean years of schooling and gross national income per capita, respectively[15]. A higher HDI value indicates a higher level of socioeconomic development, ranging from 0 to 1. Country-level HDI data were obtained from the Human Development Report 2018 released by the United Nations Development Programme (UNDP) (http://hdr.undp.org/en/data). Subnational-level HDI data were obtained from The Global Data Lab (https://hdi.globaldatalab.org/areadata/shdi/) of the Institute for Management Research, Radboud University. Using the UNDP categorization[15], countries and subnational regions were divided into four socioeconomic groups: the low-HDI group (less than 0.550), medium-HDI group (0.550–0.699), high-HDI group (0.700–0.799) and very-high-HDI group (0.800 or greater).

Solar Ultraviolet Radiation Exposure The estimated daily cloud-adjusted ambient solar UVR data were obtained from NASA Goddard Earth Sciences Data and Information Services Center readings from the Ozone Monitoring Instrument (OMI) mounted on the NASA Earth Observing System Auraspacecraft[16]. The OMI is a nadir viewing spectrometer that measures solar reflected and backscattered radiation in the 270–500 nm wavelength range with a spectral resolution of approximately 0.5 nm in the UVR range. The OMI ultraviolet data consider the impact of altitude, ozone, surface albedo, aerosols and cloud coverage to accurately measure the amount of solar UVR that reaches the Earth's surface[17]. We estimated the UVR for analysis by averaging the daily estimates (in J/m^2) in 2015 with an OMI Level 3 surface UV irradiance product, which was provided on a 1° × 1° (longitude × latitude) grid, with each cell covering an area of 110 km (north–south) × 66 km (east–west) according to the World Geodetic System 84 coordinate system. An average daily UVR level was obtained for each country using ArcGIS version 10.2 software (http://www.esri.com/software/arcgis/index.html). First, we built a raster layer in the ArcGIS program with UVR data. Second, we built a superimposed polygon vector layer on the basis of the raster layer with a world map of national and subnational borders. Third, we used the zonal statistics tool to quantify the UVR level per country. Subnational UVR data were calculated for limited countries with the corresponding value of the subnational burden of cataract blindness provided by the GBD study 2017 following similar procedures.

Covariates

The covariates were selected based on the GBD study 2017 (Supplementary Table S4 available in www.besjournal.com) and previous literature[4,5,6]. We further selected covariates if they showed a significant association (P < 0.05) with the burden of cataract blindness in the univariate analysis or if one of the regression coefficients changed by at least 10% after covariates were added to the multivariable-adjusted model. Overall, we controlled for the following potential confounding variables: country-specific male to female sex ratio, proportion of population using solid fuels, age-standardized prevalence of current tobacco smoking, age-standardized diabetes mellitus prevalence, proportion of population living in urban areas, population-mean body mass index (BMI), and GDP per capita at nominal values. Supplementary Table S3 in lists additional information for each confounder. Subnational-level covariates including male to female ratio, age-standardized diabetes mellitus prevalence and GDP per capita at nominal values were measured by region (Supplementary Table S5 available in www.besjournal.com). Other subnational variables were supposed to be homogeneous within each country.

Statistical Analyses

Data are presented as the mean ± standard deviation (SD) or median (interquartile) for continuous variables and as frequency or percentage for categorical variables. Linear regression models were used to evaluate the associations between HDI, UVR exposure, and cataract age-standardized YLD rate owing to blindness using country-level data and subnational-level data in three steps. First, we examined conditions of normality and log-transformed the outcome measures if the normality assumption was violated. Second, we built an adjusted model depending on the inclusion of covariates. Third, interaction and stratified analyses were conducted according to UVR exposure (high UVR and low UVR), HDI status (low HDI, medium HDI, high HDI, and very high HDI), and the burden of cataract-related blindness. All analyses were performed with the statistical software packages R (http://www.R-project.org, The R Foundation) and EmpowerStats (http://www.empowerstats.com, X&Y Solutions, Inc., Boston, MA). A two-sided significance level of 0.05 was used to evaluate statistical significance.

RESULTS

The GBD study 2017 was based on a geographical hierarchy that included 195 countries and territories, of which 185 countries were also included in the Human Development Report. Both HDI and age-standardized YLD rates in 2017 were available for 185 countries (Table 1, Supplementary Table S1), covering 94.87% of all countries and territories worldwide (Supplementary Figure S1 available in www.besjournal.com), including 38 very-high-HDI, 39 high-HDI, 51 medium-HDI and 57 low-HDI countries. The global distribution of country-specific age-standardized YLD rates owing to blindness in 2017 was unequal (Supplementary Figure S2 available in www.besjournal.com). The geometric means of age-standardized YLD rates owing to blindness in each HDI group ranked from low to very high HDI, were as follows: 77.98, 45.47, 19.51, and 10.48. The subnational estimation of age-standardized YLD rates owing to blindness in the GBD study 2017 included 206 subnational regions belonging to seven countries: Japan, the United States, Sweden, the United Kingdom, Mexico, Brazil, and Indonesia (Supplementary Table S5). Of these subnational regions, 22 were in the medium-HDI group, 63 were in the high-HDI group, and 121 were in the very-high-HDI group, and the corresponding geometric mean of age-standardized YLD rates owing to blindness were 122.28, 51.28, and 4.64, respectively. Additional characteristics of the covariates in this study, stratified by the HDI of included countries and subnational regions, are shown in Table 1 and Supplementary Table S6 (available in www.besjournal.com). The mean country-specific daily UVR levels ranged from 732.19 to 4876.66 $J{\cdot}m^{-2}{\cdot}day^{-1}$ (Supplementary Figure S3 available in www.besjournal.com). The mean daily UVR exposure doses declined from 3,696.64 (low HDI), 3,529.58 (medium HDI), 3,133.49 (high HDI), to

Table 1. Characteristics of included countries

Characteristics	Total	HDI categories[d]			
		Low HDI	Medium HDI	High HDI	Very high HDI
Countries n^a (%)	185	38 (20.54)	39 (21.08)	51 (27.57)	57 (30.81)
Blindness age-standardized YLD rate per 100,000 population[b]	25.59 ± 3.39	77.98 ± 1.80	45.47 ± 2.65	19.51 ± 3.07	10.48 ± 2.64
Mean UVR exposure ($J{\cdot}m^{-2}{\cdot}day^{-1}$)[c]	2939.86 ± 1143.85	3696.64 ± 453.50	3529.58 ± 657.50	3133.49 ± 1097.47	1858.61 ± 969.23
Male to female sex ratio	102.00 ± 22.09	99.56 ± 2.64	100.25 ± 5.64	99.45 ± 5.98	107.11 ± 38.81
Population using solid fuels (%)	34.91 ± 34.73	81.26 ± 22.64	52.72 ± 27.82	18.82 ± 19.04	6.23 ± 4.93
Age-standardized prevalence of current tobacco smoking (%)	21.40 ± 8.77	13.76 ± 5.84	22.44 ± 8.72	22.18 ± 7.45	25.09 ± 8.60
Age-standardized diabetes mellitus prevalence (%)	7.99 ± 3.08	6.99 ± 2.41	8.82 ± 3.74	8.81 ± 3.64	7.37 ± 1.96
Population living in urban areas (%)	55.35 ± 22.99	33.67 ± 14.73	42.89 ± 14.66	56.77 ± 19.61	77.06 ± 14.01
BMI mean ($kg{\cdot}m^{-2}$)	25.69 ± 2.19	23.41 ± 1.55	24.94 ± 2.39	26.93 ± 1.69	26.61 ± 1.27
GDP per capita (USD)[e]	5466.43	839.17	2842.94	6492.05	28671.35

Note. [a]For which data are available. [b]Geometric mean ± SD. [c]Mean ± SD (all such values). [d]Categorized as follows: < 0.550 (low HDI); 0.550–0.699 (medium HDI); 0.700–0.799 (high HDI); > 0.800 (very high HDI). [e]Median.

1,858.61 J·m^{-2}·day^{-1} (very high HDI) with the increase in HDI at the country level, and the trend was also observed at the subnational level, with a range from 4,430.78 (medium HDI) and 3,835.03 (high HDI) to 1,731.55 J·m^{-2}·day^{-1} (very high HDI).

National and subnational age-standardized YLD rates were log-transformed because of violations of the assumption of normality. In univariate analyses, population using solid fuels, current tobacco smoking prevalence, urbanization, BMI and GDP were significantly associated with the age-standardized YLD rate (P < 0.001) at the country level, and all covariates were significantly associated with the age-standardized YLD rate (P < 0.001) at the subnational level (Supplementary Table S7 available in www.besjournal.com). Urbanization and population using solid fuels were excluded due to collinear relationships in the subnational analysis.

Linear regression analysis showed that HDI was negatively associated with cataract age-standardized YLD rate owing to blindness in the crude model. In multivariable analyses, a consistent reverse association between HDI and the burden of cataract-related blindness among countries was retained in the adjusted model (Table 2). The adjusted model was adjusted for male to female sex ratio, GDP, population using solid fuels, age-standardized prevalence of current tobacco smoking, age-standardized diabetes mellitus prevalence, population living in urban areas and BMI mean. Very-high-HDI countries had an 84% lower age-standardized YLD rate [95% confidence interval (CI): 60%–93%, P < 0.001] compared to low-HDI countries. For high-HDI countries, the proportion was 76% (95% CI: 53%–88%, P < 0.001), and for medium-HDI countries, the proportion was 48% (95% CI: 15%–68%, P = 0.010; P for trend < 0.001) (Table 2). Although there was a lack of low-HDI subnational regions, the association between HDI and the burden of cataract-related blindness in subnational-level analyses had a similar trend, but a lower magnitude than that in the country-level analyses.

To assess potential effect modification by UVR

Table 2. Multivariate linear regression model analysis of the relationship between HDI and cataract age-standardized YLD rates owing to blindness

Variables	Crude model		Adjusted model[c]	
	Regression coefficient[a] (95% CI)	P value	Regression coefficient[a] (95% CI)	P value
Countries				
HDI per 0.01	0.95 (0.94, 0.96)	< 0.001	0.93 (0.91, 0.96)	< 0.001
HDI categories[b]				
Low HDI	1.00 (reference)		1.00 (reference)	
Medium HDI	0.58 (0.38, 0.89)	0.014	0.52 (0.32, 0.85)	0.010
High HDI	0.25 (0.17, 0.37)	< 0.001	0.24 (0.12, 0.47)	< 0.001
Very high HDI	0.13 (0.09, 0.20)	< 0.001	0.16 (0.07, 0.40)	< 0.001
P value for trend		< 0.001		< 0.001
Subnational regions				
HDI per 0.01	0.87 (0.86, 0.87)	< 0.001	0.96 (0.94, 0.98)	< 0.001
HDI categories[b]				
Medium HDI	1.00 (reference)		1.00 (reference)	
High HDI	0.42 (0.31, 0.57)	< 0.001	0.93 (0.70, 1.25)	0.637
Very high HDI	0.04 (0.03, 0.05)	< 0.001	0.62 (0.40, 0.97)	0.039
P value for trend		< 0.001		0.021

Note. HDI, human development index. [a]Antilog values. Outcome measures were log-transformed in the analysis. [b]Categorized as follows: < 0.550 (low HDI); 0.550–0.699 (medium HDI); 0.700–0.799 (high HDI); > 0.800 (very high HDI). [c]Adjusted for male to female sex ratio, GDP, population using solid fuels, age-standardized prevalence of current tobacco smoking, age-standardized diabetes mellitus prevalence, population living in urban areas and BMI mean.

exposure, we stratified the analysis by the median value of countries' UVR exposure (high UVR > 3251.68 and low UVR ≤ 3251.68). The age-standardized YLD rate declined with increasing HDI levels in both UVR groups, and only countries with high HDIs in different UVR categories had significant differences (P < 0.05) (Figure 1). The mean UVR exposure of the low-UVR group decreased by the order of 2947.84 (low HDI), 2796.09 (medium HDI), 2073.29 (high HDI) and 1621.24 (very high HDI). Equivalent figures for the high-UVR group were 3810.10, 3940.34, 4004.37, and 3876.17, respectively. As shown in Figure 2 and Supplementary Figure S4 (available in www.besjournal.com), adjusted linear regression analysis indicated that the age-standardized YLD rate owing to cataract blindness was negatively correlated with HDI in both UVR categories in countries and subnational regions (P < 0.001). Table 3 presents the association of HDI with the cataract age-standardized YLD rate owing to blindness modified by UVR exposure in countries. UVR exposure was an effect modifier of HDI and the burden of cataract-related blindness in the adjusted model (P value for interaction = 0.047).

DISCUSSION

This study showed that socioeconomic status was inversely correlated with the burden of cataract blindness and revealed that UVR exposure modified the association of socioeconomic status with the health burden of cataract blindness, taking into account differences in the male to female sex ratio, GDP, population using solid fuels, age-standardized prevalence of current tobacco smoking, age-standardized diabetes mellitus prevalence, population living in urban areas and BMI. Countries with higher levels of socioeconomic development were found to have lower cataract-related blindness burdens. When countries were replaced by subnational regions, the trend of the negative correlation of socioeconomic status with the burden of cataract blindness was largely retained but was lower in magnitude.

A previous study estimated the prevalence of and number of people with blindness due to cataracts and found that among 21 GBD study regions, the percentages of blindness caused by cataracts were lower in the high-income regions (< 15%) and higher (> 40%) in South and Southeast Asia and Oceania[2]. Our study showed that the cataract-related blindness burden is more concentrated in countries with lower socioeconomic status. The HDI level was independently associated with the health burden of cataract-related blindness, with lower age-standardized YLD rates in higher HDI countries. A possible explanation is that the HDI level is related to the output and quality of cataract surgery. Cataract surgery is considered one of the most cost-effective health-care interventions, with a cost per DALY saved of US$ 20–40 million, and is performed with increasing frequency in all regions[1]. However, barriers to cataract surgery services still exist in most countries; the most commonly cited barriers are socioeconomic factors, including income, insurance coverage and low government funding[18-20]. A systematic review demonstrated inequalities in cataract surgery rates were found

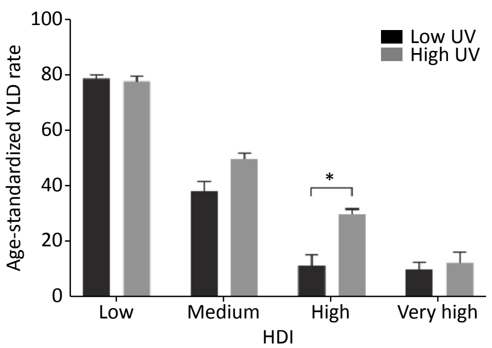

Figure 1. Geometric mean of age-standardized YLD rate owing to cataract blindness across categories of socioeconomic status expressed as HDI at the country level. *P < 0.05.

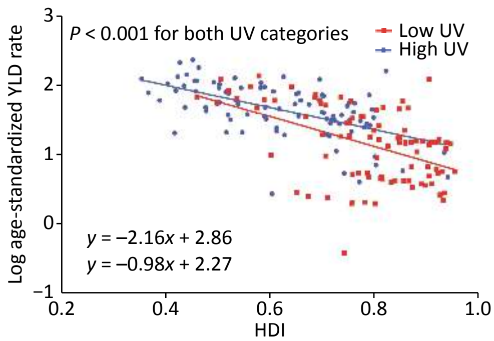

Figure 2. Relationship between HDI and log age-standardized YLD rate owing to cataract blindness for both UVR categories at the country level after adjusting for all covariates. The lines represent fitted lines. HDI, human development index. YLD, year lived with disability. UVR, ultraviolet radiation.

among countries grouped by income and were associated with socioeconomic indicators[21]. Although the global initiative known as 'VISION 2020: the Right to Sight' has made many efforts to promote cataract surgery services at a cost that all patients can afford worldwide[1], the cost still represents a significant expenditure, especially for patients of lower socioeconomic levels[20]. In developing countries worldwide, over half of people with cataract blindness do not undergo cataract surgery[22], mainly because of a low willingness to pay for it[23]. In addition, the quality of cataract surgery is still a concern, with poorer outcomes related to low socioeconomic levels[24]; this disparity aggravates between-country disparities in cataract blindness. Using subnational data, our study observed that the HDI was negatively correlated with the burden of cataract-related blindness. When subnational instead of national data were considered, the difference in socioeconomic status between regions within a country decreased, which helped us to observe the impact of socioeconomic status on the burden of cataract blindness at a smaller geographical coverage and at a detailed level. Although limited subnational data were included according to the GBD study, the findings suggest that socioeconomic disparities in the burden of cataract blindness exist not only among countries but also among subnational regions with different development levels.

Studies have shown that UVR exposure is one of the most important factors of cataractogenesis and is related to cataract development by inducing apoptosis and photooxidation[25,26]. Several findings have demonstrated that the association of UVR exposure with cataracts is dose dependent[27,28]. More UVR exposure implies an increasing risk of cataracts, leading to more cases of cataract blindness. The increased risk for cataract extraction in subjects exposed to high lifetime ambient total UVR (42.718 KJ·m^{-2}) was confirmed [odds ratio (OR) = 1.53] by comparison with subjects exposed to moderate ambient total UVR

Table 3. Effect of UVR exposure on the cataract age-standardized YLD rate owing to blindness in countries with elevated HDI

Variables	Countries *n*[a] (%)	Mean UVR exposure J·m^{-2}·day^{-1}	Crude model		Adjusted model[d]	
			Regression coefficient[b] (95% *CI*)	*P* value	Regression coefficient[b] (95% *CI*)	*P* value
High UVR	92					
HDI categories[c]						
Low HDI	33 (35.87)	3810.10	1.00 (reference)		1.00 (reference)	
Medium HDI	25 (27.17)	3940.34	0.64 (0.44, 0.94)	0.020	0.62 (0.40, 0.96)	0.036
High HDI	28 (30.43)	4004.37	0.38 (0.27, 0.56)	< 0.001	0.39 (0.21, 0.73)	0.005
Very high HDI	6 (6.52)	3876.17	0.16 (0.09, 0.31)	< 0.001	0.12 (0.04, 0.36)	< 0.001
P for trend				< 0.001		0.001
Low UVR	93					
HDI categories[c]						
Low HDI	5 (5.38)	2947.84	1.00 (reference)		1.00 (reference)	
Medium HDI	14 (15.05)	2796.09	0.49 (0.16, 1.48)	0.210	0.48 (0.15, 1.50)	0.209
High HDI	23 (24.73)	2073.29	0.15 (0.05, 0.42)	< 0.001	0.15 (0.04, 0.55)	0.006
Very high HDI	51 (54.84)	1621.24	0.13 (0.05, 0.35)	< 0.001	0.14 (0.03, 0.68)	0.016
P for trend				< 0.001		0.023
P value for interaction[e]				0.1361		0.047

Note. HDI,human development index. [a]For which data are available. [b]Antilog values. Outcome measures were log-transformed in the analysis. [c]Categorized as follows: < 0.550 (low HDI); 0.550–0.699 (medium HDI); 0.700–0.799 (high HDI); > 0.800 (very high HDI). [d]Adjusted for male to female sex ratio, GDP, population using solid fuels, age-standardized prevalence of current tobacco smoking, age-standardized diabetes mellitus prevalence, population living in urban areas and BMI mean. [e]Test for the interaction between HDI (low HDI, medium HDI, high HDI, and very high HDI) and UVR (high UVR and low UVR).

(39.887 KJ·m^{-2})[29]. High UVR exposure causes an increased cataract blindness burden and leads to added national medical expenditures related to socioeconomic level. The costs of environmental measures are often seen as an impediment to economic development. In regard to cataracts, the economic burden attributed to excess UVR is US$4.5 billion in the United States[30]. The increase in economic costs due to high UVR may be unaffordable and present a concern for low- and middle-income countries. Ambient levels of UVR have been increasing and may persist at elevated levels in the future because of continuous stratospheric ozone depletion, and the increase represents an excess cost to address additional cases of cataracts[31]. This serves as a warning that the countries with high UVR exposure and poor economic development must pay particular attention to ensuring protectionin order to reduce the incidence of cataract blindness. At low latitudes, there are a large number of countries that have lower economic conditions and suffer from high UV exposure. It is unrealistic to change the economic situation of these countries in a short time. Therefore, more economical interventions to protect the eyes from UVR exposure, to make the public realize that UVR exposure is harmful to the eyes, and to raise public recognition of UVR exposure. The WHO provides the UV Index (UVI) to guide crowd behavior, increase the population's attention to UVR exposure, and strengthen self-protection. In many countries the UVI is reported along with the weather forecast in newspapers, on TV, and on the radio. The publicity of UVI should be enhanced, and the public should be reminded to take eye protection measures such as wearing hats and sunglasses to avoid high UVR exposure in countries with lower socioeconomic status. Our findings may have significance for public health, given that cataracts are easily treatable[32], and strengthening UVR protection could be an cost-effective intervention for delaying cataract blindness.

Several potential limitations need to be considered. First, the UVR exposure dose derived from the OMI surface UVR product might be overestimated compared to ground-based spectral UVR measurements[33]. The estimated cataract-related blindness burden in the GBD study 2017 may be inadequate due to limited data sources and possible selection bias resulting from the reliance on clinical data records[13]. Second, our study might be subject to ecological fallacy and bias, because the use of aggregate country-level data did not provide information on individuals. Third, the linear regression analysis included subnational-level data of age-standardized YLD rates owing to blindness, UVR exposure, HDI, male to female sex ratio, age-standardized diabetes mellitus prevalence and GDP. The remaining variables, such as population using solid fuels, age-standardized prevalence of current tobacco smoking, population living in urban areas and BMI mean, were not available at the subnational level. We assumed that these variables had a homogeneous distribution throughout each country, which covered important subnational differences. Furthermore, the study was restricted to the locations included in the GBD study 2017, therefore, only 206 subnational regions belonging to seven countries were included. For other countries with large geographic latitude coverage, we were forced to use a single national age-standardized YLD rate to represent the burden of cataract-related blindness without detailed subnational data. The insufficient sample size, especially the lack of low-HDI subnational regions, may cause poor representativeness. Despite these limitations, ecological studies are an effective method to explore associations on a worldwide level, especially based upon openly available data[34].

CONCLUSIONS

In conclusion, long-term high-UVR exposure amplified the association of poor socioeconomic status with the burden of cataract-related blindness. The findings highlight that in addition to existing efforts toward eliminating cataract blindness, UVR exposure protection interventions, such as wearing glasses, wearing a cap and a reduction of outdoor activity time, must be reinforced in developing regions with high-UVR exposure to achieve the global target proposed by the WHO GAP.

CONFLICTS OF INTEREST STATEMENT

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

DENG Yan calculated the solar ultraviolet radiation exposure, analyzed the data, and wrote the original article. YANG Dan obtained data on the global burden of cataract blindness and other related data. YU Jia Ming and XU Jing Xian determined the covariates related to cataracts. HUA Hui, CHEN Ren Tong, and WANG Nan performed the covariate calculations, statistical analysis and graphing. OU Feng Rong helped revise the manuscript. LIU Ru Xi and WU Bo performed data processing. LIU Yang designed the experiment. All authors contributed to the writing and editing of the final paper.

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Supplementary Table S1. Countries included in the GBD study 2017 and human development report

Country_id[a]	Country_name	GBD Study 2017	Human development report
6	China	√	√
7	North Korea	√	
8	Taiwan	√	
10	Cambodia	√	√
11	Indonesia	√	√
12	Laos	√	√
13	Malaysia	√	√
14	Maldives	√	√
15	Myanmar	√	√
16	Philippines	√	√
17	Sri Lanka	√	√
18	Thailand	√	√
19	Timor-Leste	√	√
20	Vietnam	√	√
22	Fiji	√	√
23	Kiribati	√	√
24	Marshall Islands	√	√
25	Federated States of Micronesia	√	√
26	Papua New Guinea	√	√
27	Samoa	√	√
28	Solomon Islands	√	√
29	Tonga	√	√
30	Vanuatu	√	√
33	Armenia	√	√
34	Azerbaijan	√	√
35	Georgia	√	√
36	Kazakhstan	√	√
37	Kyrgyzstan	√	√
38	Mongolia	√	√
39	Tajikistan	√	√
40	Turkmenistan	√	√
41	Uzbekistan	√	√
43	Albania	√	√
44	Bosnia and Herzegovina	√	√
45	Bulgaria	√	√
46	Croatia	√	√
47	Czech Republic	√	√
48	Hungary	√	√
49	Macedonia	√	√
50	Montenegro	√	√
51	Poland	√	√
52	Romania	√	√
53	Serbia	√	√
54	Slovakia	√	√
55	Slovenia	√	√
57	Belarus	√	√
58	Estonia	√	√
59	Latvia	√	√
60	Lithuania	√	√
61	Moldova	√	√
62	Russian Federation	√	√
63	Ukraine	√	√
66	Brunei	√	√
67	Japan	√	√
68	South Korea	√	√
69	Singapore	√	√
71	Australia	√	√

Continued

Country_id[a]	Country_name	GBD Study 2017	Human development report
72	New Zealand	√	√
74	Andorra	√	√
75	Austria	√	√
76	Belgium	√	√
77	Cyprus	√	√
78	Denmark	√	√
79	Finland	√	√
80	France	√	√
81	Germany	√	√
82	Greece	√	√
83	Iceland	√	√
84	Ireland	√	√
85	Israel	√	√
86	Italy	√	√
87	Luxembourg	√	√
88	Malta	√	√
89	Netherlands	√	√
90	Norway	√	√
91	Portugal	√	√
92	Spain	√	√
93	Sweden	√	√
94	Switzerland	√	√
95	United Kingdom	√	√
97	Argentina	√	√
98	Chile	√	√
99	Uruguay	√	√
101	Canada	√	√
102	United States	√	√
105	Antigua and Barbuda	√	√
106	The Bahamas	√	√
107	Barbados	√	√
108	Belize	√	√
109	Cuba	√	√
110	Dominica	√	√
111	Dominican Republic	√	√
112	Grenada	√	√
113	Guyana	√	√
114	Haiti	√	√
115	Jamaica	√	√
116	Saint Lucia	√	√
117	Saint Vincent and the Grenadines	√	√
118	Suriname	√	√
119	Trinidad and Tobago	√	√
121	Bolivia	√	√
122	Ecuador	√	√
123	Peru	√	√
125	Colombia	√	√
126	Costa Rica	√	√
127	El Salvador	√	√
128	Guatemala	√	√
129	Honduras	√	√
130	Mexico	√	√
131	Nicaragua	√	√
132	Panama	√	√
133	Venezuela	√	√
135	Brazil	√	√
136	Paraguay	√	√
139	Algeria	√	√

Continued

Country_id[a]	Country_name	GBD Study 2017	Human development report
140	Bahrain	√	√
141	Egypt	√	√
142	Iran	√	√
143	Iraq	√	√
144	Jordan	√	√
145	Kuwait	√	√
146	Lebanon	√	√
147	Libya	√	√
148	Morocco	√	√
149	Palestine	√	√
150	Oman	√	√
151	Qatar	√	√
152	Saudi Arabia	√	√
153	Syria	√	√
154	Tunisia	√	√
155	Turkey	√	√
156	United Arab Emirates	√	√
157	Yemen	√	√
160	Afghanistan	√	√
161	Bangladesh	√	√
162	Bhutan	√	√
163	India	√	√
164	Nepal	√	√
165	Pakistan	√	√
168	Angola	√	√
169	Central African Republic	√	√
170	Congo	√	√
171	Democratic Republic of the Congo	√	√
172	Equatorial Guinea	√	√
173	Gabon	√	√
175	Burundi	√	√
176	Comoros	√	√
177	Djibouti	√	√
178	Eritrea	√	√
179	Ethiopia	√	√
180	Kenya	√	√
181	Madagascar	√	√
182	Malawi	√	√
183	Mauritius	√	√
184	Mozambique	√	√
185	Rwanda	√	√
186	Seychelles	√	√
187	Somalia	√	
189	Tanzania	√	√
190	Uganda	√	√
191	Zambia	√	√
193	Botswana	√	√
194	Lesotho	√	√
195	Namibia	√	√
196	South Africa	√	√
197	Swaziland	√	√
198	Zimbabwe	√	√
200	Benin	√	√
201	Burkina Faso	√	√
202	Cameroon	√	√
203	Cape Verde	√	√
204	Chad	√	√
205	Cote d'Ivoire	√	√

Continued

Country_id[a]	Country_name	GBD Study 2017	Human development report
206	The Gambia	√	√
207	Ghana	√	√
208	Guinea	√	√
209	Guinea-Bissau	√	√
210	Liberia	√	√
211	Mali	√	√
212	Mauritania	√	√
213	Niger	√	√
214	Nigeria	√	√
215	Sao Tome and Principe	√	√
216	Senegal	√	√
217	Sierra Leone	√	√
218	Togo	√	√
298	American Samoa	√	
305	Bermuda	√	
349	Greenland	√	
351	Guam	√	
376	Northern Mariana Islands	√	
385	Puerto Rico	√	
422	Virgin Islands, U.S.	√	
435	South Sudan	√	√
522	Sudan	√	√

Note. [a]Country_id for geographic variables comes from the GBD Study 2017 database that creates and stores unique numeric identifiers.

Supplementary Table S2. Subnational regions included in the GBD study 2017

Location_id[a]	Location_name	Level[b]
67	Japan	0
35446	Aichi	1
35428	Akita	1
35425	Aomori	1
35435	Chiba	1
35461	Ehime	1
35441	Fukui	1
35463	Fukuoka	1
35430	Fukushima	1
35444	Gifu	1
35433	Gunma	1
35457	Hiroshima	1
35424	Hokkaidō	1
35451	Hyōgo	1
35431	Ibaraki	1
35440	Ishikawa	1
35426	Iwate	1
35460	Kagawa	1
35469	Kagoshima	1
35437	Kanagawa	1
35462	Kōchi	1
35466	Kumamoto	1
35449	Kyōto	1
35447	Mie	1
35427	Miyagi	1
35468	Miyazaki	1
35443	Nagano	1
35465	Nagasaki	1

Continued

Location_id[a]	Location_name	Level[b]
35452	Nara	1
35438	Niigata	1
35467	Ōita	1
35456	Okayama	1
35470	Okinawa	1
35450	Ōsaka	1
35464	Saga	1
35434	Saitama	1
35448	Shiga	1
35455	Shimane	1
35445	Shizuoka	1
35432	Tochigi	1
35459	Tokushima	1
35436	Tōkyō	1
35454	Tottori	1
35439	Toyama	1
35453	Wakayama	1
35429	Yamagata	1
35458	Yamaguchi	1
35442	Yamanashi	1
102	United States	0
523	Alabama	1
524	Alaska	1
525	Arizona	1
526	Arkansas	1
527	California	1
528	Colorado	1
529	Connecticut	1
530	Delaware	1
531	District of Columbia	1
532	Florida	1
533	Georgia	1
534	Hawaii	1
535	Idaho	1
536	Illinois	1
537	Indiana	1
538	Iowa	1
539	Kansas	1
540	Kentucky	1
541	Louisiana	1
542	Maine	1
543	Maryland	1
544	Massachusetts	1
545	Michigan	1
546	Minnesota	1
547	Mississippi	1
548	Missouri	1
549	Montana	1
550	Nebraska	1
551	Nevada	1
552	New Hampshire	1
553	New Jersey	1
554	New Mexico	1
555	New York	1
556	North Carolina	1
557	North Dakota	1
558	Ohio	1
559	Oklahoma	1

Continued

Location_id[a]	Location_name	Level[b]
560	Oregon	1
561	Pennsylvania	1
562	Rhode Island	1
563	South Carolina	1
564	South Dakota	1
565	Tennessee	1
566	Texas	1
567	Utah	1
568	Vermont	1
569	Virginia	1
570	Washington	1
571	West Virginia	1
572	Wisconsin	1
573	Wyoming	1
93	Sweden	0
4944	Stockholm	1
4940	Sweden except Stockholm	1
95	United Kingdom	0
4749	England	1
4621	East Midlands	2
4623	East of England	2
4624	Greater London	2
4618	North East England	2
4619	North West England	2
4625	South East England	2
4626	South West England	2
4622	West Midlands	2
4620	Yorkshire and the Humber	2
433	Northern Ireland	1
434	Scotland	1
4636	Wales	1
130	Mexico	0
4643	Aguascalientes	1
4644	Baja California	1
4645	Baja California Sur	1
4646	Campeche	1
4649	Chiapas	1
4650	Chihuahua	1
4647	Coahuila	1
4648	Colima	1
4652	Durango	1
4653	Guanajuato	1
4654	Guerrero	1
4655	Hidalgo	1
4656	Jalisco	1
4657	México	1
4651	Mexico City	1
4658	Michoacán de Ocampo	1
4659	Morelos	1
4660	Nayarit	1
4661	Nuevo León	1
4662	Oaxaca	1
4663	Puebla	1
4664	Querétaro	1
4665	Quintana Roo	1
4666	San Luis Potosí	1
4667	Sinaloa	1
4668	Sonora	1

Continued

Location_id[a]	Location_name	Level[b]
4669	Tabasco	1
4670	Tamaulipas	1
4671	Tlaxcala	1
4672	Veracruz de Ignacio de la Llave	1
4673	Yucatán	1
4674	Zacatecas	1
135	Brazil	0
4750	Acre	1
4751	Alagoas	1
4753	Amapá	1
4752	Amazonas	1
4754	Bahia	1
4755	Ceará	1
4756	Distrito Federal	1
4757	Espírito Santo	1
4758	Goiás	1
4759	Maranhão	1
4762	Mato Grosso	1
4761	Mato Grosso do Sul	1
4760	Minas Gerais	1
4763	Pará	1
4764	Paraíba	1
4765	Paraná	1
4766	Pernambuco	1
4767	Piaui	1
4768	Rio de Janeiro	1
4769	Rio Grande do Norte	1
4772	Rio Grande do Sul	1
4770	Rondônia	1
4771	Roraima	1
4773	Santa Catarina	1
4775	São Paulo	1
4774	Sergipe	1
4776	Tocantins	1
11	Indonesia	0
4709	Aceh	1
4726	Bali	1
4717	Bangka-Belitung Islands	1
4725	Banten	1
4715	Bengkulu	1
4737	Gorontalo	1
4720	Jakarta	1
4713	Jambi	1
4721	West Java	1
4722	Central Java	1
4724	East Java	1
4729	West Kalimantan	1
4731	South Kalimantan	1
4730	Central Kalimantan	1
4732	East Kalimantan	1
4719	North Kalimantan	1
4718	Riau Islands	1
4716	Lampung	1
4739	Maluku	1
4740	North Maluku	1
4727	West Nusa Tenggara	1
4728	East Nusa Tenggara	1
4742	Papua	1

Continued

Location_id[a]	Location_name	Level[b]
4741	West Papua	1
4712	Riau	1
4738	West Sulawesi	1
4735	South Sulawesi	1
4734	Central Sulawesi	1
4736	Southeast Sulawesi	1
4733	North Sulawesi	1
4711	West Sumatra	1
4714	South Sumatra	1
4710	North Sumatra	1
4723	Yogyakarta	1

Note. [a]Location_id for geographic variables comes from the GBD Study 2017 database that creates and stores unique numeric identifiers. [b]Level: Level 0 = country. Levels 1 and 2 = subnational regions.

Supplementary Table S3. Additional information on the covariates used in the multivariate linear regression analysis at the country level

Covariate	Definition	Source	Period	Risk factors in the GBD
Male to female sex ratio	Sex ratio of the total population (males per 100 females)	United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition.	2015	
Population using solid fuels (%)	The percentage of the population that relies on solid fuels as the primary source of domestic energy for cooking and heating	World Health Organization. Available from http://apps.who.int/gho/data/view.main.1701?lang=en	2013	Yes
Age-standardized prevalence of current tobacco smoking (%)	The percentage of the population aged 15 years and over who currently use any tobacco product (smoked and/or smokeless tobacco) on a daily or nondaily basis. Note that most countries collect data about smoking but not smokeless tobacco use, leaving gaps in tobacco use data and preventing global and regional summaries of tobacco use rates. Until data improve, the estimates will reflect the percentage of the population aged 15 years and over who currently smoke.	World Health Organization. Available from http://apps.who.int/gho/data/node.imr.SDGTOBACCO?lang=en	2016	Yes
Age-standardized diabetes mellitus prevalence (%)	Age-standardized diabetes mellitus prevalence (%) both sexes	Global Burden of Disease Collaborative Network.Global Burden of Disease Study 2017 (GBD 2017) Results.Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018.Available from http://ghdx.healthdata.org/gbd-results-tool.	2017	Yes
Population living in urban areas (%)	The percentage of the de facto population living in areas classified as urban according to the criteria used by each area or country as of 1 July of the year indicated.	World Health Organization. Available from http://apps.who.int/gho/data/node.imr.WHS9_96?lang=en	2010	
BMI mean ($kg{\cdot}m^{-2}$)	BMI mean trends among adults, age-standardized (kg/m^2)	World Health Organization. Available from http://apps.who.int/gho/data/node.main.BMIANTHROPOMETRY?lang=en	2016	Yes
GDP per capita (USD)	GDP per capita (current US$)	World Bank national accounts data and OECD National Accounts data files.	2014	

Supplementary Table S4. GBD study 2017 risk factors and accompanying exposure definitions for cataracts

Risk factors	Exposure definition
Household air pollution from solid fuels	Individual exposure to PM2.5 due to the use of solid cooking fuel.
Smoking	The prevalence of the current use of any smoked tobacco product and the prevalence of former use of any smoked tobacco product. Among current smokers, cigarette equivalents smoked per smoker per day and cumulative pack-years of exposure. Among former smokers, number of years since quitting.
High fasting plasma glucose	Serum fasting plasma glucose measured in mmol/L.
High BMI	BMI, measured in kg/m^2.

Supplementary Table S5. Information sources for subnational-level data per country

Country	Information source
Japan	
Sex male to female ratio	Statistics Bureau. JAPAN STATISTICAL YEARBOOK 2018. Geography and Population. Population by Prefecture (1920 to 2016). Available from http://www.stat.go.jp/english/data/nenkan/67nenkan/index.html
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	The Organisation for Economic Co-operation and Development (OECD). Stats. Regional Statistics. Regional Economy. Regional GDP per Capita. Available from https://stats.oecd.org/
United States	
Sex male to female ratio	United States Census Bureau. American Fact Finder. Annual Estimates of the Resident Population for Selected Age Groups by Sex for the United States, States, Counties, and Puerto Rico Commonwealth and Municipios: April 1, 2010 to July 1, 2017. Available from https://factfinder.census.gov/faces/nav/jsf/pages/download_center.xhtml#none
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	The Organisation for Economic Co-operation and Development (OECD). Stats. Regional Statistics. Regional Economy. Regional GDP per Capita. Available from https://stats.oecd.org/.
Sweden	
Sex male to female ratio	European statistics. Population on 1 January by age, sex and NUTS 2 region (demo_r_d2jan). Eurostat Data Explorer. Available from https://ec.europa.eu/eurostat/web/regions/data/database
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	2014 GDP per capita: Twenty-one regions below half of the EU average. European statistics. News releases 2016. Archived from https://ec.europa.eu/eurostat/documents/2995521/7192292/1-26022016-AP-EN.pdf/602b34e8-abba-439e-b555-4c3cb1dbbe6e
United Kingdom	
Sex male to female ratio	European statistics. Population on 1 January by age, sex and NUTS 2 region (demo_r_d2jan). Eurostat Data Explorer. Available from https://ec.europa.eu/eurostat/web/regions/data/database.
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	2014 GDP per capita: Twenty-one regions below half of the EU average. European statistics. News releases 2016. Archived from https://ec.europa.eu/eurostat/documents/2995521/7192292/1-26022016-AP-EN.pdf/602b34e8-abba-439e-b555-4c3cb1dbbe6e.

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Country	Information source
Mexico	
Sex male to female ratio	The Organisation for Economic Co-operation and Development (OECD). Stats. Regional Statistics. Regional Demography. Sex Ratio, Total Population (% population males over females). Available from https://stats.oecd.org/.
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	Instituto Nacional De Estadística y Geografía (INEGI). Estadística - Producto interno bruto por entidad federativa, base 2013 Información. Available from https://www.inegi.org.mx/sistemas/bie/?idserPadre=10200070#D10200070.
Brazil	
Sex male to female ratio	The Organisation for Economic Co-operation and Development (OECD). Stats. Regional Statistics. Regional Demography. Sex Ratio, Total Population (% population males over females). Available from https://stats.oecd.org/.
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	IBGE: Instituto Brasileiro de Geografia e Estatística. Economic Statistics. Regional Accounts 2014: five states account for nearly two thirds of Brazilian GDP. Available from https://agenciadenoticias.ibge.gov.br/en/agencia-press-room/2185-news-agency/releases-en/10156-regional-accounts-2014-five-states-account-for-nearly-two-thirds-of-brazilian-gdp.
Indonesia	
Sex male to female ratio	2010 Population Census Data - Statistics Indonesia. Population by Age Group, Urban/Rural, and Sex in Provinces of Indonesia. Available from https://sp2010.bps.go.id/
Age-standardized diabetes mellitus prevalence (%)	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2018. Available from http://ghdx.healthdata.org/gbd-results-tool.
GDP per capita (USD)	Statistics Indonesia. Statistical Yearbook of Indonesia 2015. Available from https://www.bps.go.id/publication/2015/08/12/5933145e1d037f5148a67bac/statistik-indonesia-2015.html.

Supplementary Table S6. Characteristics of included subnational regions

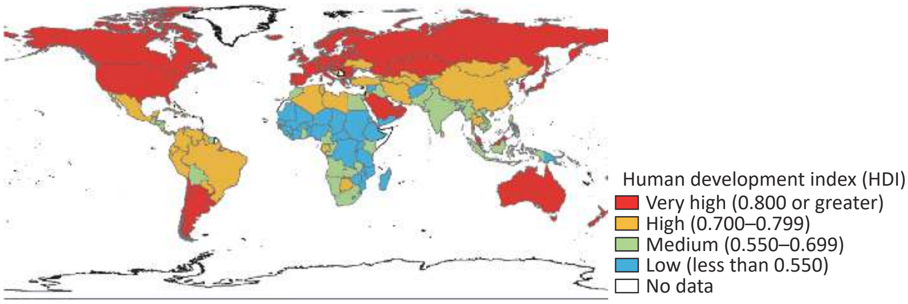
Characteristics	Total	HDI[d]		
		Medium HDI	High HDI	Very high HDI
Subnational regions *n*[a] (%)	206	22	63	121
Blindness age-standardized YLD rate per 100,000 population [b]	13.71 ± 4.33	122.28 ± 1.26	51.28 ± 1.57	4.64 ± 2.13
Mean UVR exposure ($J{\cdot}m^{-2}{\cdot}day^{-1}$) [c]	2,660.06 ± 1,231.88	4,430.78 ± 282.59	3,825.03 ± 511.14	1,731.55 ± 535.56
Sex male to female ratio	97.42 ± 4.71	102.73 ± 5.16	98.42 ± 4.25	95.94 ± 4.01
Population using solid fuels (%)	12.17 ± 12.48	37.91 ± 5.12	15.83 ± 12.73	5.58 ± 2.34
Age-standardized prevalence of current tobacco smoking (%)	22.71 ± 8.27	38.35 ± 5.39	19.34 ± 10.36	21.63 ± 2.05
Age-standardized diabetes mellitus prevalence (%)	7.00 ± 2.70	9.96 ± 1.25	7.98 ± 3.26	5.96 ± 1.87
Population living in urban areas (%)	77.98 ± 13.23	51.17 ± 5.95	74.73 ± 13.09	84.55 ± 4.86
BMI mean ($kg{\cdot}m^{-2}$)	24.29 ± 4.77	23.32 ± 1.04	21.21 ± 6.36	26.08 ± 3.07
GDP per capita (USD) [e]	33,960.50	2713.26	11,731.00	40,380.00

Note. [a]For which data are available. [b]Geometric mean ± SD. [c]Mean ± SD (all such values). [d]Categorized as follows: 0.550–0.699 (medium HDI); 0.700–0.799 (high HDI); > 0.800 (very high HDI). [e]Median.

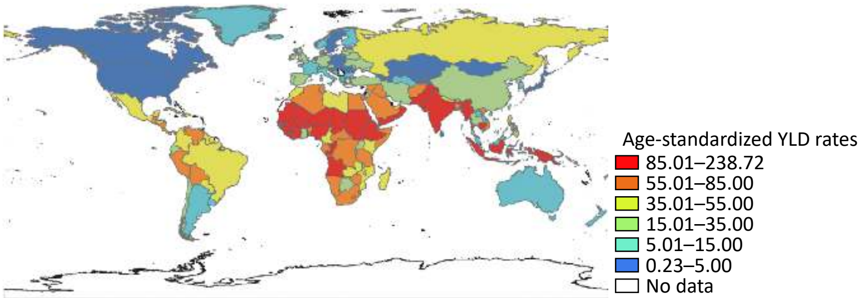
Supplementary Table S7. Univariate association between covariates and cataract blindness age-standardized YLD rate in countries

Variables	Countries		Subnational regions	
	Regression coefficient [a] (95% *CI*)	*P* value	Regression coefficient [a] (95% *CI*)	*P* value
Male to female sex ratio	1.01 (1.00, 1.01)	0.103	1.15 (1.10, 1.19)	< 0.001
Population using solid fuels (%)	1.02 (1.01, 1.02)	< 0.001	1.09 (1.08, 1.11)	< 0.001
Age-standardized prevalence of current tobacco smoking (%)	0.95 (0.93, 0.97)	< 0.001	1.06 (1.04, 1.08)	< 0.001
Age-standardized diabetes mellitus prevalence (%)	0.98 (0.93, 1.04)	0.493	1.33 (1.25, 1.42)	< 0.001
Population living in urban areas (%)	0.98 (0.98, 0.99)	< 0.001	0.92 (0.91, 0.93)	< 0.001
BMI mean ($kg \cdot m^{-2}$)	0.80 (0.75, 0.87)	< 0.001	0.88 (0.85, 0.92)	< 0.001
GDP per capita per 1000 (USD)	0.98 (0.97, 0.99)	< 0.001	0.97 (0.96, 0.97)	< 0.001

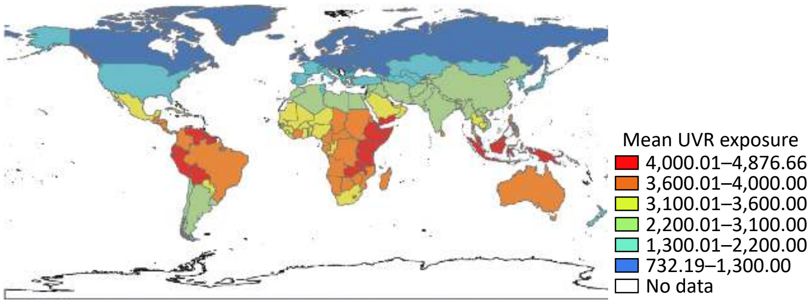
Note. [a]Antilog values. Outcome measures were log-transformed in the analysis.



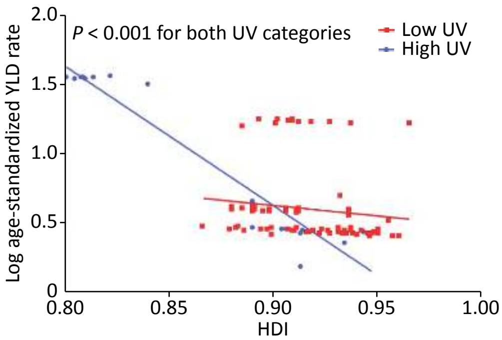
Supplementary Figure S1. Global map of the HDI in countries included in the GBD study 2017. HDI, human development index; GBD, Global Burden of Disease.



Supplementary Figure S2. Global map of health burden of cataract-related blindness with age-standardized YLD rates in 2017. YLD, year lived with disability.



Supplementary Figure S3. Global map of UVR levels in 2015. UVR, ultraviolet radiation.



Supplementary Figure S4. Relationship between HDI and log age-standardized YLD rate owing to blindness for both UVR categories at the subnational level after adjusting for all covariates. HDI, human development index; YLD, year lived with disability; UVR, ultraviolet radiation.