Prevalence and Risk Factors for Refractive Errors in Indians: The Singapore Indian Eye Study (SINDI)

Ciben-Wei Pan,1 Tien-Yin Wong,1,2,3,4 Raghavan Lavanya,2 Ren-Yi Wu,2 Ying-Feng Zheng,2 Xiao-Yu Lin,1,2 Paul Mitchell,5 Tin Aung,2,5 and Seang-Mei Saw1,2,3

**PURPOSE.** To determine the prevalence and risk factors for refractive errors in middle-aged to elderly Singaporeans of Indian ethnicity.

**METHODS.** A population-based, cross-sectional study of Indians aged over 40 years of age residing in Southwestern Singapore was conducted. An age-stratified (10-year age group) random sampling procedure was performed to select participants. Refraction was determined by autorefraction followed by subjective refraction. Myopia was defined as spherical equivalent (SE) < −0.50 diopters (D), high myopia as SE < −5.00 D, astigmatism as cylinder < −0.50 D, hyperopia as SE > 0.50 D, and anisometropia as SE difference > 1.00 D. Prevalence was adjusted to the 2000 Singapore census.

**RESULTS.** Of the 4497 persons eligible to participate, 3400 (75.6%) were examined. Complete data were available for 2805 adults with right eye refractive error and no prior cataract surgery. The age-adjusted prevalence was 28.0% (95% confidence interval [CI], 25.8–30.2) for myopia and 4.1% (95% CI, 3.3–5.0) for high myopia. There was a U-shaped relationship between myopia and increasing age. The age-adjusted prevalence was 54.9% (95% CI, 52.0–57.9) for astigmatism, 35.9% (95% CI, 33.7–38.3) for hyperopia, and 9.8% (95% CI, 8.6–11.1) for anisometropia. In a multiple logistic regression model, adults who were female, younger, taller, spent more time reading and writing per day, or had astigmatism were more likely to be myopic. Adults who were older or had myopia or diabetes mellitus had higher risk of astigmatism.

**CONCLUSIONS.** In Singapore, the prevalence of myopia in Indian adults is similar to those in Malays, but lower than those in Chinese. Risk factors for myopia are similar across the three ethnic groups in Singapore. (Invest Ophthalmol Vis Sci. 2011;52:3166–3173) DOI:10.1167/iovs.10-6210

Myopia and other refractive errors are global public health problems with high costs associated with correction1 and treatment for complications such as retinal detachment.2 The prevalence of myopia has been reported in several Caucasian populations: 28.1% in the Baltimore Eye Survey3 (aged 40–80+ years), 26.2% in the Beaver Dam Eye Study4 (aged 43–84 years), 15% in the Blue Mountains Eye Study5 (aged 49–97 years), and 17% in the Visual Impairment Project6 (aged 40–98 years). In East Asia, the prevalence of myopia is higher: 38.7% in Singapore Chinese aged 40–79 years7 and 41.5% in Japanese aged over 40 years.8 In Indian population-based studies, the Andhra Pradesh Eye Disease Study9 and the Chennai Glaucoma Study10 reported age-adjusted prevalence rates for myopia of 34.6% and 31.0%, among adults aged 40 years or older, respectively.9,10 The prevalence of myopia of adults aged over 30 years was 17% in Central India11 and 19.4% in Indians with diabetes aged over 40 years.12 An interesting finding in the Andhra Pradesh Eye Disease Study is that the prevalence of myopia was significantly higher among rural than urban residents (38.0% vs. 31.9%; P = 0.001).9 In contrast to the perception that myopia is less common in rural communities,13,14 However, the higher prevalence of myopia in rural India could be explained by the more severe nuclear cataract.9 Nuclear cataract has been found to cause myopic shift in many studies, which reflects the increased power of the lens rather than increased axial length.5,15–17

Although the exact etiology of myopia is still unclear,18–21 risk factors have been well documented, including family history,22–24 near-work activities,25–27 educational level,28,29 and astigmatism.30,31 Outdoor activity was reported as an independent protective factor of myopia.32,33 However, only limited data are available on risk factors for other refractive errors.

Singapore has a multiethnic Asian population with Chinese (75%), Malays (15%), and Indians (7%). In younger generations, the prevalence of myopia (SE ≤ −0.5 D) in Singapore Indian male conscripts aged 17–19 years was 68.7%. However, SE was assessed using noncycloplegic autorefraction, which might have caused an overestimation of myopia.34 The Tanjong Pagar Suvey and the Singapore Malay Eye Study35 documented the prevalence of myopia and other refractive errors among Singapore Chinese and Malays aged over 40 years, respectively. The Singapore Indian Eye Study (SINDI) was designed to estimate the prevalence and risk factors for major eye diseases, including myopia and other refractive errors, in Singapore Indian adults aged 40 years and older. Data from SINDI would allow more precise comparison of refractive errors across the three major Asian ethnic groups. As the majority (58%) of Singapore’s Indian residents are from the southern regions of India (Singapore Census of Population 2000), SINDI data will also allow a comparison of urban Singapore Indian adults with persons of similar genetic background from southern India.
METHODS

The SINDI is a population-based survey of major eye diseases, with detailed methodology reported elsewhere. In brief, the study was conducted in the Southwestern part of Singapore, following the same protocol as that of the Singapore Malay Eye Study (SiMES). From a list of 12,000 names of ethnic Singaporean Indians provided by the Ministry of Home Affairs, an age-stratified random sampling strategy was adopted to select 6550 aged 40 years or older. A person was considered ‘ineligible’ if he or she had moved from the residing address, had not been living there for >6 months, was deceased, or was terminally ill. Of the 6550 names selected, there were 497 subjects who were eligible to participate. From August 2007 to December 2009, a total of 3400 subjects participated, representing a 75.6% participation rate.

SINDI was conducted following the tenets of the Helsinki Declaration and was approved by the Singhealth Institutional Review Board. All participants gave written informed consent at recruitment into the study.

Clinical Examination

Presenting visual acuity was measured monocularly using the logarithm of the minimum angle of resolution (log MAR) number chart (Lighthouse International, New York, NY) at a distance of 4 m, with the participant wearing their ‘walk-in’ optical correction (spectacles or contact lenses), if any. If no numbers were read at 4 m, the participant was moved to 3, 2, or 1 m consecutively. If no numbers were identified on the chart, visual acuity was assessed as counting fingers, hand movements, perception of light, or no perception of light. Best-corrected visual acuity (BCVA) was also assessed monocularly and recorded in log MAR scores using the same test protocol as presenting visual acuity. The BCVA was determined, and both the derived refraction data and visual acuity were recorded.

Objective refraction was measured using an autorefractor (Canon RK-5 Auto Ref- Keratometer; Canon Inc., Tokyo, Japan). Manual subjective refraction was then used to refine vision, using the results of the objective refraction as the starting point. In this study, refraction data were obtained from subjective refraction techniques. If subjective refraction was then used to refine vision, using the results of the objective refraction as the starting point. In this study, refraction data were obtained from subjective refraction techniques. If subjective refraction was not available, autorefraction data were used instead.

Slit-lamp examination (model BQ-900; Haag-Streit, Koeniz, Switzerland) was performed after pupil dilation and included a clinical grading of cataract using the Lens Opacities Classification System (LOCS) III.

Each participant’s height was measured in centimeters using a wall-mounted measuring tape, after removing shoes. Weight was measured in kilograms using a digital scale, after removing heavy clothing (SECA, model 782 232 1009; Vogel & Halke, Hamburg, Germany). Systolic blood pressure, diastolic blood pressure, and pulse rate for all participants were recorded using the automated blood pressure monitor (Dinamap model Pro Series DP110X-RW, 100V2; GE Medical Systems Information Technologies, Milwaukee, WI).

Questionnaire and Interview

Questionnaires were administered by trained interviewers. Before the interview, the purpose of the study was explained and the participants were assured that the information provided would be strictly confidential. The questionnaire was administered in English or translated into Tamil, and back-translated into English, based on the participant’s choice.

At interview, data were collected on educational level (no formal education/primary education/high school/technological/degree) and near-work activities such as number of hours of computer use or reading and writing per day. Other data included smoking status (current/past/ never smoked), alcohol intake, and whether participants had previously been diagnosed with diabetes or hypertension by a doctor.

Definitions of Diseases

Spherical equivalent (SE) was defined as sphere plus half cylinder. Myopia was defined as SE of −0.50 diopter (D) or less. Other definitions of myopia such as SE less than −0.75 D or SE less than −1.00 D were also used for analyses to compare with other studies. Hyperopia was defined as SE of 0.50 D or more. Other definitions of hyperopia (SE > 2D) were also analyzed. Astigmatism was defined as cylinder less than −0.50 D, −1.00 D, or −1.50 D and anisometropia as the difference in SE greater than 1.00 D. ‘With the rule’ astigmatism was defined when the axis was 0° to 15°, ‘against the rule’ when 75° to 105°, and ‘oblique’ when axes were located from 20° to 70° and 110° to 160°.

Lens nuclear opacity was graded at the slit lamp by study ophthalmologists using modified LOCS III scores.

Any cataract was defined as the presence of any nuclear cataract (LOCS III score for nuclear opalescence or nuclear color of 4 or more), any cortical cataract (LOCS III score of 2 or more), or any posterior subcapsular cataract (LOCS III of 2 or more) in either eye. Diabetes mellitus was defined as nonfasting glucose levels greater than 200 mg/dl (11.1 mM) or physician diagnosis of diabetes and use of antidiabetic medications according to American Diabetes Association guidelines.

Hypertension was defined as systolic blood pressure > 140 mm Hg or diastolic blood pressure > 90 mm Hg or self-reported history of hypertension. Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters.

Statistical Methods

Participants with prior cataract surgery (n = 502) were excluded from these analyses. As the Spearman correlation coefficient for SE in the left and right eye was high (r = 0.85, P < 0.001), only right eye data (n = 2805) were used for analyses. Anisometropia was analyzed only in participants with refractive error data for both eyes and with no history of cataract surgery in either eye (n = 2762).

The prevalence of different refractive errors was estimated for the overall sample, and then stratified by age and sex. The age-adjusted prevalence was calculated by direct standardization of the study sample to the Singapore ethnic Indian population, using the 2000 Singapore census data (http://www.singstat.gov.sg). For risk factors, variables of interest were first analyzed in univariate models. The potential confounders considered were age, gender, education, occupation, marital status, time for reading and writing per day, time for computer use per day, alcohol use, smoking, diabetes mellitus, hypertension, height, BMI, and presence of cataract. If the P value was <0.05 in univariate models, these possible predictors were included in multiple logistic regression models, and manual backward stepwise elimination procedures were performed to choose the most parsimonious model. To control the effects of age, gender, and other potential confounders, multiple logistic regression models with sampling weights were performed. Sampling weights are the actual proportions of Indians in each age group among the entire Singapore Indian population obtained from Singapore Census 2000. The interaction terms age × cataract, age × gender, and age × education were also evaluated in multivariate models. Statistical analyses were performed using statistical software (Statistical Package for Social Science, SPSS V16.0; SPSS Inc., Chicago, IL). Two-tailed P < 0.05 was considered statistically significant. Odds ratios (OR) and 95% confidence intervals (95% CI) were shown.

RESULTS

Among the 3400 participants in our study, 813 (23.9%) were born in India and moved to Singapore after birth. Among these 813 participants born in India, 638 (78.5%) were from southern India, where the states of Andhra Pradesh and Tamil Nadu are located.

Participants (n = 3400) were significantly (P < 0.001) younger than nonparticipants (n = 1093), but there was no significant difference in gender distribution between the two groups (P = 0.28).

Compared with adults without cataract surgery, those with cataract surgery were older (P < 0.001), shorter (P < 0.001), less educated (P < 0.001), and spent less time on near-work...
Table 1. Prevalence of Myopia and High Myopia in Singapore Indian Adults Aged More than 40 Years

<table>
<thead>
<tr>
<th>Age group, y</th>
<th>Total</th>
<th>Crude rate</th>
<th>Age-standard rate</th>
<th>Total</th>
<th>Crude rate</th>
<th>Age-standard rate</th>
<th>Total</th>
<th>Crude rate</th>
<th>Age-standard rate</th>
<th>Total</th>
<th>Crude rate</th>
<th>Age-standard rate</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2805</td>
<td>733</td>
<td></td>
<td>612</td>
<td>21.8</td>
<td>23.5</td>
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<td>20.3</td>
<td>21.9</td>
<td>108</td>
<td>20.3</td>
<td>21.7</td>
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<tr>
<td></td>
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<td>26.1, 24.5–27.8</td>
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<td></td>
<td>23.5, 21.5–25.6</td>
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<td></td>
<td>19.0, 17.6–20.5</td>
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<td></td>
<td>3.9, 3.1–4.6</td>
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<td></td>
<td>26.0, 25.8–30.2</td>
<td></td>
<td></td>
<td>20.4, 18.6–22.4</td>
<td></td>
<td></td>
<td>24.6, 21.7–27.8</td>
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<td></td>
<td>4.7, 3.6–6.3</td>
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<tr>
<td></td>
<td></td>
<td>25.9, 24.3–27.8</td>
<td></td>
<td></td>
<td>18.8, 16.3–21.5</td>
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<td></td>
<td>24.6, 21.7–27.8</td>
<td></td>
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<td>4.7, 3.6–6.3</td>
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<tr>
<td></td>
<td></td>
<td>26.9, 24.0–30.2</td>
<td></td>
<td></td>
<td>21.9, 19.3–24.9</td>
<td></td>
<td></td>
<td>24.6, 21.7–27.8</td>
<td></td>
<td></td>
<td>4.7, 3.6–6.3</td>
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<td>26.7, 24.4–29.1</td>
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<td></td>
<td>23.0, 20.8–25.2</td>
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<td></td>
<td>20.3, 18.2–22.4</td>
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<td>4.7, 3.6–5.8</td>
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<td>28.5, 25.4–31.9</td>
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<td>24.6, 21.7–27.8</td>
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<td>21.7, 19.0–24.7</td>
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<td></td>
<td>4.7, 3.6–6.3</td>
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</tbody>
</table>

CI, confidence interval; D, diopter; SE, spherical equivalent.
* Age-standardized to the Singapore 2000 census population.
showed a peak at 90° (against-the-rule astigmatism). However, there were no statistically significant differences in the axis of astigmatism by gender (P = 0.92) or age group (P = 0.15).

Four multivariate logistic regression models were constructed to determine the risk factors for myopia (SE < −0.5 D), hyperopia (SE > 0.5 D), astigmatism (cylinder < −0.5 D), and anisometropia (SE difference > 1.0 D), as shown in Table 3. In these models, myopia was associated with time spent on reading and writing per day (OR = 1.19), height (OR = 1.04), and astigmatism (OR = 3.59), after adjusting for age and gender. The interaction between age and cataract was also significant in the multivariate model (P = 0.03). Age (OR = 1.07), myopia (OR = 3.59), and diabetes (OR = 1.58) were associated with astigmatism, after adjusting for other confounders, while age and astigmatism were associated with both hyperopia and anisometropia (Table 3).

**Discussion**

In this study, we reported that 28.0% of Singaporeans of Indian ethnicity aged over 40 years had myopia. The prevalence of myopia decreased with age in adults without nuclear cataract and increased with age in adults with nuclear cataract, suggesting that the U-shape curve may be explained by differences in patterns for adults with and without nuclear cataract. Our study findings should be compared with two groups, with Indians residing in India, and with other Singaporean ethnicity (Chinese and Malays).

It was suggested that subjective refraction using a phoroptor is usually preferred in cooperative patients. Subjective refraction data were preferred for analysis since the reproducibility of subjective refraction has been found to be within 0.50 D for spherical equivalent, sphere power, and cylinder power.41 Autorefraction is adequate for a preliminary refraction but is not a good substitute for subjective refraction.41 Cycloplegic autorefraction is the gold standard technique for refractive error measurement.43 Noncycloplegic refraction might have overestimated the myopia rates, but this effect seems to be marginal since our study subjects were middle-aged to elderly adults over 40 years who may have lower amplitude of accommodation.44,45

The prevalence of myopia is lower among Singaporean Indians than Indians of a similar age range residing in Southern India. In the Indian state of Andhra Pradesh, a multistage cluster, systematic, stratified random sampling method was used, and the age-gender-area adjusted prevalence of myopia of adults aged over 40 years in primarily rural areas was 34.6% (n = 3723).9 In rural Chennai, the age-gender adjusted prevalence of myopia was 31.0% (n = 2508).10 We noted that the Indians in urban Andhra Pradesh had lower myopia rates (31.9%) than rural Andhra Pradesh (38.0%) but higher myopia rates than Singaporean Indians. Comparing the prevalence of myopia in each age group, we found that myopia is more prevalent in our study than Indian studies for the 40–49 years age group, reflecting a potentially "myopicogenic" environment in Singapore. In the 50–59 years age group, Indian Indians exceed Singaporean Indians in the prevalence of myopia due to earlier onset of nuclear cataract or nuclear sclerosis among Indian Indians.9,13 In the age groups over 60 years, the differences in prevalence of myopia between Indian Indians and Singaporean Indians seem to be enlarged due to the more severity of nuclear opacity (Fig. 3). In the Andhra Pradesh Eye Disease Study, the population attributable risk percentage (PAR%) for lens nuclear opacity (NO) 2–3.5 and NO > 3.5 of myopia were estimated to be 76% and 23%, respectively.9 The high PAR% for nuclear opacity indicates that the main cause of myopia in Indian adults is nuclear cataract. Thus, if we remove the nuclear cataract patients in India from analysis, the prevalence of myopia in Indian adults in India would probably be lower than that of the Singaporean Indians due to the urban versus rural differences as expected (Fig. 3).

Our study could be directly compared with Singapore Chinese adults (the Tanjung Pagar Survey) and Malay adults (the SMES), which used identical study protocols, to explore the effect of ethnic variation within the same environment.15 However, the sampling process of the Tanjung Pagar Survey was less rigorous than that of SINDI and SMES. Comparing our results with the Tanjung Pagar Survey and the SMES, the prevalence of myopia is highest among Chinese in almost all age groups in both men and women (Fig. 4). The Tanjung Pagar Survey was conducted nearly 10 years ago. The difference in the prevalence of the Tanjung Pagar Survey, SMES, and SINDI may reflect secular trends over time as well as interethnic variation. The higher prevalence of myopia in Chinese than other ethnicities is possibly attributed to interethnic variability in risk factors such as differences in lifestyle, including more time spent on school work, fewer outdoor activities, or ethnic-specific genes relevant to Chinese. In Singapore children, Chinese were reported to spend the most time on near-work activities26 but the least time outdoors.33 The mean time outdoors was reported to be 3.05, 3.94, and 3.21 hours per day for Chinese, Malays, and Indians, respectively (P < 0.001).53

People with high myopia are reported to have a substantially higher risk of cataract, glaucoma, myopic macular degeneration, and retinal detachment.7 The age-standardized prevalence of high myopia (SE < −5.0D) in our study was 4.1%, which is significantly lower than that of Chinese population (9.1%)7 but slight higher than that of Malay adults (3.9%)35 of the same age range. Compared with Indian adults in India, the rate was slightly lower than that of the Andhra Pradesh Eye Disease Study (4.5%)9 but slightly higher than reported in the Chennai Glaucoma Study (3.7%).10 This rate was also higher than in most other ethnic population such as whites and blacks aged over 40 years in the Baltimore Eye Study (1.4%), 3 white persons aged 49 to 97 years in Blue Mountain Study (3.0%),5 Indians in Bangladesh (2.2%)46 aged over 30 years, and Hispanics (2.4%)46 aged over 40 years in the Los Angeles Latino Eye Study.47

A U-shaped relationship between myopia prevalence and increasing age was observed in our study. This similar pattern was also found in Singapore Chinese and Malays of the same age range7,5 and was modified by nuclear cataract. In subjects
### TABLE 2. Prevalence of Astigmatism, Hyperopia, and Anisometropia in Singapore Indian Adults Aged More than 40 Years

<table>
<thead>
<tr>
<th>Age group, y</th>
<th>Astigmatism (&lt; -0.5 Cylinder)</th>
<th>Astigmatism (&lt; -1.0 Cylinder)</th>
<th>Astigmatism (&lt; -1.5 Cylinder)</th>
<th>Hyperopia (SE &gt; +0.5 D)</th>
<th>Hyperopia (SE &gt; +2.0 D)</th>
<th>Anisometropia (&gt; +1.0 D Difference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All persons</td>
<td>N*</td>
<td>n (%), 95% CI</td>
<td>n (%), 95% CI</td>
<td>n (%), 95% CI</td>
<td>n (%), 95% CI</td>
<td>N†</td>
</tr>
<tr>
<td>Total</td>
<td>2805</td>
<td>1585</td>
<td>595</td>
<td>282</td>
<td>1147</td>
<td>277</td>
</tr>
<tr>
<td></td>
<td>Crude rate</td>
<td>56.5, 54.7–58.3</td>
<td>21.2, 19.7–22.7</td>
<td>10.1, 8.9–11.2</td>
<td>40.9, 39.1–42.7</td>
<td>9.9, 8.8–11.0</td>
</tr>
<tr>
<td></td>
<td>Age-standard rate‡</td>
<td>54.9, 52.0–57.9</td>
<td>21.3, 19.5–23.2</td>
<td>10.2, 8.9–11.5</td>
<td>35.9, 33.7–38.3</td>
<td>8.6, 7.5–9.7</td>
</tr>
<tr>
<td>Men</td>
<td>1417</td>
<td>820</td>
<td>510</td>
<td>156</td>
<td>565</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>Crude rate</td>
<td>57.9, 55.3–60.4</td>
<td>21.9, 19.7–24.0</td>
<td>11.0, 9.4–12.6</td>
<td>39.9, 37.4–42.4</td>
<td>8.5, 7.1–10.0</td>
</tr>
<tr>
<td></td>
<td>Age-standard rate‡</td>
<td>57.1, 52.9–61.6</td>
<td>23.0, 20.3–26.0</td>
<td>11.9, 9.9–14.1</td>
<td>35.9, 32.7–39.4</td>
<td>7.8, 6.4–9.6</td>
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<tr>
<td>Women</td>
<td>1388</td>
<td>765</td>
<td>285</td>
<td>126</td>
<td>582</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td>Crude rate</td>
<td>55.1, 52.5–57.7</td>
<td>20.5, 18.4–22.7</td>
<td>9.1, 7.6–10.6</td>
<td>41.9, 39.3–44.5</td>
<td>11.2, 9.6–12.9</td>
</tr>
<tr>
<td></td>
<td>Age-standard rate‡</td>
<td>55.6, 51.1–60.4</td>
<td>22.0, 19.1–25.3</td>
<td>9.8, 7.9–12.2</td>
<td>38.2, 34.7–42.0</td>
<td>11.1, 9.1–13.5</td>
</tr>
<tr>
<td>P (trend)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>40–49</td>
<td>874</td>
<td>372</td>
<td>122</td>
<td>52</td>
<td>154</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>42.6, 39.3–45.9</td>
<td>14.0, 11.7–16.3</td>
<td>6.0, 4.4–7.5</td>
<td>17.6, 15.1–20.2</td>
<td>1.1, 0.4–1.9</td>
<td>6.2, 4.6–7.9</td>
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<tr>
<td>50–59</td>
<td>1025</td>
<td>547</td>
<td>177</td>
<td>87</td>
<td>459</td>
<td>79</td>
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<td>53.4, 50.3–56.4</td>
<td>17.3, 15.0–19.6</td>
<td>8.5, 6.8–10.2</td>
<td>44.8, 41.7–47.8</td>
<td>7.7, 6.1–9.3</td>
<td>7.4, 5.8–9.1</td>
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<tr>
<td>60–69</td>
<td>690</td>
<td>487</td>
<td>192</td>
<td>86</td>
<td>449</td>
<td>140</td>
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<tr>
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<td>70.6, 67.2–73.4</td>
<td>27.8, 24.5–31.2</td>
<td>12.5, 10.0–14.9</td>
<td>60.7, 57.1–64.4</td>
<td>20.3, 17.3–23.3</td>
<td>14.5, 11.8–17.1</td>
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<tr>
<td>70–83</td>
<td>216</td>
<td>179</td>
<td>104</td>
<td>57</td>
<td>115</td>
<td>48</td>
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<tr>
<td></td>
<td>82.9, 77.8–87.9</td>
<td>48.2, 41.4–54.9</td>
<td>26.4, 20.5–32.3</td>
<td>53.2, 46.5–60.0</td>
<td>22.2, 16.6–27.8</td>
<td>21.5, 15.9–27.2</td>
</tr>
</tbody>
</table>

CI, confidence interval; D, diopter; SE, spherical equivalent.

* Number of subjects included in the analyses of astigmatism and hyperopia.
† Number of subjects included in the analysis of anisometropia.
‡ Age-standardized to the Singapore 2000 census population.
without nuclear cataract, the prevalence of myopia declined with age. This pattern may represent an increase in the prevalence of myopia in younger generations, possibly through a more competitive education system, or an intrinsic age-related decline in myopia prevalence.48 In subjects with nuclear cataract, the prevalence of myopia increased with age due to increasing nuclear lens opacity in elderly populations.49 However, the prevalence of myopia increased with age in India. The difference in the age-adjusted pattern of myopia prevalence between Singapore and India could be due to a higher prevalence of nuclear cataract in India9,10 (Fig. 3).

The risk factors for myopia in our study were increased time spent on near-work activities, height, and astigmatism.25,50,51 It has been reported that taller people are more likely to be myopic, because of longer axial length.52,53 Although astigmatism was only recently reported to be a risk factor in children,30,31 the association of myopia and astigmatism was very strong in our study (OR 3.59; 95% CI, 2.52–5.12).

The prevalence of astigmatism was 54.9% in our study, which was significantly higher than that of Singapore Chinese (37.8%) and Malays (33.3%) of the same age range.7,35 This prevalence is also higher than that of Andhra Pradesh Eye Disease Study (37.6%), but similar to that reported from the Chennai Glaucoma Study (54.8%).9,10 Prevalence of astigmatism increased with age, which is consistent with the findings of previous studies.3,5,17,54 “With-the-rule” astigmatism, where the vertical curve is greater than the horizontal, is common in children and adolescents. The dominant proportion of “against the rule” astigmatism (62.9%) in our study further confirmed that “with-the-rule” astigmatism tends to disappear or even reverse itself to an “against-the-rule” astigmatism with increasing age.55 The main risk factor for astigmatism in our study was diabetes mellitus, which was positively associated with astigmatism. In a multivariate logistic model in the SiMES, the association between astigmatism and diabetes mellitus was only of borderline significance (P = 0.06).55 Two cross-sectional studies on diabetic patients have reported quite high prevalence of astigmatism: 87.8% in Taiwan and 47.4% in India. However, there were no controls. It is possible that diabetes may lead to astigmatism as fluctuating blood sugar levels might

### Table 3. Multiple Logistic Regression Models of the Risk Factors Associated with Refractive Errors

<table>
<thead>
<tr>
<th>Refractive Error</th>
<th>Beta</th>
<th>Multivariable OR (95% CI)</th>
<th>P</th>
<th>Age-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time for reading and writing</td>
<td>0.17</td>
<td>1.19 (1.06-1.33)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Height, cm</td>
<td>0.04</td>
<td>1.04 (1.01-1.07)</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Any cataract</td>
<td>0.05</td>
<td>1.05 (1.02-1.07)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Myopia</td>
<td>0.18</td>
<td>1.28 (1.25-1.32)</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Cataract x age-square</td>
<td>-1.28</td>
<td>0.83 (0.72-0.96)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Astigmatism</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time for reading and writing</td>
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<td>1.35 (1.25-1.47)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Height, cm</td>
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<td>1.04 (1.03-1.06)</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Any cataract</td>
<td>0.06</td>
<td>1.06 (1.03-1.09)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Myopia</td>
<td>0.18</td>
<td>1.28 (1.25-1.32)</td>
<td>0.014</td>
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<td></td>
</tr>
</tbody>
</table>

CI, confidence interval; OR, odds ratio.
* Models were run with sampling weights applied for each strata.
† Age-square for the model for myopia to examine the U-shape distribution.

**Figure 3.** Line graphs of prevalence of myopia (right eye, SE < -0.5 D) by age in Andhra Pradesh Eye Disease Study, Chennai Glaucoma Study, and Singapore Indian Eye Study.
alter the refractive index and curvature of the crystalline lens. The hyperopia prevalence (35.9%) in this study is also higher than that of Singapore Chinese (28.4%) and Malays (27.4%), but lower than that of white populations in the lens.56

The hyperopia prevalence (35.9%) in this study is also higher than that of Singapore Chinese (28.4%) and Malays (27.4%), but lower than that of white populations in the Beaver Dam Eye Study (49.0%) and the Blue Mountains Eye Study (57.0%). The prevalence of hyperopia generally increased with age, possibly due to a decrease in the refractive power of the lens, changes in lens position, or decreased axial length. In persons aged over 70 years, decreased prevalence of hyperopia was observed in our study, possibly due to lens-induced myopic shift. The increasing trend in myopia and other refractive errors could be overestimated or underestimated. In addition, subjects with cataract surgery excluded from analyses were older, shorter and less educated and spent less time on near-work activities compared with subjects without cataract surgery. Thus, the prevalence of myopia in this population may be overestimated. Finally, non-cyclopegic refraction might have possibly overestimated the prevalence of myopia in our study.

In summary, the myopia prevalence in Singapore adult Indians is similar to that of Singapore Malays but lower than Singapore Chinese aged over 40 years. The higher myopia prevalence rates recorded among Indians in India compared with Singaporean Indians may be due to the high nuclear cataract rates in older adults in India. We also found that prevalence of astigmatism and hyperopia was higher than those recorded in Singapore Chinese and Malays. Our study completes a gap in knowledge about adult myopia and other refractive errors in an urban population in Singapore.

References

Refractive Errors in Singaporean Indians


