Global cost of correcting vision impairment from uncorrected refractive error

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Objective To estimate the global cost of establishing and operating the educational and refractive care facilities required to provide care to all individuals who currently have vision impairment resulting from uncorrected refractive error (URE).

Methods The global cost of correcting URE was estimated using data on the population, the prevalence of URE and the number of existing refractive care practitioners in individual countries, the cost of establishing and operating educational programmes for practitioners and the cost of establishing and operating refractive care facilities. The assumptions made ensured that costs were not underestimated and an upper limit to the costs was derived using the most expensive extreme for each assumption.

Findings There were an estimated 158 million cases of distance vision impairment and 544 million cases of near vision impairment caused by URE worldwide in 2007. Approximately 47 000 additional full-time functional clinical refractionists and 18 000 ophthalmic dispensers would be required to provide refractive care services for these individuals. The global cost of educating the additional personnel and of establishing, maintaining and operating the refractive care facilities needed was estimated to be around 20 000 million United States dollars (US$) and the upper-limit cost was US$ 28 000 million. The estimated loss in global gross domestic product due to distance vision impairment caused by URE was US$ 202 000 million annually.

Conclusion The cost of establishing and operating the educational and refractive care facilities required to deal with vision impairment resulting from URE was a small proportion of the global loss in productivity associated with that vision impairment.

Abstracts in عربي, 中文, Français, Русский and Español at the end of each article.

Introduction

Uncorrected refractive error (URE) is the most common cause of vision impairment worldwide and the second most common cause of blindness.[1,2] The aim of this paper was to estimate the global cost of establishing and operating health-delivery systems that are capable of providing refractive care to all individuals who currently have vision impairment resulting from URE. The estimated cost can be compared to a previously published estimate of the annual cost of the productivity lost due to refractive vision impairment worldwide, of 269 000 million international dollars, equivalent to 202 United States dollars (US$).[3] The comparison provides an indication of the economic return that society might expect from the investment required to make refractive care accessible to all. We present an idealized account of the actions needed to solve the problem of URE globally, which can serve as a guide and provide an incentive for action. In reality, uncontrollable socioeconomic, cultural and political factors complicate the process and make the cost of eliminating URE unpredictable.

Methods

For this analysis, we used the current World Health Organization (WHO) definition of distance vision impairment: a visual acuity worse than 6/18 in the better eye.[4] For near vision impairment, since WHO has not specified a standard, we used the definition suggested by the International Agency for the Prevention of Blindness: “vision at the individual’s required working distance worse than N8 in the better eye”.[5]

As it has been reported that URE cannot be dealt with by existing eye care workers,[5] we have estimated the extra staff needed. In doing so, we adhered as closely as possible to each country’s expectations of the specific personnel required to provide the various elements of refractive care.

Given the large number of individuals with URE, it was logical to assume that refractive care should be delivered in primary-care settings.[6] Moreover, WHO noted that, when refractive care is provided in primary care, the opportunity should also be taken to identify those who need treatment for eye disease.[7] Consequently, we based our costing of the infrastructure needed on a vision centre model that provides both refractive care and screening for ocular disease at the primary-care level.[8,9]

We combined data from several sources. Population data were mostly based on estimates for the middle of 2007 obtained from the International Data Base, a computerized database established by the United States Census Bureau that contains statistical tables of demographic data for 228 countries and areas of the world.[10,11] In doing this, we used the same population data as Smith et al.,[3] which enabled us to compare our findings with estimates of the cost of the productivity lost due to vision impairment made by those authors. Economic data included price level indices from the International Comparison Program of the World Bank[12] and the Asian Development Bank[13] and data on wage levels and resource use in health care were taken from WHO CHOICE databases.[14] Data on the prevalence of distance and near vision impairment due to URE in each country were obtained from the publications of Resnikoff et al.[1] and Holden et al.,[2] respectively. The number of cases of vision impairment in each country was derived

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by combining prevalence data with population data. To simplify reporting, we give estimates for the 14 subregions of the world used in the WHO publication *Global burden of disease 2002: data sources, methods and results*.[15]

New practitioners required

The number of new practitioners needed to provide clinical refraction services was estimated for each country by calculating how many refractive care practitioners were required to reach the ratio of 1:50 000 for the number of "functional clinical refractionists" to the population specified by WHO and the International Agency for the Prevention of Blindness[7] and by taking into account existing human resources. We defined a functional clinical refractionist as a person who spends 100% of his or her clinical time providing refraction services and estimated the equivalent number of full-time functional clinical refractionists available at present from the percentage of clinical time each particular type of professional spends on providing refraction services. For example, in Australia, although optometrists provide the majority of refraction services, they have other responsibilities and we estimated that the equivalent number of full-time functional clinical refractionists in the country was half the number of optometrists. Data sources for the number of practitioners who were providing refraction services worldwide are listed in Table 1.

There are individuals with vision impairment due to URE in many countries that do not require additional refractive care personnel because they exceed the functional clinical refractionists to population ratio specified by WHO and the International Agency for the Prevention of Blindness.[7] For example, an estimated 1.2 million people in Australia have distance or near vision impairment due to URE. Since the country has 2712 registered optometrists (equivalent to 1356 full-time refractionists), the functional clinical refractionists to population ratio is 1 to 15 069.[16,17] In countries like Australia, we assumed that the human resources required to provide clinical refraction services already existed and, consequently, that the cost of educating additional refractive care personnel would be zero.[18] In these cases, untreated vision impairment was regarded as resulting from difficulties accessing services.

We were unable to find any published data on the number of ophthalmic dispensing personnel required for the prevention of blindness. As dispensing personnel usually work in conjunction with refractive care personnel, our estimate for the number of dispensing personnel required in each region was a proportion of the number of functional clinical refractionists required. We varied the proportion with the average prevalence of refractive error in each region because, in areas where the prevalence is low, clinical staff will probably have to examine more people with normal vision or eye disease that require referral for each case of refractive error found. In contrast, dispensing personnel will be involved only when a refractive error is detected. Consequently, the ratio of dispensing personnel to functional clinical refractionists was taken to be 1:5 in Africa, 1:2 in Asia, 1:4 in Oceania and 1:3 in Europe, the eastern Mediterranean and the Americas. Given that these ratios were chosen arbitrarily, we used a ratio of 1:1 in every country when establishing an upper limit for costs.

Cost of educating practitioners

In estimating the cost of educating the new practitioners required to provide refractive care in each country, we made several assumptions about capital and running costs.

For economic reasons, we grouped together countries that were similar geographically and politically and assumed that a shared institution could provide education for a region requiring 1500 functional clinical refractionists. For example, we estimated the capital costs of the two educational facilities required in Anglophone eastern Africa for educating 2981 functional clinical refractionists in Ethiopia, Kenya, Uganda and the United Republic of Tanzania combined. When such combinations were not possible, we attempted to find a compromise. For example, we postulated that an institution in Mozambique could serve all of Lusophone Africa. In this case, the cultural and linguistic ties between populations were considered to outweigh the fact that the combined total of functional clinical refractionists required was only 585. The data sources for the capital and running costs of educational facilities for new refractive care practitioners are given in Table 2. When no data were available for a country, we extrapolated costs in similar countries by adjusting the price level index for differences in the cost of living between countries. Price level indices obtained from The World Bank provide a broad measure of costs rather than costs specific to education.[12] The cost of educating dispensing personnel was also included in educational costs, as was an additional sum to cover continuing professional development for all personnel for a period of 5 years.

Cost of new refractive care facilities

We estimated the cost of establishing, equipping and running refractive care facilities for the new practitioners required in each country. First, the number of new care facilities was estimated. When the functional clinical refractionists–to-population ratio was less than 1 to 50 000, we calculated the number of new practitioners required using the method described above. When the ratio was higher than 1 to 50 000, we used a problem-solving approach to estimate the cost of increasing the accessibility of the existing workforce. With the problem-solving approach, we estimated the number of new or redeployed personnel required from the total number of URE cases needing treatment by assuming that a full-time functional clinical refractionist can deal with 2067 cases of vision impairment due to URE per year on average and that each individual has to be reassessed and provided with replacement spectacles every 5 years on average. The average of 2067 cases per year was derived by assuming that a practitioner works 5 days a week, has 6.2 weeks annual leave and sees six patients with vision impairment due to URE per day. Since half of these patients will have both distance and near vision impairment, in effect a total of nine cases of vision impairment due to URE will be dealt with per working day. Regardless of which method was used to estimate the number of new or redeployed practitioners needed, we calculated the number of care facilities required by dividing by 1.3, based on an estimation of approximately four practitioners for every three vision centres.

Second, the capital cost of establishing and equipping the new facilities required was estimated. In most cases, we used an average of US$ 50 000 per care facility, which was based on information provided by the international

Table 1. **Data sources on existing refractive care practitioners, worldwide, 2006–2010**

Country	Data source
Angola, Benin, Botswana, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Niger, Senegal, South Africa, Togo, Uganda, Zimbabwe	*Human resources for eye care – Africa Region*, International Agency for the Prevention of Blindness Africa Human Resource Day, 19 September 2006
Kenya, Sudan, United Republic of Tanzania, Zambia	*Regional analysis of southern and eastern Africa*, International Centre for Eyecare Education, 2008
Cameroon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Sierra Leone	West Africa refractive error workshop, Sightsavers International, January 2008
Algeria, Bahrain, Islamic Republic of Iran, Jordan, Pakistan, Saudi Arabia, Sudan	Hasan Minto, World Conference of Optometric Education, Durban, 22–24 September 2010
Bhutan, Indonesia, Maldives, Myanmar, Sri Lanka, Thailand	Mid-level ophthalmic personnel in South-East Asia, WHO Regional Office for South-East Asia, May 2002
Australia	Horton, Kiely and Chakman, *Clin Exp Optom* 2006; Kiely, Horton and Chakman, *Clin Exp Optom* 2010; Kiely and Chakman, *Clin Exp Optom* 2011
Cook Islands, Fiji, Samoa, Tonga	Ramke et al., *Clin Exp Ophth* 2007
Nepal	Prakash Paudel, personal communication, 10 February 2009
Indonesia	Cheni Lee, personal communication 2009
India	Delhi Declaration (2010) and Prakash Paudel and GN Rao, personal communication (2009)
Singapore	http://en.wikipedia.org/wiki/Optometry_in_Singapore (accessed 5 August 2009)
Cambodia, Vanuatu, Viet Nam	Suit May Ho, personal communications, 28 July 2009 and 6 November 2009
Afghanistan, Bangladesh	Fred Hollows Foundation situational analyses (2009)
China – Hong Kong Special Administrative Region, China – Taiwan, Japan, Malaysia, Philippines, Republic of Korea	Essilor Asia-Pacific ophthalmic survey (11 October 2004)
New Zealand	New Zealand Optometrists Association (http://www.nzao.co.nz/eye_health.html, accessed 5 August 2009)
China	Daniel Cui, personal communication (2009)
Malaysia	http://www.amoptom.org/ and http://www.fskb.ukm.my/, both accessed 6 November 2009
Mongolia, Papua New Guinea, Solomon Islands	International Centre for Eyecare Education situational analyses (2009)
Nauru, Papua New Guinea	Jambi Garap, personal communication, 6 November 2009
Timor-Leste	International Centre for Eyecare Education training reports for Timor-Leste (2005)
Afghanistan	MSc theses summaries, *Community Eye Health*, 2007; 20(61):7–15
Serbia, Montenegro	Serbian Association of Opticians and Optometrists (http://www.uoosrbije.org/, accessed 6 November 2009)
Costa Rica	Ruggeiro and Gloyd, *Optom Vis Sci*, 1995
United States of America	United States Department of Labour (http://www.bls.gov/oco/ocos073.htm, accessed 10 February 2009)
Canada	University of Waterloo, Canada (http://www.optometry.uwaterloo.ca/prospective/od/career.html, accessed 10 February 2009)
Brazil, Chile, Colombia, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Uruguay, Venezuela	International Agency for the Prevention of Blindness Latin America Regional Office (http://www.v2020la.org/orbisread/Indicators05.htm) plus Van Lansingh, personal communication (2010)
Argentina, Peru	Guillermo Carrillo (International Association of Contact Lens Educators Latin America coordinator) via Percy Lazon, personal communication (27 July 2009)
Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada	Nigel St Rose presentation, World Conference of Optometric Education meeting, Durban, 22–24 September 2010
Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom	*European Council of Optometry and Optics blue book 2008* (http://www.ecoo.info/) plus Cathleen Fedke and Fabian Conrad, personal communications (2009)
Islamic Republic of Iran	Aidin Safvati, personal communication, 6 July 2009

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Country	Data source
Kuwait, Qatar, Saudi Arabia, United Arab Emirates	Ahmed Alharbi, personal communication, 18 November 2009
United Arab Emirates	AMEinfo online business information (http://www.ameinfo.com/, accessed 6 July 2009)
Syrian Arab Republic	Syrian Ophthalmological Society (http://www.sos-sy.com/index.php?id=37, accessed 6 July 2009) and Nina Tahhan, personal communication (2009)
Israel	Israeli Council of Optometrists (http://www.ico.org.il/, accessed 6 July 2009)
Russian Federation	Vadim Davydov (editor, *Actual Optometry Journal*), personal communication, 11 November 2009
Estonia	Vootele Tame (from Head of Optometry, Tallinn Health College), personal communication, 11 November 2009
Pakistan	Minto H, Awan H, Khan AA, Khan AQ, Yasmin S, Khan N. Situation analysis of refractive services in Pakistan, Academy for Ophthalmic Education (2007)

Table 2. **Data sources for capital and running costs associated with educating refractive care practitioners, worldwide, 2006–2010**

Country	Data source
Australia	Queensland University of Technology (vision science and optometry tuition fees), plus Australian Optometry (October 2009) http://www.optometrists.asn.au/Publications/AustralianOptometry/tabid/126/language/en-AU/Default.aspx (accessed 11 July 2012).
Cambodia	International Centre for Eyecare Education Cambodia project budgets (2010)
Canada	University of Waterloo (optometry tuition fees, 2009)
China, Hong Kong Special Administrative Region	Hong Kong Special Administrative Region Polytechnic University (optometry tuition fees, 2009)
Fiji	Pacific Eye Institute (course fees) and John Szeto, personal communication (2009)
Indonesia	Cheni Lee, personal communication (2009)
Malawi	Malawi School of Optometry, University of KwaZulu Natal (optometry tuition fees, 2010)
Malaysia	National University of Malaysia (2009)
Mozambique	Irish Aid grant for Mozambique School of Optometry (2010)
Nepal	Prakash Paudel, personal communication (10 February 2009)
Nigeria	University of Benin (optometry tuition fees, 2010)
Papua New Guinea	Divine Word University (postgraduate diploma in eye care for nurses course fees, 2010)
Peru	Guillermo Carrillo (International Association of Contact Lens Educators Latin America coordinator), personal communication, 27 July 2009
Singapore	Singapore Polytechnic (optometry tuition fees, 2009)
Sri Lanka	International Centre for Eyecare Education Sri Lanka project budgets (2008)
United Republic of Tanzania	Tumaini University (health science tuition fees, 2010)
United States of America	United States Association of Schools and Colleges of Optometry (http://www.opted.org/, accessed 10 February 2009)
Viet Nam	International Centre for Eyecare Education Viet Nam project budgets (2010)

charity Sightsavers and published by the International Agency for the Prevention of Blindness.[5] The amount includes the cost of equipping care facilities with bulk-purchased equipment, such as clinical refractive equipment, ocular health screening equipment, ophthalmic dispensing equipment and accounting and business equipment, and the cost of start-up stock.

Third, we estimated the cost of running the new facilities required for a period of 5 years, on the assumption that costs would be recovered from charges to patients during this period. Running costs included salaries, rent and electricity, water, telephone and consumable costs. The cost of most of these items was derived from the WHO CHOICE database for each geographical subregion.[14] The cost of consumables was calculated on the assumption that 72.4% of individuals used ready-made spectacles and 27.6% used custom-made spectacles,[19] with the cost of each type being based on the real costs reported by the International Centre for Eyecare Education.[20] In addition, it was assumed that each refractive care unit paid salaries to 1.3 refractive care practitioners, 1 receptionist, 0.2 managers and several ophthalmic dispensing personnel determined for each region separately, and that every 20 refractive care units required a support team consisting of 1 programme director, 2 administrative officers, 1 clerk, 1 messenger, 1 finance director, 1 accountant, 1 public health specialist, 1 health educator, 1 social worker, 1 supplies manager, 4 cleaners and 4 security officers. Rent was calculated assuming that each refractive care unit had 1 consulting room 3.5 m × 3 m in size and 1 general purpose room 3.5 m × 4 m in size, that each fifth refractive care unit had 1 optical workshop 3.5 m × 3 m in size and that each twentieth refractive care unit required a room 6 m × 6 m in size for the support team.

We estimated an upper limit to the cost of establishing, equipping and running refractive care facilities by altering critical assumptions so that they reflected the most expensive scenarios. First, we assumed that one ophthalmic dispenser was employed for each clinical refractionist. Second, the ratio of ready-made to custom-made spectacles was assumed to be 20 to 80, which is in line with expectations in the developed world, rather than the ratio used for the main cost estimate, which assumed the lowest acceptable quality of care.[21]

Results

The estimated number of cases of distance and near vision impairment due to URE in WHO regions and subregions are listed in Table 3. In addition, the table gives details of the existing number of functional clinical refractionists and of the number of new functional clinical refractionists required to deal with all cases of vision impairment due to URE. The estimated number of people in the world with distance vision impairment due to URE in the middle of 2007 was around 158 million and the estimated number with near vision impairment resulting from URE was around 544 million. As some individuals will have both forms of vision impairment, we estimated the total number of cases of vision impairment due to URE in the world, which was around 703 million in 2007, rather than the number of individuals.

Table 3. **Distance and near vision impairment due to uncorrected refractive error (URE) and number of functional clinical refractionists,[a] worldwide, 2006–2010**

WHO region and subregion[b]	Population (millions)	Estimated no. of people aged over 5 years with distance vision impairment due to URE (thousands)	Estimated no. of people aged over 5 years with near vision impairment due to URE (thousands)	Estimated total no. of cases of vision impairment due to URE[c] (thousands)	No. of existing functional clinical refractionists	No. of additional functional clinical refractionists required
African Region						
D	346	2 976	29 272	32 248	2 605	4 348
E	408	3 326	34 892	38 218	2 380	5 790
Total	754	6 301	64 165	70 466	4 985	10 138
Region of the Americas						
A	346	6 278	18 681	24 959	18 901	0
B	474	6 504	51 241	57 745	5 565	4 906
D	79	1 018	6 732	7 750	442	1 131
Total	898	13 800	76 654	90 454	24 908	6 038
Eastern Mediterranean Region						
B	151	1 631	12 615	14 246	4 949	516
D	409	4 220	32 607	36 827	4 164	4 024
Total	561	5 852	45 222	51 074	9 113	4 540
European Region						
A	423	8 338	6 106	14 444	43 307	16
B	216	3 049	17 222	20 271	4 653	776
C	230	3 702	4 510	8 211	3 610	1 314
Total	868	15 088	27 838	42 926	51 570	2 106
South-East Asia Region						
B	321	4 863	30 411	35 274	2 246	4 168
D	1 383	49 684	111 219	160 903	10 169	17 483
Total	1 703	54 547	141 630	196 178	12 415	21 651
Western Pacific Region						
A	157	1 415	6 756	8 171	19 849	0
B	1 604	60 482	176 553	237 035	37 707	1 560
Total	1 761	61 897	183 309	245 206	57 556	1 560
Unassigned	57	607	5 636	6 243	6 515	171
Global total	6 602	158 092	544 454	702 546	167 013	46 204

WHO, World Health Organization.

[a] A functional clinical refractionist is a person who spends 100% of his or her clinical time providing refraction services.

[b] World Health Organization subregion categories: A: very low child mortality and very low adult mortality; B: low child mortality and low adult mortality; C: low child mortality and high adult mortality; D: high child mortality and high adult mortality; and E: high child mortality and very high adult mortality.

[c] The number of cases is reported, as some individuals had both distance and near vision impairment due to URE.

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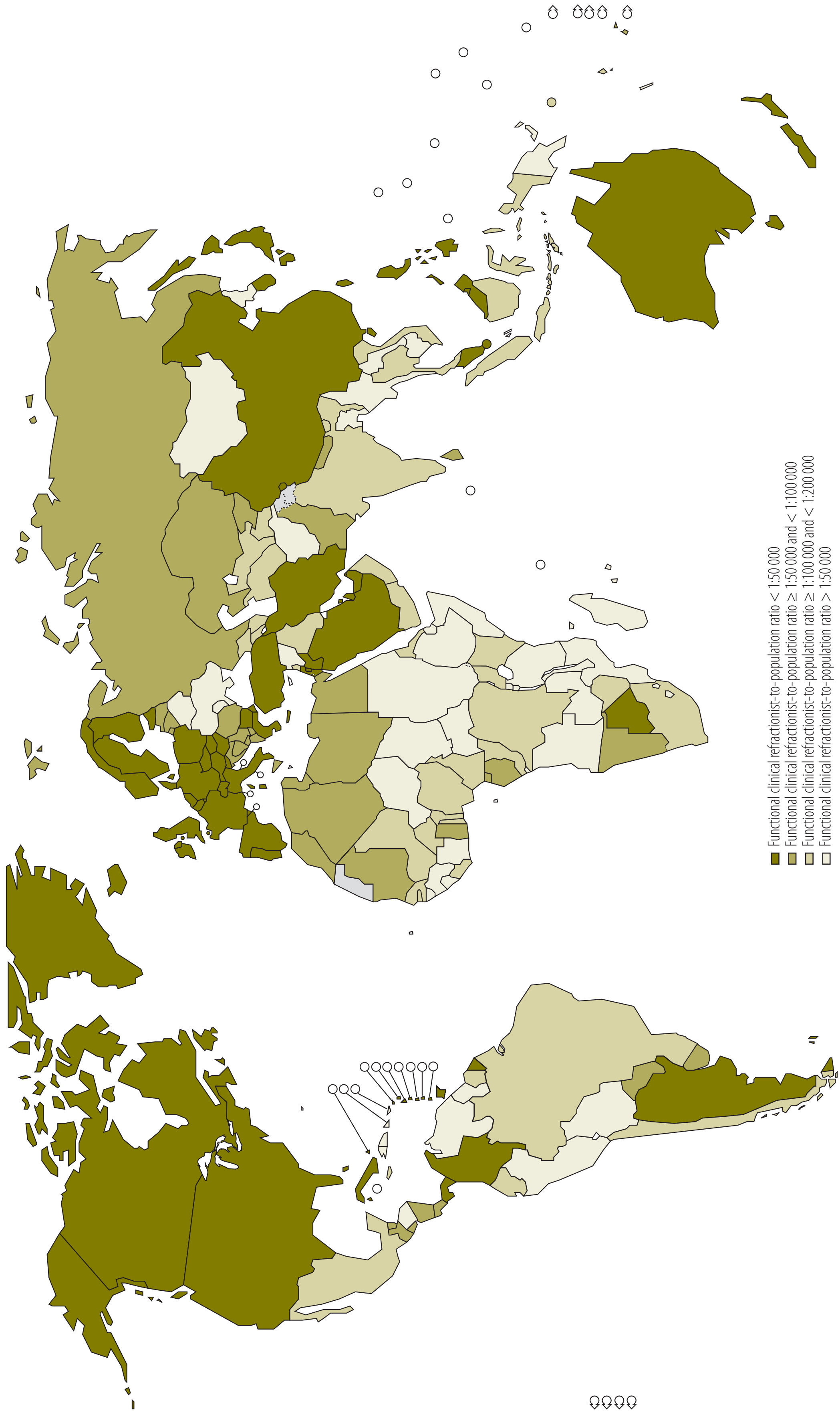


Fig. 1. **Functional clinical refractionists to population ratio, worldwide, 2006–2010**

Globally, the equivalent of around 167 000 full-time functional clinical refractionists were dealing with vision impairment due to URE in 2007. Fig. 1 shows the functional clinical refractionists to population ratio worldwide. We estimated that approximately 47 000 additional full-time functional clinical refractionists and 18 000 additional ophthalmic dispensers would be needed to deal with all cases of vision impairment due to URE. Other measures would have to be taken in some countries with an adequate number of personnel to overcome problems with access to care.

Table 4 summarizes the estimated investment required to educate new refractive care practitioners, including ophthalmic dispensing personnel, in WHO regions and subregions, to provide continuing professional development for 5 years, to establish the service delivery centres needed and to fund these centres for 5 years. The running costs of the centres included the cost of providing refractive care to the estimated backlog of 703 million cases of vision impairment due to URE. Globally, the total capital investment for establishing educational institutions with sufficient training capacity was estimated to be US$ 104 million. An

Table 4. **Cost of education and new facilities for additional refractive care practitioners[a] required to correct vision impairment due to uncorrected refractive error, worldwide, 2006–2010**

WHO region and subregion[b]	Capital costs of education (thousand US$)	Annual running costs of education (US$ per student)	Annual cost of continuing professional development for 5 years (thousand US$)	Capital costs of new refractive care facilities (thousand US$)	Annual running costs of new refractive care facilities for 5 years (thousand US$)	Total cost of education and new refractive care facilities over 5 years[c] (thousand US$)
African Region						
D	10 121	2 922	14 649	183 031	139 511	1 029 207
E	11 900	2 774	3 581	230 188	150 258	1 034 003
Total	22 020	2 803	18 230	413 220	289 769	2 063 210
Region of the Americas						
A	0	10 228	6 772	92 864	425 367	2 226 470
B	9 285	1 783	4 886	231 910	268 548	1 685 555
D	3 317	1 286	284	49 820	34 364	231 687
Total	12 601	2 458	11 942	374 595	728 279	4 143 712
Eastern Mediterranean Region						
B	1 120	2 000	470	55 472	108 996	606 112
D	6 929	1 926	916	182 881	73 537	581 844
Total	8 048	1 970	1 386	238 353	182 533	1 187 956
European Region						
A	3	19 832	4 772	53 731	349 476	1 807 157
B	1 054	3 970	3 261	76 943	91 262	545 314
C	1 443	3 682	778	51 843	41 215	278 871
Total	2 500	12 340	8 811	182 517	481 952	2 631 342
South-East Asia Region						
B	12 086	10 495	668	160 299	109 669	750 062
D	41 619	1 464	514	295 077	471 273	2 706 111
Total	53 706	4 173	1 182	455 376	580 942	3 456 173
Western Pacific Region						
A	0	17 408	1 140	30 403	132 085	691 968
B	4 753	3 495	3 252	900 587	948 088	5 657 323
Total	4 753	6 072	4 392	930 990	1 080 173	6 349 291
Unassigned	27	6 901	461	25 289	36 168	213 194
Global total	103 656	5 947	46 404	2 620 339	3 379 816	20 044 878

US$, United States dollar; WHO, World Health Organization.

[a] Refractive care practitioners include functional clinical refractionists, who spend 100% of their clinical time providing refraction services, and ophthalmic dispensers.

[b] World Health Organization subregion categories: A: very low child mortality and very low adult mortality; B: low child mortality and low adult mortality; C: low child mortality and high adult mortality; D: high child mortality and high adult mortality; and E: high child mortality and very high adult mortality.

[c] The total cost was the sum of the cost of educating the new refractive care and ophthalmic dispensing personnel (i.e. the capital costs of education, the cost of educating students and the cost of continuing professional development for 5 years) and of providing new refractive care facilities (i.e. capital costs and 5 years of running costs) needed to deal with the backlog and all incident cases of distance and near vision impairment resulting from uncorrected refractive error.

additional US$ 46 million would cover continuing professional development for new personnel for the first 5 years of their careers. The total educational costs were US$ 543 million, which includes the capital costs of education, the cost of educating student refractive care personnel and student ophthalmic dispensers and the cost of continuing professional development for all new personnel for 5 years.

Table 4 also shows that the estimated capital investment needed to establish service delivery facilities for the new and redeployed refractive care personnel required to deal with vision impairment resulting from URE worldwide was US$ 2620 million. In addition, it was estimated that these facilities would cost US$ 3380 million per year to operate for the first 5 years. Assuming that the revenue generated by the service would covers costs after the first 5 years, the total investment in service delivery required (i.e. capital costs and 5 years of running costs for new refractive care facilities) to deal with vision impairment resulting from URE was estimated to be US$ 19 501 million.

Consequently, the total estimated cost for educating the new refractive care and ophthalmic dispensing personnel, plus providing the service delivery facilities needed to deal with the backlog and all incident cases of distance and near vision impairment resulting from URE was US$ 20 045 million.

Our estimated upper limit for the cost of education and new facilities for the additional refractive care practitioners required to correct all vision impairment due to URE globally was US$ 28 452 million.

Discussion

Several considerations should be taken into account when interpreting the data reported in this paper. First, only the cost of correcting vision impairment as defined by WHO was estimated and not the cost of providing vision care to the world population at the level expected in developed countries, where the target acuity is 6/6 for distance vision and N5 for near vision and where many people want spectacles to correct refractive error that does not result in vision impairment. Although we estimate that globally over 3 000 million people have some level of refractive error, our calculations considered only the 703 million cases of distance or near vision impairment due to URE.

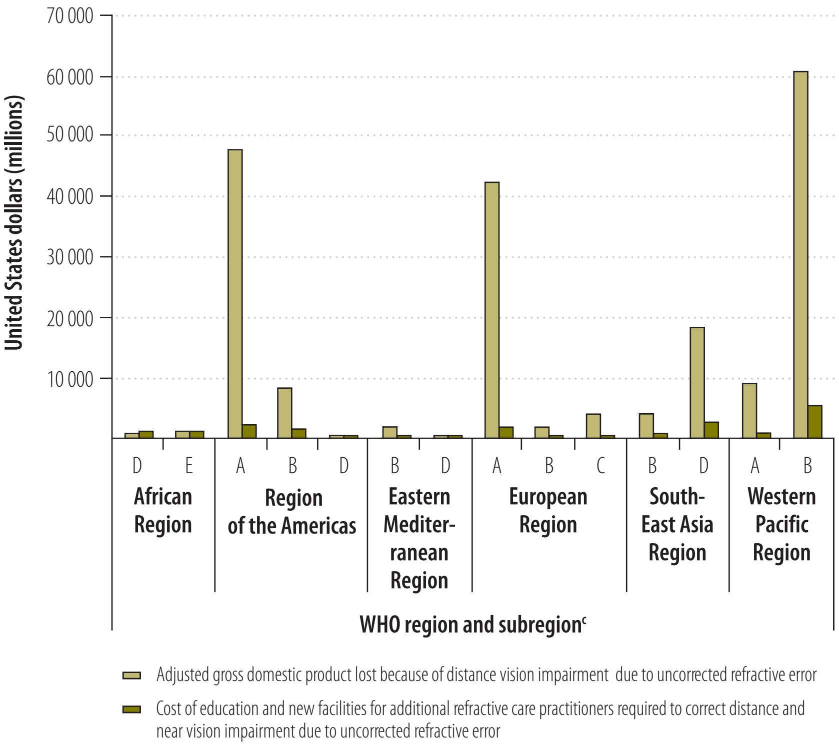
Second, the WHO protocol for eye examinations[22] states that, when visual loss is due to several coexisting primary disorders, the "most readily curable" disorder should be regarded as the cause of visual loss. It is possible, therefore, that the prevalence of vision impairment due to URE may have been overestimated.

It is rare for refractive care practitioners to be distributed throughout a country in a way that ensures equitable access for all communities and, generally, the poorer and more rural a community is, the more limited access to refractive care will be. Even in Europe, where there is an adequate number of practitioners, we estimated that an additional 2000 functional clinical refractionists as well as the redeployment of some existing refractive care personnel was required to overcome the geographical, financial and other barriers that restrict access to refractive care for some individuals with distance or near vision impairment due to URE. Consequently, our estimates included the cost of redeploying practitioners in countries where the poor distribution of service providers contributed to prevalence of vision impairment due to URE.

In our analysis, we chose not to anticipate innovative technologies that may be able to assess and correct refractive error at a lower cost because of the uncertainties involved. Our estimates of the costs of education and service delivery are, therefore, based on the use of current techniques and equipment.

Although we made several assumptions in estimating costs, we erred on the side of obtaining the highest estimates. In addition, our estimate of the upper limit of the costs, of US$ 28 000 million,

Fig. 2. **Loss of gross domestic product due to uncorrected refractive error (URE)[a] and costs for additional refractive care practitioners required to correct vision impairment,[b] by WHO region, 2006–2010**



WHO, World Health Organization.

[a] The loss in gross domestic product is that resulting only from distance vision impairment caused by URE.[3]

[b] Refractive care practitioners include functional clinical refractionists, who spend 100% of their clinical time providing refraction services, and ophthalmic dispensers. The costs given are for the additional practitioners required to treat both distance and near vision impairment caused by URE.

[c] World Health Organization subregion categories: A: very low child mortality and very low adult mortality; B: low child mortality and low adult mortality; C: low child mortality and high adult mortality; D: high child mortality and high adult mortality; and E: high child mortality and very high adult mortality.

was made by using the most extreme values for critical variables.

Smith et al.[3] estimated the value of the productivity lost because of distance vision impairment due to URE to lie between 121 400 million and 427 700 million International dollars (equivalent to US$ 91 300 million to US$ 327 700 million), depending on whether or not the figure was adjusted to take account of the labour force participation rate and the employment rate and was based on the assumption that people over 50 years of age do not contribute to the economy. These two figures give a range for the possible increase in global gross domestic product that would result from providing refractive care for all. In effect, it is the return on investment.

Fig. 2 shows a comparison between the estimated loss in gross domestic product due to distance vision impairment caused by URE in different regions and the cost of education and new facilities for the additional refractive care practitioners required to correct all vision impairment due to URE. There would be a substantial return on the investment required to deal with vision impairment resulting from URE in all regions except the African Region. Globally, the estimated rate of return on a total investment of US$ 20 045 million over 5 years, which is the total estimated cost of dealing with the backlog and all incident cases of vision impairment due to URE, would be 59%, even if it was assumed that all expenses were incurred in the first year and none of the benefits occurred until the last year and lasted only 1 year.

Existing refractive care has not been able to deal with an estimated 703 million cases of vision impairment resulting from URE, which means that the needs of around 10% of the world's population have not been met. Although our estimate of the cost of establishing and operating the educational and refractive care facilities required to deal with vision impairment resulting from URE, of around US$ 20 000 million globally, can only be approximate, the return on investment would be substantial. Even our upper limit for the cost, which is US$ 28 000 million over 5 years, is considerably below the estimated economic cost of vision impairment due to URE, which has been estimated to be US$ 202 000 million each year.[3] The scale of this return on investment means that correcting vision impairment due to URE provides a good opportunity for global development. ■

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ملخص

التكلفة العالمية لتصحيح ضعف البصر الناجم عن الأخطاء الانكسارية غير المصححة

الغرض تقدير التكلفة العالمية لإنشاء وتشغيل مرافق الرعاية التعليمية والانكسارية المطلوبة لتوفير الرعاية لجميع الأفراد الذين يعانون في الوقت الحالي من ضعف البصر الناجم عن الأخطاء الانكسارية غير المصححة (URE).

الطريقة تم إجراء تقدير للتكلفة الإجمالية لتصحيح الأخطاء الانكسارية غير المصححة (URE) باستخدام البيانات الخاصة بالسكان، وانتشار الأخطاء الانكسارية غير المصححة (URE)، والعدد الحالي لممارسي الرعاية الانكسارية في كل بلد على حدة، وتكلفة إنشاء وتشغيل البرامج التعليمية للممارسين، وتكلفة إنشاء وتشغيل مرافق الرعاية الانكسارية. وأكدت الافتراضات التي تم وضعها أن التكاليف لم تقدر بأقل مما ينبغي وأنه تم استخلاص حد أعلى للتكاليف باستخدام النهاية الأعلى لكل افتراض.

النتائج تشير التقديرات إلى وجود 158 مليون حالة تعاني من ضعف الإبصار البعيد و544 مليون حالة تعاني من ضعف الإبصار القريب في جميع أنحاء العالم ناجمة عن الأخطاء الانكسارية غير المصححة (URE) في عام 2007. وسوف توجد حاجة لحوالي 47000 أخصائي انكساري سريري إضافي بدوام كامل و18000 موزع أدوية عيون لتوفير خدمات الرعاية الانكسارية لهؤلاء الأفراد. وتم تقدير التكلفة العالمية لتثقيف أفراد إضافيين وإنشاء وصيانة وتشغيل مرافق الرعاية الانكسارية اللازمة بنحو 20 مليار دولار أمريكي، وبلغ أعلى حد للتكلفة 28 مليار دولار أمريكي. وكانت الخسارة في الناتج المحلي الإجمالي العالمي وفق التقديرات بسبب ضعف الإبصار الناجم عن الأخطاء الانكسارية غير المصححة (URE) بقيمة 202 مليار دولار أمريكي سنوياً.

الاستنتاج كانت تكلفة إنشاء وتشغيل مرافق الرعاية التعليمية والانكسارية المطلوبة للتعامل مع ضعف الإبصار الناجم عن الأخطاء الانكسارية غير المصححة (URE) نسبة صغيرة من فقدان الإنتاجية العالمي المرتبط بضعف الإبصار.

摘要

矫正因未矫正屈光不正所致视力损害的全球成本

目的 估计建立和运行为当前所有因未加矫正的屈光不正（URE）而导致视力损害的个体提供护理所需的全球教育和屈光保健设施成本。

方法 使用人口、URE的患病率以及各国现有的屈光保健医生人数、为医生建立和运行教育方案的成本、建立和运行屈光保健设施的成本等相关数据，估计矫正URE的全球成本。所做假设确保成本没有被低估，使用每个假设成本最高的极端情况推导出成本上限。

结果 在2007 年，估计URE造成全球1.58 亿例远视力损害和5.44 亿例近视力损害。而为这些人提供屈光护理，需要约4.7 万名额外的全职临床屈光眼科医生和1.8 万名眼科药剂师。教育增加人员以及建立、维护和运行所需的屈光保健设施的全球成本估计为200 亿美元（US$）左右，成本上限是280 亿美元。每年由于URE造成的远视力损害而遭受的全球国内生产总值的损失估计为2020 亿美元。

结论 相对于视力损害的相关全球生产力损失，为应对URE造成视力损害而需建立和运行的教育和屈光保健设施的成本所占比例很小。

Résumé

Coût global de correction d’une déficience visuelle induite par une erreur de réfraction non corrigée

Objectif Estimation du coût global de mise en place et de fonctionnement des établissements de traitement de la réfraction et de formation nécessaires pour fournir des soins à toutes les personnes souffrant actuellement de troubles de la vision résultant d’une erreur de réfraction non corrigée.

Méthodes Le coût global de la correction des erreurs de réfraction a été estimé à l’aide des données sur la population, de la prévalence de la pathologie et du nombre de professionnels de la réfraction existant dans les différents pays, des coûts de mise en place et de fonctionnement des programmes éducatifs pour les praticiens et du coût de création et de gestion des établissements de soins pour la réfraction. Les hypothèses retenues veillaient à ce que les coûts ne soient pas sous-estimés et un seuil de coûts maximum a été calculé en utilisant les cas de figure les plus chers pour chaque hypothèse.

Résultats On a estimé à environ 158 millions le nombre de cas de déficience de la vision de loin et à 544 millions le nombre de cas de déficience de la vision de près due à un trouble de la réfraction dans le monde entier en 2007. Environ 47 000 nouveaux réfractionnistes cliniques en exercice à temps plein et 18 000 centres ophtalmiques seraient nécessaires pour fournir des services de soins de la réfraction à ces patients. Le coût global de formation du personnel supplémentaire et de mise en place, d’entretien et d’exploitation des installations de soins de réfraction nécessaires a été estimé à environ 20 milliards de dollars américains (US $) et le coût maximum était de 28 milliards US $. La perte estimée de produit intérieur brut mondial en raison de troubles de la vision de loin causés par la réfraction était de 202 milliards US $ par an.

Conclusion Le coût de mise en place et de fonctionnement des établissements de soins de la réfraction et de formation nécessaires pour faire face aux troubles de la vision résultant de pathologies de la réfraction représente une faible proportion de la perte globale de la productivité associée à cette déficience visuelle.

Резюме

Глобальная стоимость исправления нарушений зрения, вызванных нескорректированной аномалией рефракции

Цель Оценить общую стоимость создания и функционирования образовательных учреждений и учреждений, занимающихся коррекцией аномалии рефракции, необходимых для оказания помощи всем лицам, которые в настоящее время страдают от нарушений зрения, вызванных нескорректированной аномалией рефракции (НАР).

Методы Глобальная стоимость исправления НАР оценена на основе данных о населении, распространенности НАР и количестве существующих медицинских учреждений, занимающихся коррекцией рефракции, в отдельных странах, стоимости создания и функционирования образовательных программ для специалистов-практиков и стоимости создания и функционирования медицинских учреждений для коррекции аномалии рефракции. Сделанные в работе допущения гарантируют отсутствие недооценки расходов. Был рассчитан верхний предел расходов на основе самых затратных вариантов для каждого предположения.

Результаты По оценкам, в 2007 г. по всему миру насчитывалось 158 млн. случаев дальнозоркости и 544 млн. случаев близорукости, вызванных НАР. Чтобы обеспечить медицинскими услугами этих лиц необходимо приблизительно 47 000 дополнительных штатных клинических рефракционистов и 18 000 офтальмологов. Необходимые глобальные расходы на обучение дополнительного персонала и создание, поддержание и функционирование медицинских учреждений, занимающихся коррекцией рефракции, были оценены на уровне 20 млрд. долл. США, а верхний предел расходов составил 28 млрд. долл. США. Предполагаемые потери мирового валового внутреннего продукта из-за ухудшения дистанционного зрения, вызванного НАР, находятся на уровне млрд. долл. США в год.

Вывод Стоимость создания и функционирования образовательных учреждений и учреждений, занимающихся коррекцией аномалии рефракции, необходимых для борьбы с нарушениями зрения, вызванных НАР, составляет лишь небольшую часть глобальных потерь производительности, связанных с данным нарушением зрения.

Resumen

El coste global de corregir las discapacidades visuales causadas por errores de refracción no corregidos

Objetivo Estimar el coste global del establecimiento y funcionamiento de las instalaciones educativas y de atención médica refractiva necesarias para proporcionar atención médica a todas las personas que padecen en la actualidad una discapacidad visual causada por un error de refracción no corregido (ERNC).

Métodos El coste global de corregir los ERNC se calculó utilizando datos sobre la población, la prevalencia de ERNC y el número de especialistas en atención médica refractiva existentes en cada uno de los países, el coste del establecimiento y funcionamiento de programas educativos para especialistas y el coste del establecimiento y funcionamiento de las instalaciones de atención médica refractiva. Los supuestos aceptados garantizaron que no se subestimaran los costes y el límite máximo para los costes se obtuvo utilizando el extremo más caro para cada supuesto.

Resultados Se calcularon 158 millones de casos de discapacidad en la visión de lejos y 544 millones de casos de discapacidad en la visión cercana causados por ERNC en 2007. Se necesitarían aproximadamente 47 000 refraccionistas clínicos funcionales adicionales a tiempo completo y 18 000 ópticos para proporcionar servicios de atención médica refractiva a esas personas. El coste global de formar al personal adicional y de establecer, mantener y administrar las instalaciones de atención médica refractiva necesarias se estimó en unos 20 000 millones de dólares estadounidenses (US$) y el coste límite superior se estimó en 28 000 millones de dólares estadounidenses. La pérdida estimada en el producto nacional bruto global debido a la discapacidad en la visión de lejos causada por ERNC fue de 202 000 millones de dólares estadounidenses anuales.

Conclusión El coste del establecimiento y funcionamiento de las instalaciones de atención médica refractiva necesarias para tratar la discapacidad visual resultante de ERNC fue una pequeña proporción de la pérdida global en productividad asociada con esa discapacidad visual.

References

1. Resnikoff S, Pascolini D, Mariotti S, Pokharel P. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. *Bull World Health Organ* 2008;86:63–70. doi:10.2471/BLT.07.041210 PMID:18235892
2. Holden BA, Fricke T, Ho S, Wong R, Schlenther G, Cronje S et al. Global vision impairment due to uncorrected presbyopia. *Arch Ophthalmol* 2008;126:1731–9. doi:10.1001/archopht.126.12.1731 PMID:19064856
3. Smith TST, Frick KD, Holden BA, Fricke TR, Naidoo KS. Potential lost productivity resulting from the global burden of uncorrected refractive error. *Bull World Health Organ* 2009;87:431–7. doi:10.2471/BLT.08.055673 PMID:19565121
4. *Consultation on development of standards for characterization of vision loss and visual functioning.* Geneva: World Health Organization; 2003 Available from: http://www.who.int/ncd/vision2020_actionplan/documents/VisualStandardsSept03report.pdf [accessed 4 July 2012].
5. *Strategy for the elimination of vision impairment from uncorrected refractive error.* Hyderabad: Refractive Error Program Committee International Agency for the Prevention of Blindness; 2008. Available from: http://www.vision2020.org/main.cfm?type=RECOMMITTEE&objectid=3572 [accessed 4 July 2012].
6. Laviers HR, Omar F, Jecha H, Kassim G, Gilbert C. Presbyopic spectacle coverage, willingness to pay for near correction, and the impact of correcting uncorrected presbyopia in adults in Zanzibar, East Africa. *Invest Ophthalmol Vis Sci* 2010;51:1234–41. doi:10.1167/iovs.08-3154 PMID:20042650
7. *Global initiative for the elimination of avoidable blindness – action plan 2006–2011.* Geneva: World Health Organization; 2007. Available from: http://www.who.int/blindness/Vision2020_report.pdf [accessed 4 July 2012].
8. Shah M, Shah S, Gadhvi B, Chavda A, Upadhyay H, Parikh A. A comparison of static and mobile facilities for primary eye care and refractive error services. *Community Eye Health Ind Suppl* 2006;19:s77–9.
9. Rao GN. An infrastructure model for the implementation of VISION 2020: The right to sight. *Community Eye Health* 2005;18:S61–2.
10. United States Census Bureau [Internet]. International programs: International data base. Suitland: US Census Bureau; 2006. Available from: http://www.census.gov/population/international/data/idb/informationGateway.php [accessed 12 July 2012].
11. Central Intelligence Agency [Internet]. The world factbook. Washington: CIA; 2007. Available from: https://www.cia.gov/library/publications/the-world-factbook/ [accessed 11 July 2012].
12. *Global purchasing power parities and real expenditures: 2005 international comparison program.* Washington: World Bank; 2008. Available from: http://siteresources.worldbank.org/ICPINT/Resources/icp-final.pdf [accessed 11 July 2012].
13. *Key indicators for Asia and the Pacific,* 40th edition. Manila: Asian Development Bank; 2009. Available from: http://www.adb.org/sites/default/files/pub/2009/Key-Indicators-2009.pdf [accessed 11 July 2012].
14. World Health Organization [Internet]. Choosing interventions that are cost effective (WHO-CHOICE). Geneva: World Health Organization; 2010. Available from: http://www.who.int/choice/en/ [accessed 11 July 2012].
15. Mathers C, Bernard C, Iburg K, Inoue M, Ma Fat D, Shibuya K, et al. *Global burden of disease in 2002: data sources, methods and results.* Geneva: World Health Organization; 2003. Available from: http://www.who.int/healthinfo/paper54.pdf [accessed 4 July 2012].
16. Horton P, Kiely PM, Chakman J. The Australian optometric workforce 2005. *Clin Exp Optom* 2006;89:229–40. doi:10.1111/j.1444-0938.2006.00048.x PMID:16776730
17. Kiely PM, Horton P, Chakman J. The Australian optometric workforce 2009. *Clin Exp Optom* 2010;93:330–40. doi:10.1111/j.1444-0938.2010.00506.x PMID:20718789
18. Kiely PM, Chakman J. Optometric practice in Australian Standard Geographical Classification—Remoteness Areas in Australia, 2010. *Clin Exp Optom* 2011;94:468–77. doi:10.1111/j.1444-0938.2011.00590.x PMID:21426397
19. Bourne RR, Dineen B, Noorul Huq D, Ali S, Johnson G. Correction of refractive error in the adult population of Bangladesh: meeting the unmet need. *Invest Ophthalmol Vis Sci* 2004;45:410–7. doi:10.1167/iovs.03-0129 PMID:14744879
20. Wilson DA. *Efficacious correction of refractive error in developing countries* [thesis]. Sydney: University of New South Wales; 2011.
21. Maini R, Keeffe J, Weih L, McCarty C, Taylor H. Correction of refractive error in the Victorian population: the feasibility of "off the shelf" spectacles. *Br J Ophthalmol* 2001;85:1283–6. doi:10.1136/bjo.85.11.1283 PMID:11673288
22. *Coding instructions for the WHO/PBL eye examination record (version III).* Geneva: World Health Organization; 1988 (WHO/PBL/88.1) Available from: http://whqlibdoc.who.int/hq/1988/PBL_88.1.pdf [accessed 11 July 2012].