Prevalence of Refractive Errors in a Rural South Indian Population

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PURPOSE. To report the prevalence of refractive errors in a rural south Indian population.

METHODS. Four thousand eight hundred subjects (age, >39 years) from rural south India were enumerated for a population-based study. All participants underwent complete ophthalmic evaluation. Subjects who were phakic in the right eye with best corrected visual acuity of 20/40 or better were included for analysis. Association of refractive errors with age, sex, cataract, and diabetes mellitus were analyzed.

RESULTS. Of the 3924 responders, 2508 were eligible. The unadjusted prevalence of emmetropia (spherical equivalent [SE] = −0.50 to +0.50 diopter sphere [DS]), myopia (SE < −0.50 DS), high myopia (SE < −5.00 DS), and hyperopia (SE > 0.50 DS) were 50.60%, 26.99%, 3.71%, and 18.70% and age and gender adjusted for the rural Tamil Nadu population were 46.77%, 30.97%, 4.32%, and 17.94%, respectively. The prevalence of emmetropia decreased significantly with age (P < 0.0001), and the prevalence of myopia and high myopia increased significantly with age (P < 0.001) and were significantly associated with nuclear sclerosis (P < 0.001). The prevalence of hyperopia increased until 60 years of age and then decreased. Hyperopia was more common among women than men (P < 0.001) and was negatively associated with nuclear sclerosis (P < 0.001) and positively with diabetes mellitus (P = 0.008). Of the participants with astigmatism (cylindrical error greater than 0.50 DC), 9.80% had with-the-rule (WTR) and 77.44% against-the-rule (ATR) astigmatism. The prevalence of WTR and ATR astigmatism significantly decreased (P < 0.001) and increased (P = 0.006) with age, respectively.

CONCLUSIONS. The pattern of refractive errors in this rural south Indian population is similar to those reported in other tropical regions of the world. (Invest Ophthalmol Vis Sci. 2004;45: 4268–4272) DOI:10.1167/iovs.04-0221

Uncorrected refractive error is the most common cause of reversible blindness in India.1 Studies from urban India suggest that 49.3 million of those aged ≥15 years may have refractive errors.2 As refractive errors are a major cause of mild to moderate visual impairment in the population, knowledge of the prevalence of refractive errors would be helpful in planning public health strategy. There have been a few population-based studies on the prevalence of refractive errors in older white populations.3–5 In India, screening camps at schools and villages have been conducted to assess the prevalence of refractive errors among children.6 A literature review showed only one publication of a study in the adult Indian population. Dandonia et al.7 studied an urban population in south India and reported that 42.16% of the population had refractive errors with a prevalence of 17.8% and 18.8% for myopia and hyperopia, respectively, in the 40- to 49-year age group, 29.6% and 39.6% in the 50- to 59-year age group, 44.8% and 29.7% in the 60- to 69-year age group, and 50% and 30.4% in the >70-year age group.

As age increases, the refractive status of their eyes also changes. This is predominantly attributable to changes in the crystalline lens. Several other factors including genetic7 and environmental influences (near work,8 night lighting,9 and UV exposure10) are also believed to play a role in determining the refractive status of the eye.

The rural Indian population differs from the urban in many respects. There are limited data available on the prevalence of refractive errors in the adult Indian population and no population-based data from the rural population.

In this study, we report the prevalence of refractive errors in an adult population in rural south India.

METHODS

The Chennai Glaucoma Study (CGS), a population-based cross-sectional study, sought to estimate the prevalence of glaucoma in a rural and urban south Indian population. The present study included only the rural subjects. The rural study area (defined based on the Government of India Census 2001 definition)11–14 comprised a total population of 22,000 residing in 27 villages spread over the Thiruvallur and Kancheepuram districts of Tamil Nadu. Twenty-two percent of the population was older than 40 years, as per the 1991 Census of India report.11–14 Based on this distribution, 4840 subjects aged 40 years or more were expected in our study area, of which we enrolled 4800 persons.15

The study was conducted between June 2001 and May 2003. Written, informed consent was obtained from all subjects, and the study was performed in accordance with the tenets of the Declaration of Helsinki. The institutional review board of the Vision Research Foundation, Chennai, approved the study. All subjects underwent a complete ophthalmic examination, including detailed history of ophthalmic and systemic problems, best corrected visual acuity according to the modified Early Treatment Diabetic Retinopathy Study (ETDRS) chart (Light House Low Vision Products, New York, NY), applanation tonometry, gonioscopy, grading of lens opacities using the Lens Opacities Classification System (LOCS) II,16 fundus examination, optic disc and fundus photography, and random blood sugar estimation.
Monocular visual acuity was determined with current spectacle prescription if any. Pinhole acuity was assessed in eyes with presenting visual acuity ≤20/20 (logarithm of the minimum angle of resolution \( \logMAR \), 0.0). Streak retinoscopy (Beta 200; Heine Optotechnik GMBH & Co. KG, Hersching, Germany) and subjective refraction were performed in all subjects. The best corrected visual acuity was ascertained and recorded. Refraction data are based on subjective refractions.\(^{15}\) Only the right eye of each subject was considered. Of these, those phakic eyes with best corrected visual acuity ≥20/40 \( (\logMAR 0.3) \) were included for analysis.

Emmetropia was defined as a spherical equivalent between -0.50 and +0.50 diopter sphere \( \mathrm{DS} \).\(^{17}\) Myopia was defined as a spherical equivalent less than -0.50 \( \mathrm{DS} \),\(^{2,5,17,18}\) and a spherical equivalent less than -5.00 \( \mathrm{DS} \) was classified as high myopia.\(^{3}\) Hyperopia was defined as a cylindrical error less than –0.50 diopter cylinder \( (\mathrm{DC}) \) in any axis.\(^{2,5,17,18}\) Astigmatism was defined as a cylindrical error greater than +0.50 diopter cylinder \( \mathrm{DC} \) in any axis.\(^{2,5,17,18}\) Astigmatism was defined as the rule if the axis lay between 15° on either side of the horizontal meridian, against the rule if the axis lay between 15° on either side of the vertical meridian, and oblique if the axis lay between 15° and 75° or between 105° and 165°.\(^{3}\) Significant nuclear sclerosis was defined as nuclear opalescence of N2 or more with the LOCS II grading system.\(^{15}\) Diabetes mellitus was detected based on previous history and/or random blood sugar level greater than 200 mg/dL.\(^{19}\)

Significance was assigned at \( P < 0.05 \) level for all parameters. Categorical variables between groups were compared with the \( \chi^2 \) test or the Fisher exact test. The \( t \) test was used for continuous variables. Trends with age were analyzed with \( \chi^2 \) analysis for trend. The Pearson coefficient of correlation was used to compare subjective and objective refraction and right and left eye refraction. Multivariate analyses were performed with logistic regression. Data analysis was performed on computer.

**RESULTS**

Three thousand nine hundred thirty-four (81.95%) subjects responded to the study. The mean age of the participants \( 53.79 \pm 11.00 \) years was slightly higher than that of the nonparticipants \( 52.44 \pm 10.00 \) years; \( P < 0.001 \). Sixty-five percent of the participants and 73.1% of the nonparticipants were between the ages of 40 to 59 years. A significant association was observed between gender and participation \( (P < 0.0001) \). Females were 1.4 times more likely to participate when compared with males \( \text{odds ratio [OR]} = 1.44, \text{CI} = 1.25 \) to \(-1.67\). With adjustment for the effect of other variables, the odds for increased female participation became insignificant \( \text{adjusted OR} = 1.19, \text{CI} = 0.98 \) to \(-1.46\). The proportion of men \( (45\%) \) and women \( (55\%) \) was consistent with census data for rural Tamil Nadu \( (P = 0.205) \).

This was a predominantly agricultural population. Education levels were poor, with only 10.2% of examined subjects having completed secondary education.

Of the participants, complete data were available for 3924 \( (81.75\%) \) subjects, and 3509 \( (89.42\%) \) subjects were phakic in the right eye. The remaining 415 \( (10.58\%) \) subjects had a history of cataract surgery and were either pseudophakic or aphakic in the right eye. The results were analyzed for 2508 \( (71.47\%) \) subjects whose best corrected visual acuity in the right eye was \( 20/40 \) or better. The remaining 1001 \( (28.53\%) \) subjects had visual acuity worse than \( 20/40 \); 921 due to cataract \((\text{LOCS II grade N2 or more}, C3 \text{ or more}, P2 \text{ or more}) \) and 80 due to other ocular disease. The excluded population was significantly older \( \text{mean age} = 60.91 \pm 9.44 \) years, \( P < 0.001 \). The 80 subjects with other ocular diseases were not included for analysis. The distribution of refractive errors in this subset was 41 myopes, 11 hyperopes, and 28 emmetropes.

There was no significant difference \( (P = 0.06) \) between mean objective and subjective refraction. There was good correlation between right and left eye subjective refraction \( (\text{Pearson correlation}, 0.804) \). There were 1157 \( (46.13\%) \) men and 1351 \( (53.87\%) \) women \( (\text{Table 1}) \). The age group ranged from 40 to 81 years, with the mean age being 49.06 \pm 8.17 \) years. The mean age of the men and women was 50.20 \pm 8.60 and 48.08 \pm 7.66 \) years, respectively \( (\text{statistically significant at } P < 0.001) \).

The mean refractive error was 0.56 \( \mathrm{D} \) and the median 0.00 \( \mathrm{D} \). Figure 1 shows the frequency distribution of refractive status among the men, the women, and the total population. One thousand two hundred sixty-nine subjects \( (50.60\%) \) of the phakic population were emmetropic. The prevalence of hyperopia increased with age \( (P < 0.001) \). The prevalence of myopia decreased significantly with increasing age \( (\chi^2 \text{ analysis for trend } P < 0.0001) \). There were 616 men \( (53.24\%) \) of all men and 653 women \( (48.53\%) \) of all women.

Six hundred seventy-seven \( (26.99\%) \) of the study population subjects had myopia. The prevalence after being age and gender adjusted for the rural Tamil Nadu population was \( 30.97\% \).\(^{11,14}\) The mean age among myopes was \( 53.72 \pm 9.08 \) years, which was significantly higher than that of the entire population \( (P < 0.001) \). The prevalence of myopia increased significantly with age \( (\chi^2 \text{ analysis for trend } P < 0.001) \); \( \text{Table 2} \). After adjustment for nuclear sclerosis, the association between myopia and age almost disappeared \( (\text{OR}, 1.036; 95\% \text{ CI}, 1.022–1.051) \). The mean age of the emmetropes was 46.05 \pm 6.29 \) years. The prevalence of emmetropia decreased significantly with increasing age \( (\chi^2 \text{ analysis for trend } P < 0.0001) \). There were 616 men \( (53.24\%) \) of all men and 653 women \( (48.53\%) \) of all women.

### Table 1. Age and Gender Distribution of the Phakic Population

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Male ( (n = 1157) )</th>
<th>Female ( (n = 1351) )</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–49</td>
<td>619 (42.51)</td>
<td>837 (57.49)</td>
<td>1456 (58.05)</td>
</tr>
<tr>
<td>50–59</td>
<td>337 (24.93)</td>
<td>349 (50.87)</td>
<td>686 (27.35)</td>
</tr>
<tr>
<td>60–69</td>
<td>160 (52.98)</td>
<td>142 (47.02)</td>
<td>302 (12.04)</td>
</tr>
<tr>
<td>&gt;70</td>
<td>41 (64.06)</td>
<td>23 (35.94)</td>
<td>64 (02.55)</td>
</tr>
<tr>
<td>Total</td>
<td>1157 (46.13)</td>
<td>1351 (53.87)</td>
<td>2508</td>
</tr>
</tbody>
</table>

Data are the number of participants (percentage of total group).
of N2 or more). Myopia was not significantly associated with diabetes mellitus ($P = 0.9832$).

High myopes constituted 3.71% (93 subjects) of the study population. The prevalence after age and gender adjustment for the rural Tamil Nadu population was $4.32\%$. The mean age among high myopes was $55.15 \pm 8.62$ years, which was significantly higher than that of the entire population ($P < 0.001$). However there was no significant difference between the mean age of the myopes and high myopes ($P = 0.1524$). The prevalence of high myopia significantly increased with age ($\chi^2$ for trend $P < 0.001$). There were 42 men (5.63% of all men) and 51 women (3.77% of all women). There was no significant difference in the prevalence of high myopia between the sexes ($P = 0.2718$). Significant nuclear sclerosis (LOC5 grade of N2 or more) was more common among high myopes than among myopes ($P < 0.001$).

Hyperopia was found in 469 (18.70%) subjects. The prevalence after age and gender adjustment for the rural Tamil Nadu population was $17.94\%$. The mean age of hyperopes was $49.25 \pm 7.33$ years, which was not significantly different from that of the entire population ($P = 0.6587$). The prevalence of hyperopia increased until the age of 60 years and then decreased ($\chi^2$ for trend $P = 0.7415$). There were 175 men (15.13% of all men) and 294 women (21.76% of all women; Table 4). The women had a significantly higher prevalence of hyperopia than did the men ($P < 0.001$). This difference remained after adjusting for age ($P = 0.0019$; OR, 1.33; 95% CI, 1.11–1.59). Hyperopia had a significant negative association with nuclear sclerosis ($P < 0.0001$; age-adjusted OR 0.098; 95% CI, 0.067–0.14) and a positive significant association with diabetes mellitus ($P = 0.0081$; age-adjusted OR, 1.55; 95% CI, 1.12–2.14).

One thousand three hundred seventy-four (54.78%) subjects had astigmatism less than $0.50$ DC. The prevalence of astigmatism increased significantly with age ($\chi^2$ analysis for trend, $P < 0.0001$). There were 620 (53.59%) men and 754 (55.81%) women. One hundred thirty-five (9.83%) had with-the-rule astigmatism, 1064 (77.44%) had against the rule astigmatism, and 175 (12.74%) had oblique astigmatism. The prevalences of against-the-rule and with-the-rule astigmatism increased and decreased significantly with age, respectively ($P = 0.006$, $P < 0.001$, respectively).

### DISCUSSION

This study of refractive errors is part of a population-based study of glaucoma in the Chennai Glaucoma Study. Dandona et al.$^2$ have reported the prevalence of refractive errors in an urban Indian population that included children and adults. The present study is the first population-based study on refractive errors in an adult rural south Indian population and includes the largest number of people in the >40-year age group (Table 5).

The prevalences of myopia and high myopia in our study were 26.99% and 3.71%, respectively, and increased significantly with age. This association between myopia and age almost disappeared after adjustment for nuclear sclerosis, indicating that nuclear sclerosis is responsible for the increase in myopia with age. Studies in India$^2$ and in the black population in Barbados$^{18}$ have reported a similar trend of increasing myopia with age, and also have found that nuclear sclerosis is associated with myopia. However, other population-based studies from different parts of the world in temperate climates have shown a trend of decreasing myopia with age.$^3,4,5$ Environmental influences (near work,$^8$ night lighting,$^9$ and UV exposure$^{10}$) and racial differences in the tropical countries such as India and the West Indies may be responsible for early ageing of the crystalline lens and associated myopia. As reported by the population-based studies from Australia,$^3$ Singapore,$^4,5$ and Indonesia,$^{20}$ our study also found no significant difference in the prevalence of myopia between the sexes.

We tried to minimize the confounding effect of cataract by excluding those with visual acuity of $<20/40$. Ninety-two percent of the excluded population had significant cataract, with or without associated ocular disease, as defined. The distribution of refractive errors in the 8% with visual loss due to other causes, showed higher rates of myopia than did the study population.

Comparison of our findings with the rural population-based data from Indonesia reported by Saw et al.$^{20}$ showed that the prevalence of myopia was less in our population, with similar rates of hyperopia. Studies from urban populations in South East Asian countries have reported higher prevalences of myopia than other populations. The other study from urban India by Dandona et al.$^2$ showed a similar prevalence of myopia in the 40- to 49-year age group, with a lower prevalence of myopia and a higher prevalence of hyperopia in every older age group.

The prevalence of hyperopia in our study was 18.70% and increased until the age of 60 years and then decreased. Although our finding is similar to the findings reported in the Barbados eye study$^{18}$ and the Andhra Pradesh Eye Disease Study (APEDS),$^2$ several other studies$^3,4,5$ have shown a trend of increasing hyperopia with age. Environmental factors common to tropical countries may be responsible for this phenomenon.$^8,10$ Hyperopia was significantly more prevalent among women than men. Several other studies have reported this

### TABLE 3. LOCS Distribution among Myopes and Nonmyopes

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Myopes</th>
<th>High Myopes</th>
<th>Nonmyopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–49</td>
<td>52 (14.21%)</td>
<td>15 (17.44%)</td>
<td>8 (8.89%)</td>
</tr>
<tr>
<td>50–59</td>
<td>142 (38.80%)</td>
<td>41 (47.67%)</td>
<td>46 (51.11%)</td>
</tr>
<tr>
<td>60–69</td>
<td>133 (36.34%)</td>
<td>24 (27.91%)</td>
<td>31 (34.44%)</td>
</tr>
<tr>
<td>≥70</td>
<td>39 (10.66%)</td>
<td>6 (6.98%)</td>
<td>5 (5.56%)</td>
</tr>
</tbody>
</table>

Data are the number of participants (percentage of total group).
female preponderance. This finding may be related to the fact that women have shorter axial length than men in a subset of our population.21 This study, like most published population-based studies on refractive error, does not report ocular biometric characteristics of the population. These data would have helped in classifying axial myopia and hyperopia accurately.

Diabetes mellitus was positively associated with hyperopia. This finding is interesting and has not been reported in any other population-based study, perhaps because of the change in the refractive index of the crystalline lens due to the accumulation of glucose and its metabolic products and the resultant influx of water in the lens.22 The use of a single elevated random blood sugar (RBS) reading and/or self-reported diabetes may have resulted in an underestimation or overestimation of diabetes. In addition, the determining the prevalence of diabetes by self-report carries with it the problem of reporting bias. Because logistic difficulties prevented the measurement of fasting or postprandial sugar in all subjects, we used RBS criteria for definition, which are acceptable for screening purposes.

The prevalence of astigmatism in our study was 58.70% and increased significantly with age, as has also been reported from Australia,3 Singapore,17 and Indonesia.20 We found a predominance of against-the-rule astigmatism, a finding that has also been reported by the Blue Mountains eye study3 and the APEDS.2 The prevalence of against-the-rule astigmatism significantly increased with age, and with-the-rule astigmatism significantly decreased with age. The reason for this could be increased lid laxity with age, causing flattening of the vertical corneal meridian, thereby decreasing with-the-rule astigmatism and increasing against-the-rule astigmatism.2,23,24,25

To summarize, 49.40% of people in this rural population had refractive errors. The prevalence of myopia was 26.99% and increased significantly with age. This relationship was due to the confounding effect of nuclear sclerosis. We found that hyperopia was more common among women than men, and that hyperopia was more common among diabetic subjects. The prevalence of hyperopia increased until the age of 60 years and then decreased. It was interesting to note that similar patterns have been observed in other studies performed in tropical regions of the world, whereas those observed in temperate regions were different. This difference leads us to believe that environmental influences may play an important role in the prevalence of refractive errors in the older population.

References


Table 4. Age- and Gender-Specific Prevalence of Hyperopia

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>n</th>
<th>Prev (%)</th>
<th>95% CI</th>
<th>Prev (%)</th>
<th>95% CI</th>
<th>Prev (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–49</td>
<td>1456</td>
<td>17.65</td>
<td>15.69–19.61</td>
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<td></td>
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</tr>
<tr>
<td>50–59</td>
<td>686</td>
<td>23.32</td>
<td>20.16–26.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60–69</td>
<td>302</td>
<td>14.57</td>
<td>10.59–18.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;70</td>
<td>64</td>
<td>12.5</td>
<td>4.40–20.60</td>
<td></td>
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</tbody>
</table>

Table 5. Comparison of Reported Prevalence of Refractive Errors in Different Studies

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Age (y)</th>
<th>Emmetropia (%)</th>
<th>Myopia (%)</th>
<th>High myopia (%)</th>
<th>Hyperopia (%)</th>
<th>Astigmatism (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGS†</td>
<td>2508</td>
<td>40–81</td>
<td>50.60</td>
<td>26.99</td>
<td>3.71</td>
<td>18.70</td>
<td>54.78</td>
</tr>
<tr>
<td>Barbados Eye Study*</td>
<td>4036</td>
<td>40–84</td>
<td>NR</td>
<td>21.90</td>
<td>NR</td>
<td>46.90</td>
<td>NR</td>
</tr>
<tr>
<td>Sumatra Indonesia‡§</td>
<td>2508</td>
<td>40–81</td>
<td>50.60</td>
<td>26.99</td>
<td>3.71</td>
<td>18.70</td>
<td>54.78</td>
</tr>
<tr>
<td>Beaver Dam Eye Study*</td>
<td>4275</td>
<td>43–84</td>
<td>24.80</td>
<td>17.06</td>
<td>11.26</td>
<td>8.28</td>
<td>5.17–11.59</td>
</tr>
<tr>
<td>Blue Mountains Eye Study‡</td>
<td>3174</td>
<td>43–84</td>
<td>24.80</td>
<td>17.06</td>
<td>11.26</td>
<td>8.28</td>
<td>5.17–11.59</td>
</tr>
<tr>
<td>Tanjung Pagar Singapore‡§</td>
<td>1252</td>
<td>40–79</td>
<td>32.90</td>
<td>10.23</td>
<td>6.18</td>
<td>5.80</td>
<td>12.94</td>
</tr>
<tr>
<td>APEDS</td>
<td>1122</td>
<td>&gt;15</td>
<td>NR</td>
<td>19.39</td>
<td>9.83</td>
<td>6.25</td>
<td>0.32–12.18</td>
</tr>
</tbody>
</table>

NR, not reported.

* Refractive errors defined as less than −0.50 D for myopia and greater than +0.50 D for hyperopia.
† High myopia defined as myopia less than −5.00 D.
‡ Refractive errors defined as less than −1.00 D for myopia and greater than +1.00 D for hyperopia.
§ High myopia defined as myopia less than −6.00 D.


