# Refractive Error in Urban and Rural Adult Chinese in Beijing

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***Purpose:*** To evaluate refractive error and its demographic associations in an urban and rural population in northern China.

***Design:*** Epidemiological study.

***Participants:*** The Beijing Eye Study is a population-based cohort study in northern China including 4439 subjects. Excluding pseudophakic and aphakic patients, the present study involved 4319 subjects. It was divided into a rural part (1905 [44.1%] subjects) and an urban part (2414 [55.9%] subjects). Mean age was 55.85±10.33 years (range, 40–90).

***Methods:*** Standardized ophthalmologic examination. For statistical analysis, the spherical equivalent was converted to binary variables, and logistic regression was used to investigate the association with continuous or categorical independent variables.

***Main Outcome Measure:*** Refractive error.

***Results:*** Mean refractive error measured −0.33±2.22 diopters (D) (range, −20.88 to +7.88). Myopia of >−0.50 D, −1.0 D, >−6.0 D, and >−8 D, respectively, occurred in 22.9% (95% confidence interval [CI], 21.7–24.2), 16.9% (95% CI, 15.8–18.0), 2.6% (95% CI, 2.2–3.1), and 1.5% (95% CI, 1.1–1.9) of the subjects, respectively. Myopic refractive error was associated significantly with younger age ($P<0.001$), urban region (vs. rural region) ($P<0.001$), higher educational background ($P<0.001$), higher degree of nuclear cataract ($P<0.001$), decreasing uncorrected visual acuity (UCVA) ($P<0.001$), decreasing best-corrected visual acuity (BCVA) ($P<0.001$), and female gender ($P<0.001$). Prevalence of high myopia (myopic refractive error >−8 D) was associated with age ($P<0.001$), female gender ($P = 0.020$), urban region ($P = 0.023$), and lower BCVA ($P<0.001$). Mean anisometropia was 1.09±2.03 D (median, 0.38; range, 0–22.0). Prevalence of anisometropia of ≥1 D was associated significantly with age ($P<0.001$), refractive error ($P<0.001$), BCVA ($P<0.001$), and region ($P<0.001$). Mean astigmatic error measured 0.62±0.90 D (median, 0.25; range, 0–7.50). Astigmatism of ≥1 D was associated significantly with age ($P<0.001$), lower UCVA ($P = 0.003$), lower BCVA ($P<0.001$), urban area ($P<0.001$), and degree of cortical cataract ($P = 0.027$).

***Conclusions:*** As in other population-based studies on Chinese, myopia was more prevalent in younger subjects. Myopia was associated with urban region, educational background, female gender, decreasing visual acuity, and nuclear cataract. If longitudinal studies confirm the association of refractive error with age, refractive surgery may achieve emmetropia only for a limited time. *Ophthalmology 2005;112:1676–1683 © 2005 by the American Academy of Ophthalmology.*

As any quantitative biologic parameter, refractive error shows a marked interindividual variability within an ethnic group. Previous epidemiological studies additionally have revealed an interethnic variability. The majority of these epidemiological studies have been conducted mostly in European-derived populations.[1–7] For East Asia, investigations have been performed mostly in selected subgroups of the population.[8–19] For mainland China, comparable data obtained in a large population-based study are lacking. In view of the role the ethnic background may play for refractive error of the eye, it was, therefore, the purpose of the present study to measure refractive error in a population-based study in northern China.

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## Subjects and Methods

The Beijing Eye Study is a population-based prospective cohort study in northern China. It was carried out in 4 communities in the urban district of Haidian in the north of central Beijing and in 3 communities in the village area of Yufa of the Daxing district south of Beijing. The study was performed in a rural area and in an urban area because the areas differ markedly in level of education, access to medical care, mobility, frequency of hereditable diseases, and way of life. In the rural areas, eye care services and a referral system to ophthalmologists were not available, and the cost of medical care was not covered by the government. In the urban



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areas, eye care was at a relatively high standard, with some communities supplying free ophthalmic examinations, and in these areas, the cost of medical care was covered by the government.

All people living in the 7 communities were officially registered by name, gender, and age at the local mayor's office. Using this register as the sampling frame, all subjects living in the 7 communities and fulfilling the inclusion criterion of age ≥40 years were eligible for the study. Due to the registration list at the mayor's office, communities' boundaries and populations were known before the start of the study. Home visits were performed according to the registration list, and the inclusion criterion was confirmed by door-to-door enrollment. The door-to-door visitation included all houses in the communities, and the registration list of the inhabitants served as an overview of who was residing in each of the houses. The eligible subjects were visited up to 3 times if they did not participate after the first visit in the Beijing Eye Study. About 90% of the subjects participating in the study agreed to take part in the study after the first visit of a study team member. Participation in the study was favored markedly by the mayors. The door-to-door visit was used to confirm the age of the subjects and to ask them a questionnaire including questions on their level of education and their family income. The study was described in detail recently.[20,21] The medical ethics committee of the Beijing Tongren Hospital had approved the study protocol, and all participants had given informed consent according to the tenets of the Declaration of Helsinki.

At the time of the survey in the year 2001, the 7 communities had a total population of 5324 individuals ≥40 years old, all of whom were given offers to accept the eye examination. In total, 4439 individuals (2505 women) participated in the eye examination, corresponding to an overall response rate of 83.4%. Data on refractive error were available for 4342 subjects. Of the 8555 eyes, 15 (0.2%) were aphakic, and 56 (0.7%) were pseudophakic. For further statistical analysis, these 71 eyes were excluded so that the final study group consisted of 8484 eyes of 4319 subjects. For 4165 subjects, refractive data were available for both eyes; for 154 subjects, refractive error measurements were available for only one eye. The study was divided into rural (1905 [44.1%] subjects, 1093 women, 3718 eyes) and urban (2414 [55.9%] subjects, 1331 women, 4766 eyes) parts (Table 1). Mean age was 55.85±10.33 years (median, 56; range, 40–90). According to the questionnaire given to all study participants, none had previously undergone refractive surgery.

All examinations were carried out in the communities, in either schoolhouses or community houses. After informed consent was given, uncorrected visual acuity (UCVA) was measured (Snellen charts) at a distance of 5 m. Near vision was evaluated at a distance of 25 to 30 cm using Jaeger charts, unaided, and then using an addition for near vision. For statistical analysis purposes, the visual acuity (VA) measurements were converted to logarithm of the minimum angle of resolution (logMAR) units. Automatic refractometry (Auto Refractometer AR-610, Nidek Co., Ltd., Tokyo, Japan) was performed, if UCVA was <1.0. The values obtained by automatic refractometry were verified and refined by subjective refractometry. The spherical equivalent (SE) of refractive error was calculated as the spherical value of refractive error plus half of the cylindrical value. An experienced technician measured intraocular pressure (IOP) using a noncontact pneumotonometer (CT-60 computerized tonometer, Topcon Ltd., Tokyo, Japan). Three measurements were taken, and their mean was taken for further statistical analysis. If the measurements were higher than 25 mmHg, tonometry was repeated. A slit-lamp examination was carried out by an ophthalmologist who had completed his ophthalmic residency. The pupil was dilated using tropicamide once or twice, until the pupil diameter was at least 6 mm. Digital photographs of the cornea and retroilluminated photographs of the lens were taken using a Neitz CT-R camera (Neitz Instruments Co., Tokyo, Japan). The degree of nuclear cataract was scored using the cataract grading system of the Age-Related Eye Disease Study.[22] We combined standard photographs 6 and 7 into one grade (i.e., 6). The degree of cortical lens opacification and posterior subcapsular lens opacification was assessed on photographs taken under retroillumination as described in the Age-Related Eye Disease Study.[22] Additional information was obtained on net family income.

Statistical analysis was performed using a commercially available statistical software package (SPSS for Windows, version 11.5, SPSS Inc., Chicago, IL). Only one randomly selected eye per subject was taken for statistical analysis, unless intraindividual intereye differences were evaluated. The data are given as mean ± standard deviation (SD). Chi-square tests were used to compare proportions. For statistical analysis purposes, VA measurements were converted to logMAR units. Multiple regression models were used to examine the relationship between refractive error and selected sociodemographic characteristics. The SE of refractive error was converted into a binary variable, such as myopic error (myopic refractive error > −0.5 diopter [D]) versus nonmyopic and highly myopic (myopic refractive error > −8 D) versus non–highly myopic. Logistic regression was used to investigate the association of these binary dependent variables with the continuous or categorical independent variables, such as age, gender, education level, and IOP. The statistical strength of correlations was reported as correlation coefficient $r$ or $r^2$. Odds ratios (ORs) and 95% confidence intervals (CIs) were presented. All $P$ values were 2-sided and were considered statistically significant when the values were <0.05.

## Results

Response rates were 79.30% in the rural population and 86.95% in the urban population (Table 2). Mean monthly salary (365±351 renminbi yuan [95% CI], 376–409) vs. 1781±5820 renminbi yuan [95% CI], 1521–1854), age, and level of education were significantly lower in the rural region than in the urban region (Table 1).

Taking into account the whole study population, mean refractive error measured −0.33±2.22 D (median, 0; range, −20.88 to +7.88; 95% CI, −0.37 to −0.28) (Fig 1). The distribution curve of refractive error was slightly skewed and kurtotic to the myopic end. Assuming a Gaussian distribution curve, the normal range of refractive error, defined as mean ± 2 SDs, was −4.77 to +4.11 D. Defining myopia and hyperopia as ametropias of >0.50 D, 22.9% (95% CI, 21.7–24.2) of the subjects were myopic, and 20.0% (95% CI, 18.8–21.2) of the subjects were hyperopic. Myopias of more than −1.0 D and more than −6.0 D, respectively, were found in 16.9% (95% CI, 15.8–18.0) and 2.6% (95% CI, 2.2–3.1) of subjects. High myopia with a myopic refractive error higher than −8 D was found in 1.5% (95% CI, 1.1–1.9) of subjects.

### Rural versus Urban Population

In a univariate assessment, refractive error was significantly ($P$<0.001) more myopic in the urban population (−0.55±2.43 D; 95% CI, −0.60 to −0.47) than in the rural population (−0.06±1.90 D; 95% CI, −0.12 to 0.00) (Table 1). Because the urban population group was significantly ($P$<0.001) older than the rural population group (Table 1), both populations were stratified for age. For the age groups of 40 to 44 years ($P$<0.001), 45 to 49 years ($P$<0.001), 50 to 54 years ($P$<0.001), 55 to 59 years ($P$ = 0.002), 60 to 64 years ($P$<0.001), and 65 to 69 years ($P$ = 0.001), the urban population group was significantly more myopic than the rural population group. For the elder age groups, the differences in

Table 1. Composition of the Study Population

| | Total | Rural Population | Urban Population | *P* Value* |
|---|---|---|---|---|
| n (subjects) | 4319 | 1905 | 2414 | |
| n (eyes) | 8484 | 3718 | 4766 | |
| Females/males | 2424/1895 | 1093/812 | 1331/1083 | 0.076 (NS) |
| Age (yrs) (mean ± SD) | 55.85±10.33 | 52.98±9.94 | 58.12±10.07 | <0.001 |
| Median | 56 | 51 | 59 | |
| Range | 40–90 | 40–84 | 40–90 | |
| Refractive error (diopters) (mean ± SD) | −0.33±2.22 | −0.06±1.90 | −0.55±2.43 | <0.001 |
| Median | 0 | 0 | 0 | |
| Range | −20.88 to +7.88 | −20.88 to +7.88 | −20.50 to +7.50 | |
| Level of education | | | | |
| Illiteracy† | | 15.6% | 2.0% | <0.001‡ |
| Half illiteracy§ | | 5.8% | 0.6% | <0.001‡ |
| Attended primary school | | 27.4% | 5.4% | <0.001‡ |
| Attended middle school | | 50.9% | 32.4% | <0.001‡ |
| Attended college | | 0.3% | 59.6% | <0.001‡ |

NS = nonsignificant; SD = standard deviation.
*Statistical significance of the difference between the 2 study populations.
†Inability to read any Chinese word.
‡Chi-square test.
§The subject could read a few Chinese words but could not get any useful information from them.

mean refractive error between the 2 study groups was statistically nonsignificant (Table 3).

## Correlation with Age

Mean refractive error increased significantly with age in the rural population (correlation coefficient $r$ = 0.11, $P$<0.001) and in the urban population (correlation coefficient $r$ = 0.14, $P$<0.001). Correspondingly, the frequency of myopia decreased significantly ($P$<0.001) with age. Stratification for age revealed a hyperopic shift with increasing age (Table 3).

## Correlation with Education

In the urban population group, myopic refractive error was correlated significantly ($P$<0.001) with the level of education (Table 3). Subjects with a college education were significantly more myopic than subjects with a middle school education ($P$<0.001), subjects with a primary school education ($P$<0.001), or illiterate subjects ($P$<0.001). In the rural population group, the middle school group was significantly more myopic than the primary school group ($P$ = 0.021). The urban population had a significantly higher educational background than the rural population group ($P$<0.001). Correspondingly, family income was significantly higher in the urban population group ($P$<0.001), in which educational background was correlated significantly ($P$<0.001) with family income.

## Miscellaneous Parameters

In univariate analysis, myopic refractive error was associated significantly ($P$ = 0.011) with degree of nuclear cataract in the rural population group ($P$ = 0.011). In the urban group, the relationship was not significant ($P$ = 0.84). Females (−0.31±2.44 D; 95% CI, −0.41 to −0.22) and males (−0.36±1.90 D; 95% CI, −0.45 to −0.28) did not vary significantly ($P$ = 0.45) in refractive error. Refractive error did not differ significantly ($P$ = 0.41) between right and left eyes. Myopic refractive error was signifi-

Table 2. Age- and Gender-Specific Response Rates in Rural and Urban Populations

| Age (yrs) | Registered | | Examined | | Response Rate (%) | |
|---|---|---|---|---|---|---|
| | *Male* | *Female* | *Male* | *Female* | *Male* | *Female* |
| **Rural** | | | | | | |
| 40–49 | 487 | 556 | 338 | 510 | 69.40 | 91.73 |
| 50–59 | 303 | 379 | 242 | 322 | 79.87 | 84.96 |
| 60–69 | 222 | 247 | 168 | 211 | 75.68 | 85.43 |
| ≥70 | 131 | 163 | 82 | 100 | 62.60 | 61.35 |
| Subtotal | 1143 | 1345 | 830 | 1143 | 72.62 | 84.98 |
| Total | 2488 | | 1973 | | 79.30 | |
| **Urban** | | | | | | |
| 40–49 | 357 | 381 | 257 | 344 | 71.99 | 90.29 |
| 50–59 | 301 | 421 | 214 | 408 | 71.10 | 96.91 |
| 60–69 | 469 | 533 | 441 | 470 | 94.03 | 88.18 |
| ≥70 | 216 | 158 | 192 | 140 | 88.89 | 88.61 |
| Subtotal | 1343 | 1493 | 1104 | 1362 | 82.20 | 91.23 |
| Total | 2836 | | 2466 | | 86.95 | |

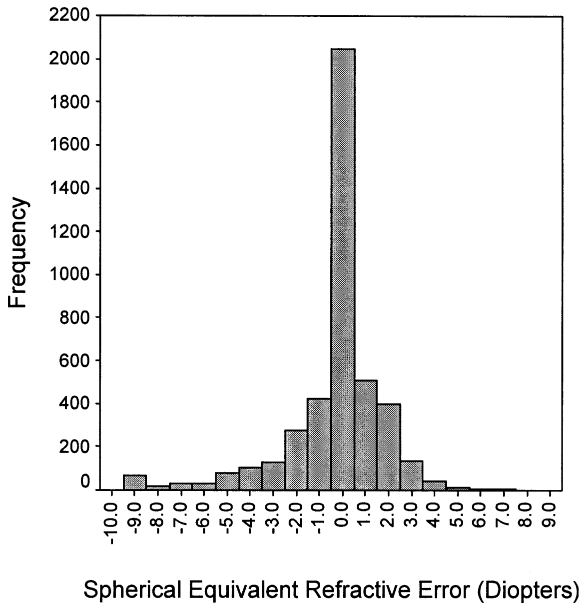


**Figure 1.** Histogram showing the distribution of refractive error in the Beijing Eye Study.

cantly associated with decreasing UCVA ($r$ = 0.36, $P$<0.001) and best-corrected VA (BCVA) ($r$ = 0.24, $P$<0.001).

## Multiple Regression Analysis

Because in univariate analysis refractive error was associated significantly with age, rural group versus urban group, educational background, UCVA, BCVA, and degree of nuclear cataract, and because some of these parameters such as degree of nuclear cataract and age were correlated significantly ($P$<0.001) with each other, a multiple logistic regression model was constructed with refractive error as the dependent variable and age, degree of nuclear cataract, rural versus urban population, UCVA, BCVA, gender, and educational background as the explanatory covariates. For that purpose, the SE of refractive error was converted to a binary variable, as described above. In a binary logistic regression analysis, the prevalence of myopia of ≥1 D was significantly associated with age ($P$<0.001), urban region versus rural region ($P$<0.001), educational background ($P$<0.001), degree of nuclear cataract ($P$ = 0.011), BCVA ($P$<0.001), UCVA ($P$<0.001), and gender ($P$<0.001).

## High Myopia

In the entire study population, 65 (1.5%; 95% CI, 1.1–1.9) subjects were highly myopic. In univariate analysis, prevalence of high myopia showed a tendency—however, not a statistically significant association ($P$ = 0.079)—to increase with age. Highly myopic eyes had significantly ($P$<0.001) lower BCVA than non–highly myopic eyes (0.59±0.54 logMAR [95% CI, 0.70–0.45] vs. 0.05±0.16 logMAR [95% CI, 0.05–0.04]). In univariate analysis, high myopia was significantly ($P$ = 0.004; OR, 2.2; 95% CI, 1.3–3.9) more prevalent in women (2.0%; 95% CI, 1.4–2.5) than in men (0.9%; 95% CI, 0.5–1.3). The prevalence of high myopia did not vary significantly ($P$ = 0.26; OR, 1.4; 95% CI, 0.08–2.2) between the rural area (1.2%; 95% CI, 0.8–1.8) and the urban area (1.7%; 95% CI, 1.2–2.2). Intraocular pressure did not vary significantly ($P$ = 0.34) between the highly myopic group (16.6±4.9 mmHg) and the non–highly myopic group (16.0±3.3 mmHg). In a binary logistic regression analysis, prevalence of high myopia was significantly associated with age ($P$<0.001), female gender ($P$ = 0.020), urban region ($P$ = 0.023), and lower BCVA ($P$<0.001). It was statistically independent of IOP ($P$ = 0.22).

## Anisometropia

Mean anisometropia (intereye difference in refractive error) was 1.09±2.03 D (median, 0.38; range, 0–22.0; 95% CI, 1.03–1.15). In univariate analysis, it increased significantly with myopic refractive error ($r$ = −0.41, $P$<0.001), decreasing VA ($r$ = −0.32, $P$<0.001), and age ($r$ = 0.11, $P$<0.001). It was significantly higher in the urban population group than in the rural population group (0.87±1.99 D [95% CI, 0.78–0.96] vs. 1.26±2.04 D [95%

Table 3. Refractive Error (Diopters) in Age-Stratified and Education Subgroups of the Rural Population and Urban Population Groups

| | Rural Group | | | Urban Group | | | |
|---|---|---|---|---|---|---|---|
| | *n* | *Mean ± SD* | *Median* | *n* | *Mean ± SD* | *Median* | **P Value*** |
| Age group (yrs) | | | | | | | |
| 40–44 | 452 | −0.27±1.44 | 0 | 278 | −1.01±2.12 | 0 | <0.001 |
| 45–49 | 393 | −0.21±1.59 | 0 | 318 | −0.87±2.09 | 0 | <0.001 |
| 50–54 | 340 | −0.19±1.96 | 0 | 253 | −0.84±2.26 | 0 | <0.001 |
| 55–59 | 216 | 0.01±2.30 | 0 | 361 | −0.59±2.15 | 0 | 0.002 |
| 60–64 | 183 | +0.46±1.94 | +0.13 | 530 | −0.51±2.29 | 0 | <0.001 |
| 65–69 | 180 | +0.42±1.94 | +0.56 | 362 | −0.34±3.32 | 0 | 0.001 |
| 70–74 | 91 | +0.08±2.47 | +0.25 | 206 | 0.21±2.24 | +0.38 | 0.26 (NS) |
| ≥75 | 50 | −0.20±3.00 | 0 | 106 | 0.01±2.34 | +0.25 | 0.67 (NS) |
| Education | | | | | | | |
| Illiteracy | 264 | −0.03±3.27 | +0.13 | 41 | +0.92±2.76 | +1.25 | |
| Some reading | 104 | 0.06±1.67 | 0 | 13 | −0.47±2.03 | 0.00 | |
| Primary school | 507 | 0.03±1.76 | 0 | 127 | 0.24±2.61 | +0.13 | |
| Middle school | 967 | −0.19±1.65 | 0 | 763 | −0.29±2.35 | 0 | |
| College | 5 | −1.10±1.23 | −1.25 | 1443 | −0.89±2.41 | 0 | |

NS = nonsignificant; SD = standard deviation.
For 58 subjects in the rural group and for 27 subjects in the urban group, data on educational background were not available.
*Statistical significance of difference between the rural and urban groups.

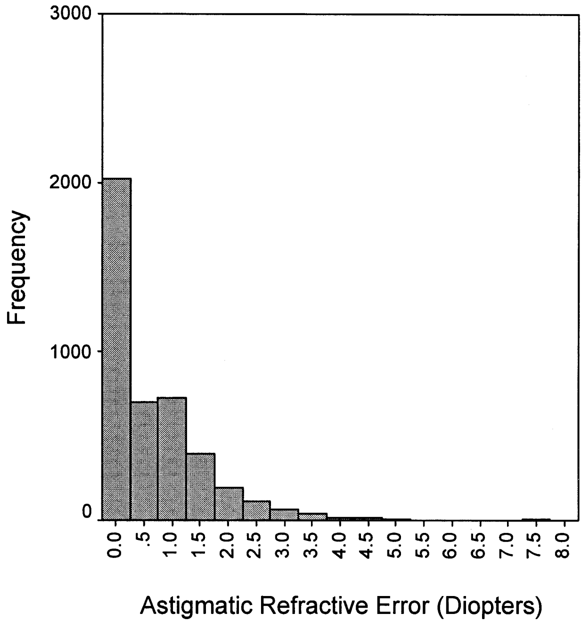


**Figure 2.** Histogram showing the distribution of the astigmatic refractive error in the Beijing Eye Study.

CI, 1.18–1.34), $P<0.001$). It was statistically independent of gender ($P = 0.99$) and IOP ($P = 0.43$). In a binary logistic regression analysis, the prevalence of anisometropia of ≥1 D was significantly associated with age ($P<0.001$), refractive error ($P<0.001$), BCVA ($P<0.001$), and region ($P<0.001$).

## Astigmatic Refractive Error

Mean astigmatic error measured in the entire study population was 0.62±0.90 D (median, 0.25; range, 0–7.50; 95% CI, 0.59–0.65). The astigmatic refractive error did not follow a Gaussian distribution curve but was skewed to the right side (Fig 2). Astigmatic refractive error increased statistically significantly with age ($r = 0.36$, $P<0.001$). It was significantly correlated with decreasing UCVA ($r = -0.32$, $P<0.001$) and decreasing BCVA ($r = -0.50$, $P<0.001$). Correspondingly, it was associated with lower educational background ($r = -0.17$, $P<0.001$) and urban population ($P<0.001$). Astigmatic refractive error was significantly ($P<0.001$) higher in women than in men (0.66±0.96 D [95% CI, 0.63–0.70] vs. 0.57±0.82 D (95% CI, 0.53–0.60). It increased significantly with degree of nuclear cataract ($r = 0.24$, $P<0.001$) and degree of cortical cataract ($r = 0.06$, $P<0.001$). Mean astigmatic error was statistically independent of IOP ($P = 0.87$). In a binary logistic regression analysis, astigmatism of ≥1 D was significantly associated with age ($P<0.001$), lower UCVA ($P<0.001$), lower BCVA ($P<0.001$), and urban area ($P = 0.032$). It was not significantly associated with gender ($P = 0.11$), degree of nuclear cataract ($P = 0.32$), and degree of cortical cataract ($P = 0.42$). If only subjects with UCVA of <1.0 were included in the statistical analysis, astigmatism of ≥1 D was still significantly associated with lower UCVA ($P = 0.003$), lower BCVA ($P<0.001$), age ($P<0.001$), and urban population ($P<0.001$). It was additionally associated with the degree of cortical cataract ($P = 0.027$). It was independent of gender ($P = 0.6$) and nuclear cataract ($P = 0.53$).

# Discussion

In the present Beijing Eye Study, myopia of more than −0.5 D occurred in 21.8% of subjects, and hyperopia of more than +0.5 D was found in 20.0% of subjects (Table 3, Fig 1). High myopia of more than −8 D was present in 1.5% of subjects. Myopia was more prevalent in younger subjects and was associated with urban region, higher educational background, female gender, decreasing VA, and degree of nuclear cataract. Similar figures for the prevalence of myopia have been reported in the Shihpai Eye Study from Taiwan,[23] a population-based survey of 1361 Chinese residents 65 years or older (Table 4). In the Shihpai Eye Study, however, the prevalence of myopia increased with age. In the Shihpai and Beijing eye studies, the frequency of myopia was considerably lower than that in population-based studies from Singapore (Table 4). In the Singaporean Tanjong Pagar study, 38.7% of the population was myopic, and 9.1% of subjects had moderate to severe myopia of more than −5 D (Table 4).[17] The prevalence of myopia in

Table 4. Frequency of Different Degrees of Myopia in Population-Based Studies

| Study | Location | Age (yrs) | >−0.5 D | >−1 D | >−5 D | >−6 D |
|---|---|---|---|---|---|---|
| Shiphai Eye* | Taiwan | ≥65 | 19.4% | 14.5% | | 2.4% |
| Beijing Eye | Beijing | ≥40 | 21.8% | 16.9% | 3.3% | 2.6% |
| Tanjong Pagar† | Singapore | ≥40 | 38.7% | | 9.1% | |
| Military conscripts‡ | Singapore | ~20 | 79.3% | | | 13.1% |
| Schoolchildren§‖ | Taiwan | 6–18 | 80% | | | |
| Students¶ | Japan | | 50% | | | |
| Van Newkirk# | Hong Kong | ≥40 | 40% | | | |

D = diopters.
*Cheng CY, Hsu WM, Liu JH, et al. Refractive errors in an elderly Chinese population in Taiwan: the Shihpai Eye Study. Invest Ophthalmol Vis Sci 2003;44:4630–8.
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§Lin LL, Chen CJ, Hung PT, Ko LS. Nation-wide survey of myopia among school children in Taiwan, 1986. Acta Ophthalmol Suppl 1988;66:29–33.
‖Lin LL, Shih YF, Tsai CB, et al. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. Optom Vis Sci 1999;76:275–81.
¶Hosaka A. Population studies—myopia experience in Japan. Acta Ophthalmol Suppl 1988;185:37–40.
#Van Newkirk MR. The Hong Kong Vision Study: a pilot assessment of visual impairment in adults. Trans Am Ophthalmol Soc 1997;95:715–49.

Singapore was about 1.5 to 2.5 times higher than that in the Shihpai Eye Study, Beijing Eye Study, studies in the United States on similarly aged European-derived populations, and studies in Barbados and in South India.[1–4,7,17,24] In Australian population-based studies, the prevalence rates of myopia were even lower than those in the studies mentioned above. The overall prevalence of myopia was 17% in the Australian Visual Impairment Project,[5] and it was 15% in the Blue Mountains Eye Study.[6]

The high prevalence figures of myopia reported in the Tanjong Pagar study are in agreement with the results of another Singaporean study in which >15 000 military conscripts were examined. Myopia was present in 79.3% of the conscripts, and high myopia of >6 D was found in 13.1% of the subjects. The prevalence rates of moderate myopia and severe myopia were higher for Chinese than for Indians and Malays.[25] One possibility to explain the differences in the prevalence figures of myopia between the Singaporean studies and the other studies might be a selection artifact due to a possibly preferred immigration of myopic Chinese to Singapore. This theory, however, is contradicted by results of other studies in Taiwan, Japan, and Hong Kong. Two Taiwanese studies covering school children showed a prevalence of myopia of >80% by the age of 18 years.[10,16] A study on a Japanese student population showed an overall prevalence of myopia of approximately 50%, and a pilot study in Hong Kong on 355 ≥40-year-old Chinese showed a prevalence of myopia of approximately 40%.[9,14]

Summarizing the results of the studies, the prevalence figures for minor, moderate, and high myopia were similar in the Beijing Eye Study; Taiwanese Shihpai Eye Study; and other population-based studies in the U.S., Barbados, Indonesia, and South India. The figures were higher than those in epidemiological studies in Australia, and they were lower than those in Singaporean population-based investigations.[17,25] Some of the reasons for the variations between the findings from these studies may be differences in ages of subjects included in the studies as well as differences in the examination techniques, such as using cycloplegia for refractometry. Future investigations may show whether differences in environmental conditions as well as genetic reasons additionally may be responsible for the observed differences in refractive error between the populations studied.

## Associations

In the present Beijing Eye Study, myopic refractive error was significantly associated with younger age, urban region, higher educational background, female gender, decreasing VA, and higher degree of nuclear cataract. Similar findings were reported from other population-based studies. These results confirm the Tanjong Pagar study, in which higher educational levels, higher individual income, and professional or office-related occupations were significantly associated with higher rates of myopia.[17] Correspondingly, in the study on Singaporean military conscripts the level of education was strongly associated with prevalence and severity of myopia.[25] In the Baltimore Eye Survey, myopia declined with age, whereas hyperopia, astigmatism, and anisometropia increased with age.[3] Myopia increased with increasing years of education. In the Blue Mountains Eye Study, in a total of 3654 residents 49 to 97 years old, prevalence of myopia decreased with age, from 21% in persons younger than 60 years to 10% of ≥80-year-old persons.[6] The mean spherical error increased with age from +0.03 D in persons younger than 60 years to +1.2 D in ≥80-year-old persons. Higher education was associated with myopia in men but not in women. In a population-based prevalence survey of 1043 adults 21 years or older in Sumatra, Indonesia, Saw et al found that myopia rates varied with age and increased with income.[26]

In the present study, myopia was associated with female gender. This agrees and disagrees with previous studies. In the Beaver Dam Eye Study, a small gender difference was seen in the rates of myopia, but in the Baltimore Eye Survey, no gender difference was found.[2,3] Similarly, the Singaporean Tanjong Pagar study did not find significant gender differences.[17] In the Shihpai Eye Study,[23] women had a higher prevalence of hyperopia than men, a finding similar to those in other reports.[6,7,17] In the Blue Mountains Eye Study, women were slightly more hyperopic (mean, +0.75 D) than men (mean, +0.59 D).[6] The marked variation in findings of whether or not refractive error is associated with gender has not been explained. It has remained unclear whether socioeconomic factors, genetic reasons, or other parameters such as the composition of the study populations may play a role.

## High Myopia

The frequency of high myopia (myopic refractive error > −8 D) was 1.5% in the present study. A myopic refractive error of more than −6.0 D was found in 2.6% of the subjects. These figures are comparable to those reported previously for Singaporean Chinese 60 years and older.[14] In the latter study, prevalence of a myopic refractive error of less than −6 D was 2.3%, and prevalence of a myopic refractive error exceeding −5 D was 4.7%. In contrast to these figures, the Baltimore Eye Survey showed a prevalence of 0.87% in whites 60 years and older.[3] The prevalence of high myopia in the general population is of clinical importance, because high myopia is associated with vision-threatening diseases such as myopic macular degeneration and myopic chronic open-angle glaucoma. Correspondingly, a recent population-based study revealed that myopic macular degeneration contributed to about 25% of visual impairment in adult Chinese.[27] In the Tanjong Pagar study, almost 7% of the population had high myopia (>−5.0 D).[17] Adjusted to the 40- to 79-year-old Chinese population in Singapore, the prevalence of high myopia was nearly 10% in the Tanjong Pagar study. This figure is higher than data in reports from European-derived populations. In the Visual Impairment Project in Australia, high myopia of similar definition was found in <2% of subjects with myopia.[28] The prevalence of high myopia in the Baltimore Eye Survey, in which a slightly different definition was used for high myopia (>−6.0 D), was approximately 1.4%.[3] In the population-based survey in Sumatra,[26] the age-adjusted overall prevalence rate of high myopia (≥−6.0 D) was 0.8%. As already discussed for the prevalence of moderate myopia, the reasons for the variations in the prevalence rates of high myopia between the populations remain unclear. In view of the marked clinical importance of high myopia, however, studies on the factors influencing the development of high myopia are indeed warranted.

### Astigmatism

Mean astigmatic error measured 0.62±0.90 D (median, 0.25; range, 0–7.50). It increased significantly with age. Because the present study has a cross-sectional design, it may not allow direct conclusions as to lifetime changes of astigmatism. The data suggest, however, that astigmatism can undergo changes when subjects grow older. This may have implications for refractive surgery, which assumes a stable refractive error during life in an attempt to achieve a lifelong correction of ametropia. If, however, astigmatism and spherical refractive error change over time, refractive surgery may achieve emmetropia only for a limited time.

There are limitations of the present study. It has to be taken into account that the present investigation is a cross-sectional study from which one draws conclusions for a longitudinal course. Considering, however, that living and society conditions are changing continuously, only longitudinal epidemiological studies with repeated examinations of the same population groups may allow more definite answers to questions of the development of a society. Another limitation of the present study may be that, for subjects with a VA of 1.0 or better, refractometry was not performed. A low degree of astigmatism as well as latent hyperopia therefore may have been overlooked in these subjects. One may take into account, however, that the mean age of the subjects was 56 years, so that the amount of latent hyperopia may not have been very high. It might have led, however, to a falsely low frequency of hyperopia in the younger group of the subjects included in the study. Therefore, one cannot exclude the possibility that the association between myopia and younger age might have been due partially to a falsely low rate of hyperopia in the younger group of subjects who still had some degree of accommodation.

In conclusion, the Beijing Eye Study showed prevalence rates for minor, moderate, and high myopia that were similar to those reported in the Taiwanese Shihpai Eye and other population-based studies in North America and South India. The rates were higher than those in epidemiological studies in Australia, and they were lower than those in Singaporean population-based investigations.[17,25] As in previous studies, the urban population was significantly more myopic than the rural population. Myopic refractive error was significantly associated with younger age, higher educational background, and higher degree of nuclear cataract. Future investigations may show whether the findings in the cross-sectional studies can be confirmed in longitudinal investigations. It may have implications for clinical issues, including refractive surgery. Future studies additionally may reveal whether the difference in the frequency of myopia is due to selection parameters, environmental conditions, or genetic factors.

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