Prevalence and Causes of Low Vision and Blindness in a Rural Chinese Adult Population

The Handan Eye Study

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Purpose: To describe the prevalence and causes of low vision and blindness in a rural population in Northern China.

Design: Population-based, cross-sectional study.

Participants: A study of 6830 Han Chinese aged 30 years and older was conducted between October 2006 and October 2007 in rural Yongnian County in Handan, Northern China.

Methods: Clustered samples of adults aged 30 years or more residing in 13 residential villages were selected randomly and were invited to participate the Handan Eye Study. Participants underwent a comprehensive eye examination, including standardized visual acuity (VA) tests using logarithm of the minimum angle resolution charts. Prevalence was age- and gender-standardized to the 2000 China Census.

Main Outcome Measures: Low vision was defined as VA <20/60 but ≥20/400, and blindness was defined as VA <20/400 following the Modified World Health Organization (WHO) definitions. Primary causes of low vision and blindness were determined by study ophthalmologists according to WHO definitions.

Results: Six thousand eight hundred thirty (90.4%) of 7577 eligible individuals participated in the study, and 6799 (89.7%) had VA data available. Population-weighted prevalence of presenting bilateral blindness was 0.6% and bilateral low vision was 4.7% for persons 30 years of age and older. Based on best-corrected visual acuity (BCVA), the corresponding prevalence of blindness was 0.5% and that of low vision was 1.0%. Blindness and low vision were strongly age related ($P<0.05$). Cataract was the predominant cause of presenting bilateral blindness (36.6%), whereas undercorrected refractive error was the predominant cause of presenting low vision (78.4%). After refractive correction, cataract became the first leading cause of blindness (41.9%), and low vision (48.2%), myopic retinopathy (16.1%), glaucoma (9.7%), and corneal opacity (9.7%) were other common causes of blindness defined using BCVA.

Conclusions: A higher prevalence of blindness and low vision was seen in this rural Chinese sample than has been reported from urban Chinese populations. The estimated numbers with BCVA-defined low vision and blindness in 2020, based on best-corrected vision in rural Chinese adults aged 30 years or more, is expected to be 12.4 million and 2.9 million, respectively. Predominant causes of low vision and blindness in China are treatable.

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Visual impairment remains a major public health problem worldwide, with an estimated 161 million people with visual impairment, of whom 37 million are blind.[1] Estimates of low vision and blindness from mainland China have been based on a small number or studies, mostly in major urban and suburban cities.[2–7] The Beijing Eye Study[3,4] examined the causes of visual impairment and blindness in 4439 Chinese persons aged 40 years and older in Beijing and a nearby county. Based on the World Health Organization definitions using best-corrected visual acuity (BCVA), 1.1% of participants of this study were found to have low vision and 0.3% were found to have blindness. The most common cause of low vision was cataract, followed by high myopia and then glaucoma. Importantly, compared with Western populations, age-related macular degeneration (AMD) and diabetic retinopathy were uncommon in this urban Chinese population. In a separate study by Zhao et al,[2] who examined the causes of visual impairment and blindness in persons aged 40 years and older residing in Shunyi County, Beijing, the prevalence of presenting visual acuity (VA)-defined bilateral blindness was 1.9% and that of low vision was 18.2%. Li et al[6] reported from Doumen County (a special economic zone in southern China) a prevalence of presenting VA bilateral blindness of 2.7% and that of low vision of 19.9%. All these estimates were based on either urban or economically well-developed regions of China and therefore could have underestimated the magnitude of visual impairment among rural Chinese living in economically underdeveloped regions, who represent 60% (800 million)[8] of the total Chinese population.

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There have been no published data on the prevalence and causes of visual impairment in rural Chinese living far from major cities. To address this gap in knowledge and to understand factors associated with vision loss and major eye diseases affecting rural Chinese people, the authors conducted a population-based survey in a sample of rural Chinese persons aged 30 years and older living in Handan County, Hebei Province. In this first report of the Handan Eye Study, we describe the prevalence and causes of low vision and blindness in this population.

Patients and Methods

Study Design and Procedure

The study adhered to the Declaration of Helsinki, ethics approval was obtained from the Beijing Tongren Hospital Ethical Committee, and written informed consent was obtained from all participants. Residents of Yongnian County, Handan, Hebei Province, aged 30 years and older were selected randomly using a stratified, clustered, sampling technique with probabilities proportionate to the size of the population in each cluster. In Yongnian County, 90% of the population are farmers, and 98% are Han. Per capita annual net income in this rural area is 3468 Yuan, approximately $470 US, which is similar to the average annual income (3255 Yuan) per capita of those living in rural areas throughout Mainland China.[9]

The total population of Yongnian County (with an area of 980 km^2) was 830 000 in 2005, with 16.0% of the population aged 30 to 39 years, 12.6% aged 40 to 49 years, 8.2% aged 50 to 59 years, 4.9% aged 60 to 69 years, 2.8% aged 70 to 79 years, and 0.66% aged 80 years and older.

Sampling Plan

Of the 458 villages in Yongnian County, stratified by geographic land form (plains or hillside), 13 were selected randomly to achieve a target sample size of 5105. The sampling frame for selection was a list of numbers 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.[2,6,10,11] All residents aged 50 years and older were invited to participate in the selected 13 villages. In addition, to study individuals aged 30 to 49 years, we randomly selected 6 of the 13 villages in which all residents aged 30 to 49 years also were invited to participate.

A total of 8653 names of individuals were selected, 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 had moved out of the village, had not lived there in the past 6 months, was deceased, or was terminally ill and had an estimated life expectancy was estimated of fewer than 3 months. Of the 8653 individuals, 7557 were considered to be eligible. Participants were asked to visit Yongnian County Hospital for a detailed examination. Those who declined to visit the hospital were offered a simplified evaluation at a temporary study field established in the village, and those who further declined to visit the temporary study field were offered a limited examination conducted at home. The survey was conducted from October 2006 through October 2007.

Visual Acuity Testing

At the hospital clinic, participants underwent an extensive and standardized eye examination, including a detailed questionnaire, VA testing, slit-lamp and fundus examination both before and after pupil dilation, and digital ocular imaging (optic nerve head imaging using the Heidelberg Retinal Tomograph II [Heidelberg Engineering, Heidelberg, Germany]; retinal photography using a Canon CR-DGi nonmydriatic retinal camera [Canon, Tokyo, Japan]; and retinal thickness measured using optical coherence tomography [Carl Zeiss, Jena, Germany]). The study protocol was modified from the Singapore Malay Eye Study.[12]

For each eye, presenting VA (wearing present correction if any) was measured binocularly and then monocularly following the Early Treatment Diabetic Retinopathy study protocol, recorded using the logarithm of the minimum angle of resolution chart at a distance of 4 m. For those who could not see any letters on the chart at 4 m, vision was tested at 1 m, allowing acuities as low as 1/40 (0.025) to be measured. If no letters could be read correctly at a 1-m distance, VA was assessed and recorded as counting fingers, hand movements, or light perception.

Subjective refraction was performed by a trained optometrist for all subjects with vision worse than $<$20/20 in either eye, using a trial frame placed and adjusted on the participant's face. Auto Refractor-Keratometer (KR8800 Topcon, Tokyo, Japan) readings were used as the starting point for subjective refraction. The visual acuity obtained was defined as the BCVA.

Primary causes of low vision or blindness were assessed by 2 senior ophthalmologists, based on the clinical history and examination results before and after pupil dilation. Main causes were determined by the examining ophthalmologist's clinical judgment on the proportion of visual loss resulting from each cause, diagnosed according to definitions specified in the study protocol. Cataract was regarded as the main cause of visual impairment if the fundus was obscured by lens opacity or if there were no evidence of fundus abnormalities in eyes with significant cataract. Undercorrected refractive error was defined as visual impairment of $<$20/60 in the better eye before refraction that improved after refraction to no impairment ($\geq$20/60). Myopic maculopathy was considered only in subjects with a refractive error exceeding -6.0 diopters in either eye, with one or more of the following ophthalmologic findings: tessellated fundus with yellowish white diffuse or grayish white patchy chorioretinal atrophy, macular hemorrhage, or posterior staphyloma.[13] Age-related macular degeneration was defined according to the Wisconsin Age-Related Maculopathy Grading System.[14] Early AMD was defined by the presence of either soft indistinct drusen or the presence of any type of drusen associated with retinal pigment epithelium depigmentation or increased retinal pigment. Late AMD was defined by the appearance of either exudative macular degeneration or pure geographic atrophy. Glaucoma was defined according to the International Society for Geographical and Epidemiological Ophthalmology classification.[15] The diagnosis of diabetic retinopathy, corneal opacity, and other diseases as causes of low vision and blindness followed standard clinical diagnostic criteria. When the primary cause of vision loss was in doubt, a second ophthalmologist examined the subject, and the determination of the primary cause was made by consensus of the 2 ophthalmologists. Amblyopia was assumed if best-corrected visual acuity was 20/30 or worse and there was no underlying structural abnormality of the eye or visual pathway that could explain the reduced vision.[16]

Definition of Low Vision and Blindness

Blindness and visual impairment were defined based on World Health Organization criteria. Blindness was present if VA was worse than 20/400 in the better eye and low vision was present if VA was 20/60 or worse but 20/400 or better.[17] In addition to reporting visual impairment in terms of the better eye (bilateral

Table 1. Demographic Characteristics for Participants and Nonparticipants in the Handan Eye Study

	Nonparticipants (n = 727), %	Participants (n = 6830), %	*P* Value*
Gender			
Male	53.2	46.3	<0.001
Age (yrs)			
Mean±SD	49.9±14.7	52.3±12.1	<0.001
30–39	32.2	18.1	<0.001
40–49	18.7	19.5	
50–59	25.0	36.5	
60–69	9.9	16.4	
70–79	11.6	8.7	
80+	2.6	1.1	
Land form			
Plains	89.4	90.0	0.63
Hills	10.6	10.0	
Married	88.0	90.4	0.04
Education†			
Illiteracy	15.9	11.6	0.00
Half-illiteracy (<1 yr)	4.7	4.4	
Primary school (1–5 yrs)	40.2	49.9	
Middle school (6–8 yrs)	36.4	31.2	
High school (9–11 yrs)	2.6	2.9	
College (12–15 yrs)	0.1	0.03	

SD = standard deviation.
*Chi-square test for categorical variables, Student *t* test for continuous variables.
†Illiteracy 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 obtain any useful information from the reading.

visual impairment), data on unilateral visual impairment based on the VA in the worse-seeing eye also are presented.

Statistical Analysis

Statistical analysis was performed using SPSS software version 14 (SPSS, Inc., Chicago, IL). Age- and gender-standardized prevalence of low vision or blindness and 95% confidence intervals (CIs) were estimated via direct standardization of the study sample to the overall Chinese population provided by 2000 China Census.

Results

Of the 7557 eligible subjects, 6830 took part in the study (90.4% response rate). One hundred forty-two (1.9%) declined to participate, 137 (1.8%) ide of Yongnian County. Of the 6830 participants, 5909 (86.5%) were examined in the hospital clinic, 807 (11.8%) in a temporary study site at the village, and 114 (1.7%) at home. Compared with nonparticipants, those who participated were more likely to be female, to be older, to have obtained more years of education, and to be married (Table 1).

Presenting VA was available for 6799 subjects (41 subjects were unable to complete VA testing), and the age-standardized prevalence was 0.6% (95% CI, 0.4%–0.8%) for bilateral blindness and 4.7% (95% CI, 4.2%–5.2%) for bilateral low vision. Blindness was uncommon in subjects younger than 50 years of age (0.12%), and this increased substantially with increasing age (prevalence, 3.9% for those 70 years of age and older; Table 2). The corresponding age- and gender-standardized prevalence of BCVA-defined bilateral blindness for subjects aged 30 years or more was 0.5% (95% CI, 0.3%–0.7%), and for those aged 50 years or more, it was 1.2% (95% CI, 0.9%–1.6%; Table 3). The age- and gender-standardized prevalence of BCVA-defined bilateral low vision for subjects aged 30 years or more was 1.0% (95% CI, 0.8%–1.2%), and this once again was higher among those 50 years of age and older (2.6%; 95% CI, 2.1%–3.1%; Table 3).

Cataract was the most common cause of presenting VA-defined bilateral blindness (36.6%) and unilateral blindness (31.0%; Table 4), whereas refractive error was the first leading cause of bilateral (78.4%) and unilateral (36.4%) presenting VA-defined low vision.

After refractive correction, cataract remained the leading cause of unilateral (41.9%) and bilateral (46.6%) BCVA-defined visual impairment (Table 5). Myopic maculopathy was the second leading cause of bilateral BCVA-defined blindness (16.1%). Glaucoma and corneal opacity were the third and fourth leading cause of BCVA-defined bilateral blindness, each accounting for 9.7%. Other less common eye diseases as causes of visual impairment were amblyopia (3.7%), diabetic retinopathy (3.7%), congenital ocular abnormality (2.8%), and AMD (1.8%; Table 5).

Cataract was the most common cause of unilateral BCVA-defined blindness (34%), whereas corneal opacity accounted for 12.3%. Glaucoma and amblyopia were the third and forth leading cause of unilateral blindness. For unilateral low vision, amblyopia accounted for 20.8% and was the second major cause after cataract (36.2%).

Discussion

We found that the population-weighted prevalence of bilateral visual impairment based on presenting VA was 2.7% in rural Chinese adults 30 years of age and older. If defined using BCVA, the population-weighted prevalence of bilateral blindness was 0.5% and that of bilateral low vision was 1.0%. In persons 40 years of age and older, the age-standardized prevalence of bilateral BCVA-defined blindness was 0.7% and that of low vision was 1.5%. These prevalence rates of blindness and low vision are substantially higher in this rural sample than previously reported prevalence rates from urban Chinese populations.

Based on our study findings, we estimate that there are currently 2.0 million adult Chinese persons 30 years of age and older with BCVA-defined blindness based on World Health Organization criteria and 3.8 million such Chinese persons with low vision in rural China. The numbers are substantially larger when considering habitual (presenting) vision, with 2.4 million functionally blind and 18.8 million functionally with low vision. These numbers will increase rapidly as the Chinese population ages. By the year 2020, the authors project, using their age-specific prevalence rates of blindness and low vision, that the numbers of Chinese adults with BCVA-defined blindness will increase by one third to 2.9 million, and the number with low vision will increase by 2-fold to 12.4 million in rural China.[18]

The Beijing Eye Study reported a similar prevalence of blindness in the rural sample, but a much lower prevalence of blindness in the urban sample (Fig 1).[3] Figure 2 shows that rates of visual impairment were much higher among rural elders in Handan than rural persons surrounding Beijing but were similar for the young in Beijing because rates of vision loss are low in a young population. Handan is located approximately 500 km south of Beijing, and resi-

Table 2. Prevalence of Presenting Low Vision and Blindness by Gender and Age in the Handan Eye Study

Group	Age (yrs)	No.	Visual Acuity in the Better-Seeing Eye				Visual Acuity in the Worse-Seeing Eye			
			<20/400		<20/60 and ≥20/400		<20/400		<20/60 and ≥20/400	
			No.	% (95% Confidence Interval)	No.	% (95% Confidence Interval)	No.	% (95% Confidence Interval)	No.	% (95% Confidence Interval)
Men	30–39	559	1	0.2 (0–0.5)	9	1.6 (0.6–2.7)	8	1.4 (0.4–2.4)	27	4.8 (3.1–6.6)
	40–49	606	0	0	9	1.5 (0.5–2.4)	9	1.5 (0.5–2.4)	21	3.5 (2.0–4.9)
	50–59	1150	0	0	27	2.3 (1.5–3.2)	34	3.0 (2.0–3.9)	67	5.8 (4.5–7.2)
	60–69	553	4	0.7 (0–1.4)	32	5.8 (3.8–7.7)	36	6.5 (4.5–8.6)	87	15.7 (12.7–18.8)
	70–79	252	2	0.8 (0–1.9)	57	22.6 (17.5–27.8)	26	10.3 (6.6–14.1)	85	33.7 (27.9–39.6)
	80+	35	2	5.7 (0–13.4)	9	25.7 (11.2–40.2)	7	20.0 (6.7–33.3)	17	48.6 (32.0–65.1)
	Total*	3155	9	0.3 (0.1–0.5)	143	3.8 (3.1–4.5)	120	3.1 (2.5–3.7)	304	8.3 (7.3–9.2)
Women	30–39	674	1	0.1 (0–0.4)	22	1.3 (0.5–2.2)	9	0.9 (0.2–1.6)	32	3.6 (2.2–5.0)
	40–49	719	1	0.1(0–0.4)	9	6.4 (4.6–8.2)	6	4.0 (2.6–5.5)	24	15.7 (13.1–18.4)
	50–59	1314	2	0.2 (0–0.4)	46	3.5 (2.5–4.5)	29	2.5 (1.7–3.4)	113	8.4 (6.9–9.9)
	60–69	557	5	0.9 (0.1–1.7)	46	14.4 (11.5–17.3)	33	9.5 (7.1–12.0)	110	23.0 (19.5–26.5)
	70–79	343	16	4.7 (2.4–6.9)	80	4.4 (2.2–6.5)	53	3.5 (1.6–5.4)	128	4.1 (2.0–6.2)
	80+	37	7	18.9 (6.3–31.5)	15	40.5 (24.7–56.4)	12	32.4 (17.3–47.5)	14	37.8 (22.2–53.5)
	Total*	3644	32	1.0 (0.7–1.3)	218	5.7 (4.9–6.4)	142	3.9 (3.3–4.5)	421	10.6 (9.6–11.6)
Women and men	30–39	1233	2	0.2 (0–0.4)	31	2.5 (1.6–3.4)	17	1.4 (0.7–2.0)	59	4.8 (3.6–6.0)
	40–49	1325	1	0.1 (0–0.2)	18	1.4 (0.7–2.0)	15	1.1 (0.6–1.7)	45	3.4 (2.4–4.4)
	50–59	2464	2	0.1 (0–0.2)	73	3.0 (2.3–3.6)	63	2.6 (1.9–3.2)	180	7.3 (6.3–8.3)
	60–69	1110	9	0.8 (0.3–1.3)	78	7.0 (5.5–8.5)	69	6.2 (4.8–7.6)	197	17.7 (15.5–20.0)
	70–79	595	18	3.0 (1.6–4.4)	137	23.0 (19.6–26.4)	79	13.3 (10.6–16.0)	213	35.8 (31.9–39.7)
	80+	72	9	12.5 (4.9–20.1)	24	33.3 (22.4–.2)	19	26.4 (16.2–36.6)	31	43.1 (31.6–54.5)
Total*	30+	6799	41	0.6 (0.4–0.8)	361	4.7 (4.2–5.2)	262	3.5 (3.1–3.9)	725	9.4 (8.7–10.1)
	40–79	5494	30	0.5 (0.3–0.7)	306	5.7 (5.1–6.4)	226	4.2 (3.6–4.7)	635	11.6 (10.7–12.4)
	40+	5566	39	0.9 (0.7–1.1)	330	6.6 (5.9–7.3)	245	4.9 (4.3–5.4)	666	12.5 (11.6–13.3)
	50+	4241	38	1.5 (1.1–1.8)	312	8.5 (7.7–9.3)	230	6.4 (5.6–7.1)	621	14.6 (13.5–15.7)

*Standardized by age and gender to the China National Census of 2000.

dents living in Handan share similar customs and social and cultural backgrounds with residents of Beijing. However, in the last 60 years, the economy of Beijing has developed much more rapidly than its surrounding rural areas. As a result of economic development, the accessibility and the relative affordability of eye care services is far superior in the metropolitan Beijing region than it is in rural areas. There are more than 60 tertiary general hospitals located in the Beijing city area, compared with only 3 in the entirety of Handan County. We found that the vast majority of causes of low vision and blindness in our study population are treatable, a finding suggesting underprovision or underuse of eye care services, or both, among rural Chinese, especially for those aged 60 years and older whose requirements of eye care services increased markedly.

A recent survey in Kunming, Yunnan Province,[19] which is an undeveloped area in southwest of China, reported a prevalence of 3.7% for bilateral presenting VA-defined blindness in those 50 years of age and older. The high altitude in Kunming (1892 vs. 100 m in Handan) may account in part for the higher prevalence of visual impairment than was seen in the current study. It is possible that living in higher altitude areas with increased exposure to ultraviolet light leads to a higher prevalence of cataract.[20] Cataract was highly prevalent in that study, and 63.2% of blindness was the result of cataract.

As reported previously,[2,6] cataract and refractive error remain the major causes of low vision in China. Even though both conditions are treatable, they were responsible for two thirds of bilateral presenting VA-defined blindness and low vision. This is not surprising given the limited availability of refractive services and the much lower cataract surgery rate, 400 operations per 1 million population annually, in rural China,[21] compared with approximately 800 to 1000 in urban China and 3000 in more developed Western countries. In our study sample, there were only 6 persons who had undergone cataract surgery in 2006, whereas 13 were blind and 41 had low vision because of cataract.

Refractive error accounted for another one third of low vision cases. Of the participants with presenting VA worse than 20/60 in the better-seeing eye, 71.4% could be improved to 20/60 or better with refractive correction. This high proportion of low vision resulting from undercorrected refractive error found in our study is similar to the findings from a survey of visual impairment in the United States.[22]

Myopic maculopathy was the second leading cause of BCVA-defined bilateral blindness and low vision, accounting for 11.0% of cases. Our findings are in keeping with previous findings from other Chinese populations: myopic maculopathy accounted for 12.5% of blindness and visual impairment in the Shihpai Eye Study in Taiwan,[13] for 32.7% of bilateral low vision and 7.7% of bilateral blindness in the Beijing Eye Study,[3] and for 9% of bilateral blindness in the Tanjong Pagar survey in Singapore.[23] There has been only one study in European-derived populations

Table 3. Prevalence of Visual Impairment According to Best-Corrected Visual Acuity by Gender and Age in the Handan Eye Study

			Visual Acuity in the Better-Seeing Eye				Visual Acuity in the Worse-Seeing Eye			
			<20/400		<20/60 and ≥20/400		<20/400		<20/60 and ≥20/400	
Group	Age (yrs)	No.	No.	% (95% Confidence Interval)	No.	% (95% Confidence Interval)	No.	% (95% Confidence Interval)	No.	% (95% Confidence Interval)
Men	30–39	559	1	0.2 (0–0.5)	0	0	7	1.3 (0.3–2.2)	6	1.1 (0.2–1.9)
	40–49	606	0	0	0	0	8	1.3 (0.4–2.2)	4	0.7 (0.0–1.3)
	50–59	1150	0	0	5	0.4 (0.1–0.8)	27	2.4 (1.5–3.2)	25	2.2 (1.3–3.0)
	60–69	553	3	0.5 (0–1.2)	9	1.6 (0.6–2.7)	30	5.4 (3.5–7.3)	38	6.9 (4.8–9.0)
	70–79	252	1	0.4 (0–1.2)	12	4.8 (2.1–7.4)	24	9.5 (5.9–13.1)	31	12.3 (8.2–16.4)
	80+	35	2	5.7 (0–13.4)	5	14.3 (2.7–25.9)	7	20.0 (6.7–33.3)	8	22.9 (8.9–36.8)
	Total*	3155	7	0.2 (0.1–0.4)	31	0.8 (0.5–1.1)	103	2.7 (2.1–3.3)	112	2.8 (2.2–3.4)
Women	30–39	674	1	0.2 (0–0.4)	0	0	6	0.9 (0.2–1.6)	4	0.6 (0.0–1.2)
	40–49	719	0	0	1	0.1 (0–0.4)	3	0.4 (0–0.9)	3	0.4 (0–0.9)
	50–59	1314	1	0.1 (0–0.2)	10	0.8 (0.3–1.2)	21	1.6 (0.9–2.3)	34	2.6 (1.7–3.4)
	60–69	557	3	0.5 (0–1.1)	5	0.9 (0.1–1.7)	23	4.1 (2.5–5.8)	3	5.6 (3.7–7.5)
	70–79	343	12	3.5 (1.6–5.4)	32	9.3 (6.3–12.4)	46	13.4 (9.8–17.0)	66	19.2 (15.1–23.4)
	80+	37	7	18.9 (6.3–31.5)	5	13.5 (2.5–24.5)	10	27.0 (12.7–41.3)	10	27.0 (12.7–41.3)
	Total*	3644	24	0.8 (0.5–1.1)	54	1.3 (0.9–1.6)	109	2.8 (2.2–3.3)	148	3.4 (2.8–4.0)
Women and men	30–39	1233	2	0.2 (0–0.4)	0	0	13	1.1 (0.5–1.6)	10	0.8 (0.3–1.3)
	40–49	1325	0	0	1	0.1 (0–0.2)	11	0.8 (0.3–1.3)	7	0.5 (0.1–0.9)
	50–59	2464	1	0.0 (0–0.1)	15	0.6 (0.3–0.9)	48	2.0 (1.4–2.5)	59	2.4 (1.8–3.0)
	60–69	1110	6	0.5 (0.1–1.0)	15	1.4 (0.7–2.0)	53	4.8 (3.5–6.0)	69	6.2 (4.8–7.6)
	70–79	595	13	2.2 (1.0–3.4)	39	7.4 (5.3–9.5)	70	11.8 (9.2–14.3)	97	16.3 (13.3–19.3)
	80+	72	9	12.5 (4.9–20.1)	10	13.9 (5.9–21.9)	17	23.6 (13.8–33.4)	18	25.0 (15.0–35.0)
Total*	30+	6799	31	0.5 (0.3–0.7)	85	1.0 (0.8–1.2)	212	2.7 (2.4–3.1)	260	3.1 (2.7–3.5)
	40–79	5494	20	0.3 (0.2–0.5)	75	1.2 (0.9–1.5)	182	3.1 (2.6–3.5)	232	3.8 (3.3–4.3)
	40+	5566	29	0.7 (0.5–1.0)	85	1.5 (1.2–1.8)	199	3.7 (3.2–4.2)	250	4.4 (3.9–5.0)
	50+	4241	29	1.2 (0.9–1.6)	84	2.6 (2.1–3.1)	188	5.7 (5.0–6.4)	243	7.1 (6.3–7.9)

*Standardized by age and gender to the China National Census of 2000.

(the Rotterdam Study) that reported a relatively high proportion (6%) of blindness and low vision cases attributable to myopic maculopathy.[24]

Glaucoma was the third leading cause of visual impairment found in our study sample (6.4%), consistent with findings from the Beijing Eye Study, which reported that 9.7% of bilateral blindness cases were the result of glaucoma, and also consistent with findings from the Shihpai Eye Study (8.3% of blindness and low vision cases).[13] Notably, glaucoma, not cataract, was also found to be the

Table 4. Cause of Presenting Visual Impairment in the Handan Eye Study

	Better-Seeing Eye						Worse-Seeing Eye					
	Blindness* (n = 41)		Low Vision† (n = 361)		Visual Impairment‡ (n = 402)		Blindness* (n = 262)		Low Vision† (n = 725)		Visual Impairment‡ (n = 987)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Cataract	15	36.6	39	10.8	54	13.4	80	31.0	208	28.7	288	29.2
Undercorrected refractive error	4	9.8	283	78.4	287	71.4	1	0.4	264	36.4	265	26.8
Amblyopia	0	0	4	1.1	4	1.0	29	11.0	112	15.4	141	14.3
Myopic maculopathy	8	19.5	5	1.4	13	3.2	24	9.2	8	1.1	32	3.2
Glaucoma	3	7.3	4	1.1	7	1.7	16	6.1	13	1.8	29	2.9
Diabetic retinopathy	1	2.4	3	0.8	4	1.0	3	1.1	7	1.0	10	1.0
Age-related macular degeneration	1	2.4	2	0.6	3	0.7	4	1.5	6	0.8	10	1.0
Corneal opacity	3	7.3	3	0.8	6	1.5	26	9.9	8	1.1	34	3.4
Other maculopathy	1	2.4	2	0.6	3	0.7	19	7.3	29	4.0	48	4.9
Ocular trauma	0	0	0	0	0	0	16	6.1	6	0.8	22	2.2
Others	5	12.2	5	1.4	10	2.5	39	15	42	5.8	81	8.2
Undetermined	0	0	11	3.0	11	2.7	5	1.9	22	3	27	2.7

*Defined as visual acuity <20/400.
†Defined as visual acuity <20/60 and ≥20/400.
‡Blindness plus low vision, defined as visual acuity <20/60.

Table 5. Causes of Blindness and Low Vision According to Best-Corrected Visual Acuity in the Handan Eye Study

Better-Seeing Eye							Worse-Seeing Eye						
	Blindness*		Low Vision†		Visual Impairment‡			Blindness*		Low Vision†		Visual Impairment‡	
Causes	No.	%	No.	%	No.	%	Causes	No.	%	No.	%	No.	%
Cataract	13	41.9	41	48.2	54	46.6	Cataract	72	34.0	93	35.8	165	35.0
Myopic retinopathy	5	16.1	8	9.4	13	11.2	Corneal opacity	26	12.3	5	1.9	31	6.6
Glaucoma	3	9.7	4	4.7	7	6.0	Glaucoma	15	7.1	12	4.6	27	5.7
Corneal opacity	3	9.7	3	3.5	6	5.2	Ocular trauma	14	6.6	5	1.9	19	4.0
Amblyopia	0	0.0	4	4.7	4	3.4	Amblyopia	12	5.7	54	20.8	66	14.0
DR	0	0.0	4	4.7	4	3.4	Myopic maculopathy	11	5.2	17	6.5	28	5.9
Congenital	2	6.5	1	1.2	3	2.6	Anophthalmus	9	4.2	0	0.0	9	1.9
AMD	1	3.2	1	1.2	2	1.7	Optic nerve atrophy	8	3.8	3	1.2	11	2.3
Others	4	12.9	7	8.2	11	9.5	Congenital	8	3.8	2	0.8	10	2.1
Uncertain	0	0.0	12	14.1	12	10.3	AMD	4	1.9	1	0.4	5	1.1
							DR	2	0.9	4	1.5	6	1.3
							Other maculopathy	14	6.6	19	7.3	33	7.0
							Others	12	5.7	21	8.1	33	7.0
							Uncertain	5	2.4	24	9.2	29	6.1
Total	31	100	85	100	116	100		212	100	260	100	472	100

AMD = age related macular degeneration; DR = diabetes retinopathy.
*Defined as visual acuity <20/400.
†Defined as visual acuity <20/60 and ≥20/400.
‡Blindness plus low vision, defined as visual acuity <20/60.

leading cause of unilateral (34%) and bilateral (60%) blindness in Singapore,[23] likely reflecting a higher cataract surgery rate in Singapore.[25] The recent study in urban Guangzhou showed a prevalence of 3.8% of primary glaucoma,[10] and nearly 42.9% rate of unilateral blindness for primary angle-closure glaucoma and 17% of for primary open-angle glaucoma, which is much higher than we have expected. Overall, glaucoma would be a great issue for blindness prevention with the urbanization of the Chinese population.

Findings from this and other studies in China[13,26] indicate that causes of visual impairment are somewhat different from the patterns observed in European-derived populations of developed countries such as the United States, where AMD is the leading cause (54.4%) of moderate to severe visual impairment, followed by cataract (8.7%), glaucoma (6.4%), and diabetic retinopathy (5.4%).[27] Apart from genetic factors, the shorter life expectancy (73.0 years in Chinese vs. 78.2 years in Western European-derived populations as of 2006)[18] and relatively poor access to eye care services may contribute to these observed differences.

Strengths of our study include a large sample size, high response rate (90.4%), and the use of standardized protocols following that used in the Singapore Malay Eye Study,[12] which incorporated methods used in the Blue Mountains Eye Study. However, this study has some limitations. First, because cataract accounted for 49% of visual impairment

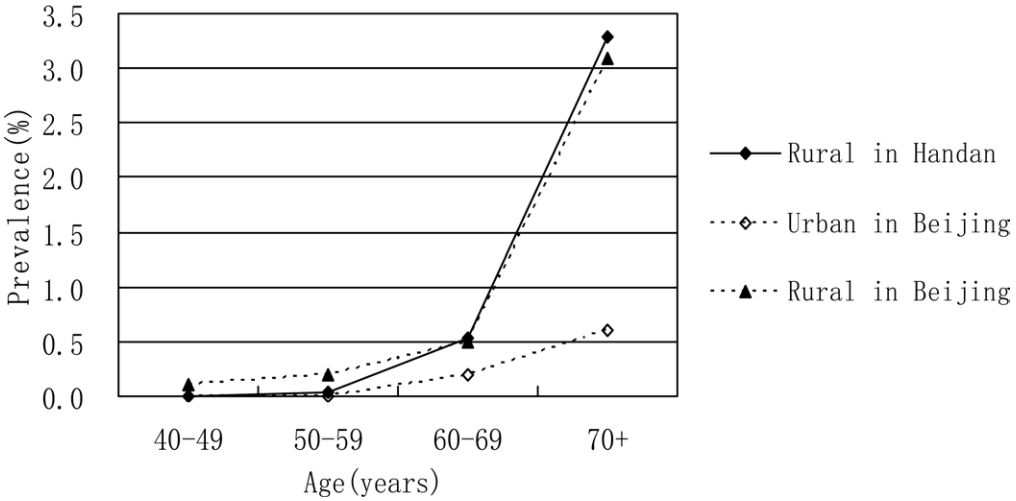

Figure 1. Graph demonstrating the prevalence of blindness by age in the Handan Eye Study in comparison with the Beijing Eye Study. Blindness was defined as best-corrected visual acuity in the better-seeing eye of less than 20/400.

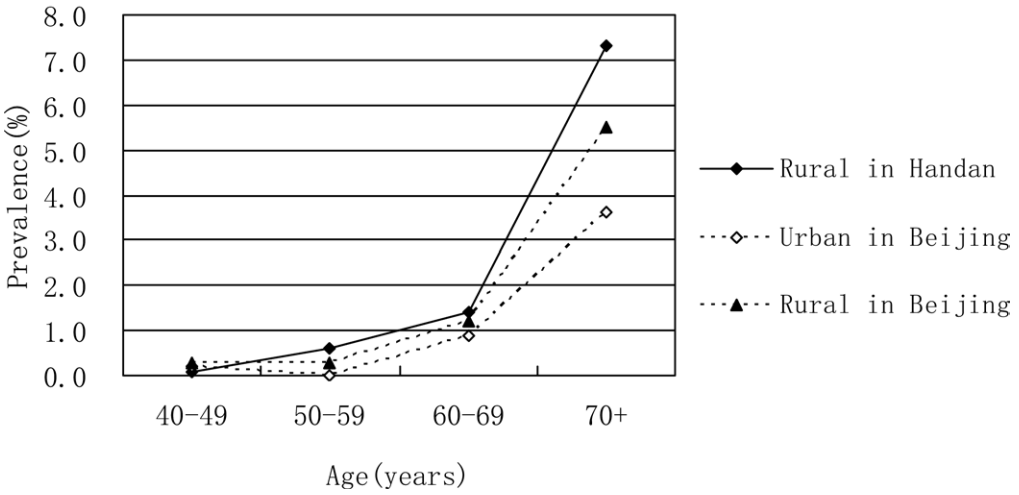

Figure 2. Graph demonstrating the prevalence of low vision by age in the Handan Eye Study in comparison with the Beijing Eye Study. Low vision was defined as best-corrected visual acuity in the better-seeing eye of less than 20/60 and 20/400 or better.

after refractive correction, severe lens opacity might have prevented us from detecting significant retinal diseases and glaucoma, leading to a possible underdetection of diabetic retinopathy, myopic maculopathy, AMD, and glaucoma. Second, there could be a selection bias as a result of excluding residents who worked outside the county for 6 months (6.8%; 585 of 8653 persons in the target population), because most of these persons were healthy and young workers and likely had normal vision. This could have led to a slight overestimation of the prevalence of blindness and low vision in the youngest persons studied.

In conclusion, we provide data on the prevalence and causes of low vision and blindness in a sample of rural Chinese residents aged 30 years and older, representative of approximately 800 million Chinese living in rural areas of mainland China. Our findings suggest that the prevalence of bilateral low vision and blindness in rural areas is higher than that observed in urban areas, and that the causes are largely treatable. Undercorrected refractive error, cataract, and myopic maculopathy are the leading causes of visual impairment among adults in rural China.

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Footnotes and Financial Disclosures

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