PERSPECTIVE

The epidemiology of age related eye diseases in Asia

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Br J Ophthalmol 2006;**90**:506–511. doi: 10.1136/bjo.2005.083733

In the past decade, several large population based studies have provided new information on the prevalence of visual impairment and the major age related eye diseases in Asia. These include epidemiological studies from India, Taiwan, Mongolia, Singapore, and Japan. In particular, the epidemiology of refractive errors and glaucoma has been well characterised, providing insights not only into the public health implications of these conditions, but also into anatomical changes of the eye with ageing. In contrast, there are few well conducted population based studies on diabetic retinopathy and age related macular degeneration in Asia, two conditions that are likely to be important causes of blindness in the future.

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Accepted for publication 5 December 2005

Asia is the world's largest continent, with more than half of the world's population. Up to 20 million Asians are estimated to be blind by the World Health Organization (WHO),[1] a figure that is expected to increase as the population ages. In Western populations, the epidemiology of visual impairment and its major causes have been well described, and summarised in a series of meta-analyses.[2–5] Until recently, similar data in Asian populations were lacking.

In the past decade, however, there have been several population based studies on the prevalence of visual impairment and common age related eye diseases in Asia. Among people of Chinese ethnicity, these include the Shihpai Eye Study in Taiwan,[6–8] the Tanjong Pagar Survey in Singapore,[9–17] and the Beijing Eye Study in mainland China.[18 19] There is increasing epidemiological data arising from India.[20] Of particular importance are the Andhra Pradesh Eye Study[21–26] and the Aravind Comprehensive Eye Study.[27–31] A survey in Sumatra, Indonesia, has provided information on the epidemiology of eye diseases in rural Indonesians,[32–35] and new studies, such as the ongoing Singapore Malay Eye Study, will provide further estimates of major eye diseases in urban Malay populations (Wong TY. *Am J Ophthalmol* 2005;**139**:S13, abstract).

In general, these Asian studies reveal important information and interesting patterns of eye diseases. The higher prevalence of myopia and angle closure glaucoma in Chinese people compared to white people is now supported by more precise population based data, underlying their potential public health importance in China.[36 37] Even within a single Asian country, significant racial/ethnic variations may exist. Of the three major racial/ethnic groups in Singapore, for example, Chinese people have a higher prevalence of myopia,[37] a higher incidence of acute angle closure glaucoma,[38 39] and higher rates of retinal detachment,[40] than Indians and Malays. Understanding these racial/ethic variations may provide invaluable insights into the aetiology and pathogenesis of these conditions and, ultimately, their prevention or treatment.

BLINDNESS AND LOW VISION

There have been a series of studies on the prevalence of blindness in Asia,[6 9 27 41–49] and these are summarised in table 1. Approximately half of the studies defined blindness using the WHO definition (visual acuity of <3/60 in the better eye), while other studies defined blindness using the US definition (visual acuity of <6/60 in the better eye). Most studies did not specify visual field criteria. Even taking into account different definitions, study population compositions and sampling strategies, the prevalence of blindness varies between Asian studies. Based on the WHO definition, the prevalence of blindness in Singapore (0.5%),[9] Malaysia (0.3%),[46] and Taiwan (0.6%)[6] appears to be similar to estimates in the United States (0.5%),[2] and lower than in Mongolia (1.5%),[41] Bangladesh (1.5%),[48] rural Indonesia (2.2%),[35] and India (4.3%).[27]

The two most common causes of blindness in Asian studies are cataract and undercorrected refractive errors (table 1). This contrasts with Western populations, in which the leading cause of blindness (accounting for more than 50% of cases) is age related macular degeneration (AMD) in white people, and cataract and glaucoma in black people.[2] However, in Singapore and Mongolia, glaucoma was the principal cause of both unilateral and bilateral blindness,[9 41] while in the Shihpai Eye Study in Taiwan, retinal diseases as a group, including AMD and myopic degeneration, were the leading cause.[6]

The prevalence of low vision (visual acuity of <6/18 in the better eye) is about 2–10 times higher than the estimates of blindness in these studies.[6 9 27 41–49] Undercorrected refractive errors appear to be an increasingly recognised condition. In the Aravind Eye Survey in India, among participants with low vision, more than 70% of subjects improved their vision by at least one line, and more than 30% by three lines after refraction, which indicates that the major cause of low vision was undercorrected refractive

Abbreviations: AMD, age related macular degeneration; CURES, Chennai Urban Rural Epidemiological Study; DR, diabetic retinopathy; LOCS III, Lens Opacity Classification III; PACG, primary angle closure glaucoma; POAG, primary open angle glaucoma; PSC, posterior subcapsular cataract; VA, visual acuity

Table 1 Prevalence of blindness in Asia, major population based studies

Year	Study and location	Population	Prevalence	Definition	Main causes
1994	Mongolia[41]	4345, ⩾40 years	1.5%	VA<3/60 in better eye*	Glaucoma, cataract
1998	Nepal[42]	5112, ⩾45 years	5.3%	VA<6/60 in better eye	Cataract
1998	Shunyi, China[43]	5052, ⩾50 years	2.8%	VA<6/60 in better eye	Cataract, refractive error
1999	Doumen China[44]	5342, ⩾50 years	4.37%	VA<6/60 in better eye	Cataract, refractive error
2001	Rajasthan, India[45]	4284, ⩾50 years	11.9%	VA<6/60 in better eye	Cataract, refractive error
2001	Andhra Pradesh Eye Study, India[21]	10 293, all ages	1.84%	VA<6/60 in better eye†	Cataract, refractive error
2002	Malaysia[46]	18 027, all ages	0.3%	VA<3/60 in better eye*	Cataract, retinal diseases
2002	Shatin Hong Kong[47]	3441 ⩾60 years	1.8%	VA<6/60 in better eye	Cataract, AMD
2003	Dhaka, Bangladesh[48]	11 624, ⩾30 years	1.53%	VA<3/60 in better eye*	Cataract, refractive error
2003	Tibet, China[49]	12 644, all ages	1.4%	VA<6/60 in the better eye	Cataract, AMD
2003	Aravind Eye Study, India[27]	5150, ⩾40 years	11.4%	VA<6/60 in better eye	Cataract, refractive error
			4.3%	VA<3/60 in better eye*	
2003	Sumatra Eye Study, Indonesia[35]	989, ⩾21 years	2.2%	VA<3/60 in better eye*	Cataract
2004	Shihpai Eye Study, Taiwan[7]	1361, ⩾65 years	0.59%	VA<3/60 in better eye*	AMD, retinal diseases
2004	Tanjong Pagar Survey, Singapore[9]	1232, ⩾40 years	0.5%	VA<3/60 in better eye*	Glaucoma, cataract

VA, visual acuity; AMD, age related macular degeneration. *WHO definition of blindness, †Or constriction of visual field <20° from fixation in the better eye.

errors.[27] In the Tanjong Pagar Survey, undercorrected refractive error, defined as an improvement of visual acuity of at least two lines or more with best possible refractive correction in the better eye, was seen in 17.3% of Chinese adult Singaporeans.[17] Similar patterns have been found in populations that have examined this particular problem.

There is some evidence that blindness rates may decline with a country's socioeconomic development. In Malaysia, two studies conducted in the same village 10 years apart showed prevalence rates of blindness decreasing from 1.7% in 1984 to 0.7% in 1994.[50 51] In a more recent Malaysian survey in 1998, the prevalence of blindness was noted to be only 0.3%.[46]

AGE RELATED CATARACT

The prevalence of cataract in different Asian studies is summarised in table 2. Like estimates of visual impairment and blindness, overall cataract prevalence vary widely between studies,[7 15 29 53–57] and comparison is hindered by differing population characteristics and diagnostic methods of lens opacity. Based on clinical examination using the Lens Opacity Classification III (LOCS III), the Tanjong Pagar Survey reported a cataract prevalence of 35% in Chinese people 40 years and older in Singapore,[15] This is similar to estimates from the Beaver Dam Eye Study in Wisconsin.[52]

In a comparative study of three countries, Reykjavik (n = 197), Australia (Melbourne) (n = 231), and Singapore (n = 92), using the same methodology to define cortical cataract, Sasaki and colleagues demonstrate higher rates of cortical cataract in Singapore compared to Melbourne and Reykjavik.[58] This study suggests that the higher prevalence of cortical cataracts in lower latitudes may be related to increased ultraviolet radiation exposure. The high prevalence of pterygium in Singapore, another condition linked to high ultraviolet radiation exposure, further supports such a theory.[14]

Several of these Asian studies have identified a range of risk factors for cataract, including female sex, lower socioeconomic status, diabetes mellitus, cigarette smoking, and lower body mass index.[7 16 29 53 56 57] Many of these risk factors are similar to studies in white populations, supporting a concept that common aetiological mechanisms are probably responsible for age related cataracts.

There are few data on cataract surgery rates in Asia. The WHO has suggested that an annual rate of 350 surgeries per 100 000 is a useful target to tackle the burden of cataract blindness.[59] In some Asian countries,[60] but not others,[61 62] this threshold may have been reached.

MYOPIA AND OTHER REFRACTIVE ERRORS

The higher prevalence of myopia in children and young adults in Singapore, Taiwan, and Hong Kong,[37 63 64] in comparison with children in western countries such as Australia,[65] is well established.

Population based data in adult Asian populations suggest a more complex picture (table 3). The Tanjong Pagar Survey first suggested that the prevalence of myopia (more than −0.5 dioptres spherical equivalent) in Chinese adults 40 years and older was nearly twice the rates in similarly aged white populations,[12] including the Baltimore Eye Study,[66] and the Melbourne Visual Impairment Project.[67] However, more recent studies in Taiwan,[8] Beijing,[19] India,[22 68] Bangladesh,[69] and Mongolia[70] indicate that the rates of myopia in other Asian adult populations are not much higher than rates in white adult populations.[3] The reasons for the higher prevalence of myopia in Singapore compared to other Asian countries are unclear, but do suggest that the concept of a myopia "epidemic" should not be generalised to all of Asia.

While the overall rates of myopia may vary between Asian populations, the majority of these studies demonstrate a clear trend of declining prevalence of myopia with age, with younger participants generally having higher myopia rates than older participants.[8 12 19 22 32] The Tanjong Pagar Survey showed that the difference in myopia rates between younger and older people was largely explained by longer axial lengths in younger people.[13] This contrasts with a study in rural Mongolia that reported a low myopia prevalence and no variation in axial lengths between younger and older participants.[70] These observations suggest that the higher myopia prevalence in younger Singaporeans are probably attributable to differences in ocular dimension between birth cohorts, related possibly to improved nutrition, higher education, and an intense near work environment.[37]

Perhaps more important than overall prevalence, there have been suggestions that a significant proportion of Asian adults have high myopia, and may therefore be at risk of potentially blinding conditions such as myopic degeneration.[37] While the prevalence of high myopia (less than −5.0 dioptres) is less than 2% in most Western studies,[66 67] it was reported to be nearly 10% in the Tanjong Pagar Survey.[12] Again, this pattern is not universal to other Asian populations. Recent data from the Beijing Eye Study indicate a high myopia (less than −5.0 dioptres) prevalence of only 3.3%,[19] and in rural populations such as in Sumatra, Indonesia, the prevalence of high myopia (less than −6.0 dioptres) was even lower (0.6%).[32]

Table 2 Prevalence of cataract in Asia, major population based studies

Year	Study and location	Population	Cataract assessment	Prevalence of cataract			
				Any	Nuclear	Cortical	PSC
1982	Punjab, India[53]	1269, ≥30 years	Clinical assessment, VA<6/18	15.1%			
1994	Mongolia[41]	4345, ≥40 years	Clinical assessment, no VA criteria	8.3%			
1989	Tibet, China[54]	1292, ≥40 years	LOCS, VA<6/12	14.6%	2.2%	7.3%	2.7%
1989	Shunyi county, China[55]	6902, >40 years	LOCS, VA<6/12	18.6%			
2000	Taipei, Taiwan[56]	2038, ≥50 years	Clinical assessment, no VA criteria	51.0%	35.0%	7.8%	15.3%
2002	Tanjong Pagar Survey, Singapore[15]	1206, ≥40 years	LOCS III, no VA criteria	34.7%	22.6%	23.9%	7.0%
2003	Aravind Eye Study, India[29]	5150 ≥40 years	LOC III, no VA criteria	61.9%	59.7%	20.0%	24.3%
2003	Shihpai Eye Study, Taiwan[7]	2045 ≥65 years	LOCS III, no VA criteria	59.2%	38.9%	21.9%	9.2%
2005	Sumatra Eye Study, Indonesia[33]	919, ≥21 years	LOCS III, no VA criteria	23.0%	35.7%	30.1%	15.1%
2005	Andhra Pradesh Eye Study, India[57]	7416, ≥16 years	LOCS III and Wilmer, no VA criteria	14.4%	9.2%	5.5%	6.0%

LOCS, Lens Opacities Classification system; PSC, posterior subcapsular cataract; VA, visual acuity.

Risk factors for myopia in adults have been reported in most studies, and include higher education, urban versus rural residential status, and various socioeconomic indicators (for example, higher income, professional occupation).[8 12 19 22 32 71] Many of these risk factors may be proxies for an intense ''near work'' visual environment, which has been investigated extensively in Asian schoolchildren.[37]

There are substantial amounts of data on the epidemiology of other refractive errors, such as hyperopia and astigmatism (table 3). Because refractive errors other than myopia have also been linked with potential ocular morbidity,[72] eye care efforts should not solely focus on the potential impact of myopia.

GLAUCOMA

It has been estimated that half of the world's 70 million people with glaucoma reside in Asia,[73] and that in China alone, nearly 10 million people have glaucoma.[36]

Previous studies in Western populations show significant racial/ethnic variation in glaucoma prevalence between white people and black people, largely related to variation in the prevalence of primary open angle glaucoma (POAG).[4] In the Baltimore Eye Survey, the prevalence of POAG was about four times higher in black people (4–5%) compared to white people (1.1%).[74]

In recent years, there have been several well conducted studies on the epidemiology of glaucoma in Asian people.[10 23 24 28 75–80] These studies indicate that the prevalence of glaucoma ranges from 2.1% in Bangladesh to 5.0% in a recent Japanese population (table 4).

Although it has been hypothesised that primary angle closure glaucoma (PACG) is the more common type of glaucoma among Chinese people,[81] this hypothesis is not supported by population based studies, which indicate that POAG is more common than PACG.[10 23 24 28 77–80] In the Tanjong Pagar Survey, of the 45 participants with glaucoma (3.2% of population), 50% had POAG and only 30% had PACG.[10] Nevertheless, the overall prevalence of PACG in Chinese populations in Singapore and Mongolia is clearly higher than that reported in Western studies.[4 74] The reasons for the higher prevalence of PACG in Chinese people compared to white people are controversial, but studies have documented important differences in anterior chamber and angle anatomy.[82 83]

Because PACG appears to be more visually damaging, the risk of blindness associated with PACG is higher than for POAG.[36] In fact, in both Singapore and Mongolia, glaucoma was the leading cause of blindness,[10 76] and Foster and Johnson have suggested that PACG will probably account for more than 90% of the bilateral glaucoma blindness in China.[36]

There are few data on the incidence of new cases of glaucoma in Asia. In Singapore, the incidence of the acute symptomatic angle closure has been reported, and was highest in Chinese people (12.2/100 000 per year) than Malays (6.0/100 000 per year) and Indians (6.3/100 000 per year).[38 39] However, the incidence of chronic PACG is unknown.

DIABETIC RETINOPATHY

There are few population based data on the prevalence of diabetic retinopathy (DR) in Asia (table 5), with most originating from India.[25 31 84–86] In a 1992 population based study in Taiwan, 35% of 527 subjects 40 years and older with diabetes had retinopathy based on clinical examination,[84] consistent with estimates from Western countries in which retinal photographs were used to diagnosed DR.[87] However, recent studies in India indicate a much lower prevalence of DR.[25 31 85 86] Based on clinical examination, the Andhra

Table 3 Prevalence of refractive errors in Asia, major population based studies

Year	Study and location	Population	Prevalence of refractive errors*		
			Myopia	Hyperopia	Astigmatism
1999	Andhra Pradesh Eye Study, India[22]	2321, ≥16 years	19.4%	9.8%	12.9%
2000	Tanjong Pagar Survey, Singapore[12]	1232, ≥40 years	38.7%	28.4%	37.8%
2002	Sumatra Eye Study, Indonesia[32]	1043, ≥21 years	36.9%	11.4%	27.9%
2003	Shihpai Eye Study, Taiwan[8]	1361, ≥65 years	19.4%	59.0%	74.0%
2004	Tamil Nadu, India[68]	2508, ≥40 years	27.0%	18.7%	54.8%
2004	Bangladesh[69]	11 624, ≥30 years	22.1%	20.6%	32.4%
2004	Mongolia[70]	1800, ≥40 years	16.2%	32.9%	40.9%
2005	Beijing Eye Study, China[19]	4319, ≥40 years	22.9%	20.0%	–

*Definition of myopia: spherical equivalent greater than −0.5 dioptres; hyperopia: spherical equivalent more than +0.5 dioptres; and astigmatism: cylinder more than +0.5 dioptres.

Pradesh Eye Study reported a DR prevalence of 22.4%,[25] while the Aravind Eye Study reported a prevalence of only 10.5%.[31]

The Chennai Urban Rural Epidemiological Study (CURES) recently examined 1382 subjects 20 years and older with known diabetes and 354 with newly diagnosed diabetes (identified using the oral glucose tolerance test) and defined retinopathy based on grading retinal photographs.[86] The CURES reported DR prevalence of 17.6% among known diabetics and 5.1% among newly diagnosed diabetics. The reasons for the lower prevalence of DR in Indians compared to white people are unknown, but should be further investigated to understand possible variations in susceptibility to microvascular complications of diabetes.

AGE RELATED MACULAR DEGENERATION

Racial/ethnic variations in AMD prevalence between black people and white people have been previously reported.[88 89] In the Baltimore Eye Survey, both early and late AMD were more common in white people than black people.[90]

There have been only two population based study on the prevalence of AMD in Asia,[31 91] and none in Chinese populations. In the Aravind Eye Study, early AMD was diagnosed clinically in 2.7% and late AMD in 0.6% of the 4917 Indian participants 40 years and older.[31] The low prevalence of early AMD may reflect the lower sensitivity of clinical examination compared to retinal photography in determining AMD signs.

In a study of 1486 residents aged 50 years and older in Hisayama, Japan, AMD was determined based on grading of retinal photographs.[91 92] The prevalence of early AMD was 12.7% and late AMD 0.87%, with exudative AMD three times as common as geographic atrophy. The 5 year follow up of the cohort showed an incidence of 8.5% for early AMD, and 0.8% for late AMD.[93] These observations suggest that AMD is less common in Japanese people than in white people.[89] The authors have hypothesised this may be related to a higher antioxidant contents in the typical Japanese diet. In the Hisayama study, of a range of possible risk factors examined at baseline, only hypertension was a significant risk factor of AMD in men but not in women,[92] while cigarette smoking was the only significant risk factor for 5 year incident AMD.[93]

LIMITATIONS AND FUTURE RESEARCH

While this review provides a broad summary of the major age related eye diseases in Asia, concentrating primarily on describing unadjusted rates from published data, several limitations should be discussed. Firstly, it is not a formal meta-analysis of Asian epidemiological data like the series of studies arising from the Eye Diseases Prevalence Research Group.[2–5] It is uncertain that such a meta-analysis using currently available Asian data is useful. One of the major problems that this review identified is the difficultly in reconciling disease outcomes defined using non-standardised methods. Cataract, for example, was assessed and defined in different studies using a range of classification schemes, mostly clinical, and by inclusion of visual acuity criteria in some[53–55] but not other studies. By contrast, the Eye Disease Prevalence Research Group were able to capture data from seven studies that defined cataract using standardised lens photography.[5] Should standardised epidemiological data from Asian studies be available in the future, a similar meta-analysis may be possible.

Secondly, comparison of any disease outcomes that are strongly age related are hindered by differences in age structure between study populations. Thus, a higher prevalence of cataract in the Shihpai study in Taiwan (59%),[7] compared to the study in Sumatra, Indonesia (23%),[33] may simply be related to the older study sample in Taiwan. Comparison of age stratified rates will provide clearer insights into relative disease prevalence between studies. Again, the availability of more precise Asian data in the future would facilitate such a comparison.

Finally, it is beyond the scope of this review to provide greater details regarding the epidemiology of specific eye diseases. For some conditions, there have already been previous, more focused reviews, such as the epidemiology

Table 4 Prevalence of glaucoma in Asia, major population based studies

Year	Study and location	Population	Prevalence of glaucoma			
			Overall	POAG	PACG	Secondary
1991	Japan[75]	8126, ≥40 years	3.6%	2.6%	0.3%	0.6%
1996	Mongolia[76]	942, ≥40 years	2.2%	0.5%*	1.4%	0.3%
2000	Tanjong Pagar Survey, Singapore[10]	1232, ≥40 years	3.2%	1.6%	1.0%	0.5%
2000	Andhra Pradesh Eye Study, India[23 24]	2522, ≥40 years		1.6%	1.1%	
2003	Aravind Eye Study, India[28 30]	5150, ≥40 years	2.6%	1.7%	0.5%	0.3%
2003	Thailand[80]	790, ≥50 years	3.8%	2.3%	0.9%	0.7%
2004	Tajimi City, Japan[78 79]	3021, ≥40 years	5.0%	3.9%	0.6%	0.5%
2004	Dhaka, Bangladesh[77]	3562, ≥35 years	2.1%	2.5%	0.4%	0.2%

POAG, primary open angle glaucoma; PACG, primary angle closure glaucoma.
*As all these subjects were older than 60years, the prevalence of POAG was 2.1% for this age group.

Table 5 Prevalence of diabetic retinopathy in Asia, major population based studies

Year	Study and location	Population with diabetes	Retinopathy diagnosis	Prevalence of retinopathy
1992	Taiwan[84]	527, ⩾40 years	Clinical examination	35.0%
1999	Andhra Pradesh Eye Study, India[25]	124, ⩾40 years	Clinical examination	22.4%
2002	Palakkad, India[85]	260, ⩾50 years	Clinical examination	26.2%
2004	Aravind Eye Study, India[31]	228, ⩾40 years	Clinical examination	10.5%
2005	Chennai Urban Rural Epidemiological Study, India[86]	1382 KD, ⩾20 years	Retinal photography	17.6%
		354 ND, ⩾20 years		5.1%

KD, known diabetes; ND, newly diagnosed diabetes.

of glaucoma in China,[36] or myopia in Singapore.[37] Rather, the current review serves to highlight areas in which precise Asian epidemiological data are now available, and areas with considerable gaps in the Asian literature (for example, incidence data, epidemiology of DR and AMD). These gaps may represent important future research opportunities.

CONCLUSION

There is an increasing body of epidemiological data on the major age related eye diseases in Asian populations. The epidemiology of glaucoma and refractive errors, in particular, appears to be well characterised. In contrast, there remains a paucity of well conducted population based studies on the prevalence of DR and AMD in Asia. This review also shows that there are no Asian data on the incidence of visual impairment or the natural history of the major age related eye diseases, with the notable exception of the Hisayama study on incident AMD in Japan.[93] These areas require further attention. Prospective follow up of existing cross sectional studies will partly address the gap in incident data.

As in Western countries, over time, the causes of visual impairment and the pattern of eye diseases in Asia will probably reflect changes related to an ageing population and socioeconomic development. Thus, one can expect blindness from cataract, undercorrected refractive errors, and corneal diseases to decline, but blindness from AMD, glaucoma, and DR to increase. A long term, multifaceted, systematic strategy to tackle these conditions is therefore needed.

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REFERENCES

1 **Thylefors B**, Negrel AD, Pararajasegaram R, *et al.* Global data on blindness. *Bull World Health Organ* 1995;**73**:115–21.
2 **Congdon N**, O'Colmain B, Klaver CC, *et al.* Eye Diseases Prevalence Research Group. Causes and prevalence of visual impairment among adults in the United States. *Arch Ophthalmol* 2004;**122**:477–85.
3 **Kempen JH**, Mitchell P, Lee KE, *et al.* Eye Diseases Prevalence Research Group. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol* 2004;**122**:495–505.
4 **Friedman DS**, Wolfs RC, O'Colmain BJ, *et al.* Eye Diseases Prevalence Research Group. Prevalence of open-angle glaucoma among adults in the United States. *Arch Ophthalmol* 2004;**122**:532–8.
5 **Congdon N**, Vingerling JR, Klein BE, *et al.* Eye Diseases Prevalence Research Group. Prevalence of cataract and pseudophakia/aphakia among adults in the United States. *Arch Ophthalmol* 2004;**122**:487–94.
6 **Hsu WM**, Cheng CY, Liu JH, *et al.* Prevalence and causes of visual impairment in an elderly Chinese population in Taiwan: the Shihpai Eye Study. *Ophthalmology* 2004;**111**:62–9.
7 **Tsai SY**, Hsu WM, Cheng CY, *et al.* Epidemiologic study of age-related cataracts among an elderly Chinese population in Shih-Pai, Taiwan. *Ophthalmology* 2003;**110**:1089–95.
8 **Cheng CY**, Hsu WM, Liu JH, *et al.* Refractive errors in an elderly Chinese population in Taiwan: the Shihpai Eye Study. *Invest Ophthalmol Vis Sci* 2003;**44**:4630–8.
9 **Saw SM**, Foster PJ, Gazzard G, *et al.* Causes of blindness, low vision, and questionnaire-assessed poor visual function in Singaporean Chinese adults: the Tanjong Pagar Survey. *Ophthalmology* 2004;**111**:1161–8.
10 **Foster PJ**, Oen FT, Machin D, *et al.* The prevalence of glaucoma in Chinese residents of Singapore: a cross-sectional population survey of the Tanjong Pagar district. *Arch Ophthalmol* 2000;**118**:1105–11.
11 **Foster PJ**, Machin D, Wong TY, *et al.* Determinants of intraocular pressure and its association with glaucomatous optic neuropathy in Chinese Singaporeans: the Tanjong Pagar study. *Invest Ophthalmol Vis Sci* 2003;**44**:3885–91.
12 **Wong TY**, Foster PJ, Hee J, *et al.* Prevalence and risk factors for refractive errors in adult Chinese in Singapore. *Invest Ophthalmol Vis Sci* 2000;**41**:2486–94.
13 **Wong TY**, Foster PJ, Ng TP, *et al.* Variations in ocular biometry in an adult Chinese population in Singapore: the Tanjong Pagar Survey. *Invest Ophthalmol Vis Sci* 2001;**42**:73–80.
14 **Wong TY**, Foster PJ, Johnson GJ, *et al.* The prevalence and risk factors for pterygium in adult Chinese population in Singapore: the Tanjong Pagar Survey. *Am J Ophthalmol* 2001;**131**:176–83.
15 **Seah SKL**, Wong TY, Foster PJ, *et al.* The prevalence of cataract in Chinese residents in Singapore: The Tanjong Pagar Survey. *Ophthalmology* 2002;**109**:2058–64.
16 **Foster PJ**, Wong TY, Johnson GJ, *et al.* Risk factors for nuclear, cortical and posterior subcapsular cataract in Chinese: the Tanjong Pagar Survey. *Br J Ophthalmol* 2003;**87**:1112–20.
17 **Saw SM**, Foster PJ, Gazzard G, *et al.* Undercorrected refractive error in Singaporean Chinese adults: the Tanjong Pagar survey. *Ophthalmology* 2004;**111**:2168–74.
18 **Xu L**, Li J, Cui T, Hu A, *et al.* Visual acuity in northern China in an urban and rural population: the Beijing Eye Study. *Br J Ophthalmol* 2005;**89**:1089–93.
19 **Xu L**, Li J, Cui T, *et al.* Refractive error in urban and rural adult Chinese in Beijing. *Ophthalmology* 2005 Aug 17 [Epub ahead of print].
20 **Murthy GV**, Gupta SK, Bachani D, *et al.* Current estimates of blindness in India. *Br J Ophthalmol* 2005;**89**:257–60.
21 **Dandona L**, Dandona R, Srinivas M, *et al.* Blindness in the Indian state of Andhra Pradesh. *Invest Ophthalmol Vis Sci* 2001;**42**:908–16.
22 **Dandona R**, Dandona L, Naduvilath TJ, *et al.* Refractive errors in an urban population in Southern India: the Andhra Pradesh Eye Disease Study. *Invest Ophthalmol Vis Sci* 1999;**40**:2810–18.
23 **Dandona L**, Dandona R, Mandal P, *et al.* Angle-closure glaucoma in an urban population in southern India: the Andhra Pradesh eye disease study. *Ophthalmology* 2000;**107**:1710–16.
24 **Dandona L**, Dandona R, Srinivas M, *et al.* Open-angle glaucoma in an urban population in southern India: the Andhra Pradesh eye disease study. *Ophthalmology* 2000;**107**:1702–9.
25 **Dandona L**, Dandona R, Naduvilath TJ, *et al.* Population based assessment of diabetic retinopathy in an urban population in southern India. *Br J Ophthalmol* 1999;**83**:937–40.
26 **Dandona R**, Dandona L. Corneal blindness in a southern Indian population: need for health promotion strategies. *Br J Ophthalmol* 2003;**87**:133–41.
27 **Thulasiraj RD**, Nirmalan PK, Ramakrishnan R, *et al.* Blindness and vision impairment in a rural south Indian population: the Aravind Comprehensive Eye Survey. *Ophthalmology* 2003;**110**:1491–8.
28 **Ramakrishnan R**, Nirmalan PK, Krishnadas R, *et al.* Glaucoma in a rural population of southern India: the Aravind comprehensive eye survey. *Ophthalmology* 2003;**110**:1484–90.
29 **Nirmalan PK**, Krishnadas R, Ramakrishnan R, *et al.* Lens opacities in a rural population of southern India: the Aravind Comprehensive Eye Study. *Invest Ophthalmol Vis Sci* 2003;**44**:4639–43.
30 **Krishnadas R**, Nirmalan PK, Ramakrishnan R, *et al.* Pseudoexfoliation in a rural population of southern India: the Aravind Comprehensive Eye Survey. *Am J Ophthalmol* 2003;**135**:830–7.
31 **Nirmalan PK**, Katz J, Robin AL, *et al.* Prevalence of vitreoretinal disorders in a rural population of southern India: the Aravind Comprehensive Eye Study. *Arch Ophthalmol* 2004;**122**:581–6.
32 **Saw SM**, Gazzard G, Koh D, *et al.* Prevalence rates of refractive errors in Sumatra, Indonesia. *Invest Ophthalmol Vis Sci* 2002;**43**:3174–80.
33 **Husain R**, Tong L, Fong A, *et al.* Prevalence of cataract in rural Indonesia. *Ophthalmology* 2005;**112**:1255–62.
34 **Gazzard G**, Saw SM, Farook M, *et al.* Pterygium in Indonesia: prevalence, severity and risk factors. *Br J Ophthalmol* 2002;**86**:1341–6.

35 **Saw SM**, Husain R, Gazzard GM, *et al.* Causes of low vision and blindness in rural Indonesia. *Br J Ophthalmol* 2003;**87**:1075–8.
36 **Foster PJ**, Johnson GJ. Glaucoma in China: how big is the problem? *Br J Ophthalmol* 2001;**85**:1277–82.
37 **Seet B**, Wong TY, Tan DTH, *et al.* Myopia in Singapore: taking a public health approach. *Br J Ophthalmol* 2001;**85**:521–6.
38 **Seah SKL**, Foster PJ, Chew PT, *et al.* Incidence of acute primary angle-closure glaucoma in Singapore. An island-wide survey. *Arch Ophthalmol* 1997;**115**:1436–40.
39 **Wong TY**, Foster PJ, Seah SKL, *et al.* Rates of hospital admissions for primary angle closure glaucoma among Chinese, Malays and Indians in Singapore. *Br J Ophthalmol* 2000;**84**:990–2.
40 **Wong TY**, Tielsch JM, Schein OD. Racial difference in the incidence of retinal detachment in Singapore. *Arch Ophthalmol* 1999;**117**:379–83.
41 **Baasanhu J**, Johnson GJ, Burendei G, *et al.* Prevalence and causes of blindness and visual impairment in Mongolia: a survey of populations aged 40 years and older. *Bull World Health Organ* 1994;**72**:771–6.
42 **Pokharel GP**, Regmi G, Shrestha SK, *et al.* Prevalence of blindness and cataract surgery in Nepal. *Br J Ophthalmol* 1998;**82**:600–5.
43 **Zhao J**, Jia L, Sui R, *et al.* Prevalence of blindness and cataract surgery in Shunyi County, China. *Am J Ophthalmol* 1998;**126**:506–14.
44 **Li S**, Xu J, He M, *et al.* A survey of blindness and cataract surgery in Doumen County, China. *Ophthalmology* 1999;**106**:1602–8.
45 **Murthy GV**, Gupta S, Ellwein LB, *et al.* A population-based eye survey of older adults in a rural district of Rajasthan: I. Central vision impairment, blindness, and cataract surgery. *Ophthalmology* 2001;**108**:679–85.
46 **Zainal M**, Ismail SM, Ropilah AR, *et al.* Prevalence of blindness and low vision in Malaysian population: results from the National Eye Survey 1996. *Br J Ophthalmol* 2002;**86**:951–6.
47 **Michon JJ**, Lau J, Chan WS, *et al.* Prevalence of visual impairment, blindness, and cataract surgery in the Hong Kong elderly. *Br J Ophthalmol* 2002;**86**:133–9.
48 **Dineen BP**, Bourne RR, Ali SM, *et al.* Prevalence and causes of blindness and visual impairment in Bangladeshi adults: results of the National Blindness and Low Vision Survey of Bangladesh. *Br J Ophthalmol* 2003;**87**:820–8.
49 **Dunzhu S**, Wang FS, Courtright P, *et al.* Blindness and eye diseases in Tibet: findings from a randomised, population based survey. *Br J Ophthalmol* 2003;**87**:1443–8.
50 **Osman A**, Rampal KG. Prevalence of visual impairment in Kuala Selangor. *Med J Malaysia* 1988;**43**:235–6.
51 **Zainal M**, Masran L, Ropilah AR. Blindness and visual impairment amongst rural Malays in Kuala Selangor, Selangor. *Med J Malaysia* 1998;**53**:46–9.
52 **Klein BE**, Klein R, Linton KL. Prevalence of age-related lens opacities in a population. The Beaver Dam Eye Study. *Ophthalmology* 1992;**99**:546–52.
53 **Chatterjee A**, Milton RC, Thyle S. Prevalence and aetiology of cataract in Punjab. *Br J Ophthalmol* 1982;**66**:35–42.
54 **Hu TS**, Zhen Q, Sperduto RD, *et al.* Age-related cataract in the Tibet Eye Study. *Arch Ophthalmol* 1989;**107**:666–9.
55 **Hu C**. An epidemiologic survey of cataract in Shunyi County, Beijing. *Chung Hua Yen Ko Tsa Chih* 1989;**25**:360–4.
56 **Cheng CY**, Liu JH, Chen SJ, *et al.* Population-based study on prevalence and risk factors of age-related cataracts in Peitou, Taiwan. *Chung Hua I Hsueh Tsa Chih (Taipei)* 2000;**63**:641–8.
57 **Krishnaiah S**, Vilas K, Shamanna BR, *et al.* Smoking and its association with cataract: results of the Andhra Pradesh eye disease study from India. *Invest Ophthalmol Vis Sci* 2005;**46**:58–65.
58 **Sasaki H**, Kawakami Y, Ono M, *et al.* Localization of cortical cataract in subjects of diverse races and latitude. *Invest Ophthalmol Vis Sci* 2003;**44**:4210–14.
59 **World Health Organization**. *Global initiative for the elimination of avoidable blindness. An informal consultation*, WHO/PBL/97.61. Geneva: WHO, 1997.
60 **Wong TY**. Cataract extraction rates among Chinese, Malays and Indians in Singapore: a population-based analysis. *Arch Ophthalmol* 2001;**119**:727–32.
61 **Dandona L**, Dandona R, Naduvilath TJ, *et al.* Is current eye-care-policy focus almost exclusively on cataract adequate to deal with blindness in India? *Lancet* 1998;**351**:1312–16.
62 **Xu J**, Zhu S, Li S, Pizzarello L. Models for improving cataract surgical rates in southern China. *Br J Ophthalmol* 2002;**86**:723–4.
63 **Lin LLK**, Shih YF, Tsai CB, *et al.* Epidemiologic study of ocular refraction among school-children in Taiwan in 1995. *Optom Vis Sci* 1999;**76**:275–81.
64 **Saw SM**, Chua WH, Hong CY, *et al.* Nearwork in early onset myopia. *Invest Ophthalmol Vis Sci* 2002;**43**:332–9.
65 **Ojaimi E**, Rose KA, Morgan IG, *et al.* Distribution of ocular biometric parameters and refraction in a population-based study of Australian children. *Invest Ophthalmol Vis Sci* 2005;**46**:2748–54.
66 **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**:334–40.
67 **Wensor M**, McCarty CA, Taylor HR. Prevalence and risk factors of myopia in Victoria, Australia. *Arch Ophthalmol* 1999;**117**:658–63.
68 **Raju P**, Ve Ramesh S, Arvind H, *et al.* Prevalence of refractive errors in a rural South Indian population. *Invest Ophthalmol Vis Sci* 2004;**45**:4268–72.
69 **Bourne RR**, Dineen BP, Ali SM, *et al.* Prevalence of refractive error in Bangladeshi adults: results of the National Blindness and Low Vision Survey of Bangladesh. *Ophthalmology* 2004;**111**:1150–60.
70 **Wickremasinghe S**, Foster PJ, Uranchimeg D, *et al.* Ocular biometry and refraction in Mongolian adults. *Invest Ophthalmol Vis Sci* 2004;**45**:776–83.
71 **Wong TY**, Foster PJ, Johnson GJ, *et al.* Refractive errors, axial ocular dimensions and age-related cataracts: the Tanjong Pagar Survey. *Invest Ophthalmol Vis Sci* 2003;**44**:1479–85.
72 **Wong TY**, Klein R, Klein BEK, *et al.* Refractive errors and ten-year incidence of age-related maculopathy. *Invest Ophthalmol Vis Sci* 2002;**43**:2869–73.
73 **Quigley HA**. Number of people with glaucoma worldwide. *Br J Ophthalmol* 1996;**80**:389–93.
74 **Tielsch JM**, Sommer A, Katz J, Royall, et al. Racial variations in the prevalence of primary open-angle glaucoma. The Baltimore Eye Survey. *JAMA* 1991;**266**:369–74.
75 **Foster PJ**, Baasanhu J, Alsbirk PH, *et al.* Glaucoma in Mongolia. A population-based survey in Hovsgol province, northern Mongolia. *Arch Ophthalmol* 1996;**114**:1235–41.
76 **Shiose Y**, Kitazawa Y, Tsukahara S, *et al.* Epidemiology of glaucoma in Japan—a nationwide glaucoma survey. *Jpn J Ophthalmol* 1991;**35**:133–55.
77 **Rahman MM**, Rahman N, Foster PJ, *et al.* The prevalence of glaucoma in Bangladesh: a population based survey in Dhaka division. *Br J Ophthalmol* 2004;**88**:1493–7.
78 **Iwase A**, Suzuki Y, Araie M, *et al.* The prevalence of primary open-angle glaucoma in Japanese: the Tajimi Study. *Ophthalmology* 2004;**111**:1641–8.
79 **Yamamoto T**, Iwase A, Araie M, *et al.* The Tajimi Study Report. 2: Prevalence of primary angle closure and secondary glaucoma in a Japanese population, *Ophthalmology* 2005 Aug 17 [Epub ahead of print].
80 **Bourne RR Sukudom P Foster PJ**, *et al.* Prevalence of glaucoma in Thailand: a population based survey in Rom Klao District, Bangkok. *Br J Ophthalmol* 2003;**87**:1069–74.
81 **Lim A**. Primary angle-closure glaucoma in Singapore. *Aust J Ophthalmol* 1979;**7**:23–30.
82 **Congdon NG**, Foster PJ, Wamsley S, *et al.* Biometric gonioscopy and the effects of age, race, and sex on the anterior chamber angle. *Br J Ophthalmol* 2002;**86**:18–22.
83 **He M**, Foster PJ, Johnson GJ, *et al.* Angle-closure glaucoma in East Asian and European people. Different diseases? *Eye* 2005 Jan 21 [Epub ahead of print].
84 **Chen MS**, Kao CS, Chang CJ, *et al.* Prevalence and risk factors of diabetic retinopathy among noninsulin-dependent diabetic subjects. *Am J Ophthalmol* 1992;**114**:723–30.
85 **Narendran V**, John RK, Raghuram A, *et al.* Diabetic retinopathy among self reported diabetics in southern India: a population based assessment. *Br J Ophthalmol* 2002;**86**:1014–18.
86 **Rema M**, Premkumar S, Anitha B, *et al.* Prevalence of diabetic retinopathy in urban India: the Chennai Urban Rural Epidemiology Study (CURES) eye study, I. *Invest Ophthalmol Vis Sci* 2005;**46**:2328–33.
87 **Kempen JH**, O'Colmain BJ, Leske MC, *et al.* Eye Diseases Prevalence Research Group. The prevalence of diabetic retinopathy among adults in the United States. *Arch Ophthalmol* 2004;**122**:552–63.
88 **Klein R**, Clegg L, Cooper LS, *et al.* Prevalence of age-related maculopathy in the Atherosclerosis Risk in Communities Study. *Arch Ophthalmol* 1999;**117**:1203–10.
89 **Friedman DS**, O'Colmain BJ, Munoz B, *et al.* Eye Diseases Prevalence Research Group. Prevalence of age-related macular degeneration in the United States. *Arch Ophthalmol* 2004;**122**:564–72.
90 **Friedman DS**, Katz J, Bressler NM, *et al.* Racial differences in the prevalence of age-related macular degeneration: the Baltimore Eye Survey. *Ophthalmology* 1999;**106**:1049–55.
91 **Oshima Y**, Ishibashi T, Murata T, *et al.* Prevalence of age related maculopathy in a representative Japanese population: the Hisayama study. *Br J Ophthalmol* 2001;**85**:1153–7.
92 **Miyazaki M**, Kiyohara Y, Yoshida A, *et al.* The 5-year incidence and risk factors for age-related maculopathy in a general Japanese population: the Hisayama study. *Invest Ophthalmol Vis Sci* 2005;**46**:1907–10.
93 **Miyazaki M**, Nakamura H, Kubo M, *et al.* Risk factors for age related maculopathy in a Japanese population: the Hisayama study. *Br J Ophthalmol* 2003;**87**:469–72.