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CLINICAL STUDY

# Prevalence and risk factors for refractive errors and ocular biometry parameters in an elderly Asian population: the Singapore Longitudinal Aging Study (SLAS)

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## Abstract

*Purpose* **To determine the prevalence rates of refractive errors and pattern of ocular biometry in a multi-ethnic elderly Asian population.**
*Methods* **A population-based study of 1835 residents aged 55–85 years, evaluating the refractive error and ocular biometry parameters, including axial length (AL) and anterior chamber depth.**
*Results* **The age-standardized prevalence of myopia, hyperopia, astigmatism, and anisometropia were 30.0% (95% confidence interval (CI): 29.6, 30.4), 41.5% (95% CI: 41.1, 41.9), 43.5% (95% CI: 43.1, 44.0), and 22.1% (95% CI: 21.7, 22.4), respectively. Male gender ($P=0.02$), age ≥75 years ($P=0.033$), and higher educational level ($P<0.001$) were significantly associated with higher rates of myopia in multivariate analyses. The prevalence of astigmatism was higher in persons with diabetes (odds ratio (OR) 1.4, 95% CI: 1.03, 1.90, $P=0.031$). AL was longer in Chinese than other ethnic groups (23.7 *vs* 23.4 mm, $P=0.018$), and in men compared with women (24.2 *vs* 23.4 mm, $P<0.001$). AL was associated with increasing height (AL increased by 0.3 mm for every 10 cm increase in height, $P<0.001$).**
*Conclusion* **There is a high prevalence of myopia in elderly Singaporeans, consistent with trends seen in younger populations in Asia. Male gender and higher education were independent risk factors for myopia. These data suggest that higher rates of myopia in East Asians compared with Caucasians may not be a recent phenomenon.**
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*Keywords:* astigmatism; biometry; hyperopia; myopia; refractive errors; risk factors

## Introduction

Myopia is a common treatable cause of visual impairment worldwide.[1,2] Studies in urban East Asian populations have shown a very high prevalence of myopia in Chinese in Singapore, Taiwan, and Hong Kong,[3–5] while the rates of myopia are lower in Western[6,7] and other Asian countries such as India,[8,9] Bangladesh,[10] and Mongolia.[11]

Early studies suggest that higher rates of myopia occur in younger age groups in East Asian populations.[1,8,12] A study in Chinese aged 40–79 years in Singapore reported a prevalence of 38.7% for myopia,[12] which was two times higher than similarly aged adults in the Blue Mountains Eye Study and Baltimore Eye Survey.[6,7] However, there are few studies of older adults (>65 years) in East Asia,[13,14] and a few population-based studies in Asia with biometry measures of axial length (AL).[11,15]

Another unresolved issue is the role of racial variations in myopia prevalence in Asia.

Although comparison of studies in different Asian countries suggest that Chinese people have higher prevalence of myopia compared with other ethnic groups,[8,9,16] studies with similar methodology are limited. A study among 110 236 young Singapore male military conscripts showed higher rates of myopia in Chinese (48.5%) compared with Indians (30.4%), and Malays (24.5%).[17] It is unclear whether these differences are seen in older Asian populations.

Our study aimed to describe the prevalence rates of refractive errors and variations in biometry among elderly Singaporeans of different ethnicities, and to evaluate risk factors associated with refractive errors, in particular, myopia.

## Materials and methods

We conducted a population-based cross-sectional study in Singapore, using participants in the ongoing Singapore Longitudinal Aging Study (SLAS),[18,19] a study of 2804 adults aged 55 years or above living in a geographically defined area in the Southeast district of Singapore. Subjects were identified using door-to-door census, and all respondents signed written informed consent. The study was performed according to the guidelines of the Declaration of Helsinki and was approved by National University of Singapore Institutional Review Board. The response rate for the total of 2804 respondents was 78.5%. Interviews were conducted in the language with which the subjects were most conversant. Of the SLAS participants, 391 subjects did not have ocular examination, and another 578 subjects were excluded because of previous cataract surgery or difficulty in obtaining accurate refraction (for example, corneal scar and dense media opacity). Of the remaining 2097 subjects, 262 declined to participate in the study. Thus, data of 1835 subjects (response rate 87.5%) were available for analysis.

### *Eye examinations*

Five consecutive refractive error (sphere, cylinder, and axis) and corneal curvature radii (CR) readings were obtained using a calibrated auto-keratorefractometer (model RK5; Canon, Tochigiken, Japan). The AL, anterior chamber depth (ACD) and CR were measured using the IOLmaster (Zeiss, Oberkochen, Germany). The AL and ACD measurements were taken as five frames automatically and averaged using the IOLmaster software, which automatically discards outliers using a custom algorithm.

### *Interviews*

A wide range of demographical, biological, clinical, psychosocial, and behavioral characteristics were collected by interviews at specified study centers as previously described.[18,19] The regular use of vitamins A and E, history of traditional medication use, cigarette smoking, and regular alcohol consumption were studied.

### *Other clinical measurements and laboratory tests*

Height (meter) was measured using a stadiometer, without shoes to the nearest 0.05 m, while weight (kilogram) was measured on a calibrated SECA beam balance (model 708 1314004, Vogel & Halke, Hamburg, Germany), without shoes and in lightweight clothing to the nearest 0.1 kg. Blood pressure (BP) was measured using a mercury sphygmomanometer (Accoson Dekamet, A C Cossor & Son (Surgical) Ltd, Harlow, UK). The measurement of plasma glucose has previously been described.[19]

### *Definitions and statistical analysis*

The results for both eyes were analyzed separately, but because of the high correlation of spherical equivalent between the right and left eyes ($r = 0.867$, $P < 0.001$), data are presented for the right eye only, with the exception of anisometropia.

Spherical equivalent (SE) was calculated as the sum of spherical error and half negative cylinder. The definitions of refractive errors were: myopia, SE of at least −0.5 D; hyperopia, SE of at least +1.0 D; astigmatism, cylinder of

**Table 1** Sociodemographic characteristics of responders

| | *Responders (n = 1835)* |
|---|---|
| *Gender, n(%)* | |
| Male | 670 (36.5) |
| Female | 1165 (63.5) |
| *Race, n(%)* | |
| Chinese | 1727 (94.1) |
| Malay | 77 (4.2) |
| Indian | 31 (1.7) |
| Age, mean (SD) | 64.4 (6.7) |
| Range | 55–89 |
| *Education, n(%)* | |
| Nil | 315 (17.2) |
| Primary | 592 (32.3) |
| Secondary | 621 (33.8) |
| Pre-university/Polytechnic | 179 (9.8) |
| University | 128 (7.0) |
| *Housing type, n(%)* | |
| 1–2 room apartment/nursing home | 99 (5.4) |
| 3 room apartment | 421 (23.0) |
| 4 room apartment | 707 (38.7) |
| Private apartment, landed house, etc | 601 (32.9) |

at least −1.0 D; and ansiometropia, difference in spherical equivalent of at least 1.0 D between the two eyes.

Diagnosis of diabetes was established based on self-report, fasting blood glucose (>7 mmol/l), and the use of anti-diabetic medications, while hypertension was based on self-report, blood pressure readings of systolic BP ≥140 mm Hg or diastolic BP ≥90 mm Hg, and the use of anti-hypertensive agents.

Age, ethnicity, and gender-specific prevalence rates and 95% confidence intervals were estimated using the Poisson's distribution. Multivariate logistic regression models with myopia or other refractive error variables as the dependent variable were constructed to obtain multivariate-adjusted *P*-values. The statistical package for the Social Sciences (SPSS) statistical software (version 14.0; SPSS Inc., Chicago, IL, USA) was used for the analysis. Statistical significance was assumed at $P<0.05$.

## Results

The characteristics of responders are shown in Table 1. Compared with non-respondents, the respondents were younger, included more women, and more residents in higher end housing (30.7 *vs* 17.3%).

Overall, the age-standardized prevalence of myopia was 30.0% (95% confidence interval (CI): 29.6, 30.4) (Table 2). The overall rate of high myopia (SE < −6.0 D) was 3.1%. Chinese had the highest prevalence rates of myopia (30.8%), compared with Indians (22.6%) and Malays (18.2%) ($P=0.04$). Males had significantly higher rates of refractive errors except for hyperopia. The mean refractive error varied from −0.16 D (subjects aged 55–64 years), to 0.36 D (65–74 years), and 0.08 D (subjects aged 75 years and older) (*P* for trend = 0.001).

For all subjects, the mean AL, ACD, and AL/CR ratio decreased with successive age groups (*P* for trend <0.001) (Table 3). In Chinese subjects, the mean AL was 23.7 mm compared with 23.4 mm in non-Chinese ($P=0.018$), and the AL/CR ratio was 3.11 *vs* 3.08 ($P=0.059$). There was no significant difference in the ACD (3.02 *vs* 3.04 mm) and CR between Chinese and non-Chinese. Compared with females, males had a higher mean AL (24.2 *vs* 23.4 mm, $P<0.001$), ACD (3.09 *vs* 2.99 mm, $P<0.001$), corneal curvature (7.69 *vs* 7.58 mm, $P<0.001$), and AL/CR ratio (3.14 *vs* 3.09, $P<0.001$).

The risk factors for myopia and other refractive errors were analyzed using multivariate logistic regression models as shown in Table 4. Even after adjusting for all other factors in the table, males had significantly higher rates of myopia (odds ratio (OR) 1.4). Subjects aged 75 years and older had a 1.6 times risk of myopia compared with those aged 55–64 years ($P=0.033$), and adults with university education had 5.4 times higher risk compared with those with no education ($P<0.001$). Females and

**Table 2** Prevalence rates of myopia, astigmatism, hyperopia, and anisometropia in Singapore adults aged 55 years and above

| | *Myopia (at least −0.5 D SE)* | *P-value* | *Astigmatism (at least +1.0 D cylinder)* | *P-value* | *Hyperopia (at least +1.0 D SE)* | *P-value* | *Anisometropia (at least +1.0 D SE difference)* | *P-value* |
|---|---|---|---|---|---|---|---|---|
| *Total crude rate* | 553/1835 (30.1, 28.0–32.3) | | 733/1835 (40.0, 37.7–42.2) | | 762/1835 (41.5, 39.2–43.8) | | 369/1756 (21.0, 19.1–23.0) | |
| Age-standardized rate[a] | (30.0, 29.6–30.4) | | (43.5, 43.1–44.0) | | (41.5, 41.1–41.9) | | (22.1, 21.7–22.4) | |
| *Race* | | | | | | | | |
| Chinese | 532/1727 (30.8, 28.6–33.0) | 0.04 | 694/1727 (40.2, 37.9–42.5) | 0.701 | 715/1727 (41.4, 39.1–43.8) | 0.890 | 347/1653 (21.0, 19.1–23.0) | 0.752 |
| Indians | 7/31 (22.6, 9.6–41.1) | | 11/31 (35.5, 19.2–54.6) | | 13/31 (41.9, 24.6–60.9) | | 5/30 (16.7, 5.6–34.7) | |
| Malays | 14/77 (18.2, 10.3–28.6) | | 28/77 (36.4, 25.7–48.1) | | 34/77 (44.2, 32.8–55.9) | | 17/73 (23.3, 14.2–34.6) | |
| *Gender* | | | | | | | | |
| Male | 261/670 (38.9, 35.2–42.8) | <0.001 | 292/670 (43.6, 39.8–47.4) | 0.016 | 218/670 (32.5, 29.0–36.2) | <0.001 | 159/636 (25.0, 21.7–28.6) | 0.002 |
| Female | 292/1165 (25.1, 22.6–27.7) | | 441/1165 (37.9, 35.1–40.7) | | 544/1165 (46.7, 43.8–49.6) | | 210/1120 (18.8, 16.5–21.2) | |
| *Age (years)* | | 0.046 | | <0.001 | | 0.036 | | <0.001 |
| 55–64 | 345/1079 (32.0, 29.2–34.9) | | 330/1079 (30.6, 27.8–33.4) | | 432/1079 (40.0, 37.1–43.0) | | 187/1052 (17.8, 15.5–20.2) | |
| 65–74 | 162/613 (26.4, 23.0–30.1) | | 308/613 (50.2, 46.2–54.2) | | 279/613 (45.5, 41.5–49.6) | | 150/578 (25.9, 22.4–29.7) | |
| 75+ | 46/141 (32.6, 25.0–41.0) | | 95/141 (67.4, 59.0–75.0) | | 51/141 (36.2, 28.3–44.7) | | 32/124 (25.8, 18.4–34.4) | |

Values are myopia/total (%, 95% CI).
[a]Age adjusted to the Singapore 2000 census population.

**Table 3** Distribution of biometry parameters by ethnicity and age

| | *Age (years)* | | | |
|---|---|---|---|---|
| | *All* | *55–64* | *65–74* | *75+* |
| *Total* | | | | |
| Axial length (mm) | 23.67 (1.29) | 23.77 (1.34) | 23.56 (1.25) | 23.42 (1.06) |
| Anterior chamber depth (mm) | 2.93 (0.41) | 2.99 (0.40) | 2.88 (0.40) | 2.72 (0.45) |
| Average corneal curvature (mm) | 7.62 (0.26) | 7.62 (0.27) | 7.63 (0.24) | 7.60 (0.24) |
| AL/CR ratio | 3.11 (0.16) | 3.12 (0.17) | 3.09 (0.16) | 3.08 (0.13) |
| Refractive error (D) | 0.03 (2.68) | −0.16 (2.74) | 0.36 (2.55) | 0.08 (2.70) |
| *Chinese* | | | | |
| Axial length (mm) | 23.68 (1.27) | 23.80 (1.35) | 23.56 (1.18) | 23.43 (1.09) |
| Anterior chamber depth (mm) | 2.93 (0.42) | 2.99 (0.40) | 2.87 (0.40) | 2.71 (0.43) |
| Average corneal curvature (mm) | 7.62 (0.26) | 7.62 (0.27) | 7.63 (0.24) | 7.60 (0.24) |
| AL/CR ratio | 3.11 (0.16) | 3.13 (0.17) | 3.09 (0.15) | 3.08 (0.13) |
| Refractive error (D) | −0.006 (2.72) | −0.21 (2.77) | 0.35 (2.59) | 0.02 (2.76) |
| *Malays* | | | | |
| Axial length (mm) | 23.28 (0.90) | 23.31 (0.97) | 23.25 (0.93) | 23.24 (0.32) |
| Anterior chamber depth (mm) | 2.95 (0.40) | 2.93 (0.37) | 2.96 (0.34) | 3.04 (0.78) |
| Average corneal curvature (mm) | 7.59 (0.25) | 7.58 (0.28) | 7.62 (0.22) | 7.56 (0.16) |
| AL/CR ratio | 3.06 (0.10) | 3.07 (0.10) | 3.05 (0.10) | 3.08 (0.04) |
| Refractive error (D) | 0.52 (1.77) | 0.63 (1.79) | 0.55 (1.83) | −0.24 (1.40) |
| *Indians* | | | | |
| Axial length (mm) | 23.98 (2.47) | 23.66 (1.4) | 25.58 (5.02) | 23.07 (0.25) |
| Anterior chamber depth (mm) | 2.94 (0.44) | 2.85 (0.44) | 2.98 (0.55) | 2.72 (0.33) |
| Average corneal curvature (mm) | 7.67 (0.27) | 7.67 (0.30) | 7.67 (0.19) | 7.58 (0.01) |
| AL/CR ratio | 3.12 (0.31) | 3.08 (0.16) | 3.33 (0.64) | 3.04 (0.04) |
| Refractive error (D) | 0.59 (2.19) | 0.59 (2.37) | 0.56 (1.15) | 0.63 (0.00) |

Values are given as mean (SD).

those with lower education had higher risks of hyperopia. The risks of astigmatism were higher in males, older adults, adults who had completed pre-university or secondary education, adults with diabetes (OR 1.4), and those who were shorter (OR 0.13). Older subjects and adults with higher levels of education had higher risks of anisometropia.

The regular use of vitamins A and E, history of traditional medication use, financial constraints, cigarette smoking, and regular alcohol use were not associated with any refractive error in multivariate analyses.

In multiple linear regression models with SE as the dependent variable, the SE was more negative in males ($P<0.001$), Chinese compared with Malays ($P=0.021$), adults aged 55–64 years compared with 65–74 years ($P=0.017$), taller subjects ($P<0.001$), and higher education compared with primary or no education ($P<0.001$).

Using multiple linear regression, longer AL was found in males ($P=0.040$), those with pre-university or university education ($P<0.001$), and varied with height (for every 10 cm increase in height, AL increases by 0.3 mm, $P<0.001$). There was no association between hypertension and AL. Age and ethnicity were not independently associated with AL.

## Discussion

Our study demonstrates a high prevalence of myopia (30.1%) among elderly Singaporeans, with a higher prevalence in Chinese (30.8%) compared with Indians (22.6%) and Malays (18.2%). This corresponded to a longer mean AL in Chinese. Myopia was associated with male gender and higher education, while the risks of astigmatism were higher in adults with diabetes and those who were shorter. AL varied with gender (males), higher education, and height.

Comparisons of prevalence rates between studies must be interpreted with caution due to differences in the definitions used, measures for refractive errors, age ranges, and type of study population. The age-adjusted prevalence rate of 30.1% for myopia is higher than in many studies of same-aged adults conducted in European-derived countries, where the overall prevalence ranged from 15.5 to 26.2%.[6,7,20,21] The prevalence rates of myopia in Asian populations,

**Table 4** Multivariate odds ratios of myopia, hyperopia, astigmatism, and anisometropia for different risk factors from four multivariate logistic regression models

| | *Myopia (at least −0.5 D SE)* | | *Astigmatism (at least +1.0 D cylinder)* | | *Hyperopia (at least +1.0 D SE)* | | *Anisometropia (at least +1.0 D SE difference)* | |
|---|---|---|---|---|---|---|---|---|
| | *Adjusted odds ratio (95% CI)* | *P-value* | *Adjusted odds ratio (95% CI)* | *P-value* | *Adjusted odds ratio (95% CI)* | *P-value* | *Adjusted odds ratio (95% CI)* | *P-value* |
| *Gender* | | | | | | | | |
| Male | 1.4 (1.1–1.9) | 0.020 | 1.6 (1.2–2.1) | 0.002 | 0.69 (0.52–0.91) | 0.009 | 1.3 (0.95–1.9) | 0.093 |
| Female | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| *Race* | | | | | | | | |
| Chinese | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| Malay | 0.74 (0.40–1.4) | 0.325 | 0.69 (0.42–1.1) | 0.152 | 0.85 (0.53–1.4) | 0.517 | 1.3 (0.73–2.3) | 0.381 |
| Indian | 0.42 (0.17–1.01) | 0.054 | 1.04 (0.48–2.2) | 0.921 | 1.4 (0.68–3.0) | 0.337 | 0.74 (0.27–2.0) | 0.556 |
| *Age (years)* | | | | | | | | |
| 55–64 | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| 65–74 | 0.98 (0.77–1.3) | 0.885 | 1.9 (1.6–2.4) | <0.001 | 1.1 (0.85–1.3) | 0.630 | 1.8 (1.4–2.3) | <0.001 |
| 75+ | 1.6 (1.03–2.4) | 0.033 | 3.6 (2.4–5.3) | <0.001 | 0.66 (0.44–0.97) | 0.036 | 1.8 (1.1–2.9) | 0.012 |
| Height (cm) | 1.5 (0.23–9.9) | 0.665 | 0.13 (0.02–0.75) | 0.022 | 0.68 (0.12–3.8) | 0.661 | 0.34 (0.04–2.8) | 0.315 |
| *Education* | | | | | | | | |
| Nil | 1.0 | | 1.0 | | 1.0 | | 1.0 | |
| Primary | 1.2 (0.85–1.8) | 0.285 | 0.75 (0.56–0.99) | 0.049 | 0.88 (0.66–1.2) | 0.363 | 1.2 (0.82–1.7) | 0.362 |
| Sec/ITE | 2.5 (1.7–3.5) | <0.001 | 0.58 (0.43–0.79) | 0.001 | 0.57 (0.42–0.76) | <0.001 | 1.3 (0.86–1.9) | 0.226 |
| Pre U/Poly | 4.8 (3.1–7.6) | <0.001 | 0.66 (0.43–0.99) | 0.047 | 0.33 (0.21–0.50) | <0.001 | 2.3 (1.4–3.8) | 0.001 |
| University | 5.4 (3.3–8.9) | <0.001 | 0.72 (0.45–1.1) | 0.154 | 0.30 (0.18–0.50) | <0.001 | 3.1 (1.8–5.2) | <0.001 |
| Diabetes | 0.85 (0.60–1.2) | 0.334 | 1.4 (1.03–1.9) | 0.031 | 0.98 (0.73–1.3) | 0.915 | 0.83 (0.57–1.2) | 0.325 |
| Hypertension | 0.84 (0.67–1.05) | 0.124 | 0.99 (0.81–1.2) | 0.913 | 1.2 (0.99–1.5) | 0.069 | 0.98 (0.77–1.3) | 0.882 |

All four logistic regression models are adjusted for all other factors shown in this table.

analyzed by specific age groups, is shown in Table 5. Several studies showed higher prevalence of myopia with increasing age, including studies in Chinese,[12] Indonesians,[16] Indians,[8,9] Bangladeshi,[10] and Mongolians.[11]

Our study showed a lower age-adjusted prevalence of myopia among Chinese compared with the Tanjong Pagar Study (30.8 *vs* 38.7%).[12] This is expected because the latter included subjects aged 40–79 years. Compared with the Shihpai Eye Study,[14] of elderly Chinese in Taiwan, our Chinese subjects had higher prevalence of myopia in the corresponding age groups: 31.5% (65–74 years) *vs* 12.8% (65–69 years) and 19.4% (70–74 years) and; 39.7% (≥75 years) *vs* 26.5% (75–79 years). In contrast, the Beijing Eye Study found a lower prevalence of 22.9%[13] and the Mongolian eye study reported rates of 21% for those aged 60–69 years and 26.5% for those aged 70 and above.[11] Studies in India[8,9] and Bangladesh[10] have reported myopia rates over 40% in those aged 60 or older.

An important finding in this study is the higher prevalence rate of myopia among males compared with females (38.9 *vs* 25.1%, $P<0.001$). This finding is uncommon compared with most other studies, who have reported either a higher rate among females,[12,13,20,21] or no difference among the genders.[6,7,14,16] The Barbados Eye Study and the National Blindness and Low Vision Prevalence Survey of Bangladesh[10] both reported higher rates of myopia among males, and the latter study reported that women were less likely to be emmetropic or myopic (OR 0.75). We also found on multivariate analyses that males had significantly more negative spherical equivalent ($P<0.001$) and longer AL compared with females ($P=0.040$).

In this study, we found that the risk of myopia increased progressively with education, with those with university education having 5.4 times the risk compared with those without education ($P<0.001$) (Table 4). Similar associations of education with myopia risk have been reported in both Western[6,7,20,21] and Asian studies.[8,12–14] In addition, studies have reported an association between myopia and other indicators of socio-economic status such as income,[12,16] profession,[12,21] and type of housing.[12]

**Table 5** Comparison of myopia rates in Asian population

| *Year* | *Study/location* | *Subjects* | *Age groups* | *Prevalence of Myopia Overall (males, females) (%)* |
|---|---|---|---|---|
| 1999 | Andhra Pradesh Eye Study, India | 2321 | 40–49 | 17.8 |
| | | | 50–59 | 29.6 |
| | | | 60–69 | 44.8 |
| | | | 70+ | 50.0 |
| 2000 | Tanjong Pagar Survey, Singpore | 1232 | 40–49 | (45.2, 51.7) |
| | | | 50–59 | (25.2, 27.1) |
| | | | 60–69 | (29.9, 30.0) |
| | | | 70–79 | (31.7, 40.3) |
| 2002 | Sumatra Eye Study, Indonesia | 1043 | 40–49 | 28.8 |
| | | | 50+ | 39.7 |
| 2003 | Shihpai Eye Study, Taiwan | 1361 | 65–69 | 12.8 |
| | | | 70–74 | 19.4 |
| | | | 75–79 | 26.5 |
| | | | 80+ | 23.3 |
| 2004 | Tamil Nadu, India | 2508 | 40–49 | 15.7 |
| | | | 50–59 | 33.8 |
| | | | 60–69 | 57.6 |
| | | | 70+ | 67.2 |
| 2004 | National Blindness and Low Vision Prevalence Survey of Bangladesh, Bangladesh | 11 624 | 40–49 | (14.5, 10.4) |
| | | | 50–59 | (25.0, 19.6) |
| | | | 60–69 | (44.9, 40.1) |
| | | | 70+ | (69.9, 57.6) |
| 2004 | Mongolia | 1617 | 40–49 | 15.6 (11.8, 18.4) |
| | | | 50–59 | 12.5 (13.0, 12.1) |
| | | | 60–69 | 21.4 (22.7, 20.3) |
| | | | 70+ | 26.5 (39.2, 26.5) |
| 2005 | Beijing Eye Study, China | 4319 | ≥40 | 21.8 |

An interesting finding in our study is the higher rates of myopia among Chinese compared with Indians and Malays, which has not previously been described in elderly Asians of varied ethnicity living within the same geographical region. An earlier study among 110 236 young Singapore males reported similar results.[17] We also found a significantly more negative spherical equivalent among Chinese compared with Malays on multivariate analysis ($P = 0.022$). Compared with the prevalence rate of myopia among Malays (18.2%), a study of refractive errors in rural Indonesian subjects[16] reported a prevalence rate of 39.7% in those aged 50 and above. The prevalence rate of myopia among Singapore Indians (22.6%) was similar to Indians in an urban Indian population (Andhra Pradesh Eye Disease Study) (19.3%)[8] but lower than that of the rural population (30.97%).[9] The more myopic refractions in Singapore Chinese compared with Singapore Malays and Indians could be attributed to inter-ethnic, environmental, or genetic differences. Ethnicity may be a surrogate for differences in the intensity of schooling, near work or outdoor activity. However, definite conclusions cannot be made because the number of Malays and Indians in our study is small.

The increase in myopia in extreme old age is likely to be due to lens-induced refractive index changes related to increase in nuclear sclerotic cataracts. However, the Beaver Dam Eye Study used two different models to account for the effect of nuclear sclerosis, but found that although this may attenuate the shift in myopia, age was still an important factor in the increase in myopia in this group.[22] The lack of definite clinical assessment and grading of cataract in our study is a potential limitation.

We studied the use of antioxidants, cigarette smoking, and alcohol consumption as possible novel risk factors for myopia. Our results found no association between these factors and the prevalence of myopia.

Our study found that astigmatism was higher in males, older, and shorter subjects, and those with higher education. Other studies have demonstrated similar associations with age,[6,14,16] race,[6] and gender.[6,16] Interestingly, our study showed that astigmatic adults were more likely to be diabetic. A study of 224 patients in Nepal found that non-diabetics had higher corneal astigmatism (0.30 D) compared with diabetics (0.07 D).[23]

A strength of our study is the review of both refractive errors and biometry in the same population, which is not frequently reported.[11,15] There are several interesting findings in our biometry results. Using multiple linear regression, the AL was significantly higher in males compared with females (24.2 *vs* 23.4 mm, $P<0.001$), corresponding to the significantly higher prevalence of myopia among males (38.9 *vs* 25.1%, $P<0.001$). The Tanjong Pagar Survey reported significantly higher AL among males compared with females (23.54 *vs* 22.98 mm, $P<0.001$),[15] but found higher rates of myopia among females, especially high myopia.[12] We also found a significant, progressive decrease in AL across successive age groups, which was also described in the Tanjong Pagar Survey,[15] but not in the study of Mongolian adults.[11]

The AL in our population (23.77 mm) was higher compared with the Tanjong Pagar Survey[15] ($n=1717$) of Chinese adults aged 40 to 81 years (23.2 mm) and in a cross-sectional study of Mongolian adults[11] ($n=1800$) aged 40 years (23.1 mm). In the latter study, the prevalence of myopia was lower than in our study (17.2 *vs* 30.8%). In our study, an increase in height was significantly associated with longer AL. Similar findings were described in the Tanjong Pagar Survey,[15] the Reykjavik Eye Study,[24] and in the school children in both Singapore[25] and Australia.[26] However, in multivariate analysis, height was not a risk factor for myopia. Several other studies have also reported no association between height and myopia,[15,27–29] although a study of Singapore children aged 7 to 9 years found height significantly associated with refractive error in females.[25] Several studies of adults have also found that AL was correlated with refractive error.[11,29] In this study, the mean AL is longer in Chinese compared with non-Chinese (23.7 *vs* 23.4 mm), but this difference was not significant in multivariate analysis.

The advantages of our population-based survey include a fairly large sample size, and the evaluation of a comprehensive list of possible risk factors for refractive error including vitamin use, diabetes, and hypertension. Potential limitations include the small number of Malay and Indian participants that may preclude any definite conclusions about inter-ethnic differences. Because the SLAS study was launched to evaluate neurodegenerative disorders, there is lack of precise clinical or photographic assessment and grading of cataract. This may limit our inferences on the effect of age on myopia rates.

In summary, our study has demonstrated a high prevalence of myopia in elderly Singaporeans, consistent with trends seen in younger East Asian populations. These data provide further evidence that the higher rates of myopia in East Asians compared with Caucasian population is not a recent phenomenon. Chinese had more myopic refractions compared with Malays and Indians.

**Summary**

**What was known before**

- Myopia has a higher prevalence among Asians compared with Western populations. The prevalence of myopia is high among younger age groups, but little is known of its prevalence among the elderly.

**What this study adds**

- There is a high prevalence of myopia among elderly Asians, demonstrating a bimodal distribution.
- The prevalence of myopia is higher among Chinese compared with non-Chinese. This corresponds to a longer axial length among Chinese.
- Myopia is significantly higher in males, those with higher education and of older age.

## Conflict of interest

The authors declare no conflict of interest.

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