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The Global Burden of Potential Productivity Loss from Uncorrected Presbyopia

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Purpose: The onset of presbyopia in middle adulthood results in potential losses in productivity among otherwise healthy adults if uncorrected or undercorrected. The economic burden could be significant in lower-income countries, where up to 94% of cases may be uncorrected or undercorrected. This study estimates the global burden of potential productivity lost because of uncorrected functional presbyopia.

Design: Population data from the US Census Bureau were combined with the estimated presbyopia prevalence, age of onset, employment rate, gross domestic product (GDP) per capita in current US dollars, and near vision impairment disability weights from the Global Burden of Disease 2010 study to estimate the global loss of productivity from uncorrected and undercorrected presbyopia in each country in 2011. To allow comparison with earlier work, we also calculated the loss with the conservative assumption that the contribution to productivity extends only up to 50 years of age.

Participants: The economic modeling did not require the use of subjects.

Methods: We estimated the number of cases of uncorrected or undercorrected presbyopia in each country among the working-age population. The number of working-age cases was multiplied by the labor force participation rate, the employment rate, a disability weight, and the GDP per capita to estimate the potential loss of GDP due to presbyopia.

Main Outcome Measures: The outcome being measured is the lost productivity in 2011 US dollars resulting from uncorrected or undercorrected presbyopia.

Results: There were an estimated 1.272 billion cases of presbyopia worldwide in 2011. A total of 244 million cases, uncorrected or undercorrected among people aged <50 years, were associated with a potential productivity loss of US $11.023 billion (0.016% of global GDP). If all those people aged <65 years are assumed to be productive, the potential productivity loss would be US $25.367 billion or 0.037% of global GDP. Correcting presbyopia to the level achieved in Europe would reduce the burden to US $1.390 billion (0.002% of global GDP).

Conclusions: Even with conservative assumptions regarding the productive population, presbyopia is a significant burden on productivity, and correction would have a significant impact on productivity in lower-income countries. *Ophthalmology 2015;122:1706-1710 © 2015 by the American Academy of Ophthalmology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).*

Presbyopia is an impairment of near vision that is common among older adults.[1] It can be divided into 2 types: functional presbyopia and objective presbyopia. Functional presbyopia describes the situation whereby the person has vision of <N8 at near (i.e., <6/18 visual acuity) that can be restored to ≥N8 with near addition lenses, but does not include moderate myopes who can read without the aid of spectacles. Objective presbyopia occurs when a person is fully corrected for distance vision but reduction in accommodation has resulted in near vision <N8. In objective presbyopia, near vision can be improved to ≥N8 with near addition lenses and it includes myopes. For the population above the average age of onset (found to be 40 for some countries and 45 for the remainder), prevalence of functional presbyopia is estimated to range from 43.8% in southern and eastern Asian countries to 83.0% in western Asia, Australia, New Zealand, North America, and Europe.[2] On the basis of these rates, 1.044 billion people were estimated to have presbyopia in 2005, and this is expected to increase to 1.782 billion by 2050.[2] The rates for objective presbyopia would be significantly higher.

Given the difficulty that people with presbyopia experience with reading and other near vision tasks, it is not surprising that presbyopia has been found to be associated with negative impacts on quality of life in the US population even when corrected.[3,4] In addition to reading, presbyopia is associated with negative impacts on quality of life and visual function; difficulties with activities, such as harvesting sorghum, threading a needle, writing letters, weeding, winnowing grain, cooking, and sorting rice in a rural Tanzanian population[5]; difficulties with activities of daily living, functional dependence, and social functioning in a rural Chinese population[6]; and difficulties with near vision tasks, such as seeing keys and displays on mobile phones, sewing or weaving baskets or mats, and sorting or cleaning lentils, rice, or other grains in a Fijian population.[7]

Although the negative impact of presbyopia can be minimized through relatively inexpensive correction with

http://dx.doi.org/10.1016/j.ophtha.2015.04.014
ISSN 0161-6420/15

near-vision spectacles, rates of correction range from an estimated 96% in Europe to as low as 6% in Africa.[2] Thus, uncorrected or undercorrected presbyopia may be hampering economic development, through both productivity losses among older otherwise healthy working adults and barriers to literacy improvements in developing countries.[1,8]

A study of the potential global productivity loss due to uncorrected or undercorrected refractive error estimated an impact of US $202 billion; however, this estimate did not include the potential productivity loss associated with presbyopia due to absence of the necessary data.[9,10] Since that time, global estimates of the prevalence of presbyopia have been published,[2] and the Global Burden of Disease (GBD) study has produced a disability weight for near vision impairment for the first time.[11] By using these new data, the objective of this study is to estimate the global burden of potential productivity loss associated with presbyopia.

Methods

The prevalence of presbyopia and age of onset were estimated for each United Nations member country on the basis of regional estimates[2] and combined with age-specific population estimates sourced from the US Census Bureau[12] to estimate the number of cases of presbyopia. Population data were not available for Niue from this source, so the total population was sourced from the Central Intelligence Agency (CIA),[13] and age structure was estimated to be equivalent to that in the Cook Islands. Numbers of cases without adequate correction in each country were calculated on the basis of the proportion estimated to be uncorrected or undercorrected in each region.[2]

Because the earlier study[1] on the burden of uncorrected distance vision used a conservative assumption that the working-age population includes only those aged 16 to 50 years, we also calculated the burden of presbyopia for this section of the population. We estimated the number of cases of uncorrected or undercorrected presbyopia in each country among the working-age population for the population up to age 50 years and up to age 65 years. The number of working-age cases was multiplied by the labor force participation rate, the employment rate, a disability weight, and the gross domestic product (GDP) per capita to estimate the potential loss of GDP due to presbyopia. To estimate the potential reduction in lost GDP as a result of full correction, we assumed that the maximum possible rate of correction was 96% of the presbyopic population, which is the estimated rate for Europe.

Labor force participation rate estimates for the population aged ≥15 years in 2011 were sourced from the International Labor Organization.[14] For the 17 countries not included in this database, we substituted the most recent labor force estimates from the CIA for 15 countries,[13] the rate for Sudan for South Sudan, and census population and labor force data from the Nauru Bureau of Statistics for Nauru.[15] Census population data for Niue for the denominator in this calculation were sourced from Niue Statistics.[16]

Employment rates were calculated on the basis of the unemployment rates published by the CIA for 2011.[13] Where countries did not have a published rate for 2011, the average for the applicable World Health Organization region was used.

Per capita GDP data for 2011 (in current US dollars) were sourced from the World Bank.[17] When a 2011 figure was not available, 2011 total GDP figures from the United Nations Statistics Division were used,[18] divided by the estimated population for 2011 (Fig 1).

Labor force participation rates	
Source	Countries or regions covered
International Labor Organization	246
CIA World Factbook	15
Sudan's data	South Sudan
Nauru Bureau of Statistics	Nauru
Niue Statistics	Niue

Employment rates	
Source	Countries or regions covered
CIA World Factbook	203
Average of WHO region	Remaining countries and regions

Per capita GDP	
Source	Number of countries or regions covered
World Bank	213
UN Statistics Division (total GDP/population)	Remaining countries and regions

Figure 1. Selection of country economic data. CIA = Central Intelligence Agency; GDP = gross domestic product; UN = United Nations; WHO = World Health Organization.

The GBD 2010 study's disability weight of 0.013 for near vision impairment was used for uncorrected or undercorrected presbyopia.[19] The lay description of this state used for the survey in the GBD survey was "has difficulty seeing things that are nearer than 3 feet, but has no difficulty with seeing things at a distance."[11] The description suggests that it applies to uncorrected presbyopia, so we applied this weight to uncorrected or undercorrected presbyopia and a weight of 0 for corrected presbyopia.

The formula used to calculate the total productivity loss was TPL = TC × population × UC × LPR × (1 − UR) × DW × GDP (PC), where TPL is total productivity loss, TC is total cases, UC is undercorrected presbyopia, LPR is labor force participation rate, UR is unemployment rate, DW is disability weight, and PC is per capita.

The study did not involve human subjects, so it did not require adherence to the guidelines of the Declaration of Helsinki or review by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

Results

Table 1 shows the numbers of cases of presbyopia in various groups by region in 2011. There were an estimated 1.272 billion cases of presbyopia worldwide in 2011. Of these, one-third of cases were among working-age people aged 40 or 45 years (depending on the age of onset in the applicable country) to 49 years, and a further 41% were aged 50 to 64 years. The proportion of cases occurring among people aged <50 years ranged from a low of 17% in parts of Europe (EUR A and EUR C) to 43% in parts of Africa (AFR E). This variation may be explained by the

Table 1. Cases of Presbyopia by Region, Proportion Working Age and Uncorrected/Undercorrected, Labor Force Participation, and Unemployment Rates in 2011

Region	Total Cases of Presbyopia	Proportion Aged 40/45–49 Years	Proportion of Cases 40/45–49 Uncorrected/Undercorrected	Average Labor Force Participation Rate	Average Unemployment Rate
AFR D	43 508 460	44%	79%	68%	16%
AFR E	46 144 638	43%	86%	75%	16%
AMR A	118 109 301	18%	19%	62%	7%
AMR B	93 290 341	39%	61%	64%	8%
AMR D	12 545 728	40%	62%	69%	7%
EMR B	22 062 463	39%	70%	58%	12%
EMR D	48 500 977	41%	73%	51%	10%
EUR A	163 111 556	17%	4%	64%	9%
EUR B	58 418 938	22%	45%	58%	13%
EUR C	78 883 574	17%	8%	58%	10%
SEAR B	48 400 017	39%	70%	65%	4%
SEAR D	180 106 555	42%	71%	70%	6%
WPR A	69 795 267	23%	17%	65%	5%
WPR B	289 380 582	42%	70%	60%	5%
Total	1 272 258 397	33%	59%	64%	10%

AFR = Africa; AMR = Americas; EMR = Eastern Mediterranean; EUR = Europe; SEAR = Southeast Asia; WPR = Western Pacific. Designations A to E refer to levels of child and adult mortality, where A is lowest.

longer life expectancy in the developed regions, thus a larger proportion of presbyopes aged >50 years.

Approximately 244 million cases of uncorrected or undercorrected presbyopia were assumed to occur in the working-age population aged <50 years (the 59% proportion in Table 1). These cases are of particular concern because they could be associated with a significant loss of productivity. Table 1 also shows that uncorrected or undercorrected presbyopia among people aged <50 years was rare in the lowest mortality parts of Europe (EUR A) at 4% of all cases, but much higher in less-developed regions, with a high of 86% in the highest-mortality parts of Africa (AFR E).

Estimated labor force participation rates (for the population aged ≥15 years) ranged from 51% to 75% across regions, although the range across individual countries was between 15% and 89%. The average unemployment rates were lowest in the Western Pacific Region (5%) and highest in Africa (16%).

Figure 2 shows the proportion of GDP in each region that may be lost as a result of uncorrected or undercorrected presbyopia. Overall, 0.016% of world GDP ($11.023 billion, current US dollars) is estimated to be lost, with an impact >1.5 times higher than that in the developing countries of the Western Pacific Region (WPR B) and the Americas (AMR B and D), and the low-mortality countries of Southeast Asia (SEAR B). We assessed the impact of our conservative assumption that the productive population was aged <50 years by conducting the same analysis under the assumption that the productive population was aged <65 years. This increased the estimate by $14.335 to $25.367 billion or 0.037% of global GDP lost due to uncorrected or undercorrected presbyopia. Universal correction of presbyopia to the highest level observed (an estimated 96% in parts of Europe) would reduce the potential productivity burden to $1.390 billion (0.002% of global GDP).

Discussion

By using new data on the prevalence, correction rates, and disability weight for presbyopia, we have calculated conservatively that the potential productivity burden of uncorrected or undercorrected presbyopia is approximately $11.023 billion (current US dollars), or 0.016% of global GDP. More realistically, by assuming the working age extends to 65 years, the potential burden is $25.367 billion or 0.037% of global GDP. Global correction of presbyopia could reduce the productivity burden by 87% to $1.390 billion. We found significant differences in the burden across regions, with the highest potential productivity loss in developing countries of the Western Pacific Region and the Americas, and the low-mortality countries of Southeast Asia. These differences are created by the variations in wages, productivity, age structures, and employment rates

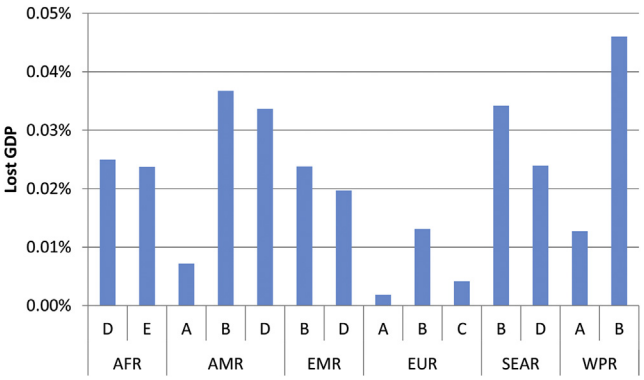

Figure 2. Proportion of gross domestic product (GDP) lost as a result of uncorrected or undercorrected presbyopia. The World Health Organization (WHO) regions are Africa (AFR), Americas (AMR), Eastern Mediterranean (EMR), Europe (EUR), Southeast Asia (SEAR), and Western Pacific (WPR). The subregions are based on child and adult mortality rates: A = very low child, very low adult mortality; B = low child, low adult mortality; C = low child, high adult mortality; D = high child, high adult mortality; E = high child, very high adult mortality.

between the more advanced high-income countries and those in lower socioeconomic development circumstances.

The distribution of the burden across regions does not exhibit a clear association with the level of mortality or development. This is because each country's potential loss of GDP depends on the combination of several different factors. For example, Pakistan and Turkey were both estimated to lose approximately 0.02% of GDP in this analysis, but for different reasons, despite Turkey having a higher prevalence of presbyopia (83.0% vs. 43.8%). Presbyopia was assumed to be uncorrected or undercorrected in 70% of cases in both countries, but Pakistan had a lower estimated age of onset (40 vs. 45 years), a higher proportion of the population in the affected age group (9.4% vs. 6.4%), a slightly higher labor force participation rate (53% vs. 50%), and a lower unemployment rate (5.6% vs. 9.8%). In fact, across all countries the simple correlation between prevalence and GDP loss was negative, having much less impact on the overall impact than the proportion of cases that were uncorrected or undercorrected.

Our findings are not directly comparable with those of a previous study that estimated that the potential productivity loss associated with uncorrected refractive error (not including presbyopia) was 0.246% of global GDP,[9] although the differences are easily addressed. However, the combined distance and near productivity loss (US $213.023 billion) of both studies provide an indication of the total benefits of providing either a distance or near spectacle correction or a combined distance and near spectacle correction. Our use of the smaller set of United Nations member countries is unlikely to have had a significant effect on the overall results because our total GDP was 1.2% lower than the World Bank estimates,[17] and our total population was just 0.4% lower than the Census Bureau estimates.[12] The lack of significant impact is confirmed by the fact that our estimate of the total number of cases of presbyopia in 2011 is consistent with estimates for 2010 and 2020 in another study.[2]

Study Limitations

Our use of more conservative disability weights from the GBD 2010 study is likely to have influenced the results relative to the study of the productivity loss associated with uncorrected refractive error.[9] That study might have found the productivity burden to be approximately 0.081% of global GDP if it had used the disability weights from the GBD 2010 study, which were approximately 67.5% lower than the weights it used (0.195 vs. 0.6 for blindness). Adding this adjusted estimate to our estimate for presbyopia suggests that the potential productivity loss from all uncorrected refractive error could be approximately 0.097% of global GDP and that uncorrected or undercorrected presbyopia is the cause of approximately 16.5% of this burden.

Our use of the GBD 2010 study's disability weight of 0.13 for uncorrected presbyopia and 0 for corrected presbyopia may be considered conservative. Another study estimated a weight of 0.02 for corrected presbyopia,[4] and members of the GBD study's Vision Loss Expert Group have expressed concerns that the vision loss weights in this study may be too low.[20] However, the GBD study's estimates remain preferable because they were derived from population-based survey estimates rather than expert opinion and may be more consistent with disability weights in other fields.[21]

In addition to uncertainty about the disability weight, data quality is a potential limitation of our study, including variations within the World Health Organization subregions. We attempted to mitigate this risk by using respected sources that used consistent methods and definitions where possible, but anomalies remain where countries are not able to provide international databanks with good-quality data according to the required specifications. For example, data for South Sudan are not yet available on many indicators and national census figures often differ from US Census Bureau projections. The numbers of people (not cases) with presbyopia in each country were calculated on the basis of the proportion within a region who had uncorrected presbyopia. Productivity losses will be minimal for people who have their presbyopia corrected in a timely manner.

Our report estimates the potential global productivity burden of uncorrected and undercorrected presbyopia. The burden seems significant in comparison with the burden of other uncorrected refractive errors, suggesting that investments in relatively inexpensive spectacles for people with presbyopia in regions with low rates of correction would generate significant benefits. Future research should consider whether such investments might be cost-effective and how they could be implemented successfully on a broad scale. Ultimately, improved correction of presbyopia would contribute to increased productivity and advanced economic development in countries where this is most needed.

References

1. Patel I, West SK. Presbyopia: prevalence, impact, and interventions. Community Eye Health 2007;20:40–1.
2. Holden BA, Fricke TR, Ho SM, et al. Global vision impairment due to uncorrected presbyopia. Arch Ophthalmol 2008;126:1731–9.
3. McDonnell PJ, Lee P, Spritzer K, et al. Associations of presbyopia with vision-targeted health-related quality of life. Arch Ophthalmol 2003;121:1577–81.
4. Luo BP, Brown GC, Luo SC, Brown MM. The quality of life associated with presbyopia. Am J Ophthalmol 2008;145:618–22.
5. Patel I, Munoz B, Burke AG, et al. Impact of presbyopia on quality of life in a rural African setting. Ophthalmology 2006;113:728–34.
6. Lu Q, Congdon N, He X, et al. Quality of life and near vision impairment due to functional presbyopia among rural Chinese adults. Invest Ophthalmol Vis Sci 2011;52:4118–23.
7. Williams S, Brian G, du Toit R. Measuring vision-specific quality of life among adults in Fiji. Ophthalmic Epidemiol 2012;19:388–95.
8. Frick KD. What the comprehensive economics of blindness and visual impairment can help us understand. Indian J Ophthalmol 2012;60:406–10.

9. Smith TS, Frick KD, Holden BA, et al. Potential lost productivity resulting from the global burden of uncorrected refractive error. Bull World Health Organ 2009;87:431–7.
10. Fricke TR, Holden BA, Wilson DA, et al. Global cost of correcting vision impairment from uncorrected refractive error. Bull World Health Organ 2012;90:728–38.
11. Salomon JA, Vos T, Hogan DR, et al. Common values in assessing health outcomes from disease and injury: disability weights measurement study for the global burden of disease study 2010. Lancet 2013;380:2129–43.
12. International Data Base (IDB) [Internet]; c2013 [cited January 13, 2013]. Available at: http://www.census.gov/population/international/data/idb/informationGateway.php. Accessed January 13, 2013.
13. The World Factbook [Internet]; c2012 [cited January 21, 2013]. Available at https://www.cia.gov/library/publications/the-world-factbook/. Accessed January 21, 2013.
14. Economically Active Population, Estimates and Projections (6th edition) [Internet]; c2011 [cited January 29, 2013]. Available at: http://laborsta.ilo.org/applv8/data/EAPEP/eapep_E.html. Accessed January 29, 2013.
15. Census 2002 [Internet]; c2007 [cited January 22, 2013]. Available at: http://www.spc.int/prism/country/nr/stats/CensusSurveys/censurvey_index.htm. Accessed January 22, 2013.
16. Niue 2001 Census of Population and Housing Report [Internet]; c2002 [cited January 22, 2013]. Available at: http://www.spc.int/prism/Country/NU/stats/Reports/Population/Population.htm. Accessed January 22, 2013.
17. Indicators [Internet]; c2013 [cited January 21, 2013]. Available at: http://data.worldbank.org/indicator. Accessed January 21, 2013.
18. National Accounts Main Aggregate Database [Internet]; c2012 [cited January 21, 2013]. Available at: http://unstats.un.org/unsd/snaama/dnlList.asp. Accessed January 21, 2013.
19. Global Burden of Disease Study 2010. Global Burden of Disease Study 2010 (GBD 2010) Disability Weights. Seattle, WA: Institute for Health Metrics and Evaluation; 2012.
20. Taylor HR, Jonas JB, Keeffe J, et al. Disability weights for vision disorders in global burden of disease study. Lancet 2013;381:23.
21. Salomon JA, Vos T, Murray CJ. Disability weights for vision disorders in global burden of disease study — authors' reply. Lancet 2013;381:23–4.

Footnotes and Financial Disclosures

Originally received: February 24, 2015.
Final revision: April 9, 2015.
Accepted: April 9, 2015.
Available online: June 16, 2015. Manuscript no. 2015-312.

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Financial Disclosure(s):
The author(s) have no proprietary or commercial interest in any materials discussed in this article.

Funded by the Brien Holden Vision Institute.

Author Contributions:

Research design: Frick, Joy

Data acquisition and/or research execution: Joy

Data analysis and/or interpretation: Frick, Naidoo, Wilson, Holden

Obtained funding: Not applicable

Manuscript preparation: Wilson, Holden

Abbreviations and Acronyms:
CIA = Central Intelligence Agency; **GBD** = Global Burden of Disease; **GDP** = gross domestic product.

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