Ocular Biometry and Refraction in Mongolian Adults

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Objective. To describe the variation in ocular biometry and its association with refraction in adult Mongolians.

Methods. The study included 1800 subjects, aged 40 years or more, who were selected in two Mongolian provinces—Hövsgöl and Ömnögobi—to participate in this population survey. Axial length (AL) and its components, as well as noncycloplegic autorefraction and corneal power (CP), were measured.

Results. Of those selected, 1617 subjects (90.0%) were examined. Mean ± SD of AL was 23.13 ± 1.15 mm. There was a very small but significant increase in mean AL with age (0.05 mm per decade, $P = 0.03$). Autorefraction was performed on 620 of 675 subjects of those examined in Ömnögobi. The age and gender standardized prevalences of myopia (< −0.5 D), emmetropia, hyperopia (>+0.5 D), astigmatism (<−0.5 D of cylinder) and anisometropia (>1.0 D difference between eyes) were 17.2%, 49.9%, 32.9%, 40.9%, and 10.7%, respectively. Prevalence of myopia showed no clear trend with increasing age, whereas hyperopia, astigmatism, and anisometropia all increased monotonically. Multiple regression models revealed that AL ($P < 0.001$) and VCD ($P < 0.001$) were the strongest determinants of refractive error.

Conclusions. In this cross-sectional study of adult Mongolians, a much lower prevalence of myopia was found than in other East Asian populations studied to date. The mean AL differed little between age groups, in marked contrast to data on Chinese people. (*Invest Ophthalmol Vis Sci.* 2004;45:776–783) DOI:10.1167/iovs.03-0456

Uncorrected refractive error is a leading cause of visual impairment and if uncorrected distance visual acuity is examined, refractive error would become the second largest cause of treatable blindness after cataract.[1] The relative contribution of genetic heritage and environment in determining refractive error remains uncertain.[2] Prevalence of myopia in European-derived people ranges between 15% and 25%,[3,4] with similar rates in African people living in the United States and the Caribbean (19%–22%).[4,5] People living in nonindustrialized regions appear less prone to myopia. Studies of Australian aborigines[6] and Solomon Islanders[7] have also revealed considerably lower rates of myopia: 2% and 5%, respectively. Among young East Asians, however, myopia appears to be approaching epidemic proportions. A recent population-based study in Singapore[8] demonstrated a 38.7% prevalence of myopia, with persons with high myopia making up 9.1% of those studied. Even higher prevalences have been noted in selected groups such as Singaporean medical students (82%)[9] and military recruits (79.3%).[10] The prevalence of myopia has also been shown to be high in other populations within the region. Among Japanese adults between 40 and 79 years,[11] the rate was 45.7% in men and 38.8% in women, whereas in Hong Kong[12] those between 19 and 39 years were found to have a prevalence of approximately 40%. The increased prevalence of myopia in these studies has been associated with greater axial length (AL).[8,12,13]

The etiology of refractive error cannot be fully understood without examination of biometric data such as AL and corneal power (CP), as well as indices of lenticular power. In children and younger adults, AL of the globe and, in particular, vitreous chamber depth (VCD) account for most of the variation in refraction.[14–17] In older adults, along with the changes in lenticular power that accompany nuclear sclerosis of the lens, AL variation has also been shown to cause refractive change.[18] In their study on clinical microscopists (aged 21–63 years), McBrien and Adams[19] demonstrated a longitudinal increase in AL (especially VCD), accompanied with a myopic shift in refractive error. The reasons for the increased AL and refractive change have not been adequately explained. However, it has been proposed that the increasing time spent on near-work activity may be a risk factor in the development of myopia in a population susceptible to myopic change.[10,20–26]

There is some evidence that Mongolia is the center of initial human colonization of Northeast Asia.[27,28] Mongolia therefore offers an opportunity to examine biometric and refractive trends in a nonindustrialized, albeit literate, Asian population. The Mongolian education system is less intensive than in other East Asian countries, although adult literacy rates are 98% in men and 95% among women.[29] The development of secular schools in rural areas, with boarding facilities for nomadic children, is a legacy of the socialist era. Mongolian authorities first claimed universal literacy in 1968. Currently, children begin compulsory full-time education between the ages of 6 and 8, for a minimum period of 10 years. As a part of a glaucoma survey, we describe the variations in ocular dimensions and associations with refraction in this population aged 40 years or more. Comparison with genetically similar populations subject to differing educational and occupational influences may help clarify the etiology of myopia in East Asian people.

Methods

Ethical approval for this project was obtained from the Mongolian Ministry of Health. The work was performed in accordance with the

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TABLE 1. Demographics of Populations Assessed in Mongolia

Aimag	Age (y)	Men	Women*	Total*
Hövsgöl, 1995	40–49	164 (40.5)	263 (49.0)	427 (45.3)
	50–59	120 (29.6)	156 (29.1)	276 (29.3)
	60–69	81 (20.0)	82 (15.3)	163 (17.3)
	70+	40 (9.9)	36 (6.7)	76 (8.1)
	Total	405 (43.0)	537 (57.0)	942 (100.0)
Ömnögobi, 1997	40–49	77 (26.1)	105 (27.6)	182 (27.0)
	50–59	80 (27.1)	110 (28.9)	190 (28.1)
	60–69	69 (23.4)	86 (22.6)	155 (23.0)
	70+	69 (23.4)	79 (20.8)	148 (21.9)
	Total	295 (43.7)	380 (56.3)	675 (100.0)

* Data are the number examined, with the percentage of the total in parentheses.

Declaration of Helsinki. The methodology of this study has been outlined previously.[30,31] However, to aid clarity, a brief summary is given.

At the time this work was performed, the country was divided into 21 provinces (aimags), which in turn were subdivided into districts (sums). Hövsgöl Aimag (100,600 km^2) is the most northerly province in Mongolia. Between May and August 1995, one thousand subjects aged 40 years or more were chosen for examination (4.8% of the province's population in this age group). Four hundred people were selected in Moron by using clustered, random sampling (8.2% of its population aged 40 years and more). Three of the 24 sums outside Mörön were chosen at random, and a combination of random and systematic sampling was used to select 200 people in each, for a total of 600.

The second phase of data collection was performed between July and October 1997 in urban and rural areas of the Ömnögobi province, the most southerly of Mongolia's aimags (165,400 km^2). Dalanzadgad (the aimag's capital) and Sevrei (one of its 15 sums) were selected for sampling. Local government census data were used to stratify the populations of these areas by age and sex. An approximately equal number of subjects were drawn from the age strata 40 to 49, 50 to 59, 60 to 69, and 70 years or more. The proportions of men and women selected were determined by the number in each decade age group. A total of 800 subjects were selected: 560 from Dalanzadgad and 240 from Sevrei. This represents 9.6% of the population of Ömnögobi aged 40 years and more and 33.7% of the combined populations of Dalanzadgad and Sevrei in this age group.

Ultrasound Ocular Biometry and Refraction

Anterior chamber depth (ACD), lens thickness (LT), and AL of the globe were measured in all subjects aged 40 years or more, with an A-mode ultrasound device with a hard-tipped corneal contact probe (model 820; Carl Zeiss Meditec, Dublin, CA). This was mounted on a tonometer set to the intraocular pressure in that eye. At least five readings were taken from each eye, and the longest, high-quality trace was chosen for measurement. VCD was calculated by subtracting the ACD and LT from the overall AL. Guttae benoxinate drops (Chauvin Pharmaceuticals, Kingston-on-Thames, UK) were instilled into both eyes before biometric assessment.

Noncycloplegic refraction and corneal diopteric power were assessed with a single reading from an autorefractor in the Ömnögobi cohort (model 597K; Carl Zeiss Meditec). Refraction was not assessed in Hövsgöl, because an autorefractor was not available in 1995.

Data Analysis

We present the data for the right eyes only, apart from the asymmetry and anisometropia analyses. Power vector analysis, as described by Thibos et al.[32] was used to analyze the refractive data. In this system, refractive error is expressed with three vectors: **M**, $\mathbf{J_0}$, and $\mathbf{J_{45}}$, with **M** being the spherical equivalent (SE) and $\mathbf{J_0}$ and $\mathbf{J_{45}}$ expressing the astigmatism. $\mathbf{J_0}$ describes the difference in diopteric power between horizontal and vertical meridians (positive for with-the-rule and negative for against-the-rule astigmatism). $\mathbf{J_{45}}$ expresses the extent of oblique astigmatism (positive if the negative cylinder axis is closer to 45° and negative if closer to 135°). To allow meaningful comparison with other studies, the prevalence of refractive error was calculated by converting refractive error to SE (spherical diopteric power plus half of the cylindrical diopteric power (identical with **M** in vector analysis notation). Myopia was defined as SE less than −0.5 D, with emmetropia being SE between −0.5 and +0.5 D. Hyperopia was more than +0.5 D, and anisometropia was more than a 1.0-D difference between the two eyes. Astigmatism was analyzed in negative cylinder and was defined as less than −0.50 D of cylinder without reference to

TABLE 2. Ocular Biometry and Noncycloplegic Refraction by Age and Gender in Adult Mongolians

Gender	Decade (y)	*n*	ACD (mm)	LT (mm)	VCD (mm)	AL (mm)	|AAL| (mm)	CP (D)	SE (D)
Men	40–49	241	3.0 ± 0.3	4.2 ± 0.3	15.9 ± 1.1	23.4 ± 1.3	0.3 ± 0.9	43.7 ± 1.7	+0.1 ± 1.8
	50–59	200	2.9 ± 0.3	4.4 ± 0.3	15.8 ± 0.7	23.3 ± 0.8	0.2 ± 0.2	43.9 ± 1.3	+0.2 ± 0.9
	60–69	150	2.8 ± 0.3	4.5 ± 0.4	15.9 ± 0.8	23.5 ± 1.0	0.3 ± 0.6	43.5 ± 1.5	0.0 ± 1.5
	>70	109	2.7 ± 0.3	4.6 ± 0.5	16.1 ± 0.9	23.6 ± 0.9	0.3 ± 0.3	43.5 ± 2.3	−0.7 ± 3.6
	Missing		136	136	131	131	139	42	25
	Total	700	564	564	569	569	561	253	270
Women	40–49	368	2.9 ± 0.3	4.1 ± 0.3	15.9 ± 1.3	23.0 ± 1.3	0.2 ± 0.4	44.5 ± 1.4	−0.3 ± 1.6
	50–59	266	2.7 ± 0.3	4.4 ± 0.3	15.9 ± 1.1	23.1 ± 1.1	0.3 ± 0.4	43.9 ± 1.9	+0.1 ± 1.9
	60–69	168	2.6 ± 0.3	4.7 ± 0.9	16.0 ± 1.1	23.2 ± 1.1	0.3 ± 0.8	44.3 ± 1.5	−0.4 ± 3.2
	>70	115	2.5 ± 0.3	4.7 ± 0.9	15.9 ± 0.9	23.1 ± 1.2	0.4 ± 1.0	44.3 ± 1.4	+0.4 ± 1.3
	Missing		174	169	173	173	176	62	30
	Total	917	743	748	744	744	741	318	350
All	40–49	609	3.0 ± 0.3	4.2 ± 0.3	16.0 ± 1.3	23.2 ± 1.3	0.3 ± 0.6	44.1 ± 1.6	−0.1 ± 1.7
	50–59	466	2.8 ± 0.3	4.4 ± 0.3	16.0 ± 1.0	23.2 ± 1.0	0.3 ± 0.4	43.9 ± 1.7	+0.1 ± 1.6
	60–69	318	2.7 ± 0.3	4.5 ± 1.6	16.0 ± 1.0	23.3 ± 1.1	0.3 ± 0.7	43.9 ± 1.6	−0.2 ± 2.5
	>70	224	2.6 ± 0.3	4.6 ± 0.5	16.0 ± 1.0	23.3 ± 1.1	0.3 ± 0.8	43.9 ± 1.9	−0.2 ± 2.6
	Missing		310	305	304	304	315	104	55
	Total	1617	1307	1312	1313	1313	1302	571	620

ACD values are true readings (minus corneal thickness). SE and CP data were collected only in the 1997 survey. Data are expressed as the mean ± SD.

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TABLE 3. Variation in Axial Length Asymmetry between Eyes with Axial Length in Adult Mongolians

	Axial Length of the Right Eye (mm)			
	<22	22 to 23.9	24 to 25.9	>26
Men				
|AAL|	0.2 ± 0.4	0.2 ± 0.4	0.4 ± 0.5	3.0 ± 2.9
% of AL	1.1 ± 1.9	0.9 ± 1.5	1.6 ± 2.0	12.0 ± 12.5
n	26	412	115	8
Women				
|AAL|	0.4 ± 0.8	0.2 ± 0.2	0.5 ± 0.7	1.9 ± 2.2
% of AL	1.8 ± 3.6	0.8 ± 1.0	2.2 ± 2.7	7.3 ± 9.4
n	82	563	83	13
Total				
|AAL|	0.4 ± 0.7	0.2 ± 0.3	0.4 ± 0.6	2.3 ± 2.5
% of AL	1.6 ± 3.2	0.9 ± 1.3	1.8 ± 2.4	9.2 ± 10.7
n	108	975	198	21

Data are expressed as the mean ± SD.

Asymmetry is the difference in axial length between right and left eyes.

Percentage asymmetry (% of AL) is the proportion of asymmetry between right and left eyes divided by the axial length of the eye closest to the population mean.

axis. These definitions were chosen to enable direct comparison between our data and findings in previous studies.[3,8] As a consequence of the weighted sampling strategy used in Ömnögobi province, gender comparisons were corrected for age, and prevalence rates were calculated by direct age and gender standardization to the national population (1994 Census).[4,33–35] The relationships between AL and refraction (SE) with age and gender were analyzed by linear regression. Further multiple-regression models were then constructed to evaluate the independent effects of different biometric components on refraction. In these models, AL was analyzed separately from VCD, ACD, and LT. Age and gender were included in all models to take account of the sampling strategy used. The standardized regression coefficient[36] (SRC) was used to assess the relative importance of each biometric component, the most important being that with the greatest absolute magnitude.

Asymmetry of AL between the eyes was defined as RAL − LAL , where RAL is the right AL and LAL, the left AL. AAL represents the absolute value of the difference RAL − LAL, irrespective of sign. The relationship between asymmetry in AL and the length of the eye closest to the population mean was examined by using linear regression analysis. For comparison of means of the continuous data, Student's *t*-test was used.

RESULTS

We examined 1617 people from the 1800 participants selected (Hövsgöl: 942/1000 and Ömnögobi: 675/800), and Table 1 summarizes the demographic characteristics of those examined. The overall response rate was 90.0%. Ocular biometric data were available for 1312 (81.1%) of the 1617 subjects. The ultrasound device malfunctioned during the 1997 survey, before data could be obtained from all participants.

Table 2 summarizes the ocular biometric characteristics of men and women in four age groups: 40 to 49, 50 to 59, 60 to 69, and 70 years or more. There was no major difference between mean RAL (23.13 ± 1.15 mm) and LAL (23.19 ± 1.19 mm; $P = 0.39$). After adjustment for age, the AL of the globe was significantly longer in men than in women (23.43 ± 1.06 versus 23.08 ± 1.20 mm; $P < 0.001$). Mean ACD was 0.10 mm deeper in men (2.87 mm) than in women (2.77 mm; $P < 0.001$). Similarly, LT was 0.06 mm greater in men (4.38 mm) than in women (4.32 mm; $P = 0.007$). Conversely, CP was 0.60 D less in men (43.65 D) than in women (44.24 D; $P < 0.001$). However, after adjustment for height, all gender differences ceased to be significant: AL ($P = 0.27$), ACD ($P = 0.30$), LT ($P = 0.12$), and CP ($P = 0.67$). After allowing for gender and height effects on AL, a very small but statistically significant increase with age was observed in mean AL (increase of 0.05 mm per decade; $P = 0.03$).

There was no significant difference in mean absolute asymmetry of AL AAL between men and women (men: 0.29 ± 0.61 mm; women: 0.28 ± 0.55 mm; $P = 0.93$) nor was there a significant change in AAL with age ($P = 0.15$). The magnitude of the asymmetry increased as AL deviated from the population mean. After allowing for age and gender, we estimate that a 1-mm increase in mean AL would be accompanied by a 0.15-mm increase in asymmetry ($P < 0.001$). Table 3 summarizes the variation in AL asymmetry with AL of the right eye. Among those with AL of less than 22 mm, there was a 0.4 ±

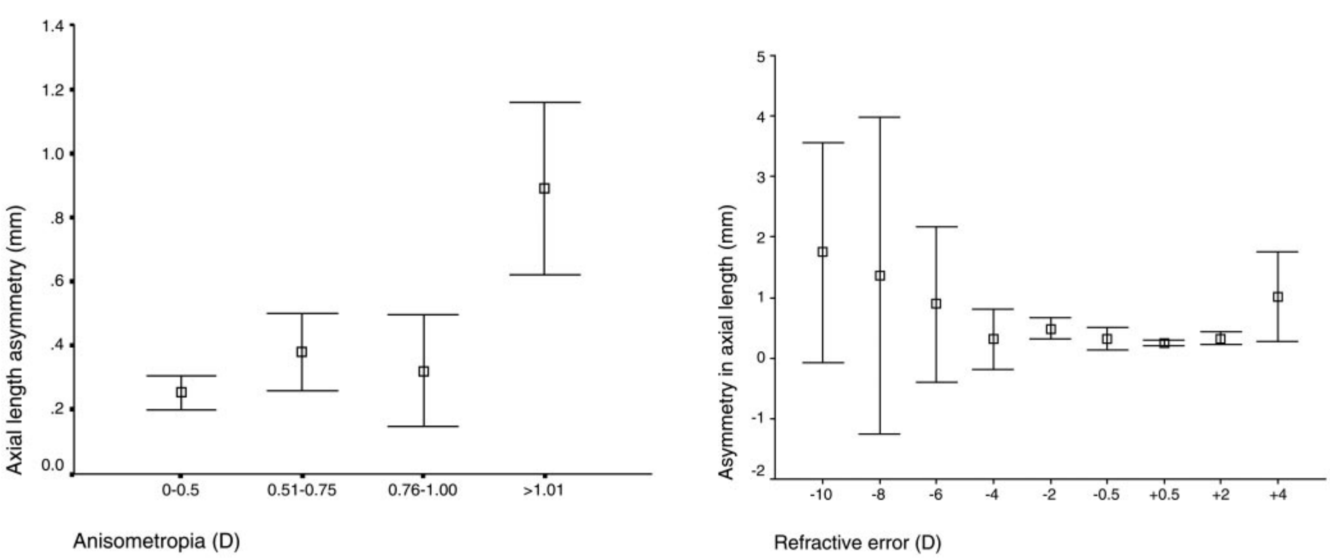

FIGURE 1. Asymmetry in AL between right and left eyes, by degree of anisometropia and by mean refractive error (SE). Vertical bars: 95% CI for the mean.

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TABLE 4. Power Vector Analysis of Refractive Error in Adult Mongolians by Age and Gender

Gender	Decade (y)	Spherical Equivalent, M (D)	Astigmatism, J_0 (D)	Astigmatism, J_{45} (D)
Men	40–49	+0.1 ± 1.8	+0.1 ± 0.5	+0.0 ± 0.2
	50–59	+0.2 ± 0.9	−0.1 ± 0.4	−0.1 ± 0.3
	60–69	+0.0 ± 1.5	+0.1 ± 0.6	−0.2 ± 0.5
	>70	−0.7 ± 3.6	+0.0 ± 0.8	−0.2 ± 0.6
Women	40–49	−0.3 ± 1.6	+0.2 ± 0.6	−0.0 ± 0.3
	50–59	+0.1 ± 1.9	+0.1 ± 0.6	−0.1 ± 0.3
	60–69	−0.4 ± 3.2	+0.2 ± 0.8	−0.2 ± 0.5
	>70	+0.4 ± 1.3	+0.1 ± 0.6	−0.1 ± 0.5
All	40–49	−0.1 ± 1.7	+0.1 ± 0.5	−0.0 ± 0.2
	50–59	+0.1 ± 1.6	+0.0 ± 0.5	−0.1 ± 0.6
	60–69	−0.2 ± 2.5	+0.1 ± 0.7	−0.2 ± 0.7
	>70	−0.2 ± 2.6	+0.0 ± 0.7	−0.1 ± 0.5

M, spherical equivalent; $\mathbf{J_0}$, difference between diopteric power of horizontal and vertical meridians; $\mathbf{J_{45}}$, oblique component of astigmatism.

Data expressed as the mean ± SD.

0.7-mm difference between the eyes. As a percentage of AL, this equated to 1.6% ± 3.2%. With AL more than 26 mm, AAL was 2.3 ± 2.5 mm (9.2% ± 10.7% of AL).

Figure 1 describes the variation in AAL with anisometropia between eyes and mean refractive error. As the degree of anisometropia increased, so did the extent of asymmetry. In terms of actual mean SE, the AAL increased with extremes of ametropia (≤ −6 D and ≥ +4 D).

Table 4 describes the power vector analysis of refractive error by age and gender. In terms of mean SE, there were no clear trends in men and women, although as a whole there was a tendency toward a greater degree of myopia in the older age groups. With-the-rule astigmatism $\mathbf{J_0}$ predominated through all age groups in men and women. For $\mathbf{J_{45}}$, the axis of the cylinder was closer to 135° than 45°.

Age-standardized prevalence of refractive errors in adult Mongolians are summarized in Table 5. The age and gender standardized rates of myopia, emmetropia, hyperopia, astigmatism, and anisometropia were 17.2%, 49.9%, 32.9%, 40.9%, and 10.7%, respectively. There were no significant differences between the sexes in mean refractive error (men: −0.06 ± 2.04 D; women: −0.08 ± 2.09 D; P = 0.90) or age-standardized prevalence of myopia (men: 17.5%; women: 16.8%; P = 0.27). Table 6 details the variation of refractive errors (SE) with age in men and women. Overall, the prevalence of myopia was at a minimum in the 50- to 59-year-old group. In men, there appeared to be a monotonic increase in prevalence with age, whereas in women, there was no discernible pattern. The rates of hyperopia, anisometropia, and astigmatism all increased monotonically with age in both men and women. The increased prevalence appeared especially pronounced after the age of 60 years.

Figure 2 shows the variation in prevalence of myopia and hyperopia with age and gender.

Table 7 illustrates how the age, AL, ACD, VCD, LT, height, and weight of subjects varied with refraction. Linear regression models were derived to evaluate the independent effects of biometric components on refraction (SE; linear regression model presented in Table 8). The SRC indicated that AL (0.62) was more important in determining SE than age (0.03), gender (0.06), or CP (0.33). In this model (model 1) we estimate that a 1-mm increase in AL would be associated with a 1.4-D (95% confidence interval [CI]: 1.2–1.6) myopic shift in SE. As VCD, ACD, and LT are components of AL, separate models were calculated to assess which components were most influential in determining refraction. In these models VCD, LT, and ACD were added to model 1 to determine which were significantly associated with refraction. These separate models suggested that VCD (−0.62D, P < 0.001) was the most influential factor (LT −0.01, P = 0.90; ACD −0.13 mm, P = 0.03). To determine whether LT or ACD was the next most important factor, two separate iterations were used: VCD and LT added to model 1 and VCD and ACD added separately to model 1. Comparing the probabilities for the respective coefficients, LT (−0.26 mm, P < 0.001) was more influential than ACD (−0.02 mm, P = 0.64). These models together show that AL, and especially its component VCD, were the strongest determinants of SE. In addition to AL and VCD, smaller but significant contributions were made by CP, LT, and ACD.

TABLE 5. Age-Gender Standardized Prevalence of Refractive Errors in Mongolian Adults

	n	Adj % (Men)	95% CI	*n*	Adj % (Women)	95% CI	*n*	Adj % (All)	95% CI
High myopia (<−5.0 D, SE)	6	2.0	0.9–3.2	11	3.1	1.8–4.4	17	2.7	2.5–2.9
Myopia (<−0.5 D, SE)	54	17.5	14.6–20.4	58	16.8	14.1–19.5	112	17.2	15.9–18.5
Emmetropia (>−0.5 D, <+0.5 D SE)	125	50.0	47.0–52.9	171	49.8	46.4–53.4	296	49.9	49.5–51.9
Hyperopia (>+0.5 D, SE)	91	32.5	29.3–35.8	121	33.4	29.3–37.4	212	32.9	32.2–33.5
Astigmatism (<−0.5 D, cyl)	126	41.5	37.6–45.3	143	39.2	35.0–43.5	269	40.9	40.2–41.6
Anisometropia (>1.00 D, diff)	32	11.4	9.3–13.5	37	10.3	7.9–12.7	69	10.7	10.2–11.2

Cyl, cylinder; diff, spherical equivalent difference between right and left eyes. Adj % (men), age standardized to the 1994 adult male Mongolian population; Adj % (women), age standardized to the 1994 adult female Mongolian population; Adj % (all), age and gender standardized to the 1994 adult Mongolian population.

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Table 6. Prevalence of Refractive Errors in Adult Mongolians by Age and Gender

	Myopia (<−0.5D)			Emmetropia (<−0.5D)			Hyperopia (>+0.5D)			Astigmatism (>−0.5D)			Anisometropia (>1.0D)			
Age	**%**	**95% CI**	***n***	**%**	**95% CI**	***n***	**%**	**95% CI**	***n***	**%**	**95% CI**	***n***	**%**	**95% CI**	***n***	**Missing *n***
Men																
40–49	11.8	8.6–15.1	9	59.3	51.9–66.5	45	28.9	28.2–29.7	22	22.4	17.9–26.8	17	10.5	7.5–13.6	8	1
50–59	13.0	9.1–16.9	10	55.8	39.2–72.5	43	31.2	27.8–34.5	24	44.2	29.3–59.0	34	9.1	2.4–15.8	7	3
60–69	22.7	11.2–34.2	15	39.4	24.3–54.5	26	37.9	23.0–52.7	25	54.5	36.7–72.4	36	16.7	6.8–26.5	11	3
>70	39.2	22.0–56.4	20	21.6	8.8–34.3	11	39.2	22.0–56.4	20	76.5	52.5–99.5	39	11.8	2.4–21.2	6	18
Total	17.5	14.6–20.4	54	50.0	47.0–52.9	125	32.5	29.3–35.8	91	41.5	37.6–45.3	126	11.4	9.3–13.5	32	25
Women																
40–49	18.4	14.8–22.1	19	61.2	54.5–67.8	63	20.4	16.5–24.2	21	22.3	18.3–26.4	23	6.8	4.6–9.0	7	2
50–59	12.1	5.5–18.8	13	57.0	42.7–71.3	61	30.8	28.0–33.6	33	41.1	29.0–53.3	44	7.5	2.3–12.7	8	3
60–69	20.3	15.5–25.0	15	35.1	21.6–48.6	26	44.6	29.4–59.8	33	43.2	28.3–58.2	32	17.6	8.0–27.1	13	12
>70	16.7	6.8–26.5	11	31.8	18.2–45.4	21	51.5	34.2–68.8	34	66.7	47.0–86.4	44	13.6	4.7–22.5	9	13
Total	16.8	14.1–19.5	58	49.8	46.4–53.4	171	33.4	29.3–37.4	121	39.2	35.0–43.5	143	10.3	7.9–12.7	37	30
All																
40–49	15.6	14.4–16.9	28	60.4	56.1–64.6	108	24.0	22.5–25.6	43	22.2	20.8–23.7	40	8.4	7.5–9.3	15	3
50–59	12.5	10.8–14.2	23	56.5	52.4–60.6	104	31.0	28.4–33.6	57	37.5	34.6–40.4	78	8.2	6.6–9.7	15	6
60–69	21.4	17.9–25.0	30	37.2	32.5–41.8	52	41.4	36.5–46.4	58	48.6	43.2–53.9	68	17.1	14.0–20.3	24	15
>70	26.5	17.2–35.8	31	27.3	17.9–36.8	32	46.2	42.9–49.4	54	70.3	55.2–85.5	83	12.8	12.5–13.2	15	31
Total	17.2	15.9–18.5	112	49.9	49.5–51.9	296	32.9	32.2–33.5	212	40.9	40.2–41.6	269	10.7	10.2–11.2	69	55

Prevalence (%) was calculated after excluding those subjects with missing data.

Discussion

Our study is the first to provide cross-sectional, population-based data on the ocular biometric characteristics of an adult Mongolian population. In common with other studies,[12,34,35] we found that men tended to have longer axial dimensions of the eye and less steeply curved corneas than women of the same age. However, we believe our data are unique in showing that the difference is no longer significant after controlling for height. Reassuringly, this suggests that the factors that determine ocular dimensions in men and women are similar, but women, on average, are simply smaller than men, and consequently have smaller eyes. The importance of biometric data in the investigation of the etiology of refractive trends in a population was highlighted by a study in Singapore that showed a bimodal trend of myopia prevalence, being highest in the 40- to 49- and 70- to 79-year-old cohorts. However, this was explained by the increasing nuclear sclerosis in older people and longer AL in younger people.[13]

Probably the most important finding of our study, which we believe is also unique among studies of East Asian people, is the

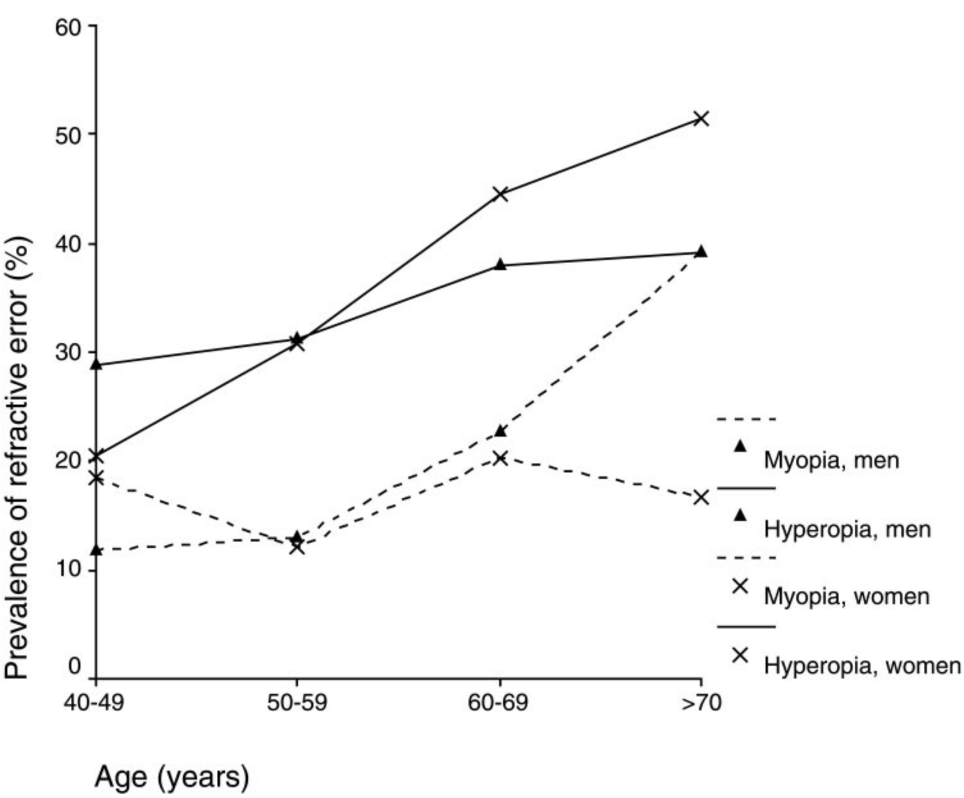

Figure 2. Prevalence of refractive error, by age and gender in adult Mongolians. Myopia: less than −0.5 D; hyperopia: more than +0.5 D.

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TABLE 7. Biometric Characteristics According to Refractive Error in Adult Mongolians

SE (D)	*n*	Age (y)	Height (cm)	Weight (kg)	ACD (mm)	LT (mm)	VCD (mm)	AL (mm)	|AAL| (mm)	CP (D)
<−5.0	17	60.1 ± 13.7	157.4 ± 7.8	60.2 ± 10.9	2.9 ± 0.5	4.5 ± 0.4	18.3 ± 1.6	25.7 ± 1.7	1.4 ± 1.1	44.1 ± 3.3
−5.0 to −3.1	12	60.9 ± 16.9	156.8 ± 10.8	57.2 ± 11.7	2.9 ± 0.4	4.4 ± 0.3	17.2 ± 0.8	24.4 ± 1.0	0.3 ± 0.5	44.1 ± 1.5
−3.0 to −1.1	49	61.3 ± 12.5	156.7 ± 9.3	59.4 ± 12.4	2.7 ± 0.4	4.5 ± 0.4	16.1 ± 1.0	23.6 ± 0.9	0.5 ± 0.5	44.5 ± 2.1
−1.0 to −0.1	113	57.5 ± 11.9	158.0 ± 7.5	61.8 ± 12.5	2.8 ± 0.3	4.4 ± 0.4	15.8 ± 0.7	23.3 ± 0.7	0.3 ± 0.8	44.3 ± 1.4
0 to 1.0	340	55.6 ± 11.1	158.7 ± 9.1	62.6 ± 12.8	2.7 ± 0.3	4.4 ± 0.4	15.6 ± 0.7	23.0 ± 0.7	0.3 ± 0.3	43.9 ± 1.5
>+1.0	89	63.1 ± 10.3	155.1 ± 8.7	59.5 ± 11.8	2.6 ± 0.4	4.6 ± 0..3	15.6 ± 0.7	22.8 ± 0.9	0.4 ± 0.4	43.4 ± 1.7
Missing data	0	0	5	5	255	256	255	255	258	55
Total	620	620	615	615	365	364	365	365	362	565

Data are expressed as the mean ± SD.

absence of a significant difference in mean AL between the different age groups. This is directly opposite to the trend in studies of Chinese people in Singapore and Taiwan, which have clearly documented an increasing prevalence of myopia among younger people and have shown that it is explained by increasing AL.[13,22,37] Cross-sectional studies in the United Kingdom have also suggested that AL decreases with increasing age.[38,39]

Opinion is divided on whether the observation that older people have shorter mean AL reflects a genuine decrease with advancing age in an individual, or whether it is a consequence of a change within birth cohorts, and not a longitudinal change. The association between greater height and longer axial dimensions of the eye in Singaporeans supports the belief that these findings may be attributable to greater mean height in younger people, and therefore probably a cohort effect associated with improved nutrition.[40,41] Our findings are the reverse of this widely observed trend of longer AL in younger people. The relative stability of corneal curvature (CC) with age has been described[42,43] and suggests that if refractive index disharmony is responsible for ametropia in this population, it is mostly likely to be lenticular in origin rather than due to changes in corneal curvature or increases in refractive index of the cornea. Although the prevalence of astigmatism increased with age in Mongolians, vector analysis indicated that there was no major change in the extent of either regular or oblique astigmatism with age. The general finding of a higher frequency of against-the-rule astigmatism[44,45] with increasing age seen in other populations was absent. Although we were not able to gather lens opacity data in this study, the increase in myopia prevalence from the age of 60 years and onward is most likely due to changes in nuclear sclerosis. Several studies[46–49] have demonstrated an association between nuclear cataract and myopia. It has been suggested that this may be due to increases in the density and hence refractive index of the lens with age.[18]

TABLE 8. Linear Regression Model of Noncycloplegic Refraction, in Spherical Equivalents, diopters, Per Unit Difference in Biometric Components in Adult Mongolians

Biometric Components	Unstandardized Regression Coefficient (95% CI)	Standardized Regression Coefficient	*P*
R^2 = 0.58			
Age (ys)	0.01 (−0.01 to 0.02)	0.03	0.51
Gender	−0.26 (−0.66 to −0.15)	−0.06	0.21
Al (mm)	−1.44 (−1.66 to −1.21)	−0.62	<0.001
CP (D)	−0.56 (−0.70 to 0.41)	−0.38	<0.001

Noncycloplegic refraction was the dependent variable with biometric components as independent variables. Unstandardized coefficients are based on noncycloplegic refraction (SE) per unit difference in Biometric components.

Pesudovs and Elliott[50] demonstrated in subjects with a single morphologic type of cataract, that those with nuclear cataracts were more likely to have had a recent myopic shift than control subjects, whereas cortical cataracts were more commonly associated with astigmatic change than control subjects.

The degree of asymmetry in AL between the two eyes of individuals increased as AL of the more normal eye deviated from the population mean value. Not surprisingly, the greatest asymmetry was found in either highly myopic or highly hyperopic subjects. The degree of asymmetry varied little between the different age groups. This suggests that asymmetry is determined at a relatively young age and varies little thereafter in this population. The finding of greater asymmetry in those who are either highly myopic or hyperopic fits in with this hypothesis, as refractive error is largely determined in youth and early adulthood.[51]

High rates of myopia have been described in East Asian populations, with lower rates in Afro-Caribbeans and aborigines and intermediate rates in whites.[4,8,12] Although direct comparison is difficult because of the different methodologies used in various studies, those with similar ages of participants and definitions of myopia are shown in Figure 3, age-adjusted to the 1994 Mongolian population. The prevalence of myopia among adult Mongolians is substantially lower than is seen in East Asians from industrialized nations, such as Chinese Singaporeans, and is closer to rates in Afro-Caribbeans and certain ethnic European peoples.[4,8,12]

Evidence for a heritable predisposition to development of myopia comes from twin studies[52,53] that show greater heredity of myopia in monozygotic than in dizygotic twins. There have also been studies showing a higher than expected correlation between the refractive status of children and that of their parents.[54] In a longitudinal study in parents with myopia and their children, Zadnik et al.[55] showed that eyes in nonmyopic children with myopic parents tended to have longer AL than those in children of nonmyopic parents, with later predisposition to myopia.

There is growing evidence to support an environmental element in the etiology of myopia, with most studies concentrating on near work as a risk factor. Many studies have shown an association between educational status,[4,33] occupation,[8,34] and income[3] and the degree of myopia. These associations may be an indicator of near work and so support the use–abuse theory[56,57] of myopia development. Further support comes from studies on occupational groups such as clinical microscopists.[19] With greater time spent on near tasks, a demonstrable progression or development of myopia was seen, predominantly due to vitreous chamber elongation.

Although there has certainly been an increase in the intensity of near-work tasks with economic development, the magnitude of myopia in the industrialized countries of the East Asian region cannot be accounted for solely by environmental

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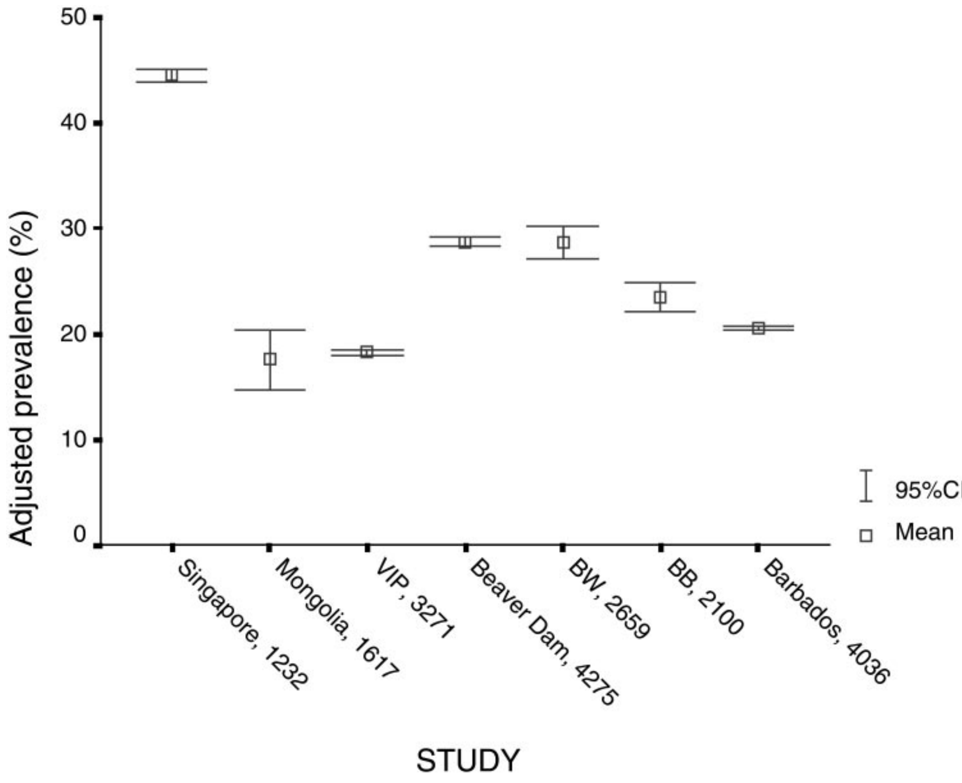

FIGURE 3. Prevalence of myopia in different population studies, adjusted to a 1994 Mongolian population. The ages of the subjects ranged from 40 to 98 years, with myopia defined as less than −0.5 D). Studies and race of participants: Singapore and Mongolia, Sino-Mongoloid; VIP, visual impairment project, white; Beaver Dam, white; BW, Baltimore, white; BB, Baltimore, black; Barbados, black. *Squares*: mean prevalence; error bars: 95% CI. *Numbers* after the study indicate number of participants.

influences. In comparison to industrialized Western societies, both the prevalence of myopia and rate of myopia progression are significantly higher. Among Chinese populations, the prevalence of myopia is higher in industrialized areas than in rural areas, with rates of 12.3% in the city-state of Singapore, compared with 9.1% in Xiamen City (China) and 3.9% in surrounding rural areas of China. Rates of hyperopia were found to be relatively constant.[58] This suggests a greater predisposition for the development of myopia in East Asians when exposed to an environmental trigger such as prolonged near activity.

The principal strength of our study was the population-based random sampling strategy, avoiding the bias that is present in studies of biometry in specific, highly selected groups of patients. Weaknesses include the problems of inferences from cross-sectional data, as already mentioned. The use of noncycloplegic refraction may have led to errors in determining refraction, especially in younger subjects, where some degree of accommodation may have been present, giving greater levels of myopia in the young, although our data did not suggest this. Finally, because of instrument malfunction in 1997, there were several patients with incomplete data.

In conclusion, Mongolians, although genetically similar to other races in East Asia, have a much lower prevalence of myopia. The mean AL differs little between age groups, in marked contrast to data from Chinese populations. This suggests that cross-sectional trends in AL observed in other East Asian populations are probably attributable to differences in ocular dimensions between birth cohorts, improved nutrition, higher educational intensity, and a predominantly near visual environment.

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