WORLD VIEW

Visual acuity in northern China in an urban and rural population: the Beijing Eye Study

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Aim: To evaluate prevalence and demographic associations of visual impairment in an urban and rural population in northern China.

Methods: In the Beijing Eye Study, a population based cohort study in northern China, visual acuity was assessed for 8876 eyes (4438 subjects) according to a response rate of 83.4%. The study was divided into a rural part (1972 subjects) and an urban part (n = 2466). Mean age was 56.20 (SD 10.59) years (median 56 years; range 40–101 years).

Results: Mean uncorrected visual acuity measured 0.72 (0.32) (median, 0.80), and mean best corrected visual acuity measured 0.91 (0.21) (median, 1.0). In a multiple regression analysis, best corrected visual acuity was significantly correlated with age ($p<0.001$), degree of nuclear cataract ($p<0.001$), amount of cortical cataract ($p=0.014$), amount of subcapsular cataract ($p<0.001$), educational background ($p<0.001$), and refractive error ($p<0.001$). Rural region versus urban region ($p=0.34$) and sex ($p=0.053$) were not statistically significantly associated with best corrected visual acuity.

Conclusions: In northern China, determinants of a low degree of best corrected visual acuity are age, cataract, low educational background, and myopia. Despite marked differences in educational background and family income, sex, and rural area versus urban area are not markedly associated with best corrected visual acuity.

Visual performance is of utmost importance for quality of life. It is described by several parameters such as visual field, colour vision, temporal resolution, and central visual acuity. It was the purpose of the present study to assess central visual acuity as one of the principal factors of visual performance in a population in northern China and to search for its ocular and demographic associations.

SUBJECTS AND METHODS

The Beijing Eye Study is a population based prospective cohort study in northern China. It included, in total, 4439 subjects (8878 eyes; 2505 women) out of 5324 subjects asked to participate, corresponding to an overall response rate of 83.4%. The medical ethics committee of the Beijing Tongren Hospital had approved the study protocol and all participants had given informed consent, according to the Declaration of Helsinki. From the 8878 eyes, data on visual acuity were available for 8876 eyes (4438 subjects), which the present study comprised. The study was divided into a rural part (1972 (44.4%) subjects; 1142 women; 3944 eyes) and an urban part (2466 (55.6%) subjects; 1362 women; 4932 eyes) (table 1). Mean age was 56.20 (10.59 years (median, 56 years; range, 40–101 years).

The survey was carried out in seven communities; four were selected from the Haidian urban district of the northern part of central Beijing, and three were selected from a rural district—that is, the county of Daxing District in the village area of Yufa situated south of Beijing. All people residing in the communities were officially registered, and home visits were performed according to the register. The eligible subjects were visited up to three times if they did not participate after the first visit in the Beijing Eye Study. At the time of the survey in the 2001, there were 5324 individuals aged 40 years or older residing in those seven communities. All target populations were given offers to accept the eye examination. In total, 4439 individuals participated in the eye examination.

All examinations were carried out in the communities, either in schoolhouses or in community houses. After obtaining the informed consent, visual acuity was measured as uncorrected visual acuity (Snellen charts) at a distance of 5 metres, and as near vision in a distance 25–30 cm using Jaeger charts, uncorrected and then corrected using an addition for near vision. Automatic refractometry (Auto Refractometer AR-610, Nidek Ltd, Tokyo, Japan) was performed, if uncorrected visual acuity was lower than 1.00. Using the results of automatic refractometry, best corrected distant visual acuity was determined for a distance of 5 metres, and as near vision at a distance 25–30 cm using Jaeger charts, uncorrected and then corrected using an addition for near vision. After dilating the pupils, digital slit lamp photographs of the lens were taken. Additionally, retroilluminated photographs of the lens were taken. The degree of nuclear cataract was graded into six grades according to the lens photographs using the classifying scheme for cataract of the Age Related Eye Disease Study.[1] We combined standard photograph 6 and 7 into one grade—that is, "grade "6." Grade "1" was no nuclear opacity in the lens, and grade "6" was very dense nuclear lens opacity. The degree of cortical lens opacification and posterior subcapsular lens opacification was graded using photographs taken by retroillumination with the Neitz CT-R camera (Neitz Instruments Co, Tokyo, Japan). The percentage area of opacity was measured using a grid. Additional information was obtained on the gross net family income.

Statistical analysis was performed by using a commercially available statistical software package (SPSS for Windows, version 11.5, SPSS, Chicago, IL, USA). Only one randomly selected eye per subject was taken for statistical analysis unless intra-individual inter-eye differences were evaluated.

Abbreviations: BCVA, best corrected visual acuity; FC, finger counting; HM, hand movements; LP, light perception

Table 1 Composition of the study population (mean (SD))

	Total study	Rural population	Urban population	p Value
Number (subjects)	4438	1972	2466	
Number (eyes)	8876	3944	4932	
Females/males	2504/1934	1142/830	1362/1104	0.077 (NS)
Age (years)	56.20 (10.59)	53.59 (10.49)	58.29 (10.20)	<0.001 (95% CI: −5.31 to −4.08)
Median	56	51	60	
Range	40–101	40–95	40–101	
Refractive error (D)	−0.31 (2.24)	−0.03 (1.94)	−0.52 (2.44)	<0.001 (95% CI: 0.36 to 0.62)
Median	0	0	0	
Range	−20.88 to +13.88	−20.88 to +12.63	−20.50 to +13.50	
Level of education*				
Illiteracy		15.6%	2.0%	
Half illiteracy		5.8%	0.6%	
Primary school		27.4%	5.%	
Middle school		50.9%	32.4%	
College		0.3%	59.6%	

p Value, statistical significance of the difference between the two study populations. *''Illiteracy'' was defined as the inability to read any Chinese word. ''Half illiteracy'' was present if the person could a few Chinese words, but could not get any useful information from the reading. The next degrees were ''Primary school,'' ''Middle school,'' and ''College education,'' if a primary school, a middle school or a college, had been attended.

Table 2 The response rate of age and sex specific in rural and urban populations in the Beijing Eye Study

		Registered		Examined		Response rate (%)	
	Age (years)	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	71.1	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	82.2	91.23
Total		2836		2466		86.95	

χ^2 Tests were used to compare proportions. Multiple regression models were used to examine the relation between visual acuity measurements and selected sociodemographic characteristics. Logistic regression was applied for the comparison of binary parameters versus categorical parameters and for the comparison of binary parameters versus continuous normally distributed parameters. Linear regression was applied for the comparison of normally distributed parameters. The statistical strength of correlations were reported as correlation coefficient r or r^2. Confidence intervals (95%) were presented. All p values were two sided and were considered statistically significant when the values were less than 0.05.

RESULTS

The response rate of the rural population and urban population, was 79% and 87%, respectively (table 2). The mean monthly salary of the rural residents was 363 Renminbi (RMB) yuan (£24, €36) (SD 349, median, 300 RMB yuan), and of the urban residents, it was 1773 RMB yuan (£118, €176) (SD 5786, median, 1700 RBM yuan). The rural population and the urban population group varied significantly in the level of education with a significantly higher frequency of illiteracy and primary school education in the rural population, and complementarily, a significantly higher frequency of literacy and college education in the urban population (table 1).

Table 3 Number of subjects (n = 4438) stratified into groups of uncorrected visual acuity in the better eye in the Beijing Eye Study

Visual acuity	Frequency	Cumulative percentage
0.00	1	0.0
LP	1	0.0
HM	2	0.1
FC	8	0.3
0.01	7	0.4
0.02	2	0.5
0.03	1	0.5
0.04	6	0.6
0.05	16	1.0
0.06	13	1.3
0.07	2	1.3
0.08	6	1.5
0.10	84	3.4
0.12	38	4.2
0.15	126	7.1
0.20	38	7.9
0.25	67	9.4
0.30	116	12.0
0.40	178	16.0
0.50	309	23.0
0.60	468	33.6
0.80	556	46.1
1.00	2393	100.0

LP, light perception; HM, hand movements; FC, finger counting.

Table 4 Number of subjects (n = 4438) stratified into groups of best corrected visual acuity in the better eye in the Beijing Eye Study

Visual acuity	Frequency	Cumulative percentage
0.00	1	0.0
LP	1	0.0
HM	2	0.1
FC	8	0.3
0.01	4	0.4
0.02	1	0.4
0.06	1	0.4
0.10	8	0.6
0.12	2	0.6
0.15	14	0.9
0.20	10	1.2
0.25	8	1.4
0.30	24	1.9
0.40	28	2.5
0.50	81	4.3
0.60	164	8.0
0.80	339	15.7
0.90	2	15.7
1.00	3718	99.5
1.20	22	100.0

LP, Light perception; HM, hand movements; FC, finger counting.

Uncorrected visual acuity

Taking the whole study population and including a randomly selected eye per subject into the statistical analysis, mean uncorrected visual acuity measured 0.72 (0.32) (median, 0.80; range, no light perception to 1.0). If eyes with a visual acuity of finger counting or less were excluded, mean uncorrected visual acuity was unchanged at 0.72 (0.32) (median, 0.80). If the eyes with better (uncorrected) visual acuity was included in the statistical analysis, mean uncorrected visual acuity was 0.77 (0.29) (median, 1.00; range, no light perception to 1.0) (table 3). Expressed as the negative value of the logarithm of the minimal angle of resolution (logMAR), mean uncorrected visual acuity in the better eye was 0.17 (0.30) logMAR units.

Corrected visual acuity

Taking the whole study population and including one randomly selected eye per subject into the statistical analysis, mean best corrected visual acuity measured 0.91 (0.21) (median, 1.0; range, no light perception to 1.2). If eyes with a visual acuity of finger counting or less were excluded, mean best corrected visual acuity was 0.91 (0.20) (median, 1.0). If the eyes with better (uncorrected) visual acuity was included in the statistical analysis, mean uncorrected visual acuity was 0.94 (0.16) (median, 1.00; range, no light perception to 1.0) (table 4). Expressed as the negative value of the logMAR, mean uncorrected visual acuity in the better eye was 0.04 (0.18) logMAR units.

Rural versus urban population

Uncorrected visual acuity was significantly ($p<0.001$) higher in the rural population group compared with the urban group (0.77 (0.31) versus 0.68 (0.32). In a similar manner, corrected visual acuity was significantly ($p<0.001$) higher in the urban population group than in the rural group (0.91 (0.20) versus 0.89 (0.23). Since the urban population group was significantly ($p<0.001$) older than the rural population group (table 1), both populations were stratified for age groups. For the age groups of 55–59 years ($p = 0.001$), 60–64 years ($p<0.001$), 65–69 years ($p<0.001$), 70–74 years ($p = 0.002$), and 75+ years ($p = 0.002$), best corrected visual acuity was significantly higher in the urban population group (table 5).

Correlation best corrected visual acuity with refractive error

Best corrected visual acuity was significantly correlated with hyperopic refractive error ($p<0.001$; $r = 0.208$). Differentiating the whole study population into the rural group and the urban group showed a similar result (rural group: $r = 0.204$; $p<0.001$; urban group: $r = 0.215$; $p<0.001$). Correspondingly, best corrected visual acuity was significantly ($p<0.001$) lower in the highly myopic group with a myopic refractive error exceeding −8 dioptres than in non-highly myopic eyes (0.41 (0.30) versus 0.93 (0.17)). Best corrected visual acuity decreased significantly with anisometropia ($r = -0.32$; $p<0.001$) and astigmatism ($r = -0.51$; $p<0.001$).

Correlation best corrected visual acuity with age

Best corrected visual acuity was significantly correlated with age ($r = -0.39$; $p<0.001$). Differentiating the whole study population into the rural group and the urban group showed a similar result (rural group: $r = -0.47$; $p<0.001$; urban group: $r = -0.36$; $p<0.001$). Since the urban population group was significantly ($p<0.001$) more myopic than the rural population group (table 1), both populations were stratified for age groups. For all myopic subgroups and for hyperopic subgroups, except of the extreme groups, best corrected visual acuity was significantly higher in the urban group than in the rural group (table 6).

Correlation of best corrected visual acuity with the degree of education

In the whole study population ($r = 0.31$; $p<0.001$), as well as differentiated into the rural group ($r = 0.37$; $p<0.001$) and the urban group ($r = 0.30$; $p<0.001$), best corrected visual acuity was significantly associated with the degree of educational background. Since the urban population group had a significantly higher level of education (table 1), both populations were stratified for subgroups according to the level of education (table 7). For the subgroups with some reading knowledge, those with primary school and those with middle school education, best corrected visual acuity

Table 5 Best corrected visual acuity in age stratified subgroups in the rural population group and the urban population group

Age group (years)	Rural group			Urban group			
	No	Mean (SD)	Median	No	Mean (SD)	Median	p Value (95% CI)
40–44	454	0.97 (0.12)	1.0	282	0.98 (0.10)	1.0	0.31 (NS) (−0.025 to 0.008)
45–49	394	0.97 (0.15)	1.0	319	0.97 (0.14)	1.0	0.56 (NS) (−0.027 to 0.015)
50–54	343	0.95 (0.16)	1.0	257	0.97 (0.14)	1.0	0.17 (NS) (−0.041 to 0.007)
55–59	220	0.89 (0.24)	0	365	0.95 (0.14)	1.0	0.001 (−0.096 to −0.027)
60–64	188	0.86 (0.25)	1.0	542	0.93 (0.18)	1.0	<0.001 (−0.117 to −0.039)
65–69	191	0.78 (0.28)	0.80	369	0.87 (0.23)	1.0	<0.001 (−0.142 to −0.050)
70–74	105	0.68 (0.27)	0.80	215	0.78 (0.24)	0.80	0.002 (−0.159 to −0.036)
75+	77	0.50 (0.31)	0.50	106	0.65 (0.31)	0.80	0.002 (−0.235 to −0.055)

p Value, statistical significance of difference between the rural group and the urban group.

Table 6 Best corrected visual acuity in age stratified subgroups in the rural population group and the urban population group

Refractive error group (D)	Rural group				Urban group				p Value (95% CI)
	No	Mean (SD)	Median	logMAR	No	Mean (SD)	logMAR	Median	
<−8.00	24	0.39 (0.25)	0.40	−0.51 (0.48)	40	0.44 (0.33)	−0.57 (0.53)	0.40	0.50 (NS) (−0.199 to 0.097)
−8.00 to −4.00	14	0.56 (0.31)	0.50	−0.49 (0.65)	145	0.88 (0.26)	−0.10 (0.29)	1.0	0.003 (−0.482 to −0.122)
−2.00 to −4.00	46	0.69 (0.26)	0.60	−0.20 (0.20)	202	0.90 (0.20)	−0.06 (0.16)	1.0	<0.001 (−0.292 to −0.126)
−2.00 to <0	253	0.87 (0.21)	1.00	−0.08 (0.17)	418	0.91 (0.19)	−0.06 (0.14)	1.0	0.013 (−0.072 to −0.008)
0	1080	1.00 (0.04)	1.00	0.00 (0.03)	948	0.99 (0.06)	0.00 (0.09)	1.0	0.37 (NS) (−0.002 to 0.007)
>0 and <2	368	0.87 (0.21)	1.00	−0.09 (0.2)0	520	0.90 (0.18)	−0.07 (0.18)	1.0	0.014 (−0.060 to −0.009)
2 to 5	74	0.77 (0.25)	0.80	−0.19 (0.41)	122	0.84 (0.21)	−0.10 (0.15)	0.80	0.041 (−0.143 to −0.003)
>5	10	0.36 (0.21)	0.40	−0.48 (0.25)	11	0.50 (0.35)	−0.48 (0.76)	0.80	0.26 (n.s.) (−0.409 to 0.120)

p Value, statistical significance of difference between the rural group and the urban group. NS, statistically not significant.

was significantly better in the rural region than in the urban region (table 7). For the college group, best corrected visual acuity was better in the urban region.

Correlation of best corrected visual acuity with degree of nuclear cataract

Taking the whole study population and performing a univariate analysis, best corrected visual acuity was significantly ($r = -0.36$; $p<0.001$) associated with the degree of nuclear cataract. Differentiating the whole study population, the correlation between degree of nuclear cataract and best corrected visual acuity was significant for the rural population group ($r = -0.42$; $p<0.001$) and the urban group ($r = -0.33$; $p<0.001$).

Correlation of best corrected visual acuity with intraocular pressure

Taking the whole study population, best corrected visual acuity was statistically independent ($r = -0.03$; $p = 0.08$) of intraocular pressure. Differentiating the study population into the rural group and the urban group showed similar results (rural group: $r = -0.04$; $p = 0.08$; urban group: $r = -0.02$; $p = 0.48$).

Correlation of best corrected visual acuity with sex, and right eyes versus left eye

In univariate analysis, best corrected visual acuity was significantly higher in males than in females (0.92 (0.20) versus 0.89 (0.22); $p<0.001$). Best corrected visual acuity did not vary significantly between the right eye and left eye ($p = 0.68$).

Multiple regression anaylsis

Since in univariate analysis, best corrected visual acuity was significantly associated with age, myopic refractive error, rural group versus urban group, educational background, degree of nuclear cataract and sex, and because some of these parameters such as degree of nuclear cataract and age were significantly ($p<0.001$) correlated with each other, a multiple regression analysis was performed. Including the parameters age, degree of nuclear cataract, rural versus urban population, refractive error, educational background and sex showed that the association with best corrected visual acuity (logarithmic value of the minimal angle of resolution, logMAR) was significant for age ($p<0.001$), degree of nuclear cataract ($p<0.001$), amount of cortical cataract ($p = 0.014$), amount of subcapsular cataract ($p<0.001$), educational background ($p<0.001$), and refractive error ($p<0.001$). Rural region versus urban region ($p = 0.34$) and sex ($p = 0.053$) were no longer statistically significantly associated with best corrected visual acuity.

DISCUSSION

Blindness and visual impairment are important public health problems which have an impact on an individual's life as well as on the society.[2] Since previous studies have shown that the prevalence of visual impairment and its associations depend on various factors such as age, general health, and ethnic background, it was the purpose of the present study to assess the visual acuity and its ocular and demographic associations in northern China, in a population group for which data so far have not been reported. The present study revealed that best corrected visual acuity was significantly correlated with age, the degree of nuclear cataract, the educational background, and refractive error. Rural region versus urban region and sex were not statistically significantly associated with best corrected visual acuity after taking into account the interdependency of the parameters between each other.

These results are in agreement with previous population based studies on groups of different ethnic backgrounds. The Los Angeles Latino Eye Study LALES[3] found that visual acuity decreased significantly with age and was lower in individuals with less than 12 years of education. Interestingly, visual acuity was lower in women than in men in the LALES study.

Table 7 Best corrected visual acuity (mean (SD); logarithmic value of the minimal angle of resolution (logMAR)) in the education subgroups in the rural population group and urban population group

Education	Rural group				Urban group				p Value (95% CI)
	No	BCVA	Median	logMAR	No	BCVA	Median	logMAR	
No data	29	0.54 (0.31)	0.60	−0.40 (0.53)	10	0.89 (0.17)	1.00	−0.33 (0.94)	<0.001 (−0.511 to −0.191)
Illiteracy	304	0.70 (0.33)	0.80	−0.26 (0.50)	49	0.62 (0.34)	0.60	−0.38 (0.57)	0.13 (NS) (−0.023 to 0.1849
Some reading	112	0.83 (0.25)	1.00	−0.14 (0.34)	14	0.59 (0.28)	0.60	−0.38 (0.35)	0.006 (0.081 to 0.417)
Primary school	533	0.89 (0.23)	1.00	−0.09 (0.29)	133	0.83 (0.26)	1.00	−0.15 (0.33)	0.010 (0.015 to 0.111)
Middle school	989	0.96 (0.14)	1.00	−0.04 (0.24)	796	0.89 (0.21)	1.00	−0.07 (0.25)	<0.001 (0.051 to 0.085)
College	5	0.84 (0.36)	1.00	−0.14 (0.31)	1464	0.94 (0.17)	1.00	−0.04 (0.17)	0.55 (NS) (−0.547 to 0.341)

BCVA, best corrected visual acuity.
For 29 subjects in the rural group and for 10 subjects in the urban group, data on the educational background were not available. For 29 (1.5%) subjects from the rural region and 10 (0.4%) subjects from the urban region, data on the level of education were not available.

In another population based study on Hispanics, the proyecto VER study[4] on Mexican Americans in Arizona, best corrected acuity in the better seeing eye decreased significantly with age and female sex, as in the LALES study, and again in contrast with the present study on Chinese people. In the Shihpai Eye Study performed in Taiwan,[5] a significant increase in the rate of low vision from 0.83% at 65–69 years of age to 8.33% at age 80 years or older was reported. Additionally, visual acuity was associated with higher education.[6] As in the present study, and in contrast with the LALES study and the proyecto VER study on Hispanics, there was no sex difference in the prevalence of blindness or low vision. In contrast with the study on Chinese people in Taiwan and the present study on Chinese people in the Greater Beijing Area, the Tibetan Eye Study[7] found that visual acuity was lower in women.

In the Australian Blue Mountains Eye Study,[8–10] increasing age and female sex were independent predictors of visual impairment. A similar result was obtained in another Australian population based study, the Melbourne Visual Impairment Project.[11 12] In the latter investigation, age was the most significant factor associated with visual impairment. Additionally, women were more affected.[13] In a meta-analysis of two Australian population based studies, female sex and age were risk factors for decrease in visual acuity.[14] In a population based study in the United States, the Salisbury Eye Evaluation Project,[15 16] black participants had more visual impairment than did white participants. Additionally, as in the studies on Hispanics and in contrast with the studies on Chinese people (including the present investigation), age and female sex were associated with decreasing visual acuity.[17]

There are several population based studies which undoubtedly have demonstrated an age related loss in visual acuity with increasing age such as the Priverno Eye Study in Italy,[18] the Italian Casteldaccia Eye Study,[19] the Copenhagen City Eye Study,[20] the Australian Longitudinal Study of Ageing,[21] the Beaver Dam Eye Study,[22] the Baltimore Eye Survey,[23] the Barbados Incidence Study of Eye Diseases,[24] and the Aravind Comprehensive Eye Survey in south India.[25] In the Indian Andra Pradesh Eye Disease Study,[26] only a slight increase in the prevalence of unilateral blindness with age was noted for the urban population.

In summary, the preceding studies agree with the present investigation, and the general clinical experience, that visual acuity decreases with age. In agreement with population based studies on Chinese people in Taiwan, and in contrast with several population based studies on Hispanics in the United States, visual acuity was statistically independent of sex. It remains unclear whether this difference between two ethnic groups may depend on differences between females and males in the access to medical care, or on other socioeconomic or biological factors. In addition to most studies published and cited above, the present study revealed an association between visual acuity and higher educational background and less myopic refractive error in the northern Chinese population.

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