# Refractive Errors in a Rural Chinese Adult Population

## *The Handan Eye Study*

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***Purpose:*** To describe the prevalence of and risk factors for myopia and other refractive errors in a rural, adult, Chinese population.

***Design:*** Population-based, cross-sectional study.

***Participants:*** A clustered, random sampling procedure was used to select 7557 Chinese people aged ≥30 years from Handan, China.

***Methods:*** All eligible subjects were invited to undergo a comprehensive eye examination, including standardized refraction. Myopia, high myopia, and hyperopia were defined as a spherical equivalent (SE) in the right eye of more than −0.5 diopter (D), less than −5.0 D, and 0.5 D or more, respectively. Astigmatism was less than −0.5 D of cylinder. Anisometropia was defined as a difference in SE of >1.0 D between the 2 eyes. Only phakic eyes were analyzed.

***Main Outcome Measures:*** Myopia and other refractive errors.

***Results:*** We included 6491 (85.9% participation rate) eligible subjects in this study. Adjusted to the 2000 China population census, the prevalence rate of myopia was 26.7% (95% confidence interval [CI], 25.6–27.8), hyperopia 15.9 % (95% CI, 15.0–16.8), astigmatism 24.5% (95% CI, 23.5–25.5), and anisometropia 7.7% (95% CI, 7.0–8.4). The prevalence of high myopia was 1.8% (95% CI, 1.5–2.1). Using a multivariate regression model, current smoking (odds ratio [OR], 0.7, 95% CI, 0.5–0.9), hours of reading (OR, 1.2; 95% CI, 1.1–1.4), diabetes (OR, 8.4; 95% CI, 2.2–32.5), and number of family members with myopia (OR, 1.3; 95% CI, 1.1–1.7, for each family member) were associated with myopia in younger persons (30–49 years). High school or higher education (OR, 1.8; 95% CI, 1.1–3.1), diabetes (OR, 1.6; 95% CI, 1.2–2.7), nuclear opacity (OR, 1.7; 95% CI, 1.2–2.3), and number of family members with myopia (OR, 1.5; 95% CI, 1.2–1.9) were risk factors in persons ≥50 years of age.

***Conclusions:*** Myopia affects more than one quarter of rural Chinese persons ≥30 years of age. Myopia is more common in younger people and is associated with different risk factors than in older people.

***Financial Disclosure(s):*** The authors have no proprietary or commercial interest in any materials discussed in this article. *Ophthalmology 2009;116:2119–2127 © 2009 by the American Academy of Ophthalmology.*

Refractive errors affect approximately one third of persons ≥40 years in the United States and Western Europe, and one fifth of Australians.[1] Eighty percent of visual impairment in the United States is related to undercorrected refractive error,[2] with the annual direct cost of correcting this estimated to be $3.8 billion.[3]

Although myopia is clearly a major problem in East Asia, nearly all research on the prevalence of this condition in China has been carried out in school-aged children, where myopia rates are extremely high.[4–6]

Recent reports from the Beijing Eye Study provide some data on the prevalence and burden of refractive errors in adult Chinese persons living in an urban setting. This study reported that 22.9% of persons ≥40 years of age had myopia, and myopia was associated with higher educational background, female gender, and nuclear cataract.[7] Whether the prevalence and risk factors for myopia in rural and village settings in China is similar is not clear. The current study was designed to estimate the prevalence and risk factors of refractive errors in rural Chinese adults, who comprise 60% of the Chinese population.

## Methods

### Study Design and Procedure

The Handan Eye Study is a population-based, cross-sectional study of eye diseases among 7557 Chinese people aged ≥30 years from Handan, China. The study adhered to the Declaration of Helsinki. Ethics approval was obtained from the Beijing Tongren Hospital Ethical Committee and all participants signed written informed consent before participating in the study.[8,9]

In brief, subjects ≥30 years of age were selected using a randomized, clustered, sampling technique with probabilities proportionate to size. All subjects came from Yongnian County, Handan, which is one of the largest vegetable-producing regions in North China. Yongnian is located in the southern part of Hebei



ISSN 0161-6420/09/$–see front matter
doi:10.1016/j.ophtha.2009.04.040

Table 1. Comparison of Subjects Included in and Excluded from Refraction Data Analyses

| | Excluded (n = 339) | Included (n = 6491) | P* |
|---|---|---|---|
| Living landform | | | |
| Plains | 84.70% | 90.20% | <0.001 |
| Hills | 15.30% | 9.80% | |
| Age (mean ± SD)† (yrs) | 61.4±11.7 | 51.9±15.7 | <0.001 |
| 30–39 | 13.90% | 18.30% | |
| 40–49 | 10.00% | 20.00% | |
| 50–59 | 18.30% | 37.10% | |
| 60–69 | 17.40% | 16.30% | |
| 70–79 | 32.40% | 7.50% | |
| ≥80 | 8.00% | 0.80% | |
| Gender | | | |
| Male | 46.90% | 46.30% | 0.835 |
| Female | 53.10% | 53.70% | |
| Educational attainment‡ | | | |
| Illiteracy | 19.20% | 11.20% | <0.001 |
| Half illiteracy | 9.90% | 4.10% | |
| Primary school | 47.00% | 50.00% | |
| Middle school | 21.90% | 31.70% | |
| High school and above | 2.10% | 3.00% | |
| Marital status | | | |
| Single | 3.30% | 1.30% | <0.001 |
| Married | 76.90% | 91.20% | |
| Divorced | 0.90% | 0.20% | |
| Widowed | 19.00% | 7.40% | |
| Medical insurance available | 35.40% | 55.90% | <0.001 |
| Individual income (annual)† | | | |
| <3500¥ | 61.20% | 49.50% | 0.018 |
| <5000¥ | 21.80% | 27.80% | |
| <9000¥ | 9.70% | 10.10% | |
| >9000¥ | 7.30% | 12.60% | |
| Hypertension | 20.10% | 20.74% | 0.827 |
| Diabetes | 2.97% | 2.16% | 0.435 |
| Current smoker | 24.50% | 27.50% | 0.618 |
| Alcohol use | 13.73% | 18.81% | 0.1028 |
| Family history of myopia | 4.70% | 6.80% | 0.179 |
| Hours of reading per day (mean ± SD) | 0.11±0.33 | 0.20±0.56 | 0.001 |
| Hours of watching TV per day (mean ± SD) | 1.90±1.55 | 2.25±1.27 | 0.006 |

SD = standard deviation.
*Chi-square test.
†1¥ = $0.7.
‡"Illiteracy" was defined as the inability to read any Chinese word. "Half illiteracy" was present if the person could understand some of Chinese words, but could not get any useful information by reading.

province, 80% of the population works as peasants, and 98% are Han. Per capita net income of rural households is 3468 Yuan (approximately 470 USD), which is similar to the average income (3255 Yuan) for those living in rural areas in the Peoples Republic of China according to the annual report of Chinese residents income (2006).[10]

## Sampling Plan

Thirteen (out of 458 villages in Yongnian County) were selected proportional to size to satisfy the target sample of 5105 subjects. The sampling frame for selection was a list of persons living in the town, obtained from the Household Resident Register Record office of the local police stations. These lists are reasonably accurate, as documented previously.[11–14] All residents aged ≥50 years living in the selected villages were invited to participate. In addition, we randomly selected 6 of the 13 villages to examine all residents aged 30–49 years.

A total of 8653 individuals were identified and their permanent residency in the villages was confirmed in a door-to-door census conducted by the study team. A person was considered ineligible if he or she had moved out of the village, had not lived there in the past 6 months, was deceased, or was terminally ill with a life expectancy estimated to be <3 months. Of the 8653 individuals, 7557 were considered eligible. Eligible subjects were requested to visit Yongnian county hospital for a detailed examination. Those who declined to visit the hospital were offered a simplified evaluation at a temporary field site established in the village and those who further declined to visit the temporary site were offered a limited examination conducted at home. All fieldwork was conducted from October 2006 to October 2007.

## Eye Examinations

At the study clinic, participants underwent an extensive and standardized examination procedure, which included visual acuity (VA) testing, a detailed clinical examination, and ocular imaging. For each eye, presenting VA (VA wearing present correction if any) was measured binocularly, and then monocularly (right eye followed by left eye) using the Early Treatment Diabetic Retinopathy testing protocol (with a log of the minimal angle of resolution chart) at a distance of 4 meters. The contralateral eye was patched during monocular testing. For those who could not see the chart at 4 meters, vision was tested at 1 meter, allowing acuities as low as 1/40 (0.025) to be measured. If no letters were identified on the chart, VA was assessed for the ability to count fingers, see hand movements, or perceive light.

Refraction and the radius of corneal curvature in the horizontal and vertical meridian were measured using an autorefractor (KR8800, Topcon, Tokyo, Japan). Final refraction was determined using subjective refraction by trained and certified study optometrists. Autorefraction readings were used as the starting point, and refinement of sphere, cylinder, and axis was performed until the best VA was obtained. Slit-lamp examinations (Topcon SL-2F, Topcon) were performed by study ophthalmologists after pupil dilation and included cataract grading using the Lens Opacities Classification System (LOCS III).[15]

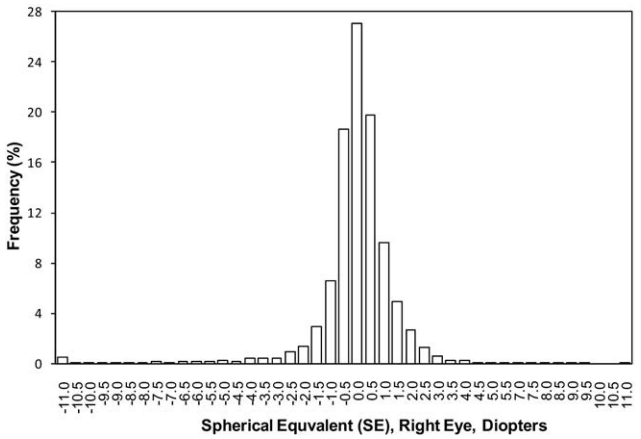


**Figure 1.** Distribution of refractive error in the Handan Eye Study.

## Interview

A detailed, interviewer-administered questionnaire was used.[9] We asked about occupation, marital status, annual income, housing, medical insurance, education level, whether the participant could read or write, and the number of hours per day spent reading, watching TV, and on the computer. We also took a detailed medical history including smoking (current/past/never), alcohol use (never/past/current), and whether the participant had previously diagnosed diabetes mellitus, hypertension, stroke, or heart disease. In addition, the participant's health status was self-rated, with 0 as poorest and 100 as best. Finally, we asked about the numbers of family members (within tertiary relatives) previously diagnosed with myopia.

## Definitions

Refraction data are reported using the subjective refraction when participants had both subjective and objective refraction and autorefraction when only this information was available (n = 3064). For our definitions of emmetropia, myopia, hyperopia, and anisometropia, the refractive data were converted to spherical equivalent (SE), which is derived by adding the spherical component of the refraction to half of the cylindrical component. Data were strongly correlated between right and left eyes ($r = 0.73$) and we therefore present data on right eyes only. Emmetropia was defined as a SE of between −0.5 and 0.5 diopters (D). Myopia was defined using a SE of less than −0.5 D, and high myopia was defined as SE of more than −5.0 D. Hyperopia was defined as a SE of >0.5 D, and anisometropia was defined as a SE difference between the right and left eyes > 1.0 D. Astigmatism was analyzed in minus cylinders and was defined as less than −0.5 D of cylinder, without reference to the axis. These definitions were chosen to enable direct comparison between our data and those published in other studies.[7,16–22] Lens opacity was defined from LOCS III scores ranging from 0.1 (least cataract) to grade 6.9 for nuclear opacity and nuclear color, and 0.1 to 5.9 for cortical and posterior subcapsular opacity.[23] We defined diabetes, hypertension, heart disease, and stroke according to the self-report from participants (previous diagnosed).

## Statistical Analysis

Because our study population was selected based on an unequal sampling technique (probabilities proportional to size), to provide a more accurate estimate of the actual prevalence of refractive errors in the population, rates were age adjusted to the population age structure of China based on the 5th national census of China completed in 2000. The association with myopia and other factors, such as gender, age, and health, was estimated by the odds ratio (OR) and its 95% confidence interval (95% CI). When the *P* value was less than 0.05 in the univariate logistic regression model for a risk factor, the risk factor was retained in the multivariate logistic regression model. Because cataract is unlikely to be a significant contributor to myopia in younger persons, we ran logistic models separately for those aged 30 to 49 years and those ≥50 years in all risk factor analyses.

# Results

A total of 6830 participants (90.4% response rate) were recruited and completed an eye examination; however, 114 (1.7%) who

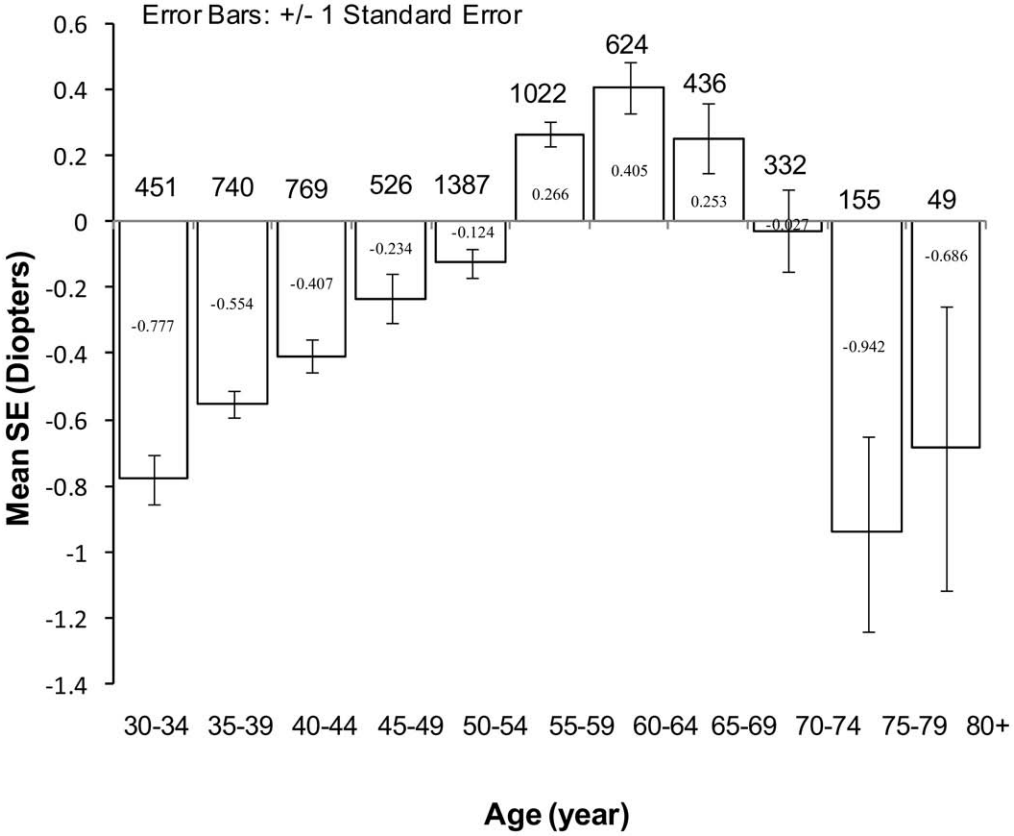


**Figure 2.** Refractive error changes with age in the Handan Eye Study. SE = spherical equivalent.

were examined at home did not have refractive error data. An additional 188 (2.8%) persons had no refraction data for their right eye (either missing or patients had corneal opacities, dense cataracts, or other media opacities), 32 subjects (0.5%) had prior cataract extraction in their right eyes, and 5 (0.1%) were phthisical or had severe anomalies of the anterior or posterior segment, leaving 6491 phakic subjects with refraction data in the right eye for this analysis. These included 749 subjects examined in village clinic, following the same protocol of VA and refraction. The correlation of autorefraction SE with subjective refraction SE was 0.99 for 3381 phakic patients for whom both were available.

Subjects included in our analysis were younger, had a higher educational level, more often resided in the plains, more frequently had medical insurance, read for a greater number of hours per day, and had higher individual incomes ($P<0.001$; Table 1) compared with the 339 subjects who were excluded from the analysis.

The mean refractive error measured in the right eye was $-0.14\pm1.75$ D (Fig 1). The mean refractive error became more hyperopic with increasing age; from $-0.78\pm1.58$D in those aged 30 to 39 years to $0.40\pm1.90$ D in those aged 60 to 64 years, and then shifted in a myopic direction to $-0.69\pm3.01$ D in those age ≥80 years (Fig 2; $P<0.001$; analysis of variance).

A total of 3649 (56.2%) subjects were classified as emmetropic; 1412 (21.8%) were myopic (refractive error less than −0.5 D) and 1430 (22.0%) were hyperopic. One hundred ten subjects (1.7%) had myopia more than −5.0 D, and 80 (1.3%) had myopia of more than −6.0 D. In addition, astigmatism was present in 1820 subjects (28.0%).

The overall age-adjusted prevalence of myopia (to the 2000 China census) for persons ≥30 years of age was 26.7% (95% CI, 25.6–27.8) for greater than −0.5 D and 13.5% (95% CI, 12.7–14.3) for greater than −1.0 D of myopia. The prevalence of myopia of greater than −5.0 D was 1.8% (95% CI, 1.5–2.1), and greater than −6.0 D, 1.3% (95% CI, 1.0–1.6). In addition, 15.9% (95% CI, 15.0–16.8) were hyperopic and 24.5% (95% CI, 23.5–25.5) had astigmatism (Table 2). Although there was no significant difference between the 2 genders in age-adjusted rates of myopia, women had a significantly higher prevalence of hyperopia and astigmatism (chi-square test; $P<0.05$).

Subjects who had previous cataract surgery, phthisis, or other abnormalities that precluded obtaining refractive error data (n = 118) were excluded from the analysis of anisometropia. Of the remaining 6373 phakic subjects with refractive data for both eyes, 515 (8.1%) had anisometropia (SE difference between the right and left eyes > 1.0 D). The standard prevalence of anisometropia was 7.7% (95% CI, 7.0–8.45).

Refractive errors varied by age. For myopia, a typical, U-shaped, bimodal pattern of myopia was seen. The age pattern was reversed for hyperopia, with the highest prevalence at the age of 60 to 69 years (Fig 3). For both astigmatism and anisometropia, there was a monotonic increase in prevalence with age (Fig 4).

Table 2. Prevalence Rates of Myopia, High Myopia, and Hyperopia by Age and Gender in the Chinese Cohort in Handan Eye Study China

| | | Myopia (SE < −0.5 D) | | Myopia (SE < −1.0 D) | | High Myopia (SE < −5.0 D) | | High Myopia (SE < −6.0 D) | | Hyperopia (SE > +0.5 D) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age (yrs)** | **N** | *n* | *% (95% CI)* | *n* | *% (95% CI)* | *n* | *% (95% CI)* | *n* | *% (95% CI)* | *n* | *% (95% CI)* |
| Men | | | | | | | | | | | |
| 30–34 | 215 | 94 | 43.7 (37.1–50.4) | 50 | 23.3 (17.6–28.9) | 5 | 2.3 (0.3–4.3) | 4 | 1.9 (0.1–3.7) | 9 | 4.2 (1.5–6.9) |
| 35–39 | 317 | 115 | 36.3 (31.0–41.6) | 57 | 18.0 (13.8–22.2) | 2 | 0.6 (0.0–1.5) | 0 | 0 | 6 | 1.9 (0.4–3.4) |
| 40–44 | 338 | 85 | 25.1 (20.5–29.8) | 29 | 8.6 (5.6–11.6) | 4 | 1.2 (0.0–2.3) | 4 | 1.2 (0.0–2.3) | 11 | 3.3 (1.4–5.1) |
| 45–49 | 248 | 43 | 17.3 (12.6–22.1) | 16 | 6.5 (3.4–9.5) | 4 | 1.6 (0.0–3.2) | 3 | 1.2 (0.0–2.6) | 25 | 10.1 (6.3–13.8) |
| 50–54 | 646 | 90 | 13.9 (11.3–16.6) | 46 | 7.1 (5.1–9.1) | 9 | 1.4 (0.5–2.3) | 8 | 1.2 (0.4–2.1) | 105 | 16.3 (13.4–19.1) |
| 55–59 | 478 | 58 | 12.1 (9.2–15.1) | 22 | 4.6 (2.7–6.5) | 2 | 0.4 (0.0–1.0) | 2 | 0.4 (0.0–1.0) | 169 | 35.4 (31.1–39.6) |
| 60–64 | 319 | 33 | 10.3 (7.0–13.7) | 18 | 5.6 (3.1–8.2) | 6 | 1.9 (0.4–3.4) | 4 | 1.3 (0.0–2.5) | 131 | 41.1 (35.7–46.5) |
| 65–69 | 207 | 38 | 18.4 (13.1–23.6) | 25 | 12.1 (7.6–16.5) | 7 | 3.4 (0.9–5.8) | 6 | 2.9 (0.6–5.2) | 89 | 43.0 (36.3–49.7) |
| 70–74 | 153 | 53 | 34.6 (21.1–42.2) | 36 | 23.5 (16.8–30.3) | 3 | 2.0 (0.0–4.2) | 2 | 1.3 (0.0–3.1) | 51 | 33.3 (25.9–40.8) |
| 75–79 | 64 | 30 | 46.9 (34.6–59.1) | 26 | 40.6 (28.6–52.7) | 4 | 6.3 (0.3–12.2) | 4 | 6.3 (0.3–12.2) | 16 | 25.0 (14.4–35.6) |
| ≥80 | 22 | 9 | 40.9 (20.4–61.5) | 8 | 36.4 (16.3–56.5) | 1 | 4.5 (0.0–13.2) | 0 | 0 | 8 | 36.4 (16.3–56.5) |
| Women | | | | | | | | | | | |
| 30–34 | 236 | 99 | 41.9 (35.7–48.2) | 47 | 19.9 (14.8–25.0) | 3 | 1.3 (0.0–2.7) | 2 | 0.8 (0.0–2.0) | 6 | 2.5 (0.5–4.6) |
| 35–39 | 423 | 146 | 34.5 (30.0–39.0) | 61 | 14.4 (11.1–17.8) | 5 | 1.2 (0.2–2.2) | 5 | 1.2 (0.2–2.2) | 7 | 1.7 (0.4–2.9) |
| 40–44 | 431 | 114 | 26.5 (22.3–30.6) | 38 | 8.8 (6.1–11.5) | 5 | 1.2 (0.1–2.2) | 4 | 0.9 (0.0–1.8) | 13 | 3.0 (1.4–4.6) |
| 45–49 | 278 | 43 | 15.5 (11.2–19.7) | 21 | 7.6 (4.4–10.7) | 3 | 1.1 (0.0–2.3) | 2 | 0.7 (0.0–1.7) | 22 | 7.9 (4.7–11.1) |
| 50–54 | 741 | 125 | 16.9 (14.2–19.6) | 51 | 6.9 (5.1–8.7) | 11 | 1.5 (0.6–2.4) | 10 | 1.3 (0.5–2.2) | 126 | 17.0 (14.3–19.7) |
| 55–59 | 544 | 59 | 10.8 (8.2–13.5) | 23 | 4.2 (2.5–5.9) | 6 | 1.1 (0.2–2.0) | 5 | 0.9 (0.1–1.7) | 195 | 35.8 (31.8–39.9) |
| 60–64 | 305 | 44 | 14.4 (10.5–18.4) | 25 | 8.2 (5.1–11.3) | 4 | 1.3 (0.0–2.6) | 3 | 1.0 (0.0–2.1) | 170 | 55.7 (50.2–61.3) |
| 65–69 | 229 | 38 | 16.6 (11.8–21.4) | 24 | 10.5 (6.5–14.4) | 8 | 3.5 (1.1–5.9) | 5 | 2.2 (0.3–4.1) | 133 | 58.1 (51.7–64.5) |
| 70–74 | 179 | 44 | 24.6 (18.3–30.9) | 32 | 17.9 (12.3–23.5) | 7 | 3.9 (1.1–6.8) | 4 | 2.2 (0.1–4.4) | 92 | 51.4 (44.1–58.7) |
| 75–79 | 91 | 40 | 44.0 (33.8–54.2) | 30 | 33.0 (23.3–42.6) | 8 | 8.8 (3.0–14.6) | 6 | 6.6 (1.5–11.7) | 35 | 38.5 (28.5–48.5) |
| ≥80 | 27 | 12 | 44.4 (25.7–63.2) | 9 | 33.3 (15.6–51.1) | 3 | 11.1 (0.0–23.0) | 1 | 3.7 (0.0–10.8) | 11 | 40.7 (22.2–59.3) |
| All persons* | | | | | | | | | | | |
| ≥30 | 6491 | 1412 | 26.7 (25.6–27.8) | 694 | 13.5 (12.7–14.3) | 110 | 1.8 (1.5–2.1) | 84 | 1.3 (1.0–1.6) | 1430 | 15.9 (15.0–16.8) |
| 40–79 | 5251 | 937 | 19.4 (18.3–20.5) | 462 | 10.2 (9.4–11.0) | 91 | 2.0 (1.6–2.4) | 72 | 1.5 (1.2–1.8) | 1383 | 23.5 (22.4–24.6) |
| ≥40 | 5300 | 958 | 18.8 (17.7–19.9) | 479 | 9.5 (8.7–10.3) | 95 | 1.8 (1.5–2.2) | 73 | 1.4 (1.1–1.7) | 1402 | 23.1 (22.0–24.2) |
| ≥50 | 4005 | 673 | 18.2 (17.0–19.4) | 375 | 11.9 (10.9–12.9) | 79 | 2.6 (2.1–3.1) | 60 | 1.8 (1.4–2.2) | 1331 | 35.6 (34.1–37.1) |

CI = confidence interval; D = diopters; SE = spherical equivalent.
*Standardized by the age and gender to China national census (2000).

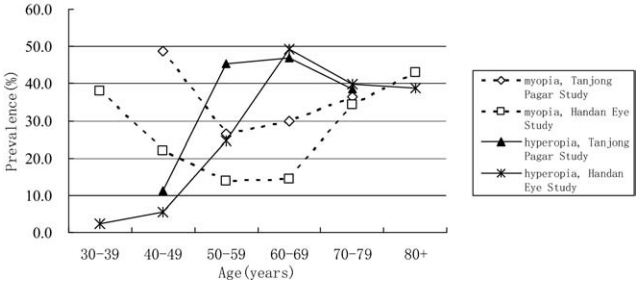


**Figure 3.** Comparison of age-specific prevalence of myopia (less than −0.5 diopters) between the Handan Eye Study and The Tanjong Pagar Study.

Table 3 shows the factors associated with my myopia in a multivariate logistic regression models in persons <50 years of age. Age and current smoking were found to be protective, and hours of reading, diabetic history, and numbers of family members with myopia were associated with the presence of myopia. In those ≥50 years of age, high school or further education (OR, 1.8; 95% CI, 1.1–3.1), the presence of diabetes (OR, 1.6; 95% CI, 1.2–2.7), increased LOCS III nuclear opacity score (OR, 1.7; 95% CI, 1.2–2.3), and greater numbers of family members with myopia (OR, 1.5; 95% CI, 1.2–1.9) were all independent risk factors; those aged 60 to 69 years had a reduced risk of myopia (OR, 0.6; 95% CI, 0.5–0.8), whereas those aged 70 to 79 years had a greater risk (OR, 1.4; 95% CI, 1.0–1.9) compared with those 50 to 59 years of age.

For high myopia (SE less than −5.0 D) in persons aged 30 to 49 years, LOCS III nuclear opacity score (OR, 1.8; 95% CI, 1.1–2.9) and numbers of family members with myopia (OR, 1.9; 95% CI, 1.1–3.2 for each additional family member with myopia) were the only independent risk factors in the multivariate analysis. In those aged ≥50 years, beside the numbers of family members (OR, 1.9; 95% CI, 1.2–2.3), nuclear opacity (OR, 2.3; 95% CI, 1.0–5.9), and posterior subcapsular opacity (OR, 1.6; 95% CI, 1.2–2.1) were associated with high myopia.

Table 4 presents the factors associated with forms of refractive error other than myopia. Hyperopia was strongly age related. The odds of hyperopia in those age ≥80 years was 44.4 times (95% CI, 14.3–138.1) the odds for those aged 30 to 39 years. Women were more likely to be hyperopic (OR, 1.5; 95% CI, 1.2–1.8). Current alcohol users had a higher risk of being hyperopic (OR, 1.3; 95% CI, 1.0–1.7). Age was also associated with astigmatism, but there was no clear trend (those 70–79 years old had an increased risk of astigmatism [OR, 3.3; 95% CI, 2.0–5.4]). Those watching more hours of TV were less likely to have astigmatism (OR, 0.94; 95% CI, 0.88–0.099), whereas diabetes was associated with an increased risk of astigmatism (OR, 2.9; 95% CI, 1.7–5.0). Age was also inconsistently associated with anisometropia with those in the 5th and 6th decades having a reduced risk. Lenticular opacity (nuclear, cortical, and posterior subcapsular) was associated with the presence of anisometropia.

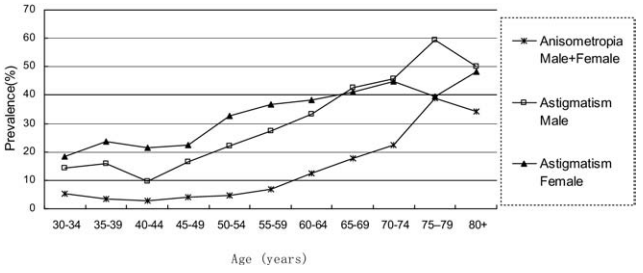


**Figure 4.** The prevalence of astigmatism and anisometropia by age in the Handan Eye Study.

Table 3. Factors Associated with Myopia Using Multivariate Logistic Regression Models in the Handan Eye Study

| Factors | OR (95% CI) | *P* |
|---|---|---|
| Age <50 years | | |
| Age 40–49 vs 30–39 years | 0.5 (0.4–0.6) | <0.0001 |
| Diabetes | 8.4 (2.2–32.5) | 0.002 |
| Smoking | | |
| Never | 1.0 | |
| Past | 0.7 (0.5–1.7) | 0.689 |
| Current | 0.7 (0.5–0.9) | 0.003 |
| Hours of reading per day | 1.2 (1.1–1.4) | 0.003 |
| No. of family members with myopia | 1.3 (1.1–1.7) | 0.012 |
| Age ≥50 years | | |
| Age (yrs) | | |
| 50–59 | 1.0 | |
| 60–69 | 0.6 (0.5–0.8) | <0.001 |
| 70–79 | 1.4 (1.0–1.9) | 0.014 |
| ≥80 | 1.6 (0.7–3.7) | 0.227 |
| Education level | | |
| Illiteracy | 1.0 | |
| Half illiteracy | 0.8 (0.5–1.3) | 0.382 |
| Primary school | 0.9 (0.7–1.2) | 0.373 |
| Middle school | 1.1 (0.7–1.4) | 0.947 |
| High school/above | 1.8 (1.1–3.1) | 0.02 |
| Diabetes | 1.6 (1.2–2.7) | 0.035 |
| Lens nuclear opacity | 1.7 (1.2–2.3) | 0.002 |
| No. of family members with myopia | 1.5 (1.2–1.9) | <0.001 |

## Discussion

This study provides new population-based data on the prevalence of refractive errors in Chinese people aged ≥30 years living in a rural village setting in mainland China. We report an overall prevalence of 26.7% for myopia, 1.8% for high myopia, and 15.9% for hyperopia. Our study showed a classic "U-shaped" pattern of myopia, with higher rates in younger and older people, the latter reflecting increasing prevalence of age-related cataract. We found that 24.5% of our subjects had astigmatism (cylinder greater than −0.5 D) and 7.7% had anisometropia (SE difference > 1.0 D).

The major finding was that myopia in the Chinese rural population is common, but the rates differ substantially from those seen in Singaporean and Hong Kong Chinese. Among ethnic Chinese ≥40 years of age, the prevalence of myopia (18.8%) in our study was lower than that reported in the Tanjong Pagar Study in Chinese Singaporeans (38.7%),[21] Hong Kong Chinese (40%),[24] and Singaporean Malayans (30.7%).[25] However, the result was comparable with the Beijing Eye Study, which examined an urban Chinese population (22.9%)[7]; The rate of myopia reported herein was not much higher than that in the whites, black, and South Asian populations (Table 5). The lower rates of myopia as compared with Singapore and Hong Kong Chinese suggest that socioeconomic development and factors associated with this development over time may have contributed to the higher prevalence of myopia in these cities.

Table 4. Factors Associated with Hyperopia, Astigmatism, and Anisometropia Remaining in the Multivariate Logistic Regression Models in the Handan Eye Study

| Characteristics | Hyperopia | | Astigmatism | | Anisometropia | |
|---|---|---|---|---|---|---|
| | *OR (95% CI)* | P | *OR (95% CI)* | P | *OR (95% CI)* | P |
| Age (yrs) | | | | | | |
| 30–39 | 1.0 | | 1.0 | | 1.0 | |
| 40–49 | 2.5 (1.5–4.3) | 0.001 | 1.0 (0.8–1.4) | 0.764 | 0.5 (0.3–0.9) | 0.013 |
| 50–59 | 13.6 (8.3–22.4) | <0.001 | 1.6 (1.2–2.1) | 0.003 | 0.6 (0.4–0.9) | 0.025 |
| 60–69 | 45.1 (26.2–77.4) | <0.001 | 2.3 (1.6–3.3) | <0.001 | 0.9 (0.5–1.5) | 0.718 |
| 70–79 | 28.0 (15.0–52.6) | <0.001 | 3.3 (2.0–5.4) | <0.001 | 1.0 (0.5–2.0) | 0.909 |
| ≥80 | 44.4 (14.3–138.1) | <0.001 | 3.4 (1.1–9.1) | 0.036 | 0.5 (0.1–1.9) | 0.271 |
| Gender | | | | | | |
| Female | 1.5 (1.2–1.8) | <0.001 | 1.4 (1.0–1.8) | 0.02 | — | |
| Lens | | | | | | |
| Nuclear opacity | — | | — | | 1.7 (1.2–2.5) | 0.003 |
| Lens color | — | | — | | 1.0 (0.7–1.45 | 0.9 |
| Cortical opacity | — | | — | | 1.2 (1.1–1.4) | <0.001 |
| Poster capsular opacity | — | | — | | 1.7 (1.3–2.3) | <0.001 |
| Life style | | | | | | |
| Hours of watching TV | — | | 0.94 (0.88–0.99) | 0.04 | 0.9 (0.8–1.0) | 0.017 |
| Alcohol use | | | | | | |
| Never | 1 | | — | | — | |
| Past | 1.1 (0.7–1.7) | 0.578 | — | | — | |
| Current | 1.3 (1.0–1.7) | 0.038 | — | | — | |
| Educational level | | | | | | |
| Illiteracy | | | 1.0 | | | |
| Half illiteracy | — | | 0.6 (0.4–0.9) | 0.02 | — | |
| Primary school | — | | 1.1 (0.9–1.4) | 0.39 | — | |
| Middle school | — | | 1.1 (0.8–1.4) | 0.679 | — | |
| High school and above | — | | 1.4 (0.8–2.3) | 0.202 | — | |
| History | | | | | | |
| Hypertension | — | | — | | 1.6 (1.1–2.1) | 0.003 |
| Diabetic | — | | 2.9 (1.7–5.0) | 0.001 | — | |
| Family history | | | | | | |
| No. of family members with myopia | 0.7 (0.5–0.9) | <0.001 | — | | — | |

CI = confidence interval; OR = odds ratio.

Alternatively, the founding populations in these regions may have a greater predisposition to myopia.

The similar rate of myopia between our rural population and the urban population in Beijing was unexpected. Differences in sampling strategies and study participant characteristics prevent a direct comparison, and the Beijing Eye Study did not enroll only urban dwelling participants. For example, more than half of the participants in the Beijing Eye Study were enrolled from 5 veteran communities[26] who were less likely to have refractive errors, possibly leading to an underestimation of the rate of myopia in those living in Beijing area. Nonetheless, the similarity in prevalence of myopia suggests that environmental/lifestyle determinants for myopia in urban and rural settings may have been similar in the older members of the Chinese population. We note that, even in Beijing, the adult population spent their early schooling years before the 1970s, when the educational system in China was not well established. In contrast, in the Refractive Error Study in Children, the prevalence of myopia in children 15 years of age from semiurban areas of Shunyi County, Beijing (36.7% in males and 55.0% in females), was substantially lower than that in urban area of Guangzhou (78.4%), which suggests that differences in urban–rural environments is more pronounced in younger people.[4,5]

The cohort of individuals born in the 1960s or later had higher rates of myopia than those who were born before 1960. This may be explained in part by a previously observed age-related hyperopic shift in this age range. The Beaver Dam Eye Study[27] found a mean change of +0.27 D over 5 years in individuals 43 to 54 years of age. Furthermore, the Blue Mountains Eye Study[28] observed a +0.42-D change in SE refractive error from 49 to 54 years, and the Barbados Eye Study[29] observed a +0.47-D change from 40 to 49 years (a 9-year span). However, we observed that the prevalence of hyperopia (23.1%) in Handan adults was lower than has been reported in other populations for those ≥40 (49% in the Blue Mountains Eye Study,[18] 57% in the Beaver Dam Eye Study,[18] and 28.4% among Singaporean Chinese in Tanjong Pagar Study[22]), although the rate of emmetropia in the present population was much higher (56.2%). This relatively low rate of hyperopia overall may, in part, explain why the age-related hyperopic shift in the Handan study population is smaller than has been seen in other populations. Furthermore, the smaller hyperopic shift seen in this age range may be due, in part,

Table 5. Comparison of Reported Prevalence of Refractive Errors in Selected Population-based Studies

| Studies | n | Population | Age (yrs) | Emmetropia (%) | Myopia (%) | High Myopia (%) | Hyperopia (%) | Astigmatism (%) |
|---|---|---|---|---|---|---|---|---|
| Handan Eye Study*† | 6491 | Chinese | 30–86 | 57.4 | 26.7 | 1.8 | 15.9 | 24.5 |
| Beaver Dam Eye Study* | 4533 | Caucasian | 43–84 | 24.8 | 26.2 | NR | 49 | NR |
| Blue Mountains Eye Study*† | 3174 | Caucasian | 49–97 | 28.6 | 14.4 | NR | 57 | NR |
| Barbados Eye Study* | 4036 | Black | 40–84 | NR | 21.9 | NR | 46.9 | NR |
| Los Angeles Latino Eye Study†‡ | 5927 | Latinos | >40 | 16.8 | 2.4 | | | |
| Summtra Eye Study‡§ | 1043 | Indonesian | >21 | NR | 48.1 | NR | 15.8 | 18.5 |
| Chennai Glaucoma Study*† | 2508 | Indian | 40–81 | 50.6 | 27 | 3.7 | 18.7 | 54.8 |
| Andhra Pradesh Eye Disease Study*† | 1722 | Indian | >15 | NR | 19.4 | 7 | 9.8 | 12.9 |
| National Blindness and Low Vision Prevalence Survey of Bangladesh*† | 11624 | Bangladeshi | >30 | 54.9 | 22.1 | 2.2 | 20.6 | 32.4 |
| Singapore Malay Eye Study*† | 2974 | Malayan | 40–80 | NR | 30.7 | 3.9 | 27.4 | 33.3 |
| Shihpai Eye Study*§ | 1361 | Chinese | >65 | 21.6 | 19.4 | 2.4 | 59 | 74 |
| Tanjong Pagar Study*† | 1232 | Chinese | 40–79 | 32.9 | 38.7 | NR | 28.4 | 37.8 |
| Beijing Eye Study*§ | 4319 | Chinese | 40–90 | NR | 22.9 | 2.6 | 20 | |
| RESC (Beijing)* | 4338 | Chinese | 5–15 | NR | 0–55 | NR | NR | NR |
| RESC (Guangzhou)* | 4364 | Chinese | 5–15 | NR | 3.3–73.1 | NR | NR | NR |

NR = not reported; RESC = refractive error study in children.
*Refractive error defined as less than −0.50 diopter for myopia and greater than +0.50 diopter for hyperopia.
†High myopia defined as myopia less than ≥5.00 diopter.
‡Refractive error defined as less than ≥1.00 diopter for myopia and greater than +1.00 diopter for hyperopia.
§High myopia defined as myopia less than ≥6.00 diopter.

to a cohort effect, with later birth cohorts more disposed to myopia.

The U-shaped, bimodal pattern of myopia owing to the development of cataract in the older age groups has been reported to begin in the 7th decade (as was seen in the Handan population) in the Tanjong Pagar Study,[22] the Singapore Malay Eye Study[25]and a study from Sumatra.[30] In contrast, white populations had a lower prevalence of myopia with age until the 8th decade, with only a slight increase in myopia rates in the oldest individuals.[1] It is possible that the higher prevalence of myopia in persons ≥70 in the Handan cohort could be due to the low surgery rate for cataract because those with more cataract were likely to have become pseudophakic in more developed countries.[31] Interestingly, the increasing myopia prevalence in older age groups started from 45 years of age in South Asian populations (i.e., those from India, Bangladesh, and Indonesia), which was 5 to 10 years earlier than was seen in the Handan population.[30,32–34] Once again, this is likely owing to the development of cataract, which occurs at a younger age in these populations.[32]

The prevalence of high myopia was 1.8% in the present study for those ≥40 years of age. Others have reported higher rates among persons of Chinese ethnicity in Singapore (9.1%),[22] although our study again has similar rates of high myopia as the Beijing Eye Study (2.6%, defined as SE less than −6.0 D),[7] and 2.3% in the Taiwan Chinese aged 60 years.[21] By contrast, the prevalence was only 0.87% in whites aged ≥60 years in the Baltimore Eye Survey.[16] This large difference in the rate of high myopia in ethnically and genetically similar populations in China and Singapore, with very different environmental exposures, points to the need to further evaluate possible public health approaches to prevent high myopia from developing in predisposed populations.

A history of diabetes was associated strongly with the presence of myopia in both younger and older rural Chinese. This finding was reported by the Los Angeles Latino Eye Study[35] and the Barbados Eye Study,[29] but others have not found this association.[7,18,20–22,25] Those with self-reported diabetes in Handan had a mean fasting blood glucose of 10.4 mmol/L, indicating that hyperglycemia was not well controlled in this population. Those with fasting blood glucose >10 mmol/L had a higher risk of myopia adjusting for age, gender, and lens opacity grade (data not presented). It is possible that chronic elevations in blood glucose result in a myopic shift. Studies showing no association with myopia and diabetes were conducted largely in developed countries where control of blood glucose is likely better.

The finding that the risk of myopia increased with a positive family history is consistent with multiple studies showing a strong familial association with the presence of myopia and high myopia.[36–38] However, it is difficult to attribute this finding solely to genetic factors, because the unmeasured shared potential confounding environmental factors, such as the same living conditions, dietary habits, educational opportunities, and so on, may increase the association seen in families with myopia. Nevertheless, genetic factors have been shown to play an important role in the development of refractive errors.[39,40]

The rate of anisometropia was strongly age related. This finding is consistent with the reports from Blue Mountains Eye Study,[18] the Tanjong Pagar Study,[22] and Singapore Malay Eye Study.[25] Anisometropia was also associated with nuclear opacity, cortical opacity, and posterior capsular opacity, almost certainly owing to the asymmetric development of cataract between the 2 eyes.

We observed that hyperopia was associated with current alcohol use. It was not observed in previous studies,[41] and contradictory to an experimental study that weak myopic

changes were found in acute ingestion of alcohol at a breath alcohol level of 0.1%.[42] It is possible that the pattern of alcohol consumption among Chinese people may differ from the consumption pattern in Western countries; this requires further study.

The strengths of our study include a large sample size and high participation rate. However, our study has some limitations. First, most of the associated factors were obtained through interview, which may not be completely accurate and can suffer from recall bias. Second, the history of heart diseases, hypertension, diabetes, and myopic family history in this rural population might be inaccurate and might not fully identify those with health problems because health care in this rural area is not routinely obtained. Third, subjects included in our analysis were younger, had a higher educational level, lived in larger housing units, and spent more hours reading. These differences indicate that the nonparticipants likely had lower rates of myopia; therefore, our estimates may be higher than the true population prevalence.

In conclusion, myopia affected a quarter of the adult rural Chinese population aged ≥30 years. The prevalence of myopia was lower than in other ethnic Chinese communities living in Singapore, Hong Kong, and Taiwan, but was similar to Chinese people living in Beijing. These findings suggest that the environmental and lifestyle determinants for myopia in older Chinese people may not be so dissimilar between urban and rural settings, supporting the concept that the "epidemic" of myopia in East Asia is a recent phenomenon.

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## Footnotes and Financial Disclosures

Originally received: November 9, 2008.
Final revision: April 22, 2009.
Accepted: April 23, 2009.
Available online: September 10, 2009. Manuscript no. 2008-1327.

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Presented at: The World Ophthalmology Congress 2008, July 2, 2008, Hong Kong, China.

Financial Disclosure(s):
The authors have no proprietary or commercial interest in any of the materials discussed in this article.

Supported by National Basic Research Program of China (973 Program), Grant 2007CB512201 from the Ministry of Science and Technology of the People's Republic of China, Program of Health Policy for blindness prevention from Ministry of Health the People's Republic of China, Partially funded by the Key Technologies R&D Program. No.2006-10903 from Bureau of Science and Technology of Handan city, Hebei Province, China. With additional support from Beijing Tongren Hospital and the key discipline fund of Bureau of Health, Handan city, Hebei Province, China.

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