

# Prevalence of Refractive Error in Bangladeshi Adults

## Results of the National Blindness and Low Vision Survey of Bangladesh

Rupert R. A. Bourne, BSc, FRCOphth,<sup>1</sup> Brendan P. Dineen, MPH,<sup>2</sup> Syed M. Ali, FRCS,<sup>3</sup> Deen M. Noorul Huq, FRCS,<sup>3</sup> Gordon J. Johnson, MD, FRCOphth<sup>4</sup>

**Purpose:** To determine the prevalence of refractive errors and to investigate factors associated with refractive error in adults 30 years of age and older in Bangladesh.

**Design:** Cross-sectional study.

**Participants:** A nationally representative sample of 12 782 adults 30 years of age and older.

**Methods:** The sample of subjects was selected based on multistage, cluster random sampling with probability-proportional-to-size procedures. The examination protocol consisted of an interview that included measures of literacy, education, occupation, and refractive correction. Visual acuity testing (logarithm of the minimum angle of resolution [logMAR]), automated refraction, and optic disc examination were performed for all subjects. Subjects with  $<6/12$  (0.3 logMAR) acuity in either eye were graded additionally for cataract and underwent a dilated fundal examination. Subjects for whom no refractive error was recorded (312 subjects; 2.7%) or who had undergone cataract surgery (123 subjects; 1.1%) were excluded from the analysis.

**Main Outcome Measures:** Refractive error and socioeconomic variables (literacy, education, occupation).

**Results:** Eleven thousand six hundred twenty-four subjects were examined (90.9% response rate; mean age  $\pm$  standard deviation,  $44 \pm 12.6$  years). Five thousand four hundred eighty-nine subjects (49.1%) were men and 5700 subjects (50.9%) were women. Mean spherical equivalent was  $-0.19$  diopters (D;  $\pm 1.50$  D). Six thousand four hundred twelve subjects (57.3%) were emmetropic, 2469 (22.1%) were myopic ( $< -0.5$  D), and 2308 (20.6%) were hypermetropic ( $> +0.5$  D). Two hundred six subjects (1.8%) were highly myopic ( $< -5$  D). Myopia was more common in men (26.3%) than in women (21.0%), whereas hyperopia was more common in women (27.4%) than in men (15.8%). Overall, myopia increased with age (17.5% of those aged 30–39 years were myopic, compared with 65.5% of those age 70 years and older). A subanalysis of subjects without cataract showed increasing hyperopia with age and an association between myopia and higher education. Myopia was more common among the employed than in unemployed subjects. Astigmatism ( $> 0.5$  D), present in 3625 subjects (32.4%), was more common among women, illiterate subjects, and unschooled subjects. Against-the-rule astigmatism was more common (58.7%) than oblique astigmatism (29.3%), which was more common than with-the-rule (WTR) astigmatism (12.1%). Against-the-rule astigmatism and oblique astigmatism increased with age, unlike WTR astigmatism. Of 830 (7.5%) subjects, women were more commonly anisometric ( $> 1.0$  D). Anisometropia increased with age.

**Conclusions:** Refractive error data are described for a country and region that previously have lacked population-based data. Prevalence and factors associated with refractive error are presented, with a detailed comparison with other population-based surveys regionally and internationally. *Ophthalmology* 2004;111:1150–1160 © 2004 by the American Academy of Ophthalmology.

Before The Bangladesh National Blindness and Low Vision Survey (1999–2000),<sup>1</sup> no nationwide eye study had been

conducted in Bangladesh—a country of more than 130 million inhabitants—concerning the extent and causes of

Originally received: December 9, 2002.

Accepted: September 30, 2003.

Manuscript no. 220963.

<sup>1</sup> Department of Epidemiology and International Eye Health, Institute of Ophthalmology, University College London & Moorfields Eye Hospital, London, United Kingdom.

<sup>2</sup> Clinical Research Unit, Department of Infectious and Tropical Diseases, London School of Hygiene and Tropical Medicine, London, United Kingdom.

<sup>3</sup> National Institute of Ophthalmology, Dhaka, Bangladesh.

<sup>4</sup> Clinical Research Unit, Department of Infectious and Tropical Diseases, London School of Hygiene and Tropical Medicine, London, United Kingdom. This study was funded by Sight Savers International, Haywards Heath, United Kingdom.

The authors have no financial interest related to this article.

Correspondence to Rupert Bourne, BSc, FRCOphth, International Centre for Eye Health, Institute of Ophthalmology, 11-43 Bath Street, London EC1V 9EL, United Kingdom. E-mail: rupert.bourne@lshtm.ac.uk.

blindness and visual impairment. Given the strategies identified in the World Health Organization publication "Global Initiative for the Elimination of Avoidable Blindness by 2020 (Vision 2020),"<sup>2</sup> the deficit of this vital information was particularly serious and presented a serious impediment to the effective national planning and implementation of an eye care program.

The survey (11 624 subjects) reported that the main cause of a presenting visual acuity of less than 6/12 (0.3 logarithm of the minimum angle of resolution [logMAR]) was cataract (73.39%), followed by refractive error (18.87%) and uncorrected aphakia (1.19%). In relation to the causes of bilateral blindness (defined as less than 3/60 [1.3 logMAR] in the better eye), cataract also was the principal disorder, having been identified for 129 of the 162 blind subjects (79.63%), followed by uncorrected aphakia (6.17%). The survey also demonstrated that refractive correction (using the result from an objective automated measurement) greatly reduced the number of subjects in each category of visual disability.

Remarkably, few population-based refractive error data on adults exist for nonwhite populations. Some studies have been conducted in East and South East Asia. A study of 443 Solomon Islanders in 1966<sup>3</sup> (aged 0–79 years) reported a prevalence of myopia ( $< -0.5$  diopters [D]) of 0.8%. A more recent study in provincial Sumatra<sup>4</sup> reported a prevalence of myopia ( $\leq -0.5$  D) of 34.1% among those aged 40 years and older, which is higher than that reported in white populations, such as in the Baltimore Eye Survey<sup>5</sup> (24.1% of white adults aged  $\geq 40$  years) or the Beaver Dam Study<sup>6</sup> (26.2% of adults aged 43–84 years). However, in urbanized South East Asia, the prevalence of myopia in adults is higher still: 38.7% of Singapore Chinese<sup>7</sup> adults aged 40 to 81 years were myopic ( $< -0.5$  D). A study involving rural and urban areas in southern India<sup>8,9</sup> reported a prevalence of 36.5% ( $< -0.5$  D) in adults aged 40 years and older. The pattern seems to be different among young adults between these regions, however, with low rates of myopia reported in southern India<sup>8,9</sup> (8.9% [ $< -0.5$  D]; age range, 16–39 years) but much higher rates (68.8%) reported in Indians living in Singapore<sup>10</sup> ( $< -0.5$  D; men aged 16–25 years). The prevalence of myopia in young adults of provincial Sumatra<sup>4</sup> ( $\leq -0.5$  D; age range, 21–29 years) and Malays in Singapore<sup>10</sup> ( $< -0.5$  D; men aged 16–25 years) has been reported as 61.6% and 65.0%, respectively. Among Chinese military recruits in Singapore<sup>10</sup> ( $< -0.5$  D; men aged 16–25 years), 82.2% were myopic. Myopia also has been shown to be very common among young Hong Kong Chinese<sup>11</sup> ( $< -0.5$  D; 71% of those aged 19–39 years) and Taiwanese children<sup>12</sup> ( $\leq 0.25$  D; 84% of those aged 16–18 years).

The prevalence rates of hyperopia in Singapore Chinese adults ( $> +0.5$  D; age range, 40–81 years)<sup>7</sup> and adults of provincial Sumatra<sup>4</sup> ( $\geq 0.5$  D; 40 years and older) have been reported as 28.4% and 32.1%, respectively. In southern India,<sup>9</sup> only 1.9% of adults aged 40 years or older were hyperopic ( $> +0.5$  D). This contrasts with the findings of the Baltimore Eye Survey,<sup>5</sup> which reported a hyperopia prevalence of 47.3% among white adults aged 40 years and older.

This article describes the prevalence and types of refractive error in adults of Bangladesh and relates the findings to

demographic and ophthalmic variables that also were measured, in addition to reporting on refractive correction within this population.

## Materials and Methods

The methodology used in the National Blindness and Low Vision Prevalence Survey of Bangladesh has been described in detail elsewhere.<sup>13</sup>

Multistage, stratified, cluster random sampling, with probability proportional-to-size procedures, was adopted as the strategy for the selection of a cross-sectional, nationally representative sample of the population. Stratification of the sample according to rural and urban residence (corresponding to official municipality ordinance status)<sup>14</sup> was incorporated in the sample selection process. Within each of the 6 regional administrative divisions in Bangladesh, a proportional number of clusters in relation to the overall national population were identified based on official census data. A total of 154 cluster sample sites were selected by probability proportional-to-size procedures, of which 104 were rural villages, whereas the remaining 50 were urban block areas. For logistical purposes, the rural cluster areas consisted of 100 subjects, whereas the urban study areas consisted of 50 subjects each. A sample size of 12 900 subjects was calculated for this study.

All participants of each of 3 survey teams (each team comprised 1 ophthalmologist, 1 ophthalmic nurse, 2 technicians, 1 interviewer, and 4 enumerators) underwent specialized training during a month-long period. Both interobserver and intraobserver agreement were determined among the groups of ophthalmic nurses and ophthalmologists with respect to visual acuity testing, intraocular pressure measurement, optic disc assessment, and lens opacity grading.

The survey commenced in October 1999 and was completed by June 2000. The examination process began with an interview in which the interviewer checked that the individual was an enumerated subject. Demographic data such as age and gender were collected, in addition to specific information regarding occupation, literacy, and religion. Self-reported literacy was recorded as "reads easily," "reads with difficulty," and "illiterate."

Distance visual acuity was measured with a reduced logMAR-based tumbling "E" chart.<sup>15</sup> The presenting vision was measured with the subject's current distance refractive correction, if worn, for each eye in turn. If a subject achieved a visual acuity of 6/6 (0.0 logMAR) in a given eye, the acuity testing session for that eye was then terminated (i.e., visual acuities better than 0.0 were not measured).

All subjects underwent automated refraction (Topcon Corporation Model RM-8000B), performed by trained medical technicians. Measurements obtained included average refractive error (based on 3 consecutive readings), spherical equivalent, and vertex distance. If the autorefractor did not yield a measurement (especially because of media opacity) in a subject with less than 6/12 (0.3 logMAR) visual acuity ("red cardholders"), the ophthalmologist attempted a manual objective and subjective refraction without cycloplegia, a technique in which each ophthalmologist had been tested and in which each had proved capable.

Subjects with less than 6/12 (0.3 logMAR) visual acuity in either eye were then retested for visual acuity in each eye, with their autorefraction result placed in a trial frame using trial lenses. This was performed to estimate the contribution of refractive error to these subjects' visual disabilities.

The subjects were asked by the ophthalmologist if they had been managed previously for cataract, glaucoma, or other disorders. To record the technique, the ophthalmologist relied on a history from the patient and subsequent findings from the examination based on direct ophthalmoscopy (Vantage 2000 Lux Illu-

minance, Keeler, UK). The presence or absence of an intraocular lens and the use of an aphakic correction also were noted.

All subjects with less than 6/12 (0.3 logMAR) visual acuity in either eye subsequently were dilated (after a check for relative afferent pupil defect), the cup/disc ratio was rechecked at that stage, and the presence or absence of retinal pathologic features was noted.

Subjects with less than 6/12 visual acuity in either eye were assessed for cataract. During the training period, it was decided that the most appropriate cataract grading system for the purposes of this field survey would be the Mehra Minassian system,<sup>16</sup> after evaluating other grading systems. This cataract classification system consists of 6 categories based on obscuration of the red reflex of an undilated normal pupil resulting from the presence of a lens opacity, as assessed using direct ophthalmoscopy. The grading ranges are: 0, clear red reflex/no opacity; 1, few small dot opacities that occupy less than 1 mm<sup>2</sup> maximum area; 2A, lens opacity obscuring red reflex with the area obscured smaller than the area of clear reflex; 2B, area obscured is equal to or greater than area of clear red reflex; 3, lens opacity totally obscuring the red reflex; 4, (pseudo-) aphakia or displaced lens; 5, unable to assess red reflex owing to corneal opacity, for instance.

Ocular examinations were carried out in a building (the survey station) within each cluster selected by the enumerator with local guidance, where the equipment was set up using local electricity or, as in most cases, an electric generator. Subjects unable to visit the survey station (146 subjects) were tested for visual acuity (using the same chart used in the survey station) and cataract in their own homes.

All persons with less than 6/18 visual acuity (0.48 logMAR) in the better eye or who were blind were referred to the nearest eye care facility (district or nongovernment hospital).

The Bangladesh Medical Research Council provided written ethical approval for this survey in March 1999. Oral informed consent was sought from each subject by the ophthalmic assistant, after explanation of the procedures to be conducted.

## Data Analysis

Spherical refractive error is presented as the spherical equivalent, which equals the sphere power plus half the cylinder power. Astigmatism was measured in negative cylinders with the axis of astigmatism defined as with the rule ( $0\pm 15^\circ$ ), against the rule ( $90\pm 15^\circ$ ), or oblique ( $20\text{--}70^\circ$  and  $110\text{--}160^\circ$ ). Standardization of data by age and gender against a reference population involved national census figures from the Bangladesh Bureau of Statistics.<sup>14</sup> Although visual acuity was measured using the logMAR scale, the text of this article has added the Snellen equivalents for purposes of comparison with previous similar studies. Statistical analysis was performed using right eyes only (except for the analysis of anisometropia), in keeping with methodology used in similar refractive error studies,<sup>5,7</sup> because correlation between the spherical equivalent of right and left eyes was very high (Pearson's coefficient, 0.783) with no significant differences between each pair (*t* test,  $P = 0.78$ ). For the analysis of right eyes, data from those that had no refractive error recorded or who had undergone cataract surgery were excluded. A further analysis involved right eyes with no visually significant cataract (it was assumed that eyes with a visual acuity of 6/12 [0.3 logMAR] or better had no visually significant cataract). Univariate analysis was performed with logistical regression of key variables with refractive error, such as age, gender, literacy, education, occupation, and residence (urban or rural). Data management and analysis was carried out in Epi Info 6.04b (Division of Public Health Surveillance and Informatics, Centers for Disease Control and Prevention, Atlanta, GA), Microsoft Excel (Redmond, WA), and SPSS 10.0 (SPSS Inc., Chicago, IL).

## Results

### Demographics

A total of 12 782 eligible adults 30 years of age and older were enumerated, of which 11 624 subjects were examined (90.9% response rate).

Stratified analysis according to 10-year age groups was used to compare the age and gender structure of those examined with the age and gender structure of Bangladesh.<sup>14</sup> This showed that substantially more women ( $P < 0.001$ ) were examined in the survey than men in the 30 to 39-year group ( $P < 0.001$ ), the 40 to 49-year group ( $P = 0.04$ ), and the 50 to 59-year group ( $P = 0.03$ ) than would be expected from the national population, whereas in the 60 to 69-year group, there was no statistical difference ( $P = 0.29$ ). In those aged 70 years and older, the pattern was reversed, with more men examined than women ( $P = 0.002$ ).

Nine thousand three hundred seventy-one subjects in the rural areas (90.9% of those enumerated) and 2253 subjects in the urban areas (91.0% of those enumerated) were examined. Regarding gender, the overall response rate was higher for women (94.6%) than for men (87.4%) in the study. Stratified analysis according to 10-year age groups identified that there were substantially more males ( $P < 0.001$ ) who did not participate in the survey as compared with females, especially among individuals of ages ranging from 30 to 59 years. The main reason identified for nonparticipation in the survey using information provided by family members or neighbors of the nonrespondents was that the subject was "working at the time of the examination." This was especially the case among males aged 30 to 59 years, which corresponds to the ages of those who are economically active in Bangladesh. There was no difference, however, in the proportions of male and female nonresponders among older subjects, that is, those aged 60 year and older, which typically relates to a status of economic dependency rather than active employment in Bangladesh.<sup>14</sup> No statistically significant difference was found in the proportion of responders and nonresponders across the 6 administrative divisions of Bangladesh or according to rural versus urban residence of the subject.

For the purposes of this report, 11 189 (96.2%) of the total 11 624 subjects were included in an analysis of right eyes after excluding 312 on account of a lack of refractive data (principally because of media opacity) and 123 subjects who had undergone cataract surgery. Comparing those included with those excluded, there were no significant differences regarding gender (Pearson's chi-square test, 2.68;  $P = 0.102$ ), religion (chi-square, 1.49;  $P = 0.47$ ), or living in rural or urban areas (chi-square, 1.43;  $P = 0.23$ ). However, those excluded were more likely to be older (chi-square, 1522.0;  $P < 0.001$ ), to be illiterate (chi-square, 90.5;  $P < 0.001$ ), not to have not attended school (chi-square, 67.4;  $P < 0.001$ ), not to have obtained a higher education (beyond primary school; chi-square, 4.85;  $P = 0.03$ ), and to be wearing spectacles at the time of examination (chi-square, 674.9;  $P < 0.001$ ).

A total of 5489 men (49.1%) and 5700 women (50.9%) comprised the 11 189 subjects included for analysis. The mean age  $\pm$  standard deviation of subjects was  $44 \pm 12.6$  years. The mean age of men ( $45.5 \pm 12.9$  years) was significantly higher than that of women ( $43.2 \pm 12.1$  years; *t* test,  $P < 0.001$ ).

### Spherical Equivalent Refractive Error

**Population Distribution of Spherical Refractive Error.** The distribution of spherical equivalent refractive error for right eyes is illustrated in Figure 1 (mean,  $-0.19 \pm 1.50$  D). The distribution shows a skew toward myopia with positive leptokurtosis (12.2). Leptokurtosis describes a property of a distribution that gives a higher peak, a thinner midrange, and wider tails than a normal distribution.

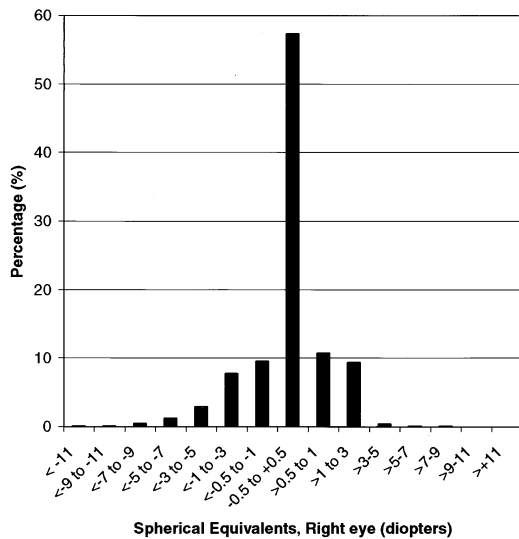


Figure 1. Frequency distribution of spherical equivalents of right eyes.

Defining emmetropia as between -0.5 and +0.5 D (inclusive), 6412 subjects (57.3%) were emmetropic, 2469 (22.1%) were myopic (<-0.5 D), and 2308 (20.6%) were hypermetropic (>+0.5 D). Two hundred six subjects (1.8%) were highly myopic (<-5 D). This highly myopic group formed 8.3% of the myopes in the study population.

**Spherical Refractive Error and Gender and Age.** The prevalences of myopia and hypermetropia in men and women are given in Tables 1 and 2. After age and gender standardization according to the national population of adults (30 years or older) in Bang-

ladesh,<sup>14</sup> women were less likely to be emmetropic (-0.5 to +0.5 D, odds ratio [OR], 0.77) or myopic (<-0.5 D, OR, 0.75; <-1.0 D, OR, 0.82; <-5 D, OR, 0.89) than men (all highly significant differences: *P*<0.001). However, women were more likely to be hypermetropic (>+0.5 D; OR, 2.02) than men (*P*<0.001).

There was a significant negative correlation of the spherical equivalent with age (Pearson's coefficient, -0.211; *P*<0.001). Figure 2 illustrates the prevalence of myopia, emmetropia, and hyperopia with age in subjects with cataract and in subjects without cataract. The pattern of myopia prevalence with age (considering all subjects) was similar in men and women, with the lowest prevalences in younger age groups (30-40 years), which then increased with age dramatically from 50 to 70+ years. The highest rates of myopia (<-0.5 D) were seen in the 70+ age group (men, 69.9% [95% confidence interval (CI), 65.1, 74.7]; women, 57.6% [95% CI, 52.7, 65.3]). In comparison with the 30 to 39-year age groups, the 50 to 59-year group (OR, 1.35 [95% CI, 1.17, 1.55]), the 60 to 69-year group (OR, 3.51 [95% CI, 3.05, 4.04]), and the 70+ group (OR, 8.94 [95% CI, 7.39, 10.81]) were significantly more myopic (Table 3). Figure 3 illustrates the prevalence of different magnitudes of myopia with age. The proportion of low degrees of myopia (<-0.5 to -1.0 D) with respect to all myopia (<-0.5 D) reduces with age; however, the higher degrees of myopia (<-1.0 D) become much more prevalent with increasing age.

In the case of hyperopia (considering all subjects), low levels of prevalence are seen in younger age groups; however, there is an increase until the 50 to 59-year age group, when it then reduces. In comparison with the 30 to 39-year age group, the 40 to 49-year group (OR, 4.17 [95% CI, 3.64, 4.78]) and the 50 to 59-year group (OR, 8.27 [95% CI, 7.14, 9.57]) were significantly more hyperopic; however, older subjects were still significantly more hyperopic, although to a lesser degree.

Table 1. Prevalence of Refractive Errors in Bangladeshi Adults (with Crude and Age- and Gender-Adjusted Prevalences after Standardization)

	Men (total = 5489)		Women (total = 5700)		All (total = 11189)	
	Crude % (95% Confidence Interval)	Adjusted* % (95% Confidence Interval)	Crude % (95% Confidence Interval)	Adjusted† % (95% Confidence Interval)	Crude % (95% Confidence Interval)	Adjusted‡ % (95% Confidence Interval)
Emmetropia (-0.5 to +0.5 D SE)	3258 59.4 (58.1, 60.6)	58.0 (59.0, 58.0)	3154 55.3 (54.0, 56.6)	51.5 (51.4, 51.5)	6412 57.3 (56.4, 58.2)	54.9 (54.9, 54.9)
Myopia						
Myopia (≤0.5 D SE)	1386 25.2 (24.1, 26.4)	26.3 (26.3, 26.3)	1083 19.0 (17.9, 20.0)	21.0 (21.0, 21.0)	2469 22.1 (21.3, 22.8)	23.8 (23.8, 23.8)
Myopia (≤1.0 D SE)	790 14.4 (13.5, 15.3)	15.5 (15.5, 15.6)	614 10.8 (9.9, 11.6)	13.1 (13.1, 13.1)	1404 12.5 (11.9, 13.2)	14.4 (14.4, 14.4)
High myopia (≤5.0 D SE)	115 2.1 (1.7, 2.5)	2.3 (2.3, 2.4)	91 1.6 (1.3, 1.9)	2.1 (2.1, 2.1)	206 1.8 (1.6, 2.1)	2.2 (2.2, 2.2)
Hypermetropia (>+0.5 D SE)	845 15.4 (14.4, 16.3)	15.8 (15.8, 15.8)	1463 25.7 (24.5, 26.8)	27.4 (27.4, 27.5)	2308 20.6 (19.9, 21.4)	21.3 (21.3, 21.3)
Astigmatism (>0.5 DC)	1816 33.1 (31.8, 34.3)	34.3 (34.3, 34.3)	1809 31.7 (30.5, 32.9)	35.0 (35.0, 35.0)	3625 32.4 (31.5, 33.3)	34.6 (34.6, 34.7)
Anisometropia (>1.0 D SE between eyes) <sup>§</sup>	440 8.1 (7.4, 8.8)	8.8 (8.8, 8.9)	390 6.9 (6.2, 7.6)	8.9 (8.9, 8.9)	830 7.5 (7.0, 8.0)	8.9 (8.9, 8.9)

D = diopters; DC = D of cylinder; SE = spherical equivalent.

\*Age adjusted to the Bangladesh Bureau of Statistics Census 1997 male population.<sup>14</sup>

†Age adjusted to the Bangladesh Bureau of Statistics Census 1997 female population.<sup>14</sup>

‡Age and gender adjusted to the Bangladesh Bureau of Statistics Census 1997 male and female populations.<sup>14</sup>

§5433 pairs of eyes were analyzed for men (48 subjects did not have the left eye refractive data to compare with the right; eight others had undergone a cataract operation in the left eye). 5653 pairs of eyes were analyzed for women (44 subjects did not have the left eye refractive data to compare with the right; three others had undergone a cataract operation in the left eye).

Table 2. Age- and Gender-Specific Prevalences

Gender	Age (yrs)	Total No. Subjects in Age Group	High Myopia (≤5.0 Diopters Spherical Equivalent)			Myopia (≤1.0 Diopters Spherical Equivalent)		
			n	%	95% Confidence Interval	n	%	95% Confidence Interval
Men	30-39	2166	6	0.3	0.1, 0.5	103	4.8	3.9, 5.7
	40-49	1500	4	0.3	0.0, 0.5	96	6.4	5.2, 7.6
	50-59	832	18	2.2	1.2, 3.1	135	16.2	13.7, 18.7
	60-69	639	42	6.6	4.7, 8.5	235	36.8	33.0, 40.5
	70+	352	45	12.8	9.3, 16.3	221	62.8	57.7, 67.8
Women	30-39	2663	9	0.3	0.1, 0.6	146	5.5	4.6, 6.3
	40-49	1447	2	0.1	0.0, 0.3	65	4.5	3.4, 5.6
	50-59	828	18	2.2	1.2, 3.2	111	13.4	11.1, 15.7
	60-69	528	42	7.9	5.6, 10.3	174	32.9	28.9, 37.0
	70+	234	20	8.5	5.0, 12.3	118	50.4	44.0, 56.8

DC = diopters of cylinder.

Figure 2 also illustrates the prevalence of myopia, emmetropia, and hyperopia in subjects who had no cataract (it is assumed in this model that eyes with a visual acuity of 6/12 or better did not have a visually significant cataract). It can be seen that cataract-induced myopia contributes to this large increase in myopia in older age groups. With cataracts excluded, age was positively correlated with the spherical equivalent (Pearson's coefficient, 0.23;  $P < 0.01$ ). Cataract severity (only graded in subjects with a visual acuity of less than 6/12 [0.3 logMAR] in either eye) was negatively correlated with the spherical equivalent (Spearman's coefficient,  $-0.521$ ;  $P < 0.01$ ).

**Spherical Refractive Error and Educational Level, Literacy, Occupation, Religion, and Home Location.** The associations of demographic variables (age, gender, literacy, geographical area, school attendance, education, occupation, and religion) with myopia and hyperopia are given in Table 3. In addition, the associations of cataract and the wearing of spectacles with the spherical equivalent were analyzed.

Literate subjects were significantly less likely to be myopic ( $< -0.5$  D) or hyperopic ( $\geq 0.5$  D) than illiterate subjects, and this was also the case if the literate and semiliterate ("reads with difficulty") were combined. Subjects living in urban areas were significantly less likely to be myopic than those living in rural

areas; however, the opposite was the case for hyperopia. School attendees were less likely to be myopic or hyperopic than those who had never been to school. Those who had undergone college or university education were more likely to be myopic or hyperopic than those who had been schooled only at the primary level; however, this finding was not statistically significant. Manual workers were significantly more likely to be myopic than unemployed subjects. Subjects with nonmanual occupations were more likely to be myopic (OR, 0.79 [95% CI, 0.69, 0.90];  $P < 0.001$ ) than manual workers, who were more likely to be hyperopic (OR, 0.80 [95% CI, 0.68, 0.93];  $P = 0.003$ ). Hindu subjects were significantly less myopic than Muslims, and also less hyperopic. No significant differences were found between Christians and Muslims regarding myopia or hyperopia. These comparisons also were made with different degrees of myopia. Similar relationships existed for myopia of  $< -1$  D and  $< -3$  D. However, there was no significant ( $P < 0.05$ ) difference in prevalence of myopia of more than 5 D in urban areas compared with rural areas, or according to the level of education. The presence of a cataract (grades 2A, 2B, or 3) was associated with an almost 13-fold risk for myopia (OR, 12.85 [95% CI, 11.26, 14.66];  $P < 0.001$ ).

A subanalysis was performed to investigate the prevalence of myopia and hyperopia in all subjects who had no visually significant cataract (9845 subjects). With cataracts (grades 2A, 2B, and 3) excluded, literacy and school attendance posed no significant risk for myopia (at various levels of magnitude), and urban habitation also had no significant risk for myopia for all levels of myopia other than high myopia ( $< -5$  D; OR, 2.66 [95% CI, 0.99, 6.97];  $P = 0.044$ ). However, a college or university education carried an increased risk for myopia at all levels of severity ( $< 0.5$  D, OR, 1.50 [95% CI, 1.21, 1.86];  $P < 0.001$ ;  $< -1.0$  D, OR, 1.40 [95% CI, 1.00, 1.98];  $P = 0.043$ ;  $< -3$  D, OR, 4.18 [95% CI, 1.50, 11.95],  $P < 0.01$ ;  $< -5$  D, OR, 6.62 [95% CI, 1.14, 49.22];  $P = 0.019$ ). In addition, this subanalysis revealed an increased risk of myopia of  $< -0.5$  D in nonmanual occupations (OR, 1.35 [95% CI, 1.16, 1.58];  $P < 0.001$ ) and manual occupations (OR, 1.38 [95% CI, 1.22, 1.57];  $P < 0.001$ ), which was not evident at the other higher levels of myopia.

Using a generalized linear model, age, cataract, attendance at school, literacy, and gender were all significantly related to the spherical equivalent ( $P < 0.001$ ), whereas geographical area (rural or urban) was not.

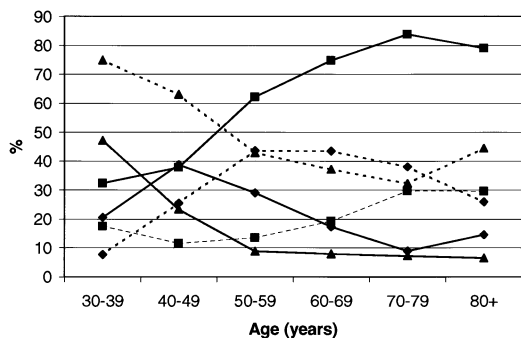


Figure 2. The prevalence of myopia, emmetropia, and hyperopia with age in Bangladesh (right eyes only) in subjects with cataract and in subjects without cataract. Cataract is defined as grade 2A or more. Full line = subjects with cataract; dashed line = subjects without cataract; squares = myopes; triangles = emmetropes; diamonds = hyperopes.

of Refractive Errors in Bangladeshi Adults

Myopia ( $\leq 0.5$ Diopters Spherical Equivalent)			Hypermetropia ( $> +0.5$ Diopters Spherical Equivalent)			Astigmatism ( $> 0.5$ DC)			Anisometropia ( $> 1.0D$ Spherical Equivalent between eyes)			
n	%	95% Confidence Interval	n	%	95% Confidence Interval	n	%	95% Confidence Interval	Total	n	%	95% Confidence Interval
427	19.7	18.0, 21.4	103	4.8	3.9, 5.7	361	16.7	15.1, 18.2	2157	26	1.2	0.7, 1.7
218	14.5	12.7, 16.3	278	18.5	16.6, 20.5	424	28.3	26.0, 30.5	1493	70	4.7	3.6, 5.8
208	25.0	22.1, 27.9	254	30.5	27.4, 33.7	344	41.3	38.0, 44.7	816	85	10.4	8.3, 12.5
287	44.9	41.1, 48.8	159	24.9	21.5, 28.2	410	64.2	60.4, 67.9	632	142	22.5	19.2, 25.7
246	69.9	65.1, 74.7	51	15.5	10.8, 18.2	277	78.7	74.4, 83.0	335	117	34.9	29.8, 40.0
420	15.8	14.4, 17.2	271	10.2	9.0, 11.3	546	20.5	19.0, 22.0	2654	56	2.1	1.6, 2.7
151	10.4	8.9, 12.0	486	33.6	31.2, 36.0	367	25.4	23.1, 27.6	1443	53	3.7	2.7, 4.6
162	19.6	16.9, 22.3	426	51.4	48.0, 54.9	381	46.0	42.6, 49.4	821	80	9.7	7.7, 11.8
212	40.1	36.0, 44.3	220	41.7	37.5, 45.9	337	63.8	59.7, 67.9	515	130	25.2	21.5, 29.0
138	57.6	52.7, 65.3	60	25.9	20.0, 31.2	178	76.1	70.6, 81.5	220	78	35.5	29.1, 41.8

**Astigmatism**

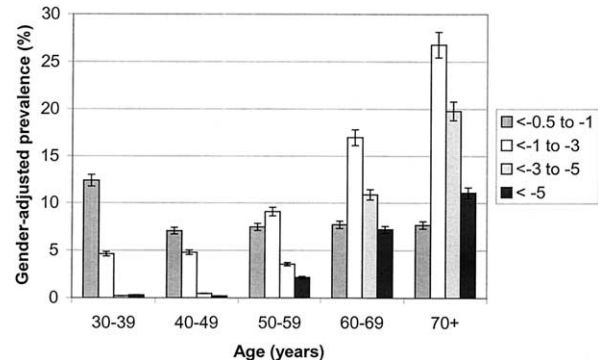
Astigmatism was analyzed in minus cylinders and was defined as more than 0.5 D of cylinder, without reference to the axis. Astigmatism was present in 3625 subjects (32.4%), with an age- and gender-standardized prevalence of 34.6% (95% CI, 34.6%, 34.7%). One thousand four subjects with astigmatism (27.7%) were myopic ( $< -0.5$  D sphere) and 976 (26.9%) were hyperopic ( $> 0.5$  D sphere). Astigmatism was more prevalent in women (OR, 1.03;  $P < 0.001$ ) than men (Table 1). The prevalence was significantly higher in successively older age groups, rising to a 15-fold increase (OR, 15.02 [95% CI, 12.15, 18.58]) in those aged 70 or older, in comparison with the 30 to 34-year group (Tables 2, 3). It was less common in those subjects who were literate or semiliterate and in those who had attended school. No significant differences existed between subject groups who had attended school compared with those with higher levels of education. No significant difference existed between rural or urban areas. Religion was not significantly associated. As would be expected, astigmats were more likely to wear spectacles. The prevalence of astigmatism in nonmanual and manual workers was significantly less than in unemployed subjects. Cataract was significantly associated with astigmatism (OR, 6.49 [95% CI, 5.71, 7.38]).

Against-the-rule astigmatism was more common (58.7%) than oblique astigmatism (29.3%), which in turn was more common than with-the-rule astigmatism (12.1%). This relationship was consistent for different magnitudes of astigmatism. The prevalence of with-the-rule astigmatism was not significantly correlated with age (Pearson's  $r$ ,  $-0.623$ ;  $P = 0.261$ ), yet against-the-rule astigmatism positively correlated with age in men and women (Pearson's  $r$ , 0.997;  $P < 0.01$  for men; 0.979;  $P < 0.01$  for women) as did oblique astigmatism in both genders (Pearson's  $r$ , 0.978;  $P < 0.01$  for men; 0.961;  $P < 0.01$  for women). These findings are illustrated in Figure 4.

**Anisometropia**

For the analysis of anisometropia, subjects in whom no refractive error data were available for the left eye were excluded (92 subjects). In addition, those who had undergone cataract surgery in the left eye were also excluded (11 subjects) from this analysis. Of the remaining 11 086 phakic subjects with refractive data for both eyes, 830 (7.5%) were anisometric (a difference in the spherical

equivalent between the right and left eyes of more than 1.0 D). After age and gender standardization, 8.8% of men and 8.7% of women were anisometric. Women were more likely to be anisometric (OR, 1.01 [95% CI, 1.01, 1.01]) than men ( $P < 0.001$ ). The prevalence of anisometropia increased significantly with age in men and women (Pearson's coefficients: 0.974 and 0.963, respectively,  $P < 0.01$ ). The presence of cataract (Grade 2A or more) in either eye was significantly associated with anisometropia (OR, 34.9 [95% CI, 28.5, 42.9];  $P < 0.001$ ). Subjects with anisometropia were more likely to be illiterate (OR, 2.03 [95% CI, 1.72, 2.39];  $P < 0.001$ ), be unschooled (OR, 1.73 [95% CI, 1.49, 2.01];  $P < 0.001$ ), be employed in manual jobs (OR, 1.63 [95% CI, 1.27, 2.09];  $P < 0.001$ ), or have no occupation (OR, 1.66 [95% CI, 1.31, 2.10];  $P < 0.001$ ) than those subjects without anisometropia who had attended school, were literate, or who had professional occupations. Anisometropia was also more common in subjects from rural areas than in those from urban areas (OR, 1.15 [95% CI, 0.95, 1.39];  $P = 0.14$ ). They were also more likely to wear spectacles than nonanisometric subjects (OR, 1.50 [95% CI, 1.04, 2.16];  $P = 0.023$ ).



**Figure 3.** Gender-adjusted prevalence of myopia for the various magnitudes of myopia in the different age groups (this includes all right eyes with cataract).

Table 3. Univariate Analysis of the Effect of Age, Gender, Literacy, Geographical Location, Education, Religion, Occupation, Refractive Correction, and Cataract on Myopia ( $\leq 0.5$  Diopters), Hyperopia ( $> +0.5$  Diopters), and Astigmatism ( $> 0.5$  Diopters)

	Total No. of Subjects*	Myopes, n	OR for Myopia (95% CI); P	Hyperopes, n	OR for Hyperopia (95% CI); P	Astigmats, n	OR for Astigmatism (95% CI); P
Cataract <sup>†</sup>							
0 or 1	9845	1531	1.00	2039	1.00	2672	1.00
2A, 2B or 3	1326	932	12.85 (11.26, 14.66); <0.001	261	0.94 (0.81, 1.09); 0.385	938	6.49 (5.71, 7.38); <0.001
Literacy							
Easily reads and writes	4625	862	0.70 (0.63, 0.77); <0.001	893	0.82 (0.74, 0.90); <0.001	1363	0.75 (0.69, 0.82); <0.001
With difficulty	1189	281	0.94 (0.81, 1.10); 0.437	194	0.67 (0.56, 0.79); <0.001	346	0.74 (0.64, 0.85); <0.001
Illiterate <sup>‡</sup>	5331	1317	1.00	1208	1.00	1905	1.00
Residence							
Rural	9030	2038	1.00	1812	1.00	2935	1.00
Urban	2159	431	0.86 (0.76, 0.96); 0.008	496	1.19 (1.06, 1.33); 0.0027	690	0.98 (0.88, 1.08); 0.627
Attended School?							
Yes	5330	1011	0.71 (0.65, 0.77); <0.001	1031	0.86 (0.78, 0.94); 0.0011	1580	0.78 (0.72, 0.85); <0.001
No	5845	1454	1.00	1276	1.00	2042	1.00
Highest level of schooling <sup>§</sup>							
Primary	2394	464	1.00	473	1.00	718	1.00
Secondary	2088	367	0.89 (0.76, 1.04); 0.121	382	0.91 (0.78, 1.06); 0.213	601	0.94 (0.83, 1.08); 0.376
College or university <sup>  </sup>	834	176	1.11 (0.91, 1.36); 0.283	172	1.06 (0.86, 1.29); 0.59	252	1.01 (0.85, 1.20); 0.90
Religion							
Islam	9940	2228	1.00	2024	1.00	3223	1.00
Hinduism	1177	225	0.82 (0.70, 0.96); 0.009	273	1.18 (1.02, 1.37); 0.023	376	0.98 (0.86, 1.12); 0.739
Christianity	36	12	1.73 (0.82, 3.62); 0.11	6	0.78 (0.29, 1.97); 0.582	16	1.67 (0.82, 3.36); 0.124
Wearing glasses?							
Yes	340	98	1.45 (1.13, 1.85); 0.002	161	3.65 (2.91, 4.56); <0.001	172	2.19 (1.76, 2.74); <0.001
No	10849	2371	1.00	2147	1.00	3453	1.00
Occupation							
Nonmanual	1848	375	1.0 (0.87, 1.14); 0.979	320	0.59 (0.52, 0.68); <0.001	542	0.80 (0.71, 0.89); <0.001
Manual	3761	919	1.27 (1.15, 1.40); <0.001	538	0.47 (0.42, 0.53); <0.001	1173	0.87 (0.79, 0.95); 0.002
Inactive or unemployed	5514	1157	1.00	1441	1.00	1890	1.00

CI = confidence interval; OR = odds ratio.

Data for the following variables were missing: literacy, 44 subjects; school attendance, 14 subjects; religion, 36 subjects; occupation, 66 subjects.

\*Includes emmetropes.

<sup>†</sup>Eyes with better than 6/12 visual acuity were assumed to have no cataract.

<sup>‡</sup>Combining "reads easily" and "with difficulty" and comparing with illiterate subjects, the values are: myopia (OR, 0.75 [0.68, 0.82]; <0.001) hyperopia (OR, 0.78 [0.72, 0.86]; <0.001), astigmatism (OR, 0.75 [0.69, 0.81]; <0.001).

<sup>||</sup>Combining college and university with secondary: OR, 0.95 (0.83, 1.09), 0.459.

## Discussion

This population-based survey of refractive error is one of the largest surveys of its kind performed in the world. It is

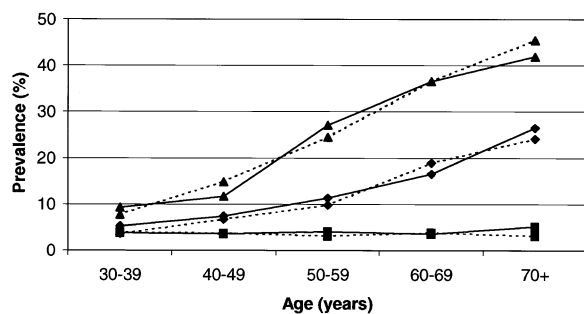


Figure 4. Prevalence of types of astigmatism by 10-year age groups for men and women. Dashed lines = men; solid lines = women; squares = with-the-rule astigmatism; triangles = against-the-rule astigmatism; diamonds = oblique astigmatism.

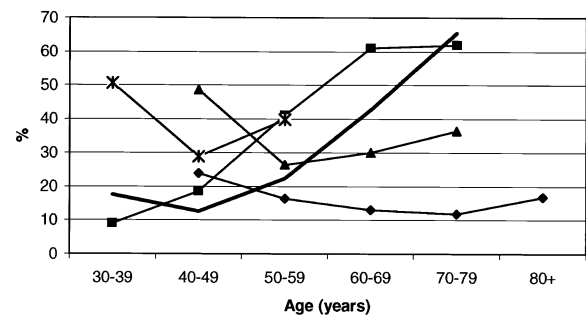
also one of the few population-based refractive error surveys in Asia.<sup>3,4,7-9</sup> In addition, the survey was designed to be nationally representative. The combination of large sample size and high response rate (90.9%) adds considerable statistical power to the analysis. Among those enumerated who were aged 30 to 59 years, substantially more males did not participate in the survey as compared with females. This gender difference between responders and nonresponders in this age group may alter the overall prevalence rates of refractive error. Comparing the demographics of those examined with those of the overall population<sup>14</sup> showed that there were relatively more women examined in younger age groups and more men in older age groups than would be expected from the age and gender structure of the Bangladeshi population. Hence, gender-specific prevalence rates were presented. The refractive error of each subject was measured using automated refraction. It is acknowledged that accommodation occurs with the use of an autorefractor when no cycloplegia is administered. This may have given a more myopic result, particularly in younger adults, than

what would have been obtained with a subjective refraction. However, subjective refraction of all subjects would have been impracticable in a study of this size. Another strength of this study was to have autorefracted every subject, regardless of visual acuity and of whether the subject wore spectacles at presentation. The maximum visual acuity that a given subject could attain in this study was 0.1 logMAR, which conveniently equated to 30 optotypes correctly identified (this equates to between 6/6 and 6/9 Snellen). Other studies potentially have underestimated the number of hyperopes by not refracting subjects with a visual acuity of 6/6 (0.0 logMAR) or better,<sup>8,9,17,18</sup> or even 6/12 (0.3 logMAR) or better.<sup>6</sup> Of the 7641 right eyes that were recorded with a visual acuity of 0.1 logMAR or less, the mean refractive error was +0.03 D (standard deviation, 0.60). Of these 7641 eyes, 1116 were hyperopic (48.3% of all hyperopes [ $> +0.5$  D] in the study) and 950 were myopic (38.5% of all myopes [ $< -0.50$  D]). A proportion of this myopia may have been the result of accommodation. This gives an indication of the potential large underestimation of hyperopia and perhaps also of myopia by these other studies.

The main analysis involved using refractive data from the right eye. This is in keeping with several other studies<sup>5,10,18</sup>; however, it does differ from a recent Indian study<sup>8,9</sup> that used the refractive error of the worse eye as representative of the refractive error for the subject in the analysis. As expected, comparison of the worse eye with the right eye using the Bangladeshi survey data showed high correlation (Pearson's  $r$ , 0.935).

The leptokurtosis and negative skewness of the distribution of spherical refractive error (Fig 1) in this population was similar in shape to that seen in several other refractive error studies.<sup>3,5,7,10,17-22</sup> However, the mean spherical equivalent ( $-0.19$  D in this study) differs between studies ( $-0.25$  D in Hong Kong Chinese adults aged 40 years and older,<sup>16</sup>  $+0.62$  D in rural Malawi aged 18 to 35 years,<sup>19</sup>  $-1.13$  D in young Singaporean Indian military conscripts,<sup>10</sup> and  $+0.67$  D in Australians aged 49 years and older<sup>17</sup>).

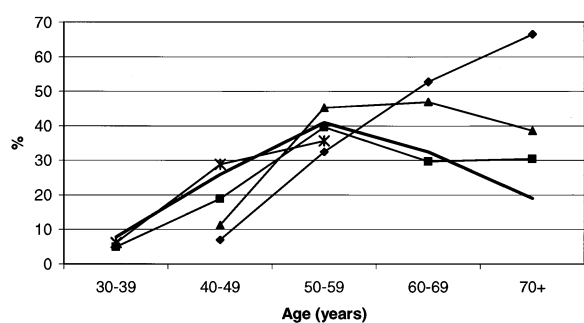
This study found an age- and gender-standardized prevalence of myopia ( $< -0.5$  D) of 23.8%. A survey in India<sup>9</sup> reported a rate of 28.6% in adults aged 30 years or older. The prevalence of high myopia in the Bangladeshi study ( $< -5$  D; 1.8%) was not dissimilar to that of Indian persons (1.2% Singaporean Indian young adults),<sup>10</sup> 4.5% of Indians (aged 15 years or older) from Andhra Pradesh,<sup>9</sup> white Australians aged 40 years and older ( $< -6$  D; 2.1%),<sup>18</sup> and some South East Asian populations (provincial Sumatrans aged 21 years and older,<sup>4</sup> 0.6%), but much lower than that reported in Singaporean Chinese adults aged 40 years and older (6.9%).<sup>7</sup> Myopia was more common in men than in women. This male preponderance has been reported in a study of white persons.<sup>21</sup> However, other studies in Asia have not shown such a significant male preponderance of myopia.<sup>7-9</sup> One study of white persons reported a female preponderance.<sup>23</sup> Much of this myopia in older age groups was the result of cataract. Both genders demonstrated an increasing prevalence of myopia with increasing age, with low prevalence in the 30 to 49-year age group, and then a dramatic increase from the age of 50 years. This was demonstrated by the subanalysis that excluded subjects with



**Figure 5.** Prevalence of myopia (less than  $-0.5$  diopters) by age in selected population-based studies. Total number of subjects in each study: Bangladesh (solid line, no marker), 11 189; India (squares),<sup>9</sup> 5434 ( $\geq 30$  years of age); Singapore Chinese (triangles),<sup>7</sup> 1113 ( $\geq 40$  years of age); Australia (diamonds),<sup>18</sup> 4528 ( $\geq 40$  years of age); Sumatra (stars),<sup>4</sup> 702 ( $\geq 30$  years of age). Each study excluded cataract-operated subjects (except the Sumatran study) and those subjects for whom no refractive data were available. The Bangladeshi and Singaporean studies recorded refractive error of all subjects, whereas the Indian and Australian studies did not record refractive error in those with a visual acuity of 6/6 or better. The oldest age group in the Indian study was 70 years or older, whereas in the Singaporean study, this was 70 to 79 years. The oldest age group in the Sumatran study was 50 years or older. Data from all studies except the Sumatran study (limited data available from the published material) was standardized for gender against the population of Bangladesh.<sup>14</sup>

cataracts, where the increase in myopia with age was slight. The effect on myopia prevalence of this interaction of cataract with age has been noted by other studies.<sup>8,18,24</sup> The finding that low degrees of myopia ( $< -0.5$  to  $-1.0$  D) reduced with age, but that the greater degrees of myopia ( $< -1.0$  D) became much more prevalent with increasing age, also concurs with the effect of cataract-induced myopia in older age. Figure 5 shows the relationship of myopia prevalence with age in several population-based surveys. It shows remarkable concurrence between the Indian<sup>9</sup> and Bangladeshi studies, with low levels of myopia in younger adults, rising to high levels in older ages; yet in India, the rise in myopia prevalence begins approximately 10 years earlier than in Bangladesh. This difference in pattern between southern India and Bangladesh may reflect differences in the pattern of cataract prevalence. It is interesting how this pattern differs from studies of white persons,<sup>5,6,17,23,25</sup> where higher prevalences of myopia exist in younger adults and then reduce with age.

The Bangladeshi survey also found a significantly higher prevalence of myopia in the 30 to 39-year age group compared with the 40 to 49-year group. This may represent a cohort effect, with a more recent increase in the prevalence of myopia in young adults that was not present 10 years ago. The southern Indian urban study<sup>8</sup> also reported a higher prevalence of myopia, but only in the 16 to 29-year age group (16.1%), which decreased in the 30 to 39-year group (13.1%). This further reflects the finding that the distribution of myopia prevalence with age seems to be shifted to the left (i.e., towards lower age groups) in the Indian survey when compared with the Bangladesh study. In the rural sites of the Indian survey,<sup>9</sup> the prevalence of myopia increased with age from the age of 15 years. Among those aged 30 to



**Figure 6.** Prevalence of hyperopia (>0.5 diopters) by age in selected population studies. Total number of subjects in each study: Bangladesh (solid line, no marker), 11 189; India (squares),<sup>9</sup> 5434 ( $\geq 30$  years of age); Singapore Chinese (triangles),<sup>7</sup> 1113 ( $\geq 40$  years of age); Australia (diamonds; unpublished data obtained from Melbourne Visual Impairment Project [Taylor HR, personal communication]), 4528 ( $\geq 40$  years of age); Sumatra (stars),<sup>4</sup> 702 ( $\geq 30$  years of age). Each study excluded cataract-operated subjects (except the Sumatran study) and those subjects for whom no refractive data were available. The Bangladeshi and Singaporean studies recorded refractive error of all subjects, whereas the Indian and Australian studies did not record refractive error in those with a visual acuity of 6/6 or better. The oldest age group in the Indian study was 70 years or older, whereas in the Singaporean study, this was 70 to 79 years. The oldest age group in the Sumatran study was 50 years or older. Data from all studies except the Sumatran study (limited data available from the published material) were standardized for gender against the population of Bangladesh.<sup>14</sup>

39 years, the Bangladesh study found a higher prevalence of myopia ( $< -0.5$  D) in subjects in urban areas (19.5%) than in rural areas (16.9%), although this was not a significant difference ( $P = 0.11$ ). A study involving Chinese schoolchildren showed higher prevalences in the city than in the countryside,<sup>26</sup> which may be in part the result of more education in an urban environment. These rural and urban differences may be less evident in Bangladesh, yet the increase in myopia prevalence in young adults is particularly dramatic in an environment such as Singapore, where, among young adult male military conscripts (aged 16–25 years), a high prevalence of myopia ( $< -0.5$  D) was reported not only in Chinese subjects (82.2%), but, interestingly, also in Indian (68.7%) and Malayan (65.0%) recruits.<sup>10</sup> These high prevalence rates among younger adults among the Chinese of Singapore<sup>7,27</sup> (also among Hong Kong Chinese<sup>11</sup> and Indonesians from provincial Sumatra<sup>4</sup>) are higher than those of Australians<sup>17,18</sup> and South Asians, but the prevalence then reduces with increasing age (Fig 5), with a suggestion of an increase again in the much older groups, an observation that has been made by several studies<sup>5,6,8,9,18,28</sup> and understood to be the result of cataract.

This study did not show a significant association between literacy, schooling, and higher education on prevalence of myopia (used in support of the use–abuse theory of myopia), unlike several other studies.<sup>5,6,8,10,18,20,23,29–34</sup> Indeed, this study actually showed a significantly reduced risk of myopia with literacy, urban living, and school attendance. However, the subanalysis that excluded subjects with cataract, and hence many of the older subjects, did show an increased risk of myopia in those who had pursued higher education. The na-

tional survey of Bangladesh showed an exceptionally high prevalence of cataract<sup>1</sup>; more than two thirds (68.59%) of eyes with a visual acuity of less than 6/12 (0.3 logMAR) were graded 2A, 2B, or 3. A total of 676 of the right eyes included in the refractive error analysis (6%) had a cataract of grade 2A, 2B, or 3. When subjects with cataract were excluded, significant associations were found between myopia and higher levels of education and nonmanual occupations, an association that has been reported by several other studies. The study did show significantly more myopia among manual workers than among those who were unemployed. Other studies have shown increased myopia among nonmanual professions.<sup>7,18</sup>

Hyperopia ( $> +0.5$  D) was recorded in 21.3% of subjects (age and gender standardized)<sup>14</sup> and was more common among women, an observation that has been reported by other studies.<sup>6,8,17,21,23,30</sup> This gender difference was less evident in the 30 to 39-year age group and was more apparent in the 40 to 69-year range. Hyperopes were less likely to be literate or to have attended school, which was interesting because other authors have commented on an association between hyperopia and reading underachievement<sup>35</sup> or lack of education.<sup>5</sup> However, no significant relationship of hyperopia with higher education was found in this study. The prevalence of hyperopia in nonmanual workers was significantly lower than in manual or unemployed subjects, which may reflect an advantage of emmetropia or myopia in attaining a nonmanual occupation, perhaps through advantages of education and schooling. The relationship between hyperopia and age is compared with that of other studies in Figure 6.<sup>4</sup> The Indian<sup>8,9</sup> and Bangladeshi populations show a remarkably similar pattern, with low levels of hyperopia in younger adults, rising to maximal levels in the 50 to 59-year group, and then declining in later years. A similar pattern is seen in the Singaporean,<sup>7</sup> Indonesian,<sup>4</sup> and Australian studies (unpublished data from the Melbourne Visual Impairment Project; Taylor HR, personal communication, 2003), yet in the Singaporean population, the later decline is less marked, and in the Australian population, it is absent.

Astigmatism ( $>0.5$  D) was prevalent in 34.6% of subjects (age and gender standardized).<sup>14</sup> The prevalence increased with increasing age, in accordance with findings of other studies in different ethnic groups.<sup>5,7,17,36</sup> Against-the-rule astigmatism was more common than oblique or with-the-rule astigmatism. This concurs with some studies,<sup>8,17</sup> but contrasts with others.<sup>37,38</sup> The female preponderance of astigmatism was interesting, as was the fact that it was more common in illiterate subjects and in those who had not attended school. It is possible that astigmatism is associated with less education, because it was also more common in those with manual occupations or the unemployed. Some studies have reported an association between education and astigmatism,<sup>39,40</sup> whereas others find no association.<sup>5,7</sup> Other studies<sup>22,41</sup> have reported a shift from with-the-rule to against-the-rule astigmatism with increasing age (thought to be the result of reduced eyelid tension with age). This study also demonstrated an increase in against-the-rule astigmatism with age, in keeping with the results of other studies.<sup>19,22,36</sup> However, the prevalence of with-the-rule astigmatism was unaffected by age. A large population-based

study of Icelanders<sup>36</sup> reported a decrease in with-the-rule astigmatism with age. The Bangladeshi study also showed oblique astigmatism to be more prevalent than with-the-rule astigmatism at all ages, with an increasing prevalence with age, which concurs with the findings of the Icelandic study. This relatively large contribution because of oblique astigmatism has not been reported in several other studies, despite variations used in its definition.<sup>8,17,19</sup>

Anisometropia was more common in women and increased in prevalence with age. Other population groups have similarly shown an increase of anisometropia with age.<sup>5,17</sup> The association of anisometropia with lack of education and manual occupations or unemployment also was an interesting finding. The association with less education also was found in the Indonesian study<sup>4</sup>; however, this study reported no gender difference.

Refractive error has been highlighted as a major cause of visual disability by the World Health Organization Vision 2020 program.<sup>2</sup> There are 42 million adults (34.6% of the total population)<sup>14</sup> aged 30 years or older in Bangladesh. Extrapolating the age- and gender-standardized prevalences from this survey, there are an estimated 10 million myopes (<-0.5 D) and 8.9 million hyperopes (>+0.5 D) in Bangladesh. An estimated 14.6 million individuals would be astigmatic (>0.5 D). The findings of this large survey have provided valuable data that contribute to the limited existing knowledge of refractive error in the region and also to the planning and implementation of eye care delivery and resource allocation in Bangladesh.

**Acknowledgments.** The authors thank the 3 teams (all recruited from the National Institute of Ophthalmology, Dhaka, Bangladesh) who performed the survey, led by Drs Syed Abdul Wadud, Shajahan Ali, and Lakshman Kumar Kar (ophthalmologists); the team of ophthalmic nurses, Smrity Arinda, Nilufa Begum, and Benju Rani Talukder; Mr Zakir Hussain Khan and Kaesur Rahman for logistical support; and Dr Clare Gilbert for reading and commenting on the manuscript.

## References

- 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.
- Global Initiative for the Elimination of Avoidable Blindness. Geneva: World Health Organization; 1997:1–7. WHO/PBL/97.61.
- Verlee DL. Ophthalmic survey in the Solomon Islands. *Am J Ophthalmol* 1968;66:304–19.
- Saw SM, Gazzard G, Koh D, et al. Prevalence rates of refractive errors in Sumatra, Indonesia. *Invest Ophthalmol Vis Sci* 2002;43:3174–80.
- 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.
- Wang Q, Klein BE, Klein R, Moss SE. Refractive status in the Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci* 1994;35:4344–7.
- 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.
- 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;40:2810–8.
- Dandona R, Dandona L, Srinivas M, et al. Population-based assessment of refractive error in India. the Andhra Pradesh eye disease study. *Clin Experiment Ophthalmol* 2002;30:84–93.
- Wu HM, Seet B, Yap EP, et al. 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.
- Goh WSH, Lam CSY. Changes in refractive trends and optical components of Hong Kong Chinese aged 19–39 years. *Ophthalmic Physiol Opt* 1994;14:378–82.
- Lin LL, Shih YF, Tsai CB, et al. Epidemiological study of ocular refraction among schoolchildren in Taiwan in 1995. *Optom Vis Sci* 1999;76:275–81.
- Bourne RR, Dineen B, Modasser Ali S, et al. The National Blindness and Low Vision Prevalence Survey of Bangladesh: research design, eye examination methodology and results of the pilot study. *Ophthalmic Epidemiol* 2002;9:119–32.
- Statistical Pocketbook of Bangladesh 1997. Dhaka: Bangladesh Bureau of Statistics; 1998:146–7.
- Rosser DA, Laidlaw DA, Murdoch IE. The development of a “reduced logMAR” visual acuity chart for use in routine clinical practice. *Br J Ophthalmol* 2001;85:432–6.
- Mehra V, Minassian D. A rapid method of grading cataract in epidemiological studies and eye surveys. *Br J Ophthalmol* 1988;72:801–3.
- Attebo K, Ivers RQ, Mitchell P. Refractive errors in an older population: the Blue Mountains Eye Study. *Ophthalmology* 1999;106:1066–72.
- Wensor M, McCarty C, Taylor HR. Prevalence and risk factors of myopia in Victoria, Australia. *Arch Ophthalmol* 1999;117:658–63.
- Lam CSY, Goh WSH, Tang YK, et al. Changes in refractive trends and optical components of Hong Kong Chinese aged over 40 years. *Ophthalmic Physiol Opt* 1994;14:383–8.
- Lewallen S, Lowden R, Courtright P, Mehl GL. A population-based survey of the prevalence of refractive error in Malawi. *Ophthalmic Epidemiol* 1995;2:145–9.
- Hyams SW, Pokotilo E, Shkurko G. Prevalence of refractive errors in adults over 40: a survey of 8102 eyes. *Br J Ophthalmol* 1977;61:428–32.
- Fledelius HC. Prevalences of astigmatism and anisometropia in adult Danes, with reference to presbyopes’ possible use of supermarket standard glasses. *Acta Ophthalmol (Copenh)* 1984;62:391–400.
- Aine E. Refractive errors in a Finnish rural population. *Acta Ophthalmol (Copenh)* 1984;62:944–54.
- Lee KE, Klein BE, Klein R. Changes in refractive error over a 5-year interval in the Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci* 1999;40:1645–9.
- Lavery JR, Gibson JM, Shaw DE, Rosenthal AR. Refraction and refractive errors in an elderly population. *Ophthalmic Physiol Opt* 1988;8:394–6.
- Saw SM, Hong RZ, Zhang MZ, et al. Near-work activity and myopia in rural and urban schoolchildren in China. *J Pediatr Ophthalmol Strabismus* 2001;38:149–55.
- 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.
- Slataper FJ. Age norms of refraction and vision. *Arch Ophthalmol* 1950;43:466–81.
- Wong L, Coggon D, Cruddas M, Hwang CH. Education, reading, and familial tendency as risk factors for myopia in

- Hong Kong fishermen. *J Epidemiol Community Health* 1993; 47:50–3.
30. Sperduto RD, Seigel D, Roberts J, Rowland M. Prevalence of myopia in the United States. *Arch Ophthalmol* 1983;101: 405–7.
  31. Parssinen O. The wearing of spectacles in different social and educational groups in a sample of the population of central Finland. *Scand J Soc Med* 1987;15:145–51.
  32. Rosner M, Belkin M. Intelligence, education, and myopia in males. *Arch Ophthalmol* 1987;105:1508–11.
  33. Saw SM, Katz J, Schein OD, et al. Epidemiology of myopia. *Epidemiol Rev* 1996;18:175–87.
  34. Teasdale TW, Fuchs J, Goldschmidt E. Degree of myopia in relation to intelligence and educational level. *Lancet* 1988;10: 1351–4.
  35. Eames TH. The influence of hypermetropia and myopia on reading achievement. *Am J Ophthalmol* 1955;39:375–7.
  36. Gudmundsdottir E, Jonasson F, Jonsson V, et al, Iceland–Japan Co-working Study Groups. “With the rule” astigmatism is not the rule in the elderly. Reykjavik Eye Study: a population based study of refraction and visual acuity in citizens of Reykjavik 50 years and older. *Acta Ophthalmol Scand* 2000; 78:642–6.
  37. Pensyl CD, Harrison RA, Simpson P, Waterbor JW. Distribution of astigmatism among Sioux Indians in South Dakota. *J Am Optom Assoc* 1997;68:425–31.
  38. McKendrick AM, Brennan NA. Distribution of astigmatism in the adult population. *J Opt Soc Am A* 1996;13:206–14.
  39. Taylor H. Racial variations in vision. *Am J Epidemiol* 1981; 113:62–80.
  40. Parssinen O. Astigmatism and school myopia. *Acta Ophthalmol (Copenh)* 1991;69:786–90.
  41. Goss D. Meridional analysis of with-the-rule astigmatism in Oklahoma Indians. *Optom Vis Sci* 1989;66:281–7.