Review Article

Evidence for an "Epidemic" of Myopia

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Abstract

Introduction: It has been widely suggested that the prevalence of myopia is growing worldwide, and that the increases observed in East Asia, in particular, are sufficiently severe as to warrant the term "epidemic". Data in favour of a cohort effect in myopia prevalence are reviewed, with attention to significant shortcomings in the quality of available evidence. Additional factors contributing to myopia prevalence, including near work, genetics and socioeconomic status, are detailed. Materials and Methods: Medline search of articles regarding myopia prevalence, trends and mechanisms. Results: Age-related changes in myopia prevalence (increase during childhood, and regression in the fifth and sixth decades) are discussed as an alternative explanation for cross-sectional patterns in myopia prevalence. There have only been a handful of studies that have examined the relative contribution of longitudinal changes in refraction over life and birth cohort differences on age-specific myopia prevalence as measured in cross-sectional studies. Available data suggest that both longitudinal changes and cohort effects may be present, and that their relative contribution may differ in different racial groups. Conclusions: In view of the relatively weak evidence in favour of a large cohort effect for myopia in East Asia, and the even greater lack of evidence for increased prevalence of secondary ocular pathology, there appears to be inadequate support for large-scale interventions to prevent or delay myopia at the present time.

Ann Acad Med Singapore 2004;33:21-6

Key words: Cohort effect, Incidence, Prevalence, Refractive error, Trends

Introduction

A number of authors have recently proposed that myopia is increasing at an "epidemic" rate, particularly in East Asia, and especially among populations of Chinese descent.[1-3] It has been reported that the prevalence of myopia among some populations in this area has reached 90%.[4-6] Some writers have suggested that this purported rapid increase in myopia may be related to changing environmental factors, in particular the demands of near work.[7-12] Finally, it has been asserted that the phenomenon of rapidly increasing myopia may lead to an increase in diseases that may be associated with myopia, such as retinal detachment, glaucoma and cataract, and that the threat of such an increase requires preventive action now on the part of health policymakers.[1,3,13] This review offers a critical examination of all of these assertions and the data that have been advanced to support them.

Age, Race, Environment and Myopia

The tendency for myopia to progress from birth until the early teenage years appears to be nearly universal among all races.[14-20] A complementary tendency for myopia to regress during the fifth and sixth decades of life has been recognised since at least the 1950s.[21-24] Significant differences exist in the prevalence of myopia between racial groups, with the Chinese reported to have particularly high rates.[24]

Other Asian populations appear to have myopia rates somewhat higher than those of European populations, but not as high as Chinese.[16,19,21,25] Myopia rates in urban areas are often significantly higher than for rural populations in China and other Asian countries.[9,16,26] It is interesting to note that myopia prevalence as high as 50% to 70% has been reported among the Chinese since at least the 1920s, depending on the definition and mode of data acquisition.[27]

In conjunction with their apparent higher prevalence of myopia, the Chinese[13,28,29] appear to have rates of myopia progression in childhood significantly higher than those of European-derived populations,[30,31] and somewhat higher than for other Asian groups.[18] Saw et al[29] have consistently found rates of myopia progression among Singaporean children aged 6 to 12 years as high as 0.6 D/year, compared to <0.1 D/year

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The authors have no financial or other interest in any of the therapies or techniques discussed in this article.

in Western studies.[14,30,31] It is clear that early refractive errors, possibly as early as in infancy, are a very strong predictor of later myopia,[32,33] and that socioeconomic and educational factors,[34] parental myopia[7] and possibly near work[7-12] also play a significant role. Accurate measurement of exposure, with regards to near work, has somewhat hampered investigation in this area. For example, one study reported that reading 3 or more hours a day is predictive of myopia risk, but reading 2 or more books per week is not.[10]

Myopia Genetics

A number of recent studies leave little doubt that myopia is under strong genetic influence. Classical twin studies in European-derived populations[35,36] have reported high heritability of myopia, in the 90% range, with similar figures for the various biometric factors known to control refractive error, axial length, anterior chamber depth and corneal curvature.[36] Young et al[37,38] have reported candidate loci for myopia genes on chromosomes 12q21-23 region and 18p11.31, while Naiglin et al[39] has reported a separate locus 7q36 . Recently, Paluru et al[40] have reported a new locus for autosomal dominant high myopia to 17q21-22 in a family of 22 individuals. At present, no actual genes controlling myopia are known. Evidence for a genetic effect in myopia among persons of East Asian descent is equally strong,[28] though some have suggested that heritability of myopia is reduced in areas where myopia prevalence is changing rapidly.[2,41,42] Rose et al[2] and Chen et al[43] have pointed out that the mere fact of strong genetic control of myopia does not preclude the possibility of the sort of cohort effect that might result in a myopia "epidemic", as has been reported in East Asia. Both genetic and environmental influences may play a significant role when populations are affected by an unusually high burden of a particular disease, just as genetic propensity, poor diet and obesity appear to combine to produce the high prevalence of diabetes seen among the Pima Indians.[44]

Methodologic Challenges in Myopia Assessment

Reported prevalence of myopia is highly sensitive to the definition used in a given study. As with other important ocular conditions such as cataract,[45] defining myopia involves imposing arbitrary cutoffs on what is essentially a continuous distribution. There is no commonly accepted definition for myopia, which makes comparability between studies in different racial groups, and even between studies done at different times within a given population, extremely difficult. One investigator has reported that the very small shift in cutoff from –0.50 to –0.75 D would decrease myopia prevalence by 22% in the population he was studying.[46] The potential impact of incompatible definitions of myopia must always be borne in mind when attempting to assess time trends or population differences in myopia prevalence.

When investigators state that an "epidemic" of myopia is occurring in East Asia, they are describing a phenomenon known formally as a "cohort effect". When a cohort effect is present, individuals born during a certain period are subject to environmental influences not present for individuals born in an earlier or later period. An example of this might be the AIDS epidemic: the life expectancy for sexually active adults in Uganda today is some 20 years less than what it was 15 years ago.[47] The cohort effect that is most commonly postulated to explain the supposed current epidemic of myopia in East Asia is the increased demand for near work due to rising educational standards in many urbanised East Asian communities, including Singapore,[6,28,48-51] Hong Kong[15] and Japan.[18]

Often, investigators draw inferences about cohort effects, which are inherently longitudinal, from cross-sectional data, simply because such data are more easily acquired. In fact, the vast majority of the data that has been adduced in favour of an Asian myopia epidemic is cross-sectional in nature. The problem with trying to make a case for increasing incidence of myopia from cross-sectional data is that, as noted above, myopia prevalence increases naturally with age in nearly all populations. Many investigators have noted the large increases in myopia prevalence observed cross-sectionally between the primary and secondary school years as evidence of a cohort effect, while in fact such data may simply point to an effect of ageing occurring among individuals in a single cohort. Similarly, cross-sectional studies showing lower prevalence of myopia among individuals in theirs 60s as compared to their 40s[48] have frequently been interpreted as evidence that the younger cohort has been subjected to more near work demands than their less-educated parents; again, however, these cross-sectional trends may simply represent a normal effect of ageing. As noted above, the decline in myopia in the decades immediately following the onset of presbyopia is a frequently described phenomenon.

Other studies have also attempted to draw inferences about a supposed "myopia epidemic" by following a single cohort over time. Studies that demonstrate the progression of myopia in a single cohort[42] are, by definition, unable to establish the presence of a cohort effect. This can only be demonstrated by comparing 2 or more cohorts measured at different points in time, ideally using identical techniques and definitions.

Available Evidence for an Epidemic of Myopia

East Asian Populations

However, such studies are extremely rare in East Asia. Lin and colleagues[4,5,52] have examined refractive error distribution among very large groups of school children in Taiwan for decades now. Based on these studies, they conclude that myopia prevalence is increasing rapidly in Taiwan.[4,5] Careful review of these manuscripts reveals significant uncertainties regarding such assertions. The publication, establishing the baseline myopia prevalence from which more recent comparisons have been drawn, does not provide a definition of myopia, nor does it clearly describe the methodology for measuring refractive error.[52] More recent work by this group has chosen an unusually low cutoff for myopia (spherical equivalent <0.25 D), leading to some very high prevalence figures, in excess of 90%, that are often quoted in this debate.[5] More importantly, Lin's group has chosen to sample children by school throughout their studies. Though efforts have been made to reflect the national distribution of school types,[5] this sampling technique is extremely susceptible to distortion. Myopia prevalence is notoriously susceptible to socioeconomic status and educational background.[9,11,21,48] As with many other countries, Taiwan has a broad variety of schools with curricula of varying rigor. A sampling scheme that selects by school will be extremely sensitive to the type of schools selected, and extraordinarily difficult to reproduce over time, as the curricula at different schools change. These methodological problems make it difficult to accept Lin et al's data as convincing evidence of a cohort effect in myopia prevalence.

Matsumura and Hirai[18] have carried out similar school-based studies of myopia among various cohorts of Japanese school children over at least a decade, and similarly conclude that myopia prevalence is increasing. Their studies appear to be free of the definitional and methodological uncertainties noted in the Taiwanese investigations, in that the same definition of myopia appears to have been applied throughout the study period to subjects at the same school. However, the school-based approach is once again susceptible to confounding found.

As the authors themselves note,[18] the best Japanese schools have become increasingly competitive. It is plausible that the more competitive schools are now attracting a more socioeconomically advantaged and more rigorously schooled subset of the Japanese population, such as those better able to afford cram schools. Of course, factors such as socioeconomic status and education are known to correlate well with increased myopia risk. Concluding from such school-based studies that the entire Japanese population is becoming more myopic might well be analogous to a fictitious sociologist's attempt to gauge the mean income of Americans by interviewing different cohorts of party-goers to Studio 54 throughout the 1970s. As entry to the club becomes more sought after, the social status, and presumably income of attendees increases, but it would likely be erroneous to conclude that this phenomenon mirrored income growth in America as a whole. Though the analogy may seem far-fetched, it underscores the very real potential for serious confounding in attempting to study myopia through schools, when education is perhaps the strongest environmental association for the condition.

Perhaps the strongest available evidence supporting a significant cohort effect in myopia comes from Singapore, where vision testing has been carried out for decades on all males as part of the compulsory system of military service. Tay et al[51] have reported on the resulting large database of over 400,000 young men, arbitrarily dividing it into two cohorts: 1974 to 1984 and 1987 to 1991. The authors conclude that the prevalence of myopia increased from 26.3% in the earlier cohort to 43.3% in the later cohort. Available evidence suggests that military recruits in Singapore do, in fact, represent a population-based sample. It appears that the racial breakdown of the sample did not change significantly over time,[51] which is an important issue, as the prevalence of myopia appears to be significantly higher among the Chinese relative to the other ethnic groups in Singapore. However, significant problems remain with this widely cited paper: myopia is defined as vision in the right eye without correction worse than 6/18 (while excluding persons whose vision could not be corrected to 6/18 or better with refraction). Such a definition is subjective and prone to manipulation by the subject, particularly when avoidance or reduction of compulsory military responsibilities may be at stake. Moreover, the impact of refractive errors other than myopia cannot be assessed. Methodologic description of the protocol for measuring vision is essentially nil, and thus important changes over time in measurement protocol cannot be excluded. Finally, although the authors indicate that vision examinations were carried out at a mean age of 17.5 to 17.75 years, no data are given to show whether this age changed over the study period. Given the tendency of myopia to increase with age in this young adult population, the impact of any change on the mean recruitment age cannot be excluded. It is interesting that, while the authors conclude that higher educational attainment to be the cause of increased prevalence of myopia between the two cohorts, their data show an increasing prevalence of myopia across the various educational strata as well.

Inuit Populations

It has been suggested that an "epidemic" of myopia is also occurring among Eskimos. Accurate data to support these assertions are even more difficult to obtain than the populations of East Asia. Many papers simply assert that such an "epidemic" is in progress, but fail to provide longitudinal or cohort data of any kind.[53] Even the most carefully-performed studies, such as those by Alsbirk[54] among Eskimos in Greenland, suffer from small population numbers and do not adjust for potentially important shifts in age and gender. Similar assertions regarding cohort changes towards myopia have been made for Australian aborigines, but the as-yet unpublished data (Taylor HR, Robin TA, Lansingh VC, Weih LM, Keefe JE. ARVO abstract 800; 2003) similarly fail to adjust for a very significant shift toward female preponderance between the 1978 and 2001 cohorts of 20- to 30-year olds. Myopia prevalence for young women is significantly higher in a number of populations, including Eskimos and Chinese.

European-derived Populations

Some investigators[1,30] have concluded that myopia prevalence is also increasing in a cohort-based fashion among European-derived populations, in addition to East Asians and Eskimos. However, the conclusion that Westerners are suffering from their own "myopia epidemic" is hardly universal. Mutti and Zadnik[22] have reviewed available evidence from the United States and conclude that these data are more consistent with increasing hyperopia in the 5th and 6th decades of life, rather than a cohort effect. Fledelius[55] similarly concludes that myopia prevalence rates among Danish medical students have not changed significantly over many decades. Once again, school-based data must be viewed with caution; it is entirely possible that confounding of the type described above, but in the reverse direction, might lead to the erroneous conclusion that myopia prevalence is stable in the population as a whole, based only on socioeconomic trends controlling school admission.

In the Framhingham Offspring Eye Study,[56] the prevalence of myopia was found to decrease with age in 1585 offspring of 1319 parents aged 23 to 78 years. In addition, the association of myopia between siblings was found to be weaker with increasing between-sibling age. The authors suggest that the decreasing prevalence of myopia with age, coupled with the decreasing association of myopia between sibling pairs of increasing age differences, is the result of a cohort effect, in which the younger of the two siblings were at a greater risk of myopia. The authors assume that the degree of myopia remains static after adolescence, and thus conclude that their findings point towards an increasing incidence of myopia. In fact, the results are consistent with a normal decrease in myopia with ageing over life.

The strongest direct evidence in favour of a cohort effect for myopia among Caucasians is provided by the 10-year follow-up of refractive information in the Beaver Dam Eye Study.[57] These data reveal a decreasing prevalence of myopia with age as the result of longitudinal changes, consistent with previous studies. However, by treating the refractions observed at each examination of a person as independent observations and plotting those by age, a birth cohort effect was also demonstrated. The average refractions in persons 55 to 59 years were +0.20 D, –0.13 D, and –0.50 D, for those born between 1928 to 1932, 1933 to 1937, and 1938 to 1942, respectively. This difference between birth cohorts in other age ranges had a similar trend, but was not statistically significant. The study concludes that, in addition to longitudinal changes in refraction, there is also a birth cohort effect in which those persons born more recently are at a higher risk of myopia.

Conclusion

It would seem reasonable to conclude, based on the weight of available evidence, that the case for a "myopia epidemic" has not yet been entirely proven. Even if one accepts that myopia prevalence is increasing dramatically in Asia, and there are good reasons as noted above to believe that this trend has been somewhat exaggerated, the attention of health policymakers should only justifiably be directed towards this "problem" if there are data to suggest that increased myopia is anything more than an inconvenience for those affected. While it is known that myopia may be associated with increased risk for retinal detachment,[58] and perhaps glaucoma[59] and cataract,[49,60,61] there is little if any data to suggest how acquired myopia from environmental factors affects the shape of the eye, and equally little data to suggest a cohort increase in retinal detachment or other eye diseases that might reasonably be attributed to an epidemic of myopia.[62] While Lam et al[63] have suggested that the majority of increase in axial length in acquired myopia occurs in the vitreous cavity, Zhang et al[64] have suggested that the anterior segment is primarily involved. The resolution of this issue might have significant implications for future prevalence of retinal detachment, or of angle-closure glaucoma, if one accepts the myopia cohort effect hypothesis.

Recent studies[65-69] have provided evidence of our ability to intervene early in life to decrease myopia progression. However, there is much uncertainty about the reality of a "myopia epidemic", and a paucity of data to suggest any significant increase in more serious diseases, such as retinal detachment. It cannot be denied that uncorrected myopia is a potentially serious public health problem.[29,70] However, it appears on the weight of the evidence that those rural areas in the developing world, which lack the resources to correct myopia with spectacles, are precisely the areas at the least risk for the problem. They are also the populations least able to afford invasive preventive measures for myopia. Just because research has potentially given us the tools to retard or prevent myopia early in life does not clearly imply that such invasive and potentially resource-intensive measures are either warranted or cost-effective.

Acknowledgement

Dr Congdon is supported by a Career Development Award from Research to Prevent Blindness and a K-23 Award from the National Eye Institute (EY00388).

REFERENCES

1. Rose K, Smith W, Morgan I, Mitchell P. The increasing prevalence of myopia: implication for Australia. Clin Exp Ophthalmol 2001;29: 116-20.
2. Rose KA, Morgan IG, Smith W, Mitchell P. High heritability of myopia does not preclude rapid changes in prevalence. Clin Exp Ophthalmol 2002;30:168-72.
3. Seet B, Wong TY, Tan DT, Saw SM, Balakrishnan V, Lee LK, et al. Myopia in Singapore: taking a public health approach. Br J Ophthalmol 2001;85:521-6.
4. Lin LL, Shih YF, Hsiao CK, Chen CJ, Lee LA, Hung PT. Epidemiologic study of the prevalence and severity of myopia among school children in Taiwan in 2000. J Formos Med Assoc 2001;100:684-91.
5. Lin LL, Shih YF, Tsai CB, Chen CJ, Lee LA, Hung PT, et al. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. Optom Vis Sci 1999;76:275-81.
6. Saw SM, Wu HM, Seet B, Wong TY, Yap E, Chia KS, et al. Academic achievement, close up work parameters, and myopia in Singapore military conscripts. Br J Ophthalmol 2001;85:855-60.
7. 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;43:3633-40.
8. Saw SM, Zhang MZ, Hong RZ, Fu ZF, Pang MH, Tad DT. Near-work activity, night-lights, and myopia in the Singapore-China study. Arch Ophthalmol 2002;120:620-7.
9. Saw SM, Hong RZ, Zhang MZ, Fu ZF, Ye M, Tan D, et al. Near-work activity and myopia in rural and urban schoolchildren in China. J Pediatr Ophthalmol Strabismus 2001;38:149-55.

10. Tan GJ, Ng YP, Lim YC, Ong PY, Snodgrass A, Saw SM. Cross-sectional study of near-work and myopia in kindergarten children in Singapore. Ann Acad Med Singapore 2000;29:740-4.
11. Saw SM, Chua WH, Wu HM, Yap E, Chia KS, Stone RA. Myopia: gene-environment interaction. Ann Acad Med Singapore 2000;29:290-7.
12. Kinge B, Midelfart A, Jacobsen G, Rystad J. The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. Acta Ophthalmol Scand 2000;78:26-9.
13. Zhao J, Mao J, Luo R, Li F, Munoz SR, Ellwein LB. The progression of refractive error in school-age children: Shunyi district, China. Am J Ophthalmol 2002;134:735-43.
14. Zadnik K, Mutti DO, Friedman NE, Adams AJ. Initial cross-sectional results from the Orinda Longitudinal Study of Myopia. Optom Vis Sci 1993;70:750-8.
15. Goldschmidt E, Lam CS, Opper S. The development of myopia in Hong Kong children. Acta Ophthalmol Scand 2001;79:228-32.
16. Dandona R, Dandona L, Srinivas M, Sahare P, Narsaiah S, Munoz SR, et al. Refractive error in children in a rural population in India. Invest Ophthalmol Vis Sci 2002;43:615-22.
17. Maul E, Barroso S, Munoz SR. Refractive Error Study in Children: results from La Florida, Chile. Am J Ophthalmol 2000;129:445-54.
18. Matsumura H, Hirai H. Prevalence of myopia and refractive changes in students from 3 to 17 years of age. Surv Ophthalmol 1999;44:S109-15.
19. Murthy GV, Gupta SK, Ellwein LB, Munoz SR, Pokharel GP, Sanga L, et al. Refractive error in children in an urban population in New Delhi. Invest Ophthalmol Vis Sci 2002;43:623-31.
20. Wang Q, Klein BE, Klein R, Moss SE. Refractive status in the Beaver Dam Eye Study. Invest Ophthalmol Vis Sci 1994;35:4344-7.
21. Shimizu N, Nomura H, Ando F, Niino N, Miyake Y, Shimokata H. Refractive errors and factors associated with myopia in an adult Japanese population. Jpn J Ophthalmol 2003;47:6-12.
22. Mutti DO, Zadnik K. Age-related decreases in the prevalence of myopia: longitudinal change or cohort effect? Invest Ophthalmol Vis Sci 2000;41:2103-7.
23. Lam CS, Goh WS, Tang YK, Tsui KK, Wong WC, Man TC. Changes in refractive trends and optical components of Hong Kong Chinese aged over 40 years. Ophthalmic Physiol Opt 1994;14:383-8.
24. Wu HM, Seet B, Yap EP, Saw SM, Lim TH, Chia KS. Does education explain ethnic differences in myopia prevalence? A population-based study of young adult males in Singapore. Optom Vis Sci 2001;78:234-9.
25. Dandona R, Dandona L, Srinivas M, Giridhar P, McCarty CA, Rao GN. Population-based assessment of refractive error in India: the Andhra Pradesh eye disease study. Clin Experiment Ophthalmol 2002;30:84-93.
26. Dandona R, Dandona L, Naduvilath TJ, Srinivas M, McCarty CA, Rao GN. Refractive errors in an urban population in Southern India: the Andhra Pradesh Eye Disease Study. Invest Ophthalmol Vis Sci 1999;40:2810-8.
27. Rasmussen OD. Incidence of myopia in China. Br J Ophthalmol 1936;20:350-36.
28. Saw SM, Nieto FJ, Katz J, Schein OD, Levy B, Chew SJ. Familial clustering and myopia progression in Singapore school children. Ophthalmic Epidemiol 2001;8:227-36.
29. Saw SM, Nieto FJ, Katz J, Schein OD, Levy B, Chew SJ. Factors related to the progression of myopia in Singaporean children. Optom Vis Sci 2000;77:549-54.
30. Hirsch MJ. Anisometropia: a preliminary report of the Ojai Longitudinal Study. Am J Optom Arch Am Acad Optom 1967;44:581-5.
31. Pointer J. A 6-year longitudinal optometric study of the refractive trend in school-aged children. Ophthalmic Physiol Opt 2001;21:361-7.
32. Zadnik K, Mutti DO, Friedman NE, Qualley PA, Jones LA, Qui P, et al. Ocular predictors of the onset of juvenile myopia. Invest Ophthalmol Vis Sci 1999;40:1936-43.
33. Edwards MH, Shing FC. Is refraction in early infancy a predictor of myopia at the age of 7 to 8 years? The relationship between cycloplegic refraction at 11 weeks and the manifest refraction at age 7 to 8 years in Chinese children. Optom Vis Sci 1999;76:272-4.
34. Saw SM, Chia SE, Chew SJ. Relation between work and myopia in Singapore women. Optom Vis Sci 1999;76:393-6.
35. Hammond CJ, Snieder H, Gilbert CE, Spector TD. Genes and environment in refractive error: the twin eye study. Invest Ophthalmol Vis Sci 2001;42:1232-6.
36. Lyhne N, Sjolie AK, Kyvik KO, Green A. The importance of genes and environment for ocular refraction and its determiners: a population based study among 20-45 year old twins. Br J Ophthalmol 2001;85:1470-6.
37. Young TL, Ronan SM, Alvear AB, Wildenberg SC, Oetting WS, Atwood LD, et al. A second locus for familial high myopia maps to chromosome 12q. Am J Hum Genet 1998;63:1419-24.
38. Young TL, Ronan SM, Drahozal LA, Wildenberg SC, Alvear AB, Oetting WS, et al. Evidence that a locus for familial high myopia maps to chromosome 18p. Am J Hum Genet 1998;63:109-19.
39. Naiglin L, Gazagne C, Dallongeville F, Thalamas C, Idder A, Rascol O, et al. A genome wide scan for familial high myopia suggests a novel locus on chromosome 7q36. J Med Genet 2002;39:118-24.
40. Paluru P, Ronan SM, Heon E, Devoto M, Wildenberg SC, Scavello G, et al. New locus for autosomal dominant high myopia maps to the long arm of chromosome 17. Invest Ophthalmol Vis Sci 2003;44:1830-6.
41. Goh WS, Lam CS. Changes in refractive trends and optical components of Hong Kong Chinese aged 19-39 years. Ophthalmic Physiol Opt 1994;14:378-82.
42. Edwards MH. Effect of parental myopia on the development of myopia in Hong Kong Chinese. Ophthalmic Physiol Opt 1998;18:477-83.
43. Chen CJ, Cohen BH, Diamond EL. Genetic and environmental effects on the development of myopia in Chinese twin children. Ophthalmic Paediatr Genet 1985;6:353-9.
44. Pratley RE. Gene environment interactions in the pathogenesis of type 2 diabetes mellitus: lessons learned from the Pima Indians. Proc Nutr Soc 1998;57:175-81.
45. Klein BE, Klein R, Lee KE, Meuer SM. Socioeconomic and lifestyle factors and the 10-year incidence of age-related cataracts. Am J Ophthalmol 2003;136:506-12.
46. Wensor M, McCarty CA, Taylor HR. Prevalence and risk factors of myopia in Victoria, Australia. Arch Ophthalmol 1999;117:658-63.
47. Boerma JT, Nunn AJ, Whitworth JA. Mortality impact of the AIDS epidemic: evidence from community studies in less developed countries. AIDS 1998;12:S3-14.
48. 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;41:2486-94.
49. Wong TY, Klein R, Tomany SC, Lee KE, Klein BE. Refractive errors and incident cataracts: the Beaver Dam Eye Study. Invest Ophthalmol Vis Sci 2001;42:1449-54.
50. Tan NW, Saw SM, Lam DS, Cheng HM, Rajan U, Chew SJ. Temporal variations in myopia progression in Singaporean children within an academic year. Optom Vis Sci 2000;77:465-72.
51. Tay MT, Au Eong KG, Ng CY, Lim MK. Myopia and educational attainment in 421,116 young Singaporean males. Ann Acad Med Singapore 1992;21:785-91.
52. Lin LL, Chen CJ, Hung PT, Ko LS. Nation-wide survey of myopia among schoolchildren in Taiwan, 1986. Acta Ophthalmol Suppl 1988;185: 29-33.
53. Morgan RW, Speakman JS, Grimshaw SE. Inuit myopia: an environmentally-induced epidemic? CMAJ 1975;112:575-7.
54. Alsbirk PH. Refraction in adult West Greenland Eskimos. A population study of spherical refractive errors, including oculometric and familial correlations. Acta Ophthalmol (Copenh) 1979;57:84-95

55. Fledelius HC. Myopia profile in Copenhagen medical students 1996-98. Refractive stability over a century is suggested. Acta Ophthalmol Scand 2000;78:501-5.
56. The Framingham Offspring Eye Study Group. Familial aggregation and prevalence of myopia in the Framingham Offspring Eye Study. Arch Ophthalmol 1996;114:326-32.
57. Lee KE, Klein BE, Klein R, Wong TY. Changes in refraction over 10 years in an adult population: the Beaver Dam Eye study. Invest Ophthalmol Vis Sci 2002;43:2566-71.
58. Fivgas GD, Capone A Jr. Pediatric rhegmatogenous retinal detachment. Retina 2001;21:101-6.
59. Mitchell P, Hourihan F, Sandbach J, Wang JJ. The relationship between glaucoma and myopia: the Blue Mountains Eye Study. Ophthalmology 1999;106:2010-5.
60. Lim R, Mitchell P, Cumming RG. Refractive associations with cataract: the Blue Mountains Eye Study. Invest Ophthalmol Vis Sci 1999;40: 3021-6.
61. Younan C, Mitchell P, Cumming RG, Rochtchina E, Wang JJ. Myopia and incident cataract and cataract surgery: the Blue Mountains Eye Study. Invest Ophthalmol Vis Sci 2002;43:3625-32.
62. Zou H, Zhang X, Xu X, Wang X, Liu K, Ho PC. Epidemiology survey of rhegmatogenous retinal detachment in Beixinjing District, Shanghai, China. Retina 2002;22:294-9.
63. Lam CS, Edwards M, Millodot M, Goh WS. A 2-year longitudinal study of myopia progression and optical component changes among Hong Kong schoolchildren. Optom Vis Sci 1999;76:370-80.
64. Zhan MZ, Saw SM, Hong RZ, Fu ZF, Yang H, Shui YB, et al. Refractive errors in Singapore and Xiamen, China – comparative study in school children aged 6 to 7 years. Optom Vis Sci 2000;77:302-8.
65. Saw SM, Gazzard G, Au Eong KG, Tan DT. Myopia: attempts to arrest progression. Br J Ophthalmol 2002;86:1306-11.
66. Saw SM, Shih-Yen EC, Koh A, Tan D. Interventions to retard myopia progression in children: an evidence-based update. Ophthalmology 2002;109:415-4.
67. Chiang MF, Kouzis A, Pointer RW, Repka MX. Treatment of childhood myopia with atropine eyedrops and bifocal spectacles. Binocul Vis Strabismus Q 2001;16:209-15.
68. Syniuta LA, Isenberg SJ. Atropine and bifocals can slow the progression of myopia in children. Binocul Vis Strabismus Q 2001;16:203-8.
69. Kennedy RH, Dyer JA, Kennedy MA, Parulkar S, Kurland LT, Herman DC, et al. Reducing the progression of myopia with atropine: a long-term cohort study of Olmsted County students. Binocul Vis Strabismus Q 2000;15:281-304.
70. Maini R, Keeffe J, Weih LA, McCarty CA, Taylor HR. Correction of refractive error in the Victorian population: the feasibility of "off the shelf" spectacles. Br J Ophthalmol 2001;85:1283-6.