The Economic and Societal Impact of Myopia and High Myopia

3

Sharon Yu Lin Chua and Paul J. Foster

Key Points
- The prevalence of myopia has increased rapidly throughout Asia. In urban areas, 80–90% of young adults are myopic and 10–20% have high myopia. By 2050, it is estimated that five billion people will be myopic. Of these, one billion people will be highly myopic. World Health Organization lists uncorrected or under-corrected myopia as a major cause of visual impairment.
- Myopia may impair many aspects of life including educational and occupational activities. The annual direct cost of myopia correction for Asian adults has been estimated at US $328 billion/annum. The cost of care is also likely to increase significantly and will be exacerbated by an even greater increase in the prevalence of high myopia.
- High myopes have greater risk of developing several vision-threatening conditions including myopic macular degeneration, retinal detachment, glaucoma, and cataract. Those affected individuals incur costs for specialist eye care, or specialist optical aids for patients with visual impairment. These costs are in the region of US $250 billion/annum.

S. Y. L. Chua · P. J. Foster (✉)
Integrative Epidemiology Cluster, NIHR Biomedical Research Centre, UCL Institute of Ophthalmology and Moorfields Eye Hospital NHS Foundation Trust, London, UK
e-mail: p.foster@ucl.ac.uk

- Myopes, especially high myopes, tend to have reduced quality of life due to adverse influences from psychological, cosmetic, practical and financial factors. Hence, affecting productivity, mobility, and activities of daily living.
- Treatments such as under-correction of myopia, gas permeable contact lenses, and bifocal or multifocal spectacles have all been proven to be ineffective for myopia control. The most effective methods are the use of orthokeratology contact lenses, soft bifocal contact lenses, and topical pharmaceutical agents, such as low-dose atropine or pirenzepine. These will have differing implications for personal finances and quality of life. Hence, the best modality should be selected by the eye care practitioner, parent or individual, based on the lifestyle of the individual.

3.1   Introduction

The prevalence of myopia is most pronounced in the industrialized nations of East Asia, where rates of 95% among young adults have been recorded [1]. In this context, the impact of myopia is profound and far reaching, and recent study by Naidoo et al. [2] suggests that myopia has a global economic impact, with the greatest burden throughout Asia. Its economic impact is very significant. This chapter seeks to examine the impact of myopia on individuals and the wider society, both from the monetary perspective and also in terms of emotional well-being and quality of life. Peer-reviewed data on this subject are comparatively sparse, and in some areas, it is necessary to make inferences on the basis of indirect evidence.

The impact of myopia illustrates an interesting dichotomy. The condition appears to be an exaggerated adaptive response which has a predilection for the most affluent and educated in society. Low myopia [up to around −3 D (diopters)] is arguably an ideal state for the older urban professional, in that the frustration of presbyopia is avoided, and hence maximum efficiency in an office-based career is maintained, and the ability to pursue leisure activities, such as reading, creative arts, and many household tasks, is enhanced. Myopes are among the best educated and thus highest earning members of any society. Furthermore, they confer on their children a range of advantages—they are typically well educated, and in turn benefit from higher career prospects and incomes. The offspring are also more likely to be myopes [3].

3.2   Economic Impact of Myopia

Myopia is the most common distance refractive error. The global prevalence of myopia is expected to increase from 27% of the world's population in 2010 to 52% by 2050 [4]—a 2.6-fold increase. A recent meta-analysis estimated a significant

increase in the global prevalence of myopia and high myopia, affecting nearly five billion people and one billion people, respectively, by 2050 [4]. The projected increases in myopia and high myopia may be due to environmental factors, such as a combination of decreased time outdoors and increased near work activities, among other factors [5]. Uncorrected distance refractive error was estimated in 2013 to affect 108 million people globally, and myopia is the most common refractive error [6]. It is the leading cause of moderate and severe vision impairment (VI; 42%) and a major cause of blindness (3%) [2]. Uncorrected myopia as low as −1.50 D will result in moderate VI, and uncorrected myopia of −4.00 D is sufficient refractive error to be classified as blindness [7]. Depending on national legislation, people with moderate VI may not be allowed to drive. Moderate VI may also require the use of aids and/or accommodations/adaptions for some tasks in the learning environment.

If the increasing prevalence of myopia is not addressed, a similar increase in uncorrected refractive error can be expected. These projections are based on con-servative assumptions and, given the published relationship between level of edu-cation and myopia, increased provision of education could markedly increase these trends. Furthermore, uncorrected distance refractive error has been estimated to result in a global loss of productivity of international dollar (I$) 269 billion [8] (US $202 billion) annually [9], which will also increase if there is a significant increase in uncorrected myopia. International dollar allows comparison of prices and currency values between countries after adjustment of currency exchange rate. An international dollar has the same purchasing power as the U.S. dollar has in the United States [10]. A recent meta-analysis estimated the global potential loss associated with VI in 2015 was US $244 billion/annum [95% confidence interval (CI) US $49 billion—US $697 billion] from uncorrected myopia and US $6 bil-lion/annum (95% CI US $2 billion–US $17 billion) from myopic macular degen-eration [2]. The cost of care is also likely to increase significantly, and will be exacerbated by an even greater increase in the prevalence of high myopia, from 2.8% (190 million people) to 9.7% (924 million people) by 2050 [4], representing a 4.9-fold increase in high myopia. In some populations of young adults in Asia, the prevalence of high myopia has already reached 38% [11]. The annual direct cost of optical correction of myopia for Singaporean adults has been estimated at US $755 million. Refractive correction comprising of optometry visits, spectacles, and/or contact lenses is the most significant cost domain and it accounts for 65.2% of the total costs [12]. In Singapore, the estimates in an adult (SG $587 or US $455 per patient per year) is significantly higher than a child aged 7–9 years (SG $222 or US $175 per patient per year) [13]. The higher cost could be because of the greater likelihood that adults may undergo laser-assisted in situ keratomileusis (LASIK), wear contact lens, or develop ocular complications due to high myopia. Furthermore, adults tend to have higher spending power compared to a child. It has been estimated that if such prevalence rates were extrapolated to all cities in Asia in which the prevalence of myopia is approximately equal to the rates in Singapore, the estimated direct cost would be US $328 billion/annum. It is estimated that US $8.1 billion/annum was spent on vision products including eyeglass frames, lenses, and contact lenses in the USA in 1990 [14]. In United States, a cross-sectional study demonstrated that 110 million Americans could achieve normal vision with

refractive correction and the estimated cost was US $3.8 billion/annum [15]. Of this amount, the annual cost of providing distance vision correction for adults older than 65 years old was US $780 million. The types of refractive error included correction for myopia, hyperopia, and presbyopia. This represents approximately US $35 per person or US $13 per capita annually, based on the cost of a pair of spectacles and refractive examination. Possible reasons for the difference in direct costs of refractive correction are the treatment costs may be borne by the individual, who may be willing to pay for other factors such as aesthetics. Whereas in some countries (e.g., the United Kingdom), some segments of the population are entitled to free eye glasses subsidized by the government. As the prevalence of myopia increase in East Asia, the total cost of treating myopia will be high. There is likely to be an increase in the demand for optical services as the number of older people increases and if, as suggested, the number of younger people with myopia increases. It is estimated that partial sight and blindness in adults costs the UK economy around £22 billion per year [16].

The cost of spectacles varies, but there may some individuals who may not be able to afford a basic pair of spectacles, and hence refractive error may not be fully corrected. Health economic analyses in the United States and Australia have reported the economic burden of refractive correction associated with medical care expenditure, informal care days, and healthy utility is greater than age-related macular degeneration, primary open-angle glaucoma, and diabetic retinopathy, while it was secondary to the medical cost of age-related cataract [17, 18]. As the economic costs of myopia are high, more efforts and resources could be directed toward having new strategies to prevent and slow down myopia progression to high myopia and its associated visually disabling ocular complications.

3.3 Secondary Impact of Myopia from Other Eye Diseases and Sight Loss

High myopia increases the risk of other eye diseases such as cataract, glaucoma, retinal detachment, and myopic macular degeneration (MMD), which may lead to irreversible vision loss. MMD has been reported to cause 12.1% of VI (approximately 200,000 people) in Japan [19]. Visual impairment and blindness impact the individuals, their families, caregivers, and the community, which lead to a significant cost burden. In Australia, visual disorders were ranked seventh among diseases in terms of economic burden on the health system, which is ahead of coronary heart disease, diabetes, depression, and stroke [20]. Naidoo et al. estimated the potential global economic productivity loss resulting from VI and blindness as a result of uncorrected myopia and MMD in 2015 [2]. Their study suggests that the greatest burden of VI resulting from uncorrected refractive error is older people in rural areas of the least developed countries. The regional productivity loss owing to VI resulting from myopia may be reflected in Southeast Asia, South Asia, and East Asia as having a percentage gross domestic product (GDP) of 1.35%, 1.3%,

and 1.27%, respectively. Differences in productivity loss arises from the interplay between country-specific variables, such as myopia and high myopia prevalence, demographics, Health Development Index (HDI), health expenditure, urbanization, labor force participation, employment, GDP, and population. There are other components that contribute to the overall burden of myopia, such as cost of eye examinations, refractive corrections, managing pathologic consequences of myopia such as MMD, and related opportunity costs. The value of any investment to prevent myopia, slow progression of myopia, improve spectacle correction rates, and improve outcomes in MMD depends on a comparison of lost productivity owing to VI resulting from myopia with the cost of prevention and management interventions. Fricke et al. estimated the global cost of facilities and personnel for establishing refractive care services US $20 billion over 5 years [9]. Direct medical costs occur mostly due to hospitalization, the use of direct medical services, and medical products. Hospitalization and use of medical services around diagnosis and treatment at the onset of VI and blindness were the two largest components related to direct medical costs. The mean annual expenses per patient to be US$ purchasing power parities (PPPs) 12,175–14,029 for moderate VI, US$ PPPs 13,154–16,321 for severe VI, and US$ PPPs 14,882–24,180 for blindness [21]. PPPs account for differences in price levels between countries, and convert local currencies into international dollars by taking into account the purchasing power of different national currencies and eliminates the difference in price levels between countries [22]. Direct nonmedical costs include assistive devices and aids, home modifications, and costs for healthcare services such as home-based nursing or nursing home placements. The cost for support services and assistive devices increased from US$ PPP 54 for a person with visual acuity (VA) 20/20 or better up to US$ PPP 609 for a person with VA 20/80 or worse. Indirect costs include productivity losses, changes in employment (employer and/or area of work), loss of income, premature mortality, and dead-weight losses [21]. Dead-weight losses, also known as excess burden, describe the costs to society created by market inefficiency. In the study by Köberlein et al., it is referred to as an excess financial burden on society caused by VI and blindness [21]. The annual estimates of productivity losses and absenteeism range from US$ PPP 4974 to 5724 million and a decrease in workforce participation range was estimated to be US$ PPP 7.4 billion [21].

Value of the Commercial Optical Good Sector
In the UK in 2017, the optical goods and services industry had total consumer spending estimated at £3.1 billion (2.0 billion US$ = @ 0.66 £:$). Growth was estimated at 2% for 2017, and forecasts projected further 3.2% growth in 2018. Market research suggests this was primarily driven by an aging population. In the UK, 70% of consumers are reported to wear some form of prescription eyewear. Just 11% of those with vision correction need wear contact lenses, with this sector characterized by a high rate of premium and daily wear lenses. Contact lenses account for 20% of the total spending on optical products, with the sale of contact lens solutions made up an additional 3% of the market, compared to 60% market share for spectacle frames and lenses. Only one in six (18%) people have

purchased optical products online. Reports suggest that consumers perceive buying prescriptions eyewear online as harder—49% of people buying prescription eyewear saying it is more difficult than buying in-store, although 45% of consumers who said they have not bought optical products online before, would consider doing so in the future [23].

3.4   Quality of Life

Quality of life is a multidimensional construct with different domains. The identified domains related to ophthalmic quality of life include activity limitation, mobility, convenience, health concerns, visual symptoms, ocular-comfort symptoms, general symptoms, emotional well-being, and social and economic issues [24]. Impaired vision will lead to significant reduction in activities associated with participation in society and religion, mobility, daily living, and visually intensive tasks. This may impact education, employment, child development, mental health, and functional capacity in older people, increasing the risk of hip fractures and the need for community or family support or nursing home placement [25–27]. A cross-sectional study in Germany reported that mild VI affected emotional well-being [28]. Depression was considered to cause further functional decline in visually impaired patients by reducing motivation, initiative, and resiliency [29–31]. Visual impairment and blindness associated with myopic macular degeneration will increase significantly, hence affecting the quality of life and causing socioeconomic impact [32]. A cross-sectional study reported the functional status in daily life and quality of life of pathologic myopia patients were reduced compared with control subjects [33]. The influence of pathologic myopia on a patient's daily life was primarily the result of three major factors: handicap, disability, and support. Wong et al. reported that those with VI, measured in terms of presenting vision (i.e., wearing their habitual correction), had statistically significantly lower scores for total quality of life (-3.8; 95% CI -7.1 to -0.5; $P = 0.03$), psychosocial functioning (-4.2; 95% CI -8.1 to -0.3; $P = 0.03$), and school functioning (-5.5; 95% CI -10.2 to -0.9; $P = 0.02$) [34]. Another study indicates that correction of refractive errors by the provision of spectacles in low socioeconomic areas in China would markedly improve educational outcomes since the major medium of instruction is the blackboard [35].

Patients with cataract may experience vision-related problems, such as decreased visual acuity, loss of contrast sensitivity, problems under glare conditions, and altered color recognition [36]. Studies in Japan and Canada reported a loss of well-being as disability adjusted life years (DALYs) and an associated cost of US$ PPP 51.8 billion/annum and US$ PPP 15.11 billion/annum, respectively [37, 38]. The global burden of diseases study 2010 estimated the burden of disease related to vision disorders has increased by 47% from 12,858,000 disability adjusted life years (DALYs) in 1990 to 18,837,000 DALYs in 2010 [39]. The Melbourne Visual Impairment Project (VIP) cohort showed the association between VI and mortality to increase linearly from 4.5% in people with a VA of 20/20 or better to 22.2% in blind people with VA of 20/200 or worse [40].

3.5   Impact of Myopia Treatments on Quality of Life

Current treatment options for control of myopia progression include optical correction such as bifocal spectacle lenses, progressive addition spectacle lenses, under-correction, orthokeratology, multifocal contact lenses, increased exposure to outdoor activities, and the use of atropine eye drops. Surgical techniques, such as LASIK, have become increasingly popular and over a million surgical procedures are performed annually in the United States [41]. Choice of refractive correction leads to various quality-of-life implications. Often, the type of refractive correction depends on prescription, lifestyle including occupational and recreational needs, economic issues, and personality. If refractive error may be corrected through the provision of corrective spectacles, visual acuity, and therefore functional vision could be improved. Patient reported outcomes (PROs) have been used to assess the outcomes of interventions on people's lives. A PRO is described as a report that comes directly from a patient regarding the impact of the condition and outcome of an intervention [42]. The Quality of Life Impact of Refractive Correction (QIRC) is useful to detect differences in quality of life impact from various refractive corrections (spectacles, contact lenses, and refractive surgery). Pesudovs et al. reported that QIRC score was highest in refractive surgery patients (mean QIRC score of 50.2 ± 6.3), followed by contact lens wearers (mean QIRC score 46.7 ± 5.5), and spectacle wears (mean QIRC score 44.1 ± 5.9) [43]. Orthokeratology (OrthoK) contact lenses (CL) are worn while sleeping to reshape the cornea and are used to correct refractive error and slow the progression of myopia [44]. Quality of life using the National Eye Institute Refractive Error Quality of Life (NEI RQL)-42 questionnaire was evaluated in a group of subjects with low to moderate myopia who had undergone four types of refractive correction, namely, LASIK, OrthoK, soft contact lens (SCL), and spectacles [45]. Results showed decrease in quality of life for most of the subscales in the treatment groups compared to emmetropic subjects. The average decrease in quality of life compared with emmetropes were -7.1% ($P = 0.021$) for LASIK, -13.0% ($P = 0.001$) for OrthoK, -15.8% ($P = 0.001$) for spectacles, and -17.3% ($P = 0.001$) for SCL. The subscales which were affected in LASIK and OrthoK patients compared to emmetropes were as follows: clarity of vision, expectations, glare, and worry. This suggests that both types of treatment affected the quality of life due to high-order aberrations [46]. LASIK and OrthoK are commonly associated with experiencing haloes and glare because of the dramatic changes in the corneal shape [47]. Spectacle wearers had the worse scores in expectations, dependence on correction, worry, and appearance as compared to the other three treatment modalities [45]. The primary motivation for undergoing LASIK was a desire to improve uncorrected visual acuity, without a need to wear glasses and improved ease to pursue sports or recreational activities [48]. Although LASIK patients may have excellent vision during day time, they may experience disturbances in night vision such as halo and glare disability [49]. An estimated 12–57% of patients experience night vision symptoms and 30% have difficulty with night driving after undergoing photorefractive keratectomy (PRK) and LASIK [50, 51]. In addition, these patients may experience poor vision in low light setting due to contrast sensitivity decreasing initially after LASIK [52].

OrthoK allows patients to enjoy good vision without needing to wear vision correction during their waking hours. This benefits patients who have an active lifestyle as they are more mobile without the need for refractive correction. OrthoK provides excellent vision and improves vision related quality of life [45, 53]. Side effects of OrthoK include halos secondary to spherical aberration, which may reduce visual acuity and contrast sensitivity or discomfort from the lenses [54]. Although the most serious complication with CL wear is infection, these occurrences are relatively rare [55, 56]. Most common complaints are related to intolerance or limited wearing time due to fluctuations of vision, dryness and discomfort [57]. Atropine has been used to control myopia progression [58]. As atropine causes pupil dilation and temporary paralysis of accommodation, patients may experience glare, discomfort, blurred vision, or allergic/hypersensitivity reactions. Complications of LASIK include corneal ectasia [59], dry eyes [60], and night vision disturbances [49].

Cataract surgery is a highly effective, cost-effective health-care intervention [61], and results in almost immediate visual rehabilitation. In addition to visual rehabilitation from media opacities, it offers once in a lifetime opportunity for refractive manipulation that benefits the majority of people with a refractive error. Previous studies have utilized Visual Functioning Index-14 (VF-14) or similar vision-functioning tools and reported the impact of cataract surgery can be translated beyond visual acuity. Evidence has shown several fold improvements in other critical daily tasks such as read critical daily living tasks such as reading newspapers or books; driving; watching TV; cooking; negotiating steps; sewing, knitting, crocheting, or doing handicrafts; noticing traffic, information or shop signs; and recognizing people [62]. In addition, there are improvements in several psychosocial aspects such as social interaction; mental and emotional well-being; psychological distress; adaptation; and coping.

3.6   Summary

Myopia is a major global public health concern due to its high and increasing prevalence in Asian countries, where it is a common cause of vision dysfunction. Uncorrected myopia is a leading cause of visual impairment. People with high myopia have increased risk of developing myopic pathologies which may lead to blindness. The economic burden of uncorrected distance refractive error, largely caused by myopia, is estimated to be US $202 billion annually. Direct cost of refractive correction comprises of cost from spectacles, contact lenses, and refractive surgeries. Other medical costs include those associated with treatment of ocular complications from high myopia, such as retinal detachment, myopic macular degeneration, glaucoma and cataract, and its associated visual impairment and blindness. This global cost will continue to increase as the number of people with myopia rises. Patients with higher myopic refractive error tend to have adverse effect on the quality of life and lead to lower health, economic, and social outcomes. Effective methods to control or correct myopia include the use of optical devices, pharmacological drops, surgical, or outdoor exposure. Each treatment method will have various quality of life implications; thus, it is important to ensure prescription, lifestyle including occupational and recreational needs, and economic issues are discussed. Although a broader societal perspective is

useful for informing policy, the patient's perspective is essential for designing service models to improve the social interaction and mental and emotional well-being of these individuals. In conclusion, the impact that myopia and its associated visual impairment have on individuals is substantial. Myopia preferentially affects the more highly educated and potentially most productive sectors of the population, the individual and societal costs involved. Developing appropriate public health policies to prevent and reduce myopia progression will benefit the individual and the wider society.

References

1. Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. Ann Acad Med Singap. 2004;33(1):27–33.
2. Naidoo KS, Fricke TR, Frick KD, et al. Potential lost productivity resulting from the global burden of myopia: systematic review, meta-analysis, and modeling. Ophthalmology. 2018;126(3):338–46.
3. Mutti DO, Mitchell GL, Moeschberger ML, et al. Parental myopia, near work, school achievement, and children's refractive error. Invest Ophthalmol Vis Sci. 2002;43(12):3633–40.
4. Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology. 2016;123(5):1036–42.
5. Morgan IG, Ohno-Matsui K, Saw S-M. Myopia. Lancet. 2012;379(9827):1739–48.
6. Bourne RRA, Stevens GA, White RA, et al. Causes of vision loss worldwide, 1990–2010: a systematic analysis. Lancet Glob Health. 2013;1(6):e339–e49.
7. Rabbetts RB. Bennett & Rabbetts' clinical visual optics. New York: Elsevier/Butterworth Heinemann; 2007.
8. 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(6):431–7.
9. Fricke T, Holden B, Wilson D. Global cost of correcting vision impairment from uncorrected refractive error. Bull World Health Organ. 2012;90:728–38.
10. World Health Organization. Purchasing power parity. 2005. https://www.who.int/choice/costs/ppp/en/. Accessed 20 June 2019.
11. Wang TJ, Chiang TH, Wang TH, et al. Changes of the ocular refraction among freshmen in National Taiwan University between 1988 and 2005. Eye. 2009;23(5):1168–9.
12. Zheng YF, Pan CW, Chay J, et al. The economic cost of myopia in adults aged over 40 years in Singapore. Invest Ophthalmol Vis Sci. 2013;54(12):7532–7.
13. Lim MC, Gazzard G, Sim EL, et al. Direct costs of myopia in Singapore. Eye. 2009;23(5):1086–9.
14. Letsch SW, Lazenby HC, Levit KR, Cowan CA. National health expenditures, 1991. Health Care Financ Rev. 1992;14(2):1–30.
15. Vitale S, Cotch MF, Sperduto R, Ellwein L. Costs of refractive correction of distance vision impairment in the United States, 1999-2002. Ophthalmology. 2006;113(12):2163–70.
16. England N. Improving eye health and reducing sight loss: a call to action. 2014. https://www.england.nhs.uk/2014/06/eye-cta/. Accessed 6 Feb 2019.
17. Frick KD, Gower EW, Kempen JH, Wolff JL. Economic impact of visual impairment and blindness in the United States. Arch Ophthalmol. 2007;125(4):544–50.
18. Keeffe JE, Chou SL, Lamoureux EL. The cost of care for people with impaired vision in Australia. Arch Ophthalmol. 2009;127(10):1377–81.
19. Yamada M, Hiratsuka Y, Roberts CB, et al. Prevalence of visual impairment in the adult Japanese population by cause and severity and future projections. Ophthalmic Epidemiol. 2010;17(1):50–7.
20. Taylor HR, Pezzullo ML, Keeffe JE. The economic impact and cost of visual impairment in Australia. Br J Ophthalmol. 2006;90(3):272–5.
21. Koberlein J, Beifus K, Schaffert C, Finger RP. The economic burden of visual impairment and blindness: a systematic review. BMJ Open. 2013;3(11):e003471.

22. Organisation for Economic Co-operation and Development. OECD health statistics. 2018. http://www.oecd.org/els/health-systems/health-data.htm. Accessed 6 Feb 2019.
23. Mintel. Optical goods retailing: UK. 2018. http://reports.mintel.com/display/858753/. Accessed 6 Feb 2019.
24. Khadka J, Fenwick E, Lamoureux E, Pesudovs K. Methods to develop the eye-tem bank to measure ophthalmic quality of life. Optom Vis Sci. 2016;93(12):1485–94.
25. Cieza A, Kocur I, Mariotti S, McCoy M. The future of eye care in a changing world. Bull World Health Organ. 2017;95:667.
26. Klein BE, Klein R, Lee KE, Cruickshanks KJ. Performance-based and self-assessed measures of visual function as related to history of falls, hip fractures, and measured gait time. The Beaver Dam Eye Study. Ophthalmology. 1998;105(1):160–4.
27. Mitchell P, Hayes P, Wang JJ. Visual impairment in nursing home residents: the Blue Mountains Eye Study. Med J Aust. 1997;166(2):73–6.
28. Finger RP, Fenwick E, Marella M, et al. The impact of vision impairment on vision-specific quality of life in Germany. Invest Ophthalmol Vis Sci. 2011;52(6):3613–9.
29. Rovner BW, Casten RJ, Tasman WS. Effect of depression on vision function in age-related macular degeneration. Arch Ophthalmol. 2002;120(8):1041–4.
30. Horowitz A, Reinhardt JP, Boerner K, Travis LA. The influence of health, social support quality and rehabilitation on depression among disabled elders. Aging Ment Health. 2003;7(5):342–50.
31. Tolman J, Hill RD, Kleinschmidt JJ, Gregg CH. Psychosocial adaptation to visual impairment and its relationship to depressive affect in older adults with age-related macular degeneration. Gerontologist. 2005;45(6):747–53.
32. Fricke TR, Jong M, Naidoo KS, et al. Global prevalence of visual impairment associated with myopic macular degeneration and temporal trends from 2000 through 2050: systematic review, meta-analysis and modelling. Br J Ophthalmol. 2018;102(7):855–62.
33. Takashima T, Yokoyama T, Futagami S, et al. The quality of life in patients with pathologic myopia. Jpn J Ophthalmol. 2001;45(1):84–92.
34. Wong HB, Machin D, Tan SB, et al. Visual impairment and its impact on health-related quality of life in adolescents. Am J Ophthalmol. 2009;147(3):505–11.e1.
35. Ma X, Zhou Z, Yi H, et al. Effect of providing free glasses on children's educational outcomes in China: cluster randomized controlled trial. BMJ. 2014;349:g5740.
36. Crabtree HL, Hildreth AJ, O'Connell JE, et al. Measuring visual symptoms in British cataract patients: the cataract symptom scale. Br J Ophthalmol. 1999;83(5):519–23.
37. Cruess AF, Gordon KD, Bellan L, et al. The cost of vision loss in Canada. 2. Results. Can J Ophthalmol. 2011;46(4):315–8.
38. Roberts CB, Hiratsuka Y, Yamada M, et al. Economic cost of visual impairment in Japan. Arch Ophthalmol. 2010;128(6):766–71.
39. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2197–223.
40. McCarty CA, Nanjan MB, Taylor HR. Vision impairment predicts 5 year mortality. Br J Ophthalmol. 2001;85(3):322–6.
41. Hammond MD, Madigan WP, Bower KS. Refractive surgery in the United States Army, 2000-2003. Ophthalmology. 2005;112(2):184–90.
42. Denniston AK, Kyte D, Calvert M, Burr JM. An introduction to patient-reported outcome measures in ophthalmic research. Eye. 2014;28(6):637–45.
43. Pesudovs K, Garamendi E. Elliott DB. A quality of life comparison of people wearing spectacles or contact lenses or having undergone refractive surgery. J Refract Surg. 2006;22(1):19–27.
44. Lipson MJ, Brooks MM, Koffler BH. The role of orthokeratology in myopia control: a review. Eye Contact Lens. 2018;44(4):224–30.
45. Queiros A, Villa-Collar C, Gutierrez AR, et al. Quality of life of myopic subjects with different methods of visual correction using the NEI RQL-42 questionnaire. Eye Contact Lens. 2012;38(2):116–21.

46. Queiros A, Villa-Collar C, Gonzalez-Meijome JM, et al. Effect of pupil size on corneal aberrations before and after standard laser in situ keratomileusis, custom laser in situ keratomileusis, and corneal refractive therapy. Am J Ophthalmol. 2010;150(1):97–109.e1.
47. al-Kaff AS. Patient satisfaction after photorefractive keratectomy. J Refract Surg. 1997;13(5 Suppl):S459–60.
48. McGhee CN, Craig JP, Sachdev N, et al. Functional, psychological, and satisfaction outcomes of laser in situ keratomileusis for high myopia. J Cataract Refract Surg. 2000;26(4):497–509.
49. Villa C, Gutierrez R, Jimenez JR, Gonzalez-Meijome JM. Night vision disturbances after successful LASIK surgery. Br J Ophthalmol. 2007;91(8):1031–7.
50. Bailey MD, Mitchell GL, Dhaliwal DK, et al. Patient satisfaction and visual symptoms after laser in situ keratomileusis. Ophthalmology. 2003;110(7):1371–8.
51. Schein OD, Vitale S, Cassard SD, Steinberg EP. Patient outcomes of refractive surgery. The refractive status and vision profile. J Cataract Refract Surg. 2001;27(5):665–73.
52. Chan JWW, Edwards MH, Woo GC, Woo VCP. Contrast sensitivity after laser in situ keratomileusis: one-year follow-up. J Cataract Refract Surg. 2002;28(10):1774–9.
53. Hiraoka T, Okamoto C, Ishii Y, et al. Patient satisfaction and clinical outcomes after overnight orthokeratology. Optom Vis Sci. 2009;86(7):875–82.
54. Johnson KL, Carney LG, Mountford JA, et al. Visual performance after overnight orthokeratology. Cont Lens Anterior Eye. 2007;30(1):29–36.
55. Morgan PB, Efron N, Hill EA, et al. Incidence of keratitis of varying severity among contact lens wearers. Br J Ophthalmol. 2005;89(4):430.
56. Schein OD. Microbial keratitis associated with overnight orthokeratology: what we need to know. Cornea. 2005;24(7):767–9.
57. Pritchard N, Fonn D. Dehydration, lens movement and dryness ratings of hydrogel contact lenses. Ophthalmic Physiol Opt. 1995;15(4):281–6.
58. Pineles SL, Kraker RT, VanderVeen DK, et al. Atropine for the prevention of myopia progression in children: a report by the American Academy of Ophthalmology. Ophthalmology. 2017;124(12):1857–66.
59. Randleman JB, Russell B, Ward MA, et al. Risk factors and prognosis for corneal ectasia after LASIK. Ophthalmology. 2003;110(2):267–75.
60. De Paiva CS, Chen Z, Koch DD, et al. The incidence and risk factors for developing dry eye after myopic LASIK. Am J Ophthalmol. 2006;141(3):438–45.
61. Lansingh VC, Carter MJ, Martens M. Global cost-effectiveness of cataract surgery. Ophthalmology. 2007;114(9):1670–8.
62. Lamoureux EL, Fenwick E, Pesudovs K, Tan D. The impact of cataract surgery on quality of life. Curr Opin Ophthalmol. 2011;22(1):19–27.