Original Article

The economic and social costs of visual impairment and blindness in India

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Purpose: To provide a current estimate of the economic and social costs (or welfare costs) of visual impairment and blindness in India. **Methods:** Using evidence from the recently conducted Blindness and Visual Impairment Survey across India, the *Lancet Global Health* Commission on Global Eye Health and other sources, we developed an economic model that estimates the costs of reduced employment, elevated mortality risk, education loss for children, productivity loss in employment, welfare loss for the unemployed, and caregiver costs associated with moderate and severe visual impairment (MSVI) and blindness. Probabilistic sensitivity analyses were also conducted by varying key parameters simultaneously. **Results:** The costs of MSVI and blindness in India in 2019 are estimated at INR 1,158 billion (range: INR 947–1,427 billion) or $54.4 billion at purchasing power parity exchange rates (range: $44.5–67.0 billion), accounting for all six cost streams. The largest cost was for the loss of employment, whereas the the second largest cost was for caregiver time. A more conservative estimate focusing only on employment loss and elevated mortality risk yielded a cost of INR 504 billion (range: INR 348–621 billion) or $23.7 billion (range: $16.3–29.2 billion). **Conclusion:** Poor eye health imposes a non-trivial recurring cost to the Indian economy equivalent to 0.47% to 0.70% of GDP in the primary scenario, a substantial constraint on the country's growth aspirations. Furthermore, the absolute costs of poor eye health will increase over time as India ages and becomes wealthier unless further progress is made in reducing the prevalence of MSVI and blindness.

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Despite notable progress over several decades, the burden of poor eye health in India remains large. According to the National Blindness and Visual Impairment Survey 2015–2019, there were 4.8 million people with blindness and 29.2 million people with moderate or severe visual impairment (MSVI) in 2017.[1] Understanding the economic and social costs of visual impairment and blindness is critical for efficient resource allocation; however, the evidence base is limited. Two peer-reviewed estimates are more than 20 years old.[2,3] Given how much has changed in the landscape of eye care in India, a fresh look is warranted. This study combines information on three recent, important publications to estimate the economic and social costs (or welfare costs) of MSVI and blindness in India using the latest evidence, data, and methods: The *Lancet Global Health Commission* on Global Eye Health, which provides the most up-to-date literature summary of the productivity and health impacts of blindness and MSVI globally[4]; The National Blindness and Visual Impairment Survey, which provides the most recent nationally representative figures for MSVI and blindness in India;[1] and The *Reference Case Guidelines for the Conduct for Benefit-Cost Analysis in Global Health and Development*, which provides the best practice guidance for valuing mortality risk reduction and changes in time use.[5]

A study estimating the economic cost of visual impairment in 2020 was published while this paper was undergoing peer review.[6] Our study differs from this most recent analysis on several dimensions. Notably, we incorporate a wider scope of costs including welfare losses associated with increased mortality, education loss, and productivity losses in non-paid work. Moreover, we included evidence of productivity losses derived from the reviews of the *Lancet Global Health* Commission.

Methods

Point estimates of the welfare cost of MSVI and blindness are derived using an economic model focusing on six categories of loss with parameters drawn from the literature. Probabilistic sensitivity analyses were conducted by varying key parameters simultaneously. The reported figures in this analysis are for

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2019, the most recent year for which most data are readily available and were not affected by the COVID-19 pandemic.

Estimation of the prevalence of MSVI and Blindness by 5-year age cohort

The National Blindness and Visual Impairment Survey provides prevalence estimates for only two age cohorts, above and below 50 years.[1] Further age sub-division is required to avoid overstating the cost of poor eye health. This is because eye health challenges increase with age, whereas each category of welfare impact generally decreases with age. Due to the unavailability of microdata from the national survey,[1] we use the Global Burden of Disease modeled estimates of prevalence rates for "blindness and vision loss" to estimate the *relative* difference in MSVI and blindness prevalence across 5-year age cohorts.[7] We then calibrated the figures so that the prevalence of MSVI and blindness nationwide matches with what is reported in the national survey.[1] To estimate the total number of people suffering from MSVI and blindness, we drew population numbers for 5-year age cohorts from the population projections based on the 2011 Census Data[8] and multiplied by the age-stratified prevalence rates. Results are reported in Table 1.

Model parameters – point estimates

Six different social and economic costs of poor eye health were considered. These are:

1. Loss of employment
2. Elevated mortality risk
3. Education loss for children
4. Reduced productivity in employment
5. Caregiver costs
6. Productivity loss of unpaid work.

Table 2 summarizes the estimation approach to calculate the costs of MSVI and blindness.

Loss of employment: Two related studies found that the average loss of employment associated with MSVI or blindness is 30.2% globally.[4,9] We applied this global average figure in this analysis because there was no specific figure for India or South Asia, nor was there an obvious distinction between high-income and lower-middle-income countries. Furthermore, the studies reported that the literature did not differentiate between blindness and MSVI, so the 30.2% employment loss was applied to both as with the *Lancet Global Health* Commission's analyses.[4,9]

Table 1: Prevalence of MSVI and blindness by 5-year age cohort

Age group	MSVI (millions)	Blindness (millions)
0-4	0.06	0.01
5-9	0.09	0.01
10-14	0.10	0.01
15-19	0.10	0.01
20-24	0.12	0.02
25-29	0.16	0.02
30-34	0.28	0.04
35-39	0.49	0.07
40-44	0.81	0.11
45-49	1.24	0.17
50-54	4.42	0.74
54-59	4.89	0.82
60-64	4.65	0.78
65-69	3.99	0.67
70-74	3.30	0.55
75-79	2.38	0.40
80-84	2.11	0.35
Total	29.19	4.79

Income is proxied by GDP per capita, reported as INR 148,936 in 2019, and the employment-to-population ratio is 46%.[21] The working age was assumed to be 15 to 64 following similar studies.[2-4,9,22] The economic cost of lost employment is calculated as the prevalence of MSVI or blindness multiplied by the employment-to-population ratio, GDP per capita, and the reduction in employment of 30.2%.[4]

Elevated mortality risk: A meta-analysis of studies that estimated the mortality risk from MSVI and blindness found that visual acuity <6/12 was associated with a 29% elevated mortality risk compared to no vision impairment, visual acuity <6/18 was associated with a 43% elevated mortality risk compared to better vision and, visual acuity <6/60 had an 89% elevated mortality risk compared to visual acuity <6/18.[4,10] To make these findings relevant for this analysis, we estimated risk ratios for individual states relative to no visual impairment by solving three simultaneous equations:

$$1.29 * RR_{no} = \frac{\omega_{mild} * RR_{mild} + \omega_{mod} * RR_{mod} + \omega_{sev} * RR_{sev}}{\omega_{mild} + \omega_{mod} + \omega_{sev}} \quad (1)$$

$$1.43 * \frac{(\omega_{no} * RR_{no} + \omega_{mild} * RR_{mild})}{\omega_{no} + \omega_{mild}} = \frac{\omega_{mod} * RR_{mod} + \omega_{sev} * RR_{sev}}{\omega_{mod} + \omega_{sev}} \quad (2)$$

$$1.89 * \frac{(\omega_{no} * RR_{no} + \omega_{mild} * RR_{mild})}{\omega_{no} + \omega_{mild}} = RR_{sev} \quad (3)$$

where ω_k and RR_k represent the population weights and relative risks for visual impairment states, respectively, k = no, mild, moderate, or severe relative to no visual impairment. Population weights for each state of visual impairment are drawn from,[1] whereas $RR_{no} = 1$, by definition. The results indicated that RR_{mild}, RR_{mod} and RR_{sev} equal 1.16, 1.26, and 1.90 respectively. These are assumed to be 10-year mortality risk ratios based on median and mean follow-up time frames over reviewed studies.[10]

To estimate the welfare cost of elevated mortality, we sourced age-specific all-cause mortality rates[7] and estimated the additional deaths attributable to MSVI and blindness using the calculated risk ratios. For conservatism, we assumed the MSVI mortality risk was 1.26, the risk of moderate visual impairment only, whereas the mortality risk from blindness was 1.90, corresponding to the risk of severe visual impairment and blindness. Lifetables were used to estimate years of life lost for each cohort. The results indicated that MSVI and blindness led to 32,900 additional deaths per year combined, or around 422,000 life years [Table 3].

Life years lost are converted to welfare losses by first calculating the value of statistical life (VSL) of India, and then divided by half the life expectancy at birth to identify the value of statistical life year (VSLY).[5] The ratio of VSL to income per capita was estimated using the following equation:

$$VSL\,income\,ratio = \left[\frac{GDP\,per\,capita\ (India)}{GDP\,per\,capita\ (USA)}\right]^{e-1} \times 160 = 52.4,$$

Table 2: Summary of estimation approach for welfare costs of MSVI and blindness, point estimates, and probabilistic sensitivity analysis (PSA)

Welfare cost	Impact from MSVI	Impact from Blindness	Sources
Loss of employment	Point: 30.2% reduction in employment PSA: Uniform distribution with a range=19.5% to 43.5%	Point: 30.2% reduction in employment PSA: Same draw as for MSVI	Based on review in[4,9]
Elevated mortality risk	Point: 1.26=10-year all-cause mortality risk ratio relative to no visual impairment PSA: Normal distribution with mean=1.26 and standard deviation=0.06	Point: 1.92=10-year all-cause mortality risk ratio relative to no visual impairment PSA: Normal distribution with mean=1.90 and standard deviation=0.26	Based on meta-analysis reported in[4,10]
Education loss for children	Point: 3.6% reduction in future income PSA: Uniform distribution with a range=2.2% to 5.0%	5.5% reduction in future income PSA: 1.53x the draw for MSVI	Based on evidence in[11-14]
Reduced productivity in employment	Point: 20% productivity loss PSA: Uniform distribution with a range=17% to 23%	Point: 20% productivity loss PSA: Same draw as for MSVI	Based on evidence in[15-18]
Caregiver costs	Point: 5% of productive time for one person PSA: Uniform distribution with a range=2.5% to 10%	Point: 10% of productive time for one person PSA: 2x the draw for MSVI	Assumption following[19]
Productivity loss of unpaid work	Point: 20% loss of productivity in household, non-market activities with value of loss estimated at 50% of wages PSA Productivity loss equal to draw from productivity loss in employment; Value of time: uniform distribution with range=25% to 75%	Point: 20% loss of productivity in household, non-market activities with value of loss estimated at 50% of wages PSA: Same draw as for MSVI	Assume same loss as for productivity in employment; Time valuation from[20]

Table 3: Mortality and life years lost from MSVI and blindness in India, 2019

Age group	MSVI - additional mortality in 2019	Blindness - additional mortality in 2019	MSVI - additional life years lost in 2019	Blindness - additional life years lost in 2019
0-4	11	5	809	382
5-9	1	1	99	47
10-14	1	1	86	41
15-19	2	1	131	62
20-24	4	2	228	107
25-29	6	3	301	142
30-34	14	7	632	298
35-39	32	15	1,305	616
40-44	71	33	2,526	1,191
45-49	154	73	4,815	2,271
50-54	890	520	23,931	13,984
54-59	1,483	867	33,812	19,758
60-64	2,103	1,229	39,752	23,228
65-69	2,738	1,600	41,889	24,477
70-74	3,519	2,057	42,586	24,884
75-79	3,866	2,259	35,570	20,785
80-84	5,867	3,428	38,720	22,625
Total	20,763	12,099	267,191	154,897

Where the income elasticity, e = 1.5, and GDP per capita and GDP per capita were measured in PPP terms.[5] Using this equation and noting an income per capita of INR 148,936 for 2019, the VSL of India was estimated at INR 7,812,000. The VSLY was estimated at INR 255,100 in 2019. The sum of life years lost was multiplied by the VSLY to estimate the welfare losses from increased mortality risk.

Education loss for children: Children who suffer from poor eyesight do not learn as much in school as those without visual impairment.[4] Three studies have estimated the impact of experimentally encouraging or providing eyeglasses to school students, indicating improved learning as measured by increased test scores with a range of 0.11 to 0.25 standard deviations.[11-13] For this study, we adopted the midpoint value

of 0.18 standard deviation test score loss as the base case estimate for MSVI. This may be an underestimate because the referenced studies looked at the benefits of addressing general myopia, which included impacts less severe than MSVI.

Less learning in school implies lower earnings in adulthood. To translate this figure into a future productivity loss, we noted that a 1 standard deviation improvement in test scores was correlated with a 20% increase in adult income in India.[14] A 0.18 standard deviation reduction in test scores was, therefore, equal to a 3.6% loss in future income for each year a child suffered MSVI while in school. For blind children, we assumed that they did not go to school, or learned minimally,[23] experiencing a reduction in future income equivalent to reported returns to 1 year of schooling from primary school education – 5.5%.[24] [1*] Future incomes were proxied by the stream of future GDP per capita, estimated using the time series of GDP (growth), and population growth rates (middle-of-the-road scenario) from the Shared Socioeconomic Pathways database by the International Institute for Applied Systems Analysis.[25]

We considered only those aged 5–14 years old as suffering education loss from MSVI and blindness. The estimated percentage income loss from MSVI or blindness was multiplied by the discounted stream of future income from ages 15–64 years at an 8% discount rate, and the appropriate enrolment rate (primary net enrolment of 92% for 5–9-year-old children or the secondary net enrolment rate of 62% for 10–14-year-old children). One year of schooling with MSVI led to a loss of INR 76,160 (87,130) for children aged 5–9 (10–14) years. For blindness, the loss was estimated at INR 116,355 (133,115) for children aged 5–9 years (10-14).

Productivity Loss in Employment: For this category of loss, only one high-quality study was referenced in the *Lancet Global Health* Commission.[4] This study showed that the provision of spectacles to correct presbyopia in tea pickers increased productivity by 22%.[15] Although the evidence base is limited, there is additional supporting literature that suggests, conditional on employment, individuals, with MSVI, and blindness are much less productive than those without visual impairment.[16-18] In this analysis, we assumed a productivity reduction of 20% due to MSVI or blindness, conditional on employment as a reasonable, albeit imprecise, estimate. Due to imprecision in the data, we did not assume different rates between MSVI and blindness.

To estimate welfare costs, we took the fraction of individuals employed with MSVI and blindness. Given our assumed loss of employment was 30.2%, those counterfactually employed would be 1-30.2% = 69.8% multiplied by the employment to population ratio (46%). This figure was then multiplied by the prevalence of MSVI or blindness, the 20% reduction in the productivity assumed above, and the GDP per capita in 2019 as a proxy for income.

[1*]An alternative specification is to assume that a vast majority of those who are visually impaired are enrolled in school and do not suffer any learning losses. In this case, the social costs are the additional schooling costs for the blind and visually impaired. As an upper bound sensitivity analysis, we assume 80% of blind and visually impaired children are in school, and extra schooling costs are approximately INR 13,000 based on figures provided by the National Association of the Blind. Using this specification reduces the headline results by 0.9% to Int$ 53.9 billion.

Caregiver Costs: In high-income countries, people with visual impairment require significant caregiver time, with an average amount of 5.8 h per week for those with visual acuity 6/18 rising to 94 h per week for those with visual acuity 6/60.[26] Assuming a 40-h working week, these represented 14.5% to more than 200% of productive time dedicated to caregiving. In this analysis, we assumed that 5% of productive time was required to assist those with MSVI and 10% of productive time was required for those who are blind following a previous systematic review.[19] These parameters were deliberately chosen to be lower than those reported in high-income countries because substantially lower incomes and limited safety nets in India make it less likely that household members would divert time away from income-generating activities, and not all caregivers may be fully employed, reducing the value of their productive time. In India, it is common for extended family networks and neighbors to provide care for those suffering from visual impairment while employed household members are working. The loss parameters are multiplied by GDP per capita to estimate the costs per caregiver time per person with MSVI and blindness, respectively.

Productivity Loss of Unpaid Work: With an employment-to-population ratio of 46%, less than half of the working-age population is employed in India. The remainder is typically engaged in household activities, with women aged 15–64 spending almost 6 h per day on unpaid activities and men of the same age range, spending almost 1 h per day.[27] A household that contains one woman and one man of working age, would therefore spend 50 h per week on domestic activities. Suffering from MSVI or blindness is likely to impede these activities, particularly considering the evidence that those with visual impairment suffer from lower employment-related productivity, mobility, and social status.[4,15,16]

Given a lack of relevant studies, we adopted the same value of productivity loss as for employment, that is, 20%, as a reasonable estimate of the productivity loss for the unemployed. We valued the productivity decrease at the extra time it would take to generate the production of the same level as a non-blind or non-MSVI person and valued the changes in time use at 50% of market wages.[5,20] We only included losses for those aged 15 to 64 years.

Probabilistic sensitivity analysis

To determine the impact of uncertainty on the reported results, a probabilistic sensitivity analysis was conducted by varying several parameters simultaneously across 10,000 Monte Carlo simulations. We varied a range of parameters, including the main effect sizes of each category of loss [Table 2]. Except for mortality risk, all distributions were assumed to be uniform, given the generally limited number of studies from which the parameters were drawn.

Employment loss was assumed to range uniformly from 19.5% to 43.5% for both MSVI and blindness with the low value taken from the EuroStat database and the upper value from the maximum regional estimate reported in the *Lancet Global Health* Commission's systematic review.[9] All-cause mortality risks for MSVI and blindness were assumed to be normally distributed with means equal to the point estimates. Standard deviations were calculated by first solving the simultaneous equations using the low end and high end of each of the 95% confidence intervals reported in,[10] and then taking half the average distance between these values and the mean. Productivity loss

in employment for both MSVI and blindness was assumed to range uniformly from 17% to 23%, based on the confidence interval reported in a study examining the productivity loss from presbyopia in Indian tea pickers.[15]

Caregiver costs were assumed to vary uniformly from 2.5% to 10% for MSVI, with blindness equal to 2× the cost. The future income loss for being in school with 1 year of MSVI was assumed to range from 2.2% to 5.0%, based on the lower and upper bounds of improvement in test scores from correcting visual impairment reported in the literature (i.e., 0.11 SD to 0.25 SD[11,12]). The impact from blindness was assumed to equal 1.53 × the draw from MSVI, assuming the same proportional differential as for the point estimates. Finally, for productivity loss of unpaid work, the value was assumed to equal the draw from productivity loss in employment, whereas the value of this loss was assumed to vary uniformly from 25% to 75%.[20]

Results

Point estimates

Table 4 summarizes the results of the analysis. Overall, the results suggest that the costs of poor eye health in India in 2019 were INR 1,158 billion (PPP $54.4 billion) summing across all six categories of loss. The results indicated that the loss of employment was the greatest contributor to the total cost of poor eye health, followed by caregiver costs and productivity loss in employment. Education loss for children and mortality risk figures were relatively small. MSVI generated a substantially higher welfare cost than blindness in India, contributing to more than 80% of the total burden. This was predominantly driven by the fact that MSVI was six times more prevalent than blindness.

Because there were differences in the evidence base for each type of cost, we reported results based on a conservative scenario valuing the loss of employment and elevated mortality risk. These two impact estimates were derived from a review and meta-analysis of the most recent evidence as reported in the *Lancet Global Health* Commission on Global Eye Health and could be considered a relatively stronger evidence base.[4] This conservative scenario indicated a total cost of INR 504 billion (PPP $23.7 billion) or 0.25% of GDP.

Probabilistic estimates

The results of the probabilistic sensitivity analysis are presented as a cumulative distribution function [Fig. 1]. The results showed that 95% of the results lay between INR 947 billion (PPP $44.5 billion) and INR 1,427 billion (PPP $67.0 billion) or 0.47% to 0.70% of GDP, with a median of INR 1,187 billion (PPP $55.8 billion) or 0.58% of GDP for the main scenario. For the conservative scenario (cumulative distribution function not shown), 95% of the results lay between INR 348 billion (PPP $16.3 billion) and INR 621 billion (PPP $29.2 billion) or 0.17% to 0.31% of GDP, with a median of INR 482 billion (PPP $22.7 billion) or 0.24% of GDP.

Discussion

This report estimated the economic and social costs of MSVI and blindness in India across six types of loss, contributing to the broader literature that estimated the economic impacts of poor eye health both nationally and globally.[2,3,9,22,18-19,28-30] The analysis indicated that in the main scenario, the total welfare cost of MSVI and blindness in India in 2019 equaled

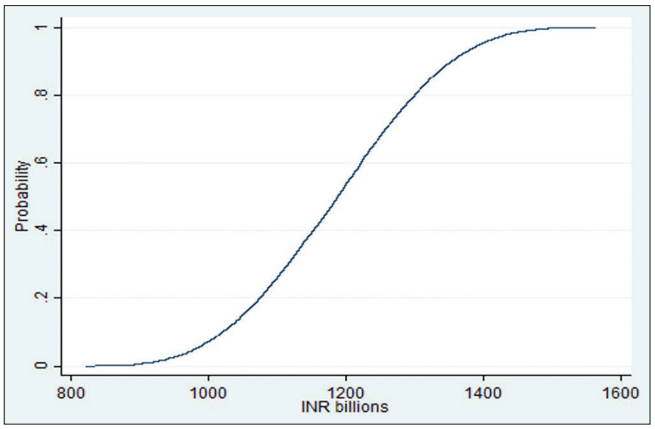

Figure 1: Cumulative distribution function of welfare costs of MSVI and blindness in India. Source: Estimates by the authors

Table 4: Estimated social and economic costs by type of impact, INR billions

	MSVI	Blindness	Total
Loss of employment	352.1	57.0	409.1
Elevated mortality risk	60.1	34.9	95.0
Sub-total (conservative scenario)	412.2	91.9	504.1
Education loss for children	11.5	2.4	13.9
Reduced productivity in employment	162.8	26.4	189.1
Caregiver costs	217.4	71.4	288.8
Productivity loss of unpaid work	139.1	22.5	161.6
TOTAL (primary scenario)	943.0	214.6	1,157.5
% of GDP	0.46%	0.11%	0.57%

Source: Estimate by the authors, all figures are for 2019

INR 1,158 billion (range: INR 947 billion to INR 1,427 billion) or 0.57% of GDP (range: 0.47% to 0.70%). MSVI and blindness impose mostly immediate productivity losses on the Indian economy, both for those who are in the workforce or those who take care of them. Poor eye health represents a non-trivial constraint toward reaching the country's growth goals such as becoming a $5 trillion economy by 2024–2025.

We presented an additional scenario including only two impacts that were highlighted in the *Lancet Global Health* Commission on Global Eye Health,[4] namely reduced employment and elevated mortality risk, and for which there was arguably a stronger evidence base. Although the evidence for the remaining impacts was drawn from fewer studies, and in some cases were less representative of India, it is unlikely that these other impacts would equal zero, and so ignoring them altogether would represent an underestimate of the challenge of MSVI and blindness in India. We believe that the range estimated under the probabilistic sensitivity analysis for the main scenario, INR 947 billion to INR 1,427 billion, or 0.47% to 0.70% of GDP, represented the most realistic cost estimate of MSVI and blindness in India.

There are several limitations to our analysis. We did not include intangible quality of life impacts for those who suffer from MSVI or blindness, nor did we include the costs of mild vision impairment in this assessment. Including these would

raise the cost of poor eye health in India. Additionally, because microdata from the National Survey[1] were unavailable, we drew upon the Global Burden of Disease[7] modeling to estimate the prevalence by 5-year age cohorts. If we had instead used the flat 0-49 and 50 + prevalence rates for MSVI and blindness reported in the survey (without further age adjustment), the costs of MSVI and blindness would increase by 17%.

All things equal, the absolute welfare costs of poor eye health will continue to grow over time as India ages and becomes wealthier if the age-specific prevalence of MSVI and blindness do not improve. Encouragingly, research indicates that poor eye health can be addressed efficiently in India. For example, one study estimated that it would cost USD 2.6 billion to eliminate cataract-related blindness and low vision in India, yielding USD 16 billion in benefits in the first year alone.[31]

Conclusion

In summary, poor eye health is a large problem, and solving it holds the potential for enormous welfare gains in the Indian context.

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Conflicts of interest

There are no conflicts of interest.

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