Eye (2014) 28, 202–208

www.nature.com/eye

Epidemiology of myopia

PJ Foster[1,2] and Y Jiang[1]

[1]Division of Genetics & Epidemiology, UCL Institute of Ophthalmology, London, UK

[2]NIHR Biomedical Research Centre, Moorfields Eye Hospital, London, UK

Correspondence: PJ Foster, Division of Genetics & Epidemiology, UCL Institute of Ophthalmology, 11-43 Bath Street, London EC1V 9EL, UK.
Tel: +44 (0)207 608 6899; Fax: +44 (0)207 608 4012.
E-mail: p.foster@ucl.ac.uk

Received: 8 October 2013
Accepted in revised form: 21 November 2013
Published online: 10 January 2014

Abstract

Myopia is one of the most prevalent disorders of the eye. Higher myopia is associated with comorbidities that increase risks of severe and irreversible loss of vision, such as retinal detachment, subretinal neovascularization, dense cataract, and glaucoma. In recent years, reports from population-based prevalence studies carried out in various geographical areas now give a clear picture of the current distribution of refractive error. The scarcity of data from well-designed longitudinal cohort studies is still yet to be addressed. These studies have confirmed the previous data indicating that prevalence of refractive error varies according to ethnicity and geographic regions, and also point to an increase in myopia prevalence over the past half-century. The problem is particularly pronounced in affluent, industrialised areas of East Asia. Environmental risk factors for myopia related to socioeconomic status and lifestyle have been identified. The past decade has seen a greater understanding of the molecular biological mechanisms that determine refractive error, giving further support to the belief that myopia is the result of a complex interaction between genetic predisposition and environmental exposures. This review summarizes data on the prevalence, incidence, progression, associations, risk factors, and impact from recent epidemiological studies on myopia.
Eye (2014) **28,** 202–208; doi:10.1038/eye.2013.280; published online 10 January 2014

Keywords: myopia; epidemiology; incidence; risk factors; prevalence

Myopia is one of the most prevalent disorders of the eye. It causes visual impairment in both children and adults that is usually correctable using optical aids such as spectacles and contact lenses, or through increasingly popular surgical means. Higher myopia may result in comorbidities associated with significantly increased risks of severe and irreversible loss of vision, such as retinal detachment, subretinal neovascularization, dense cataract, and glaucoma.[1–6] The prevalence, risk factors, and associations of myopia have been well documented. Over the past decade, there has been a number of reports on large-scale population-based prevalence studies carried out in various geographical areas, although the scarcity of data from well-designed longitudinal cohort studies is still yet to be addressed. These studies have confirmed the previous data indicating that prevalence of refractive error varies according to ethnicity and geographic regions.[7–17] Recent epidemiological studies also point to an increase in myopia prevalence over the past half-century. Various environmental factors related to socioeconomic status and lifestyle have been reported, and are widely considered to be possibly responsible for these changes.[15,18,19] Increasing evidence has also been generated over the past decades in regard to the possible biological mechanisms that determine refractive error, giving further evidence to the theory that myopia is the result of a complicated interaction between genetic predisposition and environmental exposures.

This review serves to summarize data on the prevalence, incidence, progression, associations, risk factors, and impact from recent epidemiological studies on myopia.

How big is the problem

Comparison of prevalence data between studies is frequently complex. Different researchers may categorize their results in different ways, and representativeness of data can be affected by various factors such as response rate and sampling frame. The definition used for the identification of individuals with myopia is of crucial importance. Myopia is generally defined as a spherical refractive error caused by excessive refractive power and/or axial lengthening of the eye, which result in anterior displacement of focus from the retina.[20] In recent epidemiological studies reporting prevalence rates of myopia, although a majority of studies defined myopia as spherical equivalence (SE) ≤ -0.5 dioptres (D), a wide variety of definitions was adopted for the identification of individuals with myopia: from an SE ≤ -0.12 D to SE ≤ -1.0 D.[7,8,10–12] Great variation in methodology, including sampling procedure, cut-off points for definition of age groups, and methods used for measuring refractive error, still exists in recent epidemiological studies on myopia.

Prevalence in children

Many recent cross-sectional studies have reported a considerable variation in prevalence of myopia among children of different ethnic backgrounds, different locations, and different age. A recent population-based cross-sectional study on preschool American children aged 6–72 months reported a myopia prevalence of 1.2% in non-Hispanic whites, 3.7% in Hispanics, 3.98% in Asians, and 6.6% in African Americans.[7,21] Greater difference in the prevalence of myopia was found in older school-aged children of different ethnicity. The cross-sectional prevalence of myopia in Australian schoolchildren was reported to be 42.7% and 59.1% in 12-year-old and 17-year-old school-aged children of East Asian ethnicity, respectively, whereas the corresponding prevalence rates in European Caucasian children of the same age were 8.3% and 17.7%, respectively.[9]

Variations in the prevalence of myopia in children of different geographical areas have also been widely reported. Considerable regional difference exists from country to country even within the same geographical area. Prevalence rates in East Asian and Southeast Asian countries were found to be generally higher than other parts of the world. Recent prevalence surveys in China using cycloplegic autorefraction showed that 16.2% of school-aged children in rural areas of northern China aged between 5 and 15 years were myopic.[22] Comparatively, much higher prevalence rates of myopia were reported from recent studies on schoolchildren of similar age in large metropolitan cities in southern China: 38.1% in Guangzhou[23] and 36.7% in Hong Kong.[24] Myopia seems to be more prevalent among young schoolchildren in Singapore than in southern China. Prevalence of myopia in children aged 7–9 years reported from the Singapore-China study[25] was 36.7% in Singapore, 18.5% in Xiamen City southern China, *vs* 6.6% in rural Xiamen. In contrast, the prevalence of myopia was much lower in some other countries in East Asia. In rural Mongolian schoolchildren aged 7–17 years, the prevalence of myopia was 5.8%.[26] Only 1.2% of Nepalese children aged 5–15 years were shown to be myopic.[27]

Prevalence in adults

Fewer data are available detailing the prevalence of myopia in adults. The prevalence rates were found to vary with age. Owing to the relative scarcity of data from large-scale cohort studies, a more precise statement might be the prevalence rates of myopia in older adults are generally lower than in younger adults. In the Beaver Dam Eye Study,[28] data collected between 1988 and 1990 showed a significant decrease with age among individuals aged above 43 years. The prevalence of myopia decreased from 42.9% in adults aged 43–54 years to 25.1% in adults aged 55–64 years, further decreased to 14.8% in the 65-to-74-year age group, and then slightly decreased to 14.4% among individuals aged 75 years and above. Another large-scale population-based study in urban Americans aged 40 years or above also showed apparent decline in prevalence of myopia with increased age in females of different ethnicity and the male Whites. However, a bimodal pattern was observed in the prevalence of myopia among African Americans of different age, with the peak prevalence rates found in individuals aged 40–49 years as well as 80 years or above.[29] A similar bimodal pattern of myopia prevalence was found in adult Singaporeans aged 40–81 years. Of the relatively high prevalence of myopia across all age groups in both men and women (range: 25.2–51.7%), the prevalence was also highest among individuals in their forties and seventies.[30] It is still under debate whether this age-related variation in the prevalence of myopia results from longitudinal effects or cohort effects.[31] However, the bimodal distribution is likely owing to differing influences of axial myopia among younger people, and greater index myopia, due to lens nuclear sclerosis in older people (See Figure 1).

Incidence and progression

The data concerning incidence of myopia from longitudinal cohort studies is still more scarce. According to a recent report of a population-based cohort study on two cohorts of Australian schoolchildren aged 12 and 17 years, the annual incidence of myopia was 2.2% in the younger cohort and 4.1% in the older cohort. The annual incidence rates of myopia in East Asian children (6.9% in the younger cohort, 7.3% in the older) were much higher than in European Caucasian children (younger, 1.3%; older, 2.9%). A remarkable increase in prevalence over time was observed in children of both age groups: from 1.4–14.4% in the younger cohort (over a follow-up period

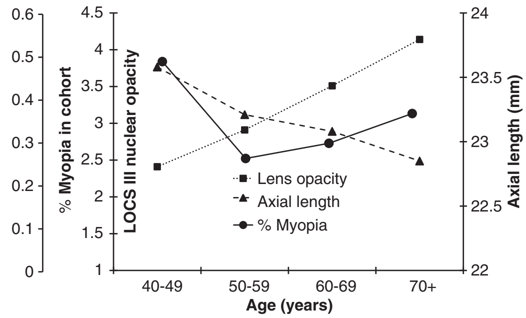

Figure 1 Determinants of refraction in adult Singaporeans. This graph shows cross-sectional data for mean axial length (AL) and mean LOCS nuclear opacity (NO) lens grade in a Chinese Singaporean population aged 40–82 years. NO grade increases linearly with age, whereas there is a clear pattern for axial length to be longer in younger people. The AL differences presumably reflect a cohort effect with each age-group having static, lifelong differences in axial length, rather than indicating an age-related decline in AL. The population % myopia is shown in overlay, and appears to show a greater effect of AL on refractive status in people aged 40–59 years. From the age of 60, the impact of nuclear opacity grade (NO) increases, resulting in a greater impact of 'index myopia'.

of 6.1 ± 0.8 years) and from 13.0–29.6% in the older cohort (over a follow-up period of 4.5 ± 0.3 years).

According to a review of five nationwide prevalence surveys carried out in Taiwan between 1983 and 2000, the prevalence of myopia steadily and significantly increased among children aged from 7–18 years. The magnitude of increase in prevalence over the 17 years varied between 14% (for children aged between 16 and 18 years) and 262% (for 7-year-old children).[32] A similar trend was reported in another review of change in myopia prevalence over 30 years in the United States between 1971 and 2004. Among all age groups in which the prevalence of myopia was shown to be significantly increased over three decades, the prevalence of myopia in schoolchildren aged 12–17 years increased from 12.0% (between 1971 and 1972) to 31.2% (between 1999 and 2004).[33] A cross-sectional study comparing myopia prevalence over two generations of Singaporean Indians aged over 40 years found the prevalence of both myopia and high myopia in the first-generation immigrants was significantly lower than in the second-generation immigrants (myopia: 23.4% *vs* 30.2%, high myopia: 2.5% *vs* 4.8%).[12]

The trend towards higher rates of myopia by these previous studies, however, was not replicated in a study in Hong Kong. An analysis of changes over two decades in the prevalence of myopia among Chinese schoolchildren showed similar prevalence rates in the early 1990s and from 2005 to 2010.[13] In Finland, a review of studies in the 20th century showed a (relatively) constant prevalence of myopia in children aged 7–8 years over the recent more than 20 years, whereas the prevalence rate almost doubled in children age 14–15 years.[11] In further contrast to the widely reported trend of increasing prevalence of myopia over recent decades, a retrospective study comparing myopia prevalence of Danish conscripts in years 1882, 1964, and 2004 showed a significant decrease in myopia prevalence over time,[34] although the comparability has been questioned because of difference in study methodologies in different years.[35]

Associations or risk factors of myopia

The exact pathogenic mechanisms of myopia remain unclear. Recent evidence suggests that myopia is likely to result from the combined and interacting effects of hereditary and environmental factors.[36] Many factors have been documented for having possible associations with risks for developing myopia, such as parental myopia, gender, ethnicity, education, occupation, income, near-work load, outdoor activities, lens opacity, and ocular dimensions.[26,30,37,38]

Parental myopia

Myopia appears to be more frequently seen in children with myopic parents. Mutti and colleagues[39] reported that the proportions of myopia were 6.3% in schoolchildren aged 13.7 ± 0.5 years whose both parents are emmetropic, 18.2% in children with one myopic parent, and 32.9% in children whose both parents are myopic. In this study, the interaction between near work and parental myopia was evaluated to test the hypothesis of inherited susceptibility. No evidence was found to support the hypothesis that children with myopic parents can inherit a susceptibility to the environment.[39] Similar association between parental myopia and the prevalence of myopia was found after adjusting for environmental and demographic factors in another population of 12-year-old schoolchildren in Australia.[40] Children with two myopic parents were also found to have most negative spherical equivalent refraction and longest axial length. Substantially higher odds of myopia were found in children of East Asian than those of European Caucasians in the same population, whereas increased load of near work was not significantly associated with odds of myopia when factors including parental myopia, demographics, and outdoor activities were adjusted for.[40] Another study in Hong Kong also showed that myopic Chinese children aged 5–16 years with a stronger parental history of myopia also had more myopic spherical equivalent refraction and tended to be less hyperopic before the onset of myopia. Different from the findings in Australian children, a stronger parental history of myopia was not associated with longer axial length but was significantly associated with more rapid eye growth and myopic shift in refraction over time.[41] A recent study in Guangzhou, China showed the existent but small impact of parental myopia on the prevalence of myopia in 15-year-old children. Compared with children without myopic parents, those with one myopic parent are twice as likely to be myopic, and those with two parents myopic are three times more likely to be myopic themselves.[42] Although more severe parental myopia results in increased risk of myopia in children, the impact of parental myopia on high myopia in children remains undetermined.[43]

Socioeconomic factors

Population-based prevalence studies showed increased prevalence of myopia in Singaporeans with higher levels of education, better housing, higher individual monthly income. and occupations associated with near work after adjusting for age and gender.[44] Higher odds for myopia were also found in Korean children from families of higher income.[45] Myopic children were also found to have a stronger parental history of myopia in families with higher parental level of education, higher income, and white collar or professional occupations.[42]

Near-work and outdoor activity

Near-work activities, such as reading, writing, computer use, and playing video games, have been suggested to be possibly responsible for the remarkable increase in the prevalence of myopia[40] as well as increased odds for myopia.[46] However, there also have been some studies reporting a weak or absent association between heavier load of near work and the prevalence or incidence of myopia,[39,46] especially early myopia.[47] A cohort study in Australian schoolchildren showed that those with incident myopia performed significantly more near work.[48] Measurement of axial length following prolonged near work using IOLMaster showed significantly greater magnitude of increase in axial length in eyes with early-onset myopia or progressing myopia.[49]

Outdoor activity, as either a potential prophylactic measure or a possible risk factor, has aroused considerable interest. Although it is still not clear whether outdoor activity can help prevent the onset and progression of myopia,[42] several recent epidemiological studies suggested that greater time spent outdoors might be associated with reduced prevalence of myopia.[50,51] The underlying mechanism of this association remains poorly understood. The 'light-dopamine' theory was proposed as a possible mechanism. Increased light intensity during time spent outdoors can stimulate the release of dopamine, which has been suggested to be able to reduce axial elongation of the eye.[50,52–54] Another recent study on rural Chinese children aged around 15 years found no association between time spent either outdoors or on near activities after adjustment for age, sex, and parental education.[55] Information about near-work and outdoor activities was collected using a questionnaire survey in most of the studies. Without a universal standardised method of assessment, which produces comparable results across racial, cultural, and geographical boundaries, there is scope for systematic bias influencing results. The quality of data and accuracy of assessment can be affected by many factors, such as definitions of near work, validation of the questionnaire, training of the interviewer, and recall bias.

Impact

Myopia, as the 'most common eye condition', has been shown to have diverse medical, social, and financial impacts. Congenital or acquired high myopia may be accompanied by or result in serious ocular pathologies.[2,3,56] Uncorrected myopia has shown to be a major cause of visual impairment as well as compromise in the quality of life. The adverse impacts from myopia may also be reflected socioeconomically considering the loss of productivity owing to visual impairment caused by myopia, the cost of treatment for comorbidities of myopia, and the cost of various ways of correction.[15]

According to a most recent report published by the World Health Organization (WHO)[57] primarily based on population data acquired in 2007, using the definition of distance vision impairment as a visual acuity worse than 6/18 in the better eye, there were an estimated 158 million cases of distance vision impairment caused by uncorrected refractive error in 2007. Of the 14 subregions of the world included in the WHO report, the number was highest in the Western Pacific Region (61.9 million) followed by the Southeast Asia Region (54.5 million). The estimated loss in global gross domestic product owing to distance vision impairment caused by uncorrected refractive error was US$202 billion annually, a drastic increase over two decades compared with the statistics reported previously.[58] Another regional cross-sectional investigation revealed a considerable financial burden for myopic individuals in Singapore.[59]

It has also been well documented that myopes, especially high myopes, tend to suffer from compromised quality of life owing to various influences from functional, psychological, cosmetic, and financial factors.[60–62] Individuals with high myopia were reported to have significantly lower vision-related quality of life than those with none, mild, or moderate myopes.[60,61] The vision-related quality of life in those with high myopia could even drop down close to that of patients with severe corneal pathologies.[60]

Myopia, especially high myopia (often defined as $SE \leq -6.0$ D), has been associated with various ocular comorbidities. Vitreoretinal pathologies, especially peripheral pathologic changes in the retina, are well-recognized conditions related to high myopia. In a cross-sectional study, up to 61.7% of highly myopic eyes were found to have peripheral retinal change. The most common pathologies included optic nerve crescent (52.5%), white-without-pressure (51.7%), lattice degeneration (5.8%), microcystoid degeneration (5%), and pigmentary degeneration (4.2%).[63] High myopia was also suggested to be associated with bilateral rhegmatogenous retinal detachment, a condition of very severe visual morbidity.[3] Highly myopic eyes with increased axial length were found to be more predisposed to nuclear cataract. Compared with normal controls, high myopes also tended to have cataract of higher nuclear density.[1] This is in accordance with findings from a population-based study in Singapore, which found myopia being significantly associated with both nuclear and posterior subcapsular cataract.[44] High myopia was reported to be associated with idiopathic focal subretinal neovascularization.[56]

In conclusion, myopia is one of the most common disorders of the eye. Its prevalence is increasing alarmingly in East Asia's rapidly developing economies, such as China. Various environmental risk factors related to socioeconomic status and lifestyle have been identified, and appear strongly associated with these changes. Evidence has also been generated over the past decade in regard to the molecular biological mechanisms that determine refractive error, lending further weight to the theory that myopia is the result of a complicated interaction between genetic predisposition and environmental exposures. Measures to control this epidemic of disease are urgently needed.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

Financial Support: Paul Foster is funded by the National Institute for Health Research (NIHR) Biomedical Research Centre at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology. Yuzhen Jiang is funded by the British Council for Prevention of Blindness and UCL Overseas Research Scholarship.

References

1 Praveen MR, Vasavada AR, Jani UD, Trivedi RH, Choudhary PK. Prevalence of cataract type in relation to axial length in subjects with high myopia and emmetropia in an Indian population. *Am J Ophthalmol* 2008; **145**(1): 176–181.
2 Polkinghorne PJ, Craig JP. Northern New Zealand Rhegmatogenous Retinal Detachment Study: epidemiology and risk factors. *Clin Experiment Ophthalmol* 2004; **32**(2): 159–163.
3 Li X. Incidence and epidemiological characteristics of rhegmatogenous retinal detachment in Beijing, China. *Ophthalmology* 2003; **110**(12): 2413–2417.
4 Vongphanit J, Mitchell P, Wang JJ. Prevalence and progression of myopic retinopathy in an older population. *Ophthalmology* 2002; **109**(4): 704–711.
5 Mitchell P, Hourihan F, Sandbach J, Wang JJ. The relationship between glaucoma and myopia: the Blue Mountains Eye Study. *Ophthalmology* 1999; **106**(10): 2010–2015.
6 Wong TY, Foster PJ, Johnson GJ, Seah SKL. Education, socioeconomic status, and ocular dimensions in Chinese adults: the Tanjong Pagar Survey. *Br J Ophthalmol* 2002; **86**(9): 963–968.
7 Wen G, Tarczy-Hornoch K, McKean-Cowdin R, Cotter SA, Borchert M, Lin J *et al*. Prevalence of myopia, hyperopia, and astigmatism in non-Hispanic white and Asian children: multi-ethnic pediatric eye disease study. *Ophthalmology* 2013; **120**(10): 2109–2116.
8 Lee JH, Jee D, Kwon JW, Lee WK. Prevalence and risk factors for myopia in a rural korean population. *Invest Ophthalmol Vis Sci* 2013; **54**(8): 5466–5471.
9 French AN, Morgan IG, Burlutsky G, Mitchell P, Rose KA. Prevalence and 5- to 6-year incidence and progression of myopia and hyperopia in Australian schoolchildren. *Ophthalmology* 2013; **120**(7): 1482–1491.
10 Sun J, Zhou J, Zhao P, Lian J, Zhu H, Zhou Y *et al*. High prevalence of myopia and high myopia in 5060 Chinese university students in Shanghai. *Invest Ophthalmol Vis Sci* 2012; **53**(12): 7504–7509.
11 Parssinen O. The increased prevalence of myopia in Finland. *Acta Ophthalmol* 2012; **90**(6): 497–502.
12 Pan CW, Zheng YF, Wong TY, Lavanya R, Wu RY, Gazzard G *et al*. Variation in prevalence of myopia between generations of migrant indians living in Singapore. *Am J Ophthalmol* 2012; **154**(2): 376–381; e1.
13 Lam CS, Lam CH, Cheng SC, Chan LY. Prevalence of myopia among Hong Kong Chinese schoolchildren: changes over two decades. *Ophthalmic Physiol Opt* 2012; **32**(1): 17–24.
14 Hashemi H, Khabazkhoob M, Jafarzadehpur E, Yekta AA, Emamian MH, Shariati M *et al*. High prevalence of myopia in an adult population, Shahroud, Iran. *Optom Vis Sci* 2012; **89**(7): 993–999.
15 Rahi JS, Cumberland PM, Peckham CS. Myopia over the lifecourse: prevalence and early life influences in the 1958 British birth cohort. *Ophthalmology* 2011; **118**(5): 797–804.
16 Charman N. Myopia: its prevalence, origins and control. *Ophthalmic Physiol Opt* 2011; **31**(1): 3–6.
17 Rudnicka AR, Owen CG, Nightingale CM, Cook DG, Whincup PH. Ethnic differences in the prevalence of myopia and ocular biometry in 10- and 11-year-old children: the Child Heart and Health Study in England (CHASE). *Invest Ophthalmol Vis Sci* 2010; **51**(12): 6270–6276.
18 Park DJ, Congdon NG. Evidence for an 'epidemic' of myopia. *Ann Acad Med Singapore* 2004; **33**(1): 21–26.
19 Morgan I, Rose K. How genetic is school myopia? *Prog Retin Eye Res* 2005; **24**(1): 1–38
20 Angle J, Wissmann DA. The epidemiology of myopia. *Am J Epidemiol* 1980; **111**(2): 220–228.

21 Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of myopia and hyperopia in 6- to 72-month-old african american and Hispanic children: the multi-ethnic pediatric eye disease study. *Ophthalmology* 2010; **117**(1): 140–147; e3.
22 Zhao J, Pan X, Sui R, Munoz SR, Sperduto RD, Ellwein LB. Refractive Error Study in Children: results from Shunyi District, China. *Am J Ophthalmol* 2000; **129**(4): 427–435.
23 He M, Zeng J, Liu Y, Xu J, Pokharel GP, Ellwein LB. Refractive error and visual impairment in urban children in southern china. *Invest Ophthalmol Vis Sci* 2004; **45**(3): 793–799.
24 Fan DS, Lam DS, Lam RF, Lau JT, Chong KS, Cheung EY *et al.* Prevalence, incidence, and progression of myopia of school children in Hong Kong. *Invest Ophthalmol Vis Sci* 2004; **45**(4): 1071–1075.
25 Saw SM, Zhang MZ, Hong RZ, Fu ZF, Pang MH, Tan DT. Near-work activity, night-lights, and myopia in the Singapore-China study. *Arch Ophthalmol* 2002; **120**(5): 620–627.
26 Morgan A, Young R, Narankhand B, Chen S, Cottriall C, Hosking S. Prevalence rate of myopia in schoolchildren in rural Mongolia. *Optom Vis Sci* 2006; **83**(1): 53–56.
27 Pokharel GP, Negrel AD, Munoz SR, Ellwein LB. Refractive Error Study in Children: results from Mechi Zone, Nepal. *Am J Ophthalmol* 2000; **129**(4): 436–444.
28 Wang Q, Klein BE, Klein R, Moss SE. Refractive status in the Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci* 1994; **35**(13): 4344–4347.
29 Katz J, Tielsch JM, Sommer A. Prevalence and risk factors for refractive errors in an adult inner city population. *Invest Ophthalmol Vis Sci* 1997; **38**(2): 334–340.
30 Wong TY, Foster PJ, Hee J, Ng TP, Tielsch JM, Chew SJ *et al.* Prevalence and risk factors for refractive errors in adult Chinese in Singapore. *Invest Ophthalmol Vis Sci* 2000; **41**(9): 2486–2494.
31 Mutti DO, Zadnik K. Age-related decreases in the prevalence of myopia: longitudinal change or cohort effect? *Invest Ophthalmol Vis Sci* 2000; **41**(8): 2103–2107
32 Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. *Ann Acad Med Singapore* 2004; **33**(1): 27–33.
33 Vitale S, Sperduto RD, Ferris 3rd, FL. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. *Arch Ophthalmol* 2009; **127**(12): 1632–1639.
34 Jacobsen N, Jensen H, Goldschmidt E. Prevalence of myopia in Danish conscripts. *Acta Ophthalmol Scand* 2007; **85**(2): 165–170.
35 Sangtam T, Maheshwar B, Eong KG. Prevalence of myopia in Danish conscripts: a response. *Acta Ophthalmol* 2009; **87**(8): 914 (author reply 913-4).
36 Saw SM, Hong CY, Chia KS, Stone RA, Tan D. Nearwork and myopia in young children. *Lancet* 2001; **357**(9253): 390.
37 Wong TY, Foster PJ, Johnson GJ, Klein BE, Seah SK. The relationship between ocular dimensions and refraction with adult stature: the Tanjong Pagar Survey. *Invest Ophthalmol Vis Sci* 2001; **42**(6): 1237–1242.
38 Ahmed I, Mian S, Mudasir S, Andrabi KI. Prevalence of myopia in students of srinagar city of kashmir, India. *Int J Health Sci (Qassim)* 2008; **2**(1): 77–81.
39 Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci* 2002; **43**(12): 3633–3640.
40 Ip JM, Huynh SC, Robaei D, Rose KA, Morgan IG, Smith W *et al.* Ethnic differences in the impact of parental myopia: findings from a population-based study of 12-year-old Australian children. *Invest Ophthalmol Vis Sci* 2007; **48**(6): 2520–2528.
41 Lam DS, Fan DS, Lam RF, Rao SK, Chong KS, Lau JT *et al.* The effect of parental history of myopia on children's eye size and growth: results of a longitudinal study. *Invest Ophthalmol Vis Sci* 2008; **49**(3): 873–876.
42 Xiang F, He M, Morgan IG. The impact of parental myopia on myopia in Chinese children: population-based evidence. *Optom Vis Sci* 2012; **89**(10): 1487–1496.
43 Xiang F, He M, Morgan IG. The impact of severity of parental myopia on myopia in Chinese children. *Optom Vis Sci* 2012; **89**(6): 884–891.
44 Wong TY, Foster PJ, Johnson GJ, Seah SK. Refractive errors, axial ocular dimensions, and age-related cataracts: the Tanjong Pagar survey. *Invest Ophthalmol Vis Sci* 2003; **44**(4): 1479–1485.
45 Lim HT, Yoon JS, Hwang SS, Lee SY. Prevalence and associated sociodemographic factors of myopia in Korean children: the 2005 third Korea National Health and Nutrition Examination Survey (KNHANES III). *Jpn J Ophthalmol* 2012; **56**(1): 76–81.
46 Saw SM, Chua WH, Hong CY, Wu HM, Chan WY, Chia KS *et al.* Nearwork in early-onset myopia. *Invest Ophthalmol Vis Sci* 2002; **43**(2): 332–339.
47 Low W, Dirani M, Gazzard G, Chan YH, Zhou HJ, Selvaraj P *et al.* Family history, near work, outdoor activity, and myopia in Singapore Chinese preschool children. *Br J Ophthalmol* 2010; **94**(8): 1012–1016.
48 French AN, Morgan IG, Mitchell P, Rose KA. Risk factors for incident myopia in Australian schoolchildren: the Sydney Adolescent Vascular and Eye Study. *Ophthalmology* 2013; **120**(10): 2100–2108.
49 Woodman EC, Read SA, Collins MJ, Hegarty KJ, Priddle SB, Smith JM *et al.* Axial elongation following prolonged near work in myopes and emmetropes. *Br J Ophthalmol* 2011; **95**(5): 652–656.
50 Rose KA, Morgan IG, Ip J, Kifley A, Huynh S, Smith W *et al.* Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology* 2008; **115**(8): 1279–1285.
51 Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, Mackey DA, Foster PJ. The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis. *Ophthalmology* 2012; **119**(10): 2141–2151.
52 Megaw PL, Boelen MG, Morgan IG, Boelen MK. Diurnal patterns of dopamine release in chicken retina. *Neurochem Int* 2006; **48**(1): 17–23.
53 Megaw P, Morgan I, Boelen M. Vitreal dihydroxy phenylacetic acid (DOPAC) as an index of retinal dopamine release. *J Neurochem* 2001; **76**(6): 1636–1644.
54 McCarthy D, Lueras P, Bhide PG. Elevated dopamine levels during gestation produce region-specific decreases in neurogenesis and subtle deficits in neuronal numbers. *Brain Res* 2007; **1182**: 11–25.
55 Lu B, Congdon N, Liu X, Choi K, Lam DS, Zhang M *et al.* Associations between near work, outdoor activity, and myopia among adolescent students in rural China: the

Xichang Pediatric Refractive Error Study report no. 2. *Arch Ophthalmol* 2009; **127**(6): 769–775.
56 Machida S, Hasegawa Y, Kondo M, Fujiwara T, Asano T, Murai K *et al*. High prevalence of myopia in Japanese patients with idiopathic focal subretinal neovascularization. *Retina* 2006; **26**(2): 170–175.
57 Fricke TR, Holden BA, Wilson DA, Schlenther G, Naidoo KS, Resnikoff S *et al*. Global cost of correcting vision impairment from uncorrected refractive error. *Bull World Health Organ* 2012; **90**(10): 728–738.
58 Javitt JC, Chiang YP. The socioeconomic aspects of laser refractive surgery. *Arch Ophthalmol* 1994; **112**(12): 1526–1530.
59 Lim MC, Gazzard G, Sim EL, Tong L, Saw SM. Direct costs of myopia in Singapore. *Eye (Lond)* 2009; **23**(5): 1086–1089.
60 Rose K, Harper R, Tromans C, Waterman C, Goldberg D, Haggerty C *et al*. Quality of life in myopia. *Br J Ophthalmol* 2000; **84**(9): 1031–1034.
61 Takashima T, Yokoyama T, Futagami S, Ohno-Matsui K, Tanaka H, Tokoro T *et al*. The quality of life in patients with pathologic myopia. *Jpn J Ophthalmol* 2001; **45**(1): 84–92.
62 Yokoi T, Moriyama M, Hayashi K, Shimada N, Tomita M, Yamamoto N *et al*. Predictive factors for comorbid psychiatric disorders and their impact on vision-related quality of life in patients with high myopia. *Int Ophthalmol;* e-pub ahead of print 21 June 2013; doi:10.1007/s10792-013-9805-8.
63 Cheng SC, Lam CS, Yap MK. Prevalence of myopia-related retinal changes among 12-18 year old Hong Kong Chinese high myopes. *Ophthalmic Physiol Opt* 2013; **33**(6): 652–660.