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ORIGINAL RESEARCH

Prevalence, Causes, and Factors Associated with Visual Impairment in a Chinese Elderly Population: The Rugao Longevity and Aging Study

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Purpose: This study aimed to explore the current prevalence, causes, and factors associated with visual impairment in a Chinese elderly population.

Methods: A random sample of 2164 candidates aged ≥70 years was selected. Among them, 1914 participants (response rate: 88.4%) underwent comprehensive eye examinations. The prevalence and causes of visual impairment were estimated, and the associated factors were identified.

Results: The standardized prevalence of mild visual impairment (<6/12 to ≥6/18), moderate to severe visual impairment (MSVI) (<6/18 to ≥3/60), and blindness (<3/60) in the better eye were 20.5%, 25.8%, and 3.4%, respectively. The leading cause of visual impairment was cataract (49.7%), followed by uncorrected refractive error (26.5%), myopic maculopathy (5.8%), and posterior capsular opacification (5.5%). Optical coherence tomography revealed that vitreoretinal interface abnormalities were the third most common cause of monocular mild visual impairment (2.2%) and MSVI (4.4%) in the elderly population. A large number of patients with visual impairment (81.7%) were amenable to undergo the interventions. Visual impairment was associated with advanced age (odds ratio [OR], 1.09 per year; $p<0.001$), female sex (OR, 1.59; $p=0.003$), self-reported visual impairment (OR, 1.91; $p<0.001$), cognitive impairment (OR, 1.40, $p=0.005$), and high educational level (OR, 0.75; primary, $p=0.045$; and OR, 0.53, secondary or higher; $p<0.001$).

Conclusion: Visual impairment was common in the Chinese elderly population and a severe health and social problem. Practicable policies are urgently needed to popularize eye health knowledge and promote treatments for visual impairment in elderly people in rural China.

Keywords: visual impairment, blindness, elderly, aging

Plain Language Summary

Vision impairment is common in later life. It may severely impact the quality of life and subjective well-being, and increase the risk of disability and depression in older age. However, little attention has been paid to investigating this phenomenon occurring among older adults.

Our findings show that nearly half of the elderly individuals aged ≥70 years living in rural China had visual impairment, which was predominantly treatable Cataract and uncorrected refractive error remain the leading causes of vision loss, highlighting the significant challenges in popularizing cataract surgery and the use of spectacles for the elderly individuals. In particular, optical coherence tomography revealed that vitreoretinal interface abnormality was a frequent cause of visual impairment in the elderly population. Advanced age, female sex, self-reported visual impairment, cognitive impairment, and low education level were associated with a higher prevalence of visual impairment.

Given the rapid growth of the elderly population, practicable policies, such as raising awareness of eye healthcare and increasing cataract surgery coverage, are urgently needed to promote visual impairment rehabilitation services in the Chinese elderly population.

Introduction

Visual impairment among adults remains an important public health problem worldwide.[1] In the elderly population, visual impairment severely impacts the quality of life and subjective well-being, and increases the risk of disability and depression.[2–4] China has the world's largest population and is facing a rapid growth in the elderly population. By 2050, the number of elderly individuals is projected to reach approximately one quarter of the national population.[5] Visual impairment substantially aggravates the social and medical burdens led by societal aging, which are much more serious in rural areas than that in urban areas due to the rural-urban migration of young people.[6]

Unfortunately, to date, the number of population-based epidemiological studies on visual impairment in elderly people in China is limited. Several studies have reported the prevalence of visual impairment in patients aged 40 years and older, but little attention has been paid to assessing people aged ≥70 years.[7–10] Moreover, the most recent survey on visual impairment was conducted before 2014. Therefore, an updated epidemiologic study is warranted to provide a more precise assessment of the visual health status in the rapidly growing elderly population. This study aimed to determine the current prevalence, causes, and associated factors of visual impairment in a Chinese elderly population.

Materials and Methods
Study Population

The Rugao Longevity and Aging Study (RuLAS) is an ongoing, dynamic, population-based, observational cohort study conducted in Rugao, a typical medium-sized county in Jiangsu Province, China. The cohort study aimed to investigate the prevalence, trajectories, and risk factors of various age-related phenotypes in a Chinese elderly population. The study protocol of RuLAS has been reported before.[11] In brief, 1788 elderly individuals aged 70–84 years from 31 rural communities in Jiang'an township, one of the 14 townships in Rugao, were randomly recruited using the 5-year age and gender strata in November 2014 (Wave 1). Follow-up surveys were conducted 1.5 years later (April–June 2016, Wave 2), 3 years later (November– December 2017, Wave 3), and 5 years later (December 2019 – January 2020, Wave 4). A flow diagram of the aging arm of the RuLAS is shown in Supplementary Figure.

We performed ophthalmic examinations on 2200 participants (aged 60–97) in Wave 4. Among them, 2164 participants of the fourth-wave cohort aged ≥70 years were enrolled in the current study. This study was approved by the Human Ethics Committee of the School of Life Sciences of Fudan University and the Ethics Committee of Shanghai General Hospital, Shanghai Jiao Tong University School of Medicine. Informed consent was obtained from all participants according to the Declaration of Helsinki.

Clinical and Ophthalmic Examinations

All recruited participants were invited to the local clinics. Fasting blood samples were collected for biochemical tests (eg, complete blood count and hemoglobin A1c). Physical examinations (eg, grip strength test and blood pressure measurement) were performed by trained physicians from Rugao People's Hospital. Body mass index (BMI, weight in kilograms divided by height in meters squared) was categorized into four groups: underweight (<18.0), normal (18.0–23.9), overweight (24.0–27.9), and obese (≥28.0). This classification of BMI is used as the gold standard in the Chinese population.[12] A structured face-to-face questionnaire (eg, sociodemographic characteristics, lifestyles, and cognitive function) was completed by each participant. All interviews were tape recorded, and 5% of the recordings were randomly evaluated for quality of interviews. Cognitive assessment was performed using the Mini-Mental State Examination (MMSE), which is the most widely used tool for screening cognitive function in older adults.[13] Cognitive impairment was defined as MMSE scores of ≤ 6 for illiterate, ≤19 for individuals with 1–6 years of education, and ≤23 for individuals with 7 or more years of education.

Ophthalmic examination was performed using a standardized protocol. Presenting visual acuity (PVA, wearing current optical correction if any) was measured using a retro-illuminated logarithm of the minimum angle of resolution E chart at a distance of 4 m,[14] and the eyes were measured separately. Visual acuity test was used to determine the smallest line read with one or no errors. Participants failing to read the top line at 1 m were tested for finger counting, hand movement, or light perception. If PVA was less than 6/12 in either eye, the best-corrected visual acuity (BCVA) was measured using the pinhole test. The intraocular pressure was measured using the Icare rebound tonometer (ic100, TAO11, Helsinki, Finland).

Anterior and posterior segment assessments were performed by an experienced ophthalmologist (Dr. HS) using a slit lamp (YZ3, 6 6 Vision Tech Co., Ltd., Suzhou, China) and direct ophthalmoscopy (YZ11D, 6 6 Vision Tech Co., Ltd., Suzhou, China) without pupillary dilation. For each eye, fundus photographs (45°) showing the macular and optic discs were obtained using a non-mydriatic hand-held fundus camera (MicroClear Medical Instruments Co., Suzhou, China) in a darkened room to allow for physiological mydriasis. Spectral-domain optical coherence tomography (OCT) (HS100, Canon Inc., Tokyo, Japan) images were obtained using a macular 3D scan within a 10×10 mm area.

Definitions of Visual Impairment

Bilateral visual impairment was defined as a PVA of <6/12 in the better eye, according to the World Health Organization (WHO) criteria.[1] Visual impairment was subdivided into mild visual impairment (PVA <6/12 and ≥6/18), moderate to severe visual impairment (MSVI) (PVA <6/18 and ≥3/60), and blindness (PVA <3/60). The United States criteria was also used, which defined visual impairment as PVA values of <6/12 and ≥6/60 in the better eye and blindness as a PVA value of <6/60 in the better eye.[15]

Unilateral vision impairment was also defined as follows:[16] (1) mild (PVA <6/12 in the worse eye and ≥6/12 in the better eye), (2) moderate to severe (PVA <6/18 in the worse eye and ≥6/18 in the better eye), and (3) blindness (PVA <3/60 in the worse eye and ≥3/60 in the better eye).

Causes of Visual Impairment

Eye conditions were determined by an ophthalmologist (Dr. HS). Two experienced ophthalmologists (Drs. HS and WG) determined the principal cause of visual impairment based on clinical history and examination records. If a primary diagnosis was not definite during the initial assessment, the final adjudication was made by a senior ophthalmologist (Dr. TQ). The principal causes were determined according to the following itemized list: ocular atrophy or prosthetic eye, amblyopia, pterygium, corneal opacity, uncorrected refractive error, cataract, posterior capsular opacification, glaucoma, other optic atrophy, uveitis, age-related macular degeneration, myopic maculopathy, diabetic retinopathy, retinal detachment, vitreoretinal interface abnormality, other posterior segment eye disease, and undetermined disease. In eyes with two or more pathological alterations that might lead to visual impairment, the cause with the greatest impact on visual acuity was designated as the principal cause.

At the individual level, if the causes of visual impairment both eyes were different, the cause that could be more easily treated was designated as the principal cause.[17] For instance, if uncorrected refractive error was the cause of visual impairment in one eye and cataract in the other eye, the principle cause of visual impairment was considered uncorrected refractive error because the disease is easier to manage compared with cataract surgery.

The presence of cataract was determined based on the Lens Opacities Classification System III.[18] Cataract was considered as the main cause of visual impairment if the fundus details were obscured due to significant lens opacity without evidence of other ocular abnormalities. Visual impairment was attributed to uncorrected refractive error when the PVA in the better eye was initially <6/12 and improved to ≥6/12 after performing a refractive correction.[19] Myopic maculopathy was defined according to a simplified meta-analysis of the pathologic myopia classification system.[20] The prevalence of vitreoretinal interface abnormality was determined by fundus photography and OCT, as defined by the International Vitreomacular Traction Study Group, including the epiretinal membranes, vitreomacular traction, full thickness macular hole, and lamellar macular hole.[21] We assumed that visual impairment caused by cataract, uncorrected refractive error, and posterior capsular opacification were amenable to interventions such as cataract surgery, spectacle correction, and Nd:YAG laser capsulotomy.[17]

Statistical Analysis

The categorical data were analyzed using the chi-square test, while continuous data were analyzed using the t-test (after Bonferroni correction). The age- and gender-standardized prevalence of visual impairment was estimated based on the latest China National Census (2010), with its 95% confidence intervals (CIs). Univariate logistic regression analyses were used to investigate the relationships between demographic factors and bilateral visual impairment, and variables with a p value of <0.05 were included in the multivariate models. A p value (two tailed) less than 0.05 was considered significant.

Results

Study Population

A flow diagram of study participants is shown in Figure 1. Among the total cohort of 2164 individuals aged ≥70 years, 1914 (response rate, 88.4%) eligible participants
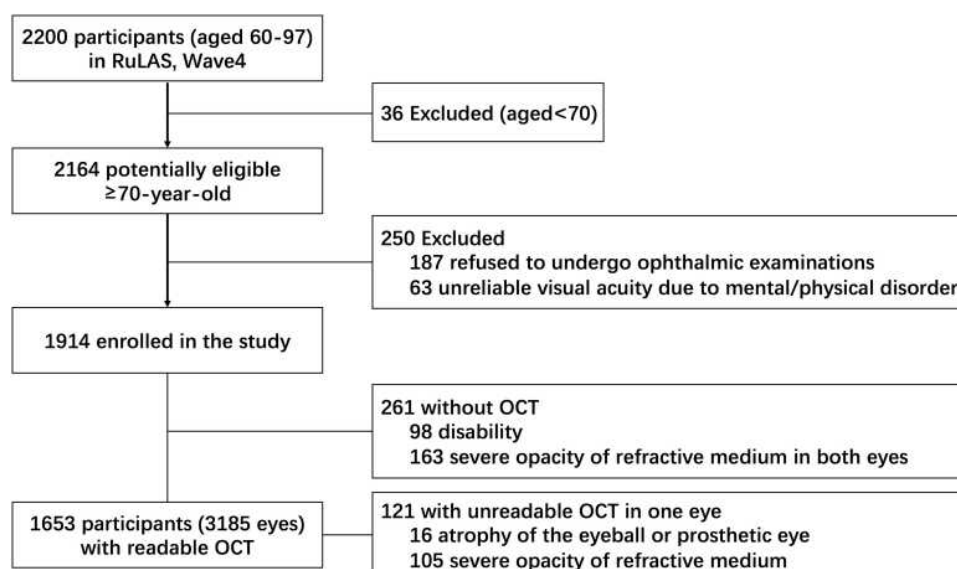
Figure 1 Flow diagram of study participants.
Abbreviations: RuLAS, Rugao Longevity and Aging Study; OCT, optical coherence tomography.

completed the eye examinations. The mean age of the participants was 79.1±4.6 years (median [range], 79 [70–97] years), which was younger than the mean age of the non-participants (80.1±4.9, *p* = 0.002) (Table 1). Approximately 54.0% of the participants were women. Among the 1914 participants constituting the analysis cohort, readable OCT images were available in 1653 (76.4%) participants (3185 eyes). No significant difference was observed in the mean age (*p*=0.677) or the prevalence of visual impairment (*p*=0.830) between patients with and without OCT scan.

Prevalence of Visual Impairment

Based on the WHO criteria, the age- and gender-standardized prevalence of bilateral presenting visual impairment was 48.9% (95% CI, 46.7–51.2%), which included mild visual impairment in 20.5% (95% CI, 18.7–22.3%), MSVI in 25.8% (95% CI, 23.9–27.8%), and blindness in 3.4% (95% CI, 2.6–4.2%). The age- and gender-standardized prevalence of bilateral best-corrected visual impairment was 33.1% (95% CI, 31.0–35.2%), which included mild visual impairment in 12.4% (95% CI, 10.9–13.8%), MSVI 17.7% (95% CI, 16.0–19.4%), and blindness in 3.0% (95% CI, 2.2–3.8%) (Table 2).

Based on the United States criteria, the age- and gender-standardized prevalence of bilateral presenting visual impairment and blindness were 43.5% (95% CI, 41.3–45.7%) and 5.5% (95% CI, 4.5–6.5%), respectively. The age- and gender-standardized prevalence of bilateral best-corrected visual impairment and blindness were 28.2% (95% CI,

26.1–30.2%) and 4.9% (95% CI, 4.3–5.9%), respectively (Supplementary Table 1).

Causes of Visual Impairment

Cataract (49.7%) was the major cause of bilateral visual impairment, followed by uncorrected refractive error (26.5%) and myopic maculopathy (5.8%) (Table 3). Uncorrected refractive error was the most frequent cause of mild bilateral visual impairment. The main causes of blindness were cataracts (28.0%), myopic maculopathy (20.7%), and corneal opacity (12.2%).

The leading causes of monocular visual impairment were cataract (60.1%), uncorrected refractive error (14.4%), myopic maculopathy (3.8%), and vitreoretinal interface abnormalities (3.5%) (Table 4). Vitreoretinal interface abnormality was the third cause of monocular mild visual impairment and MSVI, accounting for 2.2% and 4.4% of all cases, respectively. The leading causes of monocular blindness were cataract (32.7%), corneal opacity (12.7%), and atrophy of the eyeball or prosthetic eye (9.7%).

Altogether, a large number of bilateral and monocular visual impairment cases (81.7% and 77.1%, respectively) were caused by treatable pathologies including cataract, uncorrected refractive error, and posterior capsular opacification.

Factors Associated with Visual Impairment

Bilateral MSVI and blindness were associated with age (both *p*<0.001) and sex (*p*<0.001 and *p*=0.018, respectively)

Table 1 Characteristics for Participants and Nonparticipants

	Participants (n=1914), %	Nonparticipants (n=250), %	Response Rate	*p* value*
Age (yrs, Mean ± SD)	79.1±4.6	80.1±4.9		0.002
70–74	16.1	11.2	91.7%	0.014
75–79	40.6	35.6	89.7%	
80–84	29.4	34.0	86.9%	
85~	13.9	19.2	84.8%	
Gender				
Male	46.0	42.4	89.2%	0.29
Female	54.0	57.6	87.8%	
Education				
Less than primary	46.9	50.6	88.0%	0.36
Primary	29.5	29.9	88.7%	
Secondary or higher	23.6	19.5	90.6%	
Total	100.0	100.0	88.4%	

Note: *Student's *t*-test for continuous variables, and chi-square for categorical variables.
Abbreviation: SD, standard deviation.

(Figure 2). Table 5 shows the univariate and multivariate logistic regression results of the factors associated with visual impairment. Advanced age (per year, odds ratio [OR], 1.09; 95% CI, 1.06–1.12; *p*<0.001), female sex (OR, 1.59; 95% CI, 1.18–2.15; *p*=0.003), self-reported visual impairment (OR, 1.91; 95% CI, 1.51–2.41; *p*<0.001), and cognitive impairment (OR, 1.40; 95% CI, 1.11–1.76, *p*=0.005) were significantly associated with a higher prevalence of visual impairment. By contrast, higher educational level (OR, 0.75; 95% CI, 0.56–0.99; p=0.045 for primary; OR, 0.53; 95% CI, 0.38–0.74; *p*<0.001 for secondary or higher) was significantly associated with a lower prevalence of visual impairment.

Discussion

The current study is a large population-based survey that is aimed to assess the current prevalence and causes of visual impairment in an elderly Chinese population aged ≥70 years. After adjusting the China National Census for age and gender, 48.9% of the elderly individuals had bilateral visual impairment, of whom 20.5% had mild visual impairment, 25.8% had bilateral MSVI, and 3.4% were blind, according to the WHO criteria. In mainland China, approximately 38.1 million elderly individuals aged ≥70 years have visual impairment, of whom 19.5 million had MSVI and 2.6 million were blind. China is experiencing a rapid population aging; the population of adults aged ≥70 years is projected to reach 290 million by 2050.[22] This trend of societal aging may result in 140 million elderly

people aged ≥70 years developing bilateral visual impairment in China by 2050. Cataract and uncorrected refractive errors are the leading causes of visual impairment. In particular, a high prevalence of vitreoretinal interface abnormality-related visual impairment was detected by OCT and fundus examination.

The prevalence of visual impairment varies among different regions in China and in other countries, based on the WHO criteria for PVA and BCVA in the better eye (Supplementary Table 2 and Supplementary Table 3). In the current study, the prevalence of MSVI and blindness among adults aged ≥70 years was comparable to that in the Nine Provinces Eye Survey[23] and Taizhou study.[10] On the contrary, a remarkably lower prevalence of best-corrected visual impairment among the elderly population was observed in the Shihpai Eye Study that included elderly people aged ≥65 years (8.2% vs 33.1% in the current study). This discrepancy was due to the significantly higher prevalence of visual impairment in rural areas than in urban areas.[7,8] The lack of ophthalmologists, limited facilities, and transportation barriers between rural and urban regions are significant obstacles that need to be addressed during the expansion of eye care services to rural residents in China.

Compared with other countries, the prevalence of visual impairment in mainland China was higher than that observed in developed countries (Supplementary Table 2 and Supplementary Table 3). These substantial differences could be explained by the variations in

Table 2 Prevalence of Bilateral Visual Impairment Using the World Health Organization Definition

Group	Age (yrs)	Participants	< 6/12 and ≥ 6/18						< 6/18 and ≥ 3/60						< 3/60					
			Presenting Visual Acuity			Best-Corrected Visual Acuity			Presenting Visual Acuity			Best-Corrected Visual Acuity			Presenting Visual Acuity			Best-Corrected Visual Acuity		
			No.	%	95% CI	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI
Men	70–74	144	19	13.2	7.7–18.7	6	4.2	0.9–7.4	20	13.9	8.2–19.5	14	9.7	4.9–14.6	2	1.4	0–3.3	1	0.7	0–2.1
	75–79	374	77	20.6	16.5–24.7	52	13.9	10.4–17.4	53	14.2	10.6–17.7	35	9.4	6.4–12.3	5	1.3	0.2–2.5	4	1.1	0–2.1
	80–84	248	58	23.4	18.1–28.7	39	15.7	11.2–20.3	58	23.4	18.1–28.7	44	17.7	13.0–22.5	8	3.2	1.0–5.4	8	3.2	1.0–5.4
	≥85	114	34	29.8	21.4–38.2	28	24.6	16.7–32.5	38	33.3	24.7–42.0	31	27.2	19.0–35.4	8	7.0	2.3–11.7	7	6.1	1.7–10.5
	Total	880	188	21.4	18.7–24.1	125	14.2	11.9–16.5	169	19.2	16.6–21.8	124	14.1	11.8–16.4	23	2.6	1.6–3.7	20	2.3	1.3–3.3
	Age-adjusted	/	/	18.4	15.9–21.0	/	10.7	8.6–12.7	/	22.5	20.0–25.1	/	12.3	10.1–14.4	/	2.1	1.2–3.1	/	1.6	0.8–2.5
Women	70–74	164	35	21.3	15.1–27.6	16	9.8	5.2–14.3	35	21.3	15.1–27.6	18	11.0	6.2–15.8	2	1.2	0–2.9	2	1.2	0–2.9
	75–79	403	102	25.3	21.1–29.6	61	15.1	11.6–18.6	126	31.3	26.7–35.8	89	22.1	18.0–26.1	16	4.0	2.1–5.9	14	3.5	1.7–5.3
	80–84	314	76	24.2	19.5–28.9	61	19.4	15.1–23.8	132	42.0	36.6–47.5	102	32.5	27.3–37.7	22	7.0	4.2–9.8	21	6.7	3.9–9.5
	≥85	153	23	15.0	9.4–20.0	25	16.3	10.5–22.2	87	56.9	49.0–64.7	74	48.4	40.4–56.3	20	13.1	7.7–18.4	19	12.4	7.2–17.6
	Total	1034	236	22.8	20.3–25.4	163	15.8	13.5–18.0	380	36.8	33.8–39.7	283	27.4	24.7–30.1	60	5.8	4.4–7.2	56	5.4	4.0–6.8
	Age-adjusted	/	/	22.3	19.8–24.9	/	13.9	11.8–16.0	/	32.2	29.3–35.0	/	17.0	14.6–19.5	/	4.5	3.2–5.7	/	4.2	3.0–5.4
Total	70–74	308	54	17.5	13.3–21.8	22	7.1	4.3–10.0	55	17.9	13.6–22.1	32	10.4	7.0–13.8	4	1.3	0–2.6	3	1.0	0–2.1
	75–79	777	179	23.0	20.1–26.0	113	14.5	12.1–17.0	179	23.0	20.1–26.0	124	16.0	13.4–18.5	21	2.7	1.6–3.8	18	2.3	11.9–16.9
	80–84	562	134	23.8	20.3–27.4	100	17.8	14.6–21.0	190	33.8	29.9–37.7	146	26.0	22.4–29.6	30	5.3	3.5–7.2	29	5.2	3.3–7.0
	≥85	267	57	21.3	16.5–26.3	53	19.9	15.1–24.6	125	46.8	40.8–52.8	105	39.3	33.5–45.2	28	10.5	6.8–14.2	26	9.7	6.2–13.3
	Total	1914	424	22.2	20.3–24.0	288	15.0	13.4–16.6	549	28.7	26.7–30.7	407	21.3	19.4–23.1	83	4.3	3.4–5.2	76	4.0	3.1–4.8
Age- and gender-standardized	≥70	/	/	20.5	18.7–22.3	/	12.4	10.9–13.8	/	25.8	23.9–27.8	/	17.7	16.0–19.4	/	3.4	2.6–4.2	/	3.0	2.2–3.8
	≥80	/	/	22.7	19.8–25.5	/	18.4	15.7–21.0	/	36.8	33.6–40.1	/	31.2	28.0–34.3	/	7.3	5.5–9.1	/	6.9	5.2–8.7

Notes: /= data not available. The prevalence of visual impairment or blindness was estimated via the latest China National Census 2010.
Abbreviation: CI, confidence interval.

Table 3 Causes of Bilateral Visual Impairment and Blindness Using the World Health Organization Criteria

	Mild Visual Impairment		Moderate to Severe Visual impairment		Blindness		All	
	No. (Prevalence %)	Distribution (%)	No. (Prevalence %)	Distribution (%)	No. (Prevalence %)	Distribution (%)	No. (Prevalence %)	Distribution (%)
Cataract	165 (8.6)	38.9	337 (17.6)	61.3	23 (1.2)	28.0	525 (27.4)	49.7
Uncorrected refractive error	203 (10.6)	47.9	77 (4.0)	14.0	0 (0.0)	0.0	280 (14.6)	26.5
Myopic maculopathy	7 (0.4)	1.7	37 (1.9)	6.7	17 (0.9)	20.7	61 (3.2)	5.8
Posterior capsular opacification	21 (1.1)	5.0	35 (1.8)	6.4	2 (0.1)	2.4	58 (3.0)	5.5
Cornea opacity	5 (0.3)	1.2	8 (0.4)	1.5	10 (0.5)	12.2	23 (1.2)	2.2
AMD	3 (0.2)	0.7	13 (0.7)	2.4	5 (0.3)	6.1	21 (1.1)	2.0
Vitreoretinal interface abnormality	7 (0.4)	1.7	12 (0.6)	2.2	0 (0.0)	0.0	19 (1.0)	1.8
Other posterior segment eye disease	3 (0.2)	0.7	6 (0.3)	1.1	6 (0.3)	7.3	15 (0.8)	1.4
Glaucoma	4 (0.2)	0.9	6 (0.3)	1.1	5 (0.3)	6.1	15 (0.8)	1.4
Pterygium	3 (0.2)	0.7	7 (0.4)	1.3	1 (0.1)	1.2	11 (0.6)	1.0
Diabetic retinopathy	1 (0.1)	0.2	5 (0.3)	0.9	2 (0.1)	2.4	8 (0.4)	0.8
Other optic atrophy	2 (0.1)	0.5	1 (0.1)	0.2	4 (0.2)	4.9	7 (0.4)	0.7
Amblyopia	0 (0.0)	0.0	1 (0.1)	0.2	2 (0.1)	2.4	3 (0.2)	0.3
Uveitis	0 (0.0)	0.0	1 (0.1)	0.2	1 (0.1)	1.2	2 (0.1)	0.2
Atrophy of the eyeball or prosthetic eye	0 (0.0)	0.0	0 (0.0)	0.0	1 (0.1)	1.2	1 (0.1)	0.1
Retinal detachment	0 (0.0)	0.0	0 (0.0)	0.0	0 (0.0)	0.0	0 (0.0)	0.0
Unknown eye disease	0 (0.0)	0.0	4 (0.2)	0.7	3 (0.2)	3.7	7 (0.4)	0.7
Subjects	424 (22.2)	100.0	550 (28.5)	100.0	82 (4.1)	100.0	1056 (54.8)	100.0

Notes: Mild visual impairment was defined as presenting visual acuity measurements of ≥6/18 and <6/12 in the better eye, moderate to severe visual impairment was defined as presenting visual acuity measurements of ≥3/60 and <6/18 in the better eye, and blindness was defined as presenting a visual acuity of <3/60 in the better eye. **Abbreviation:** AMD, age-related macular degeneration.

Table 4 Causes of Monocular Visual Impairment and Blindness Using the World Health Organization Criteria

	Mild Visual Impairment		Moderate to Severe Visual Impairment		Blindness		All	
	No. (Prevalence %)	Distribution (%)	No. (Prevalence %)	Distribution (%)	No. (Prevalence %)	Distribution (%)	No. (Prevalence %)	Distribution (%)
Cataract	133 (6.9)	59.4	294 (15.4)	71.5	54 (2.8)	32.7	481 (25.1)	60.1
Uncorrected refractive error	78 (4.1)	34.8	37 (1.9)	9.0	0 (0.0)	0.0	115 (6.0)	14.4
Myopic maculopathy	2 (0.1)	0.9	17 (0.9)	4.1	11 (0.6)	6.7	30 (1.6)	3.8
Vitreoretinal interface abnormality	5 (0.3)	2.2	18 (0.9)	4.4	5 (0.3)	3.0	28 (1.5)	3.5
Cornea opacity	0 (0.0)	0.0	6 (0.3)	1.5	21 (1.1)	12.7	27 (1.4)	3.4
AMD	0 (0.0)	0.0	12 (0.6)	2.9	10 (0.5)	6.1	22 (1.1)	2.8
Posterior capsular opacification	3 (0.2)	1.3	14 (0.7)	3.4	4 (0.2)	2.4	21 (1.1)	2.6
Atrophy of the eyeball or prosthetic eye	0 (0.0)	0.0	0 (0.0)	0.0	16 (0.8)	9.7	16 (0.8)	2.0
Other posterior segment eye disease	1 (0.1)	0.4	4 (0.2)	1.0	8 (0.4)	4.8	13 (0.7)	1.6
Amblyopia	0 (0.0)	0.0	4 (0.2)	1.0	9 (0.5)	5.5	13 (0.7)	1.6
Glaucoma	1 (0.1)	0.4	2 (0.1)	0.5	7 (0.4)	4.2	10 (0.5)	1.3
Other optic atrophy	0 (0.0)	0.0	0 (0.0)	0.0	6 (0.3)	3.6	6 (0.3)	0.8
Diabetic retinopathy	0 (0.0)	0.0	2 (0.1)	0.5	3 (0.2)	1.8	5 (0.3)	0.6
Retinal detachment	0 (0.0)	0.0	0 (0.0)	0.0	5 (0.3)	3.0	5 (0.3)	0.6
Pterygium	1 (0.1)	0.4	1 (0.1)	0.2	3 (0.2)	1.8	5 (0.3)	0.6
Uveitis	0 (0.0)	0.0	0 (0.0)	0.0	0 (0.0)	0.0	0 (0.0)	0.0
Unknown eye disease	0 (0.0)	0.0	0 (0.0)	0.0	3 (0.2)	1.8	3 (0.2)	0.4
Subjects	224 (11.7)	100.0	411 (21.5)	100.0	165 (8.6)	100.0	800 (41.8)	100.0

Notes: Mild visual impairment was defined as presenting visual acuity measurements worse than 6/12 in the worse eye and ≥6/12 in the better eye; moderate to severe was defined as presenting visual acuity measurements worse than 6/18 in the worse eye and ≥6/18 in the better eye, and blindness was defined as presenting visual acuity measurements worse than 3/60 in the worse eye and ≥3/60 in the better eye.
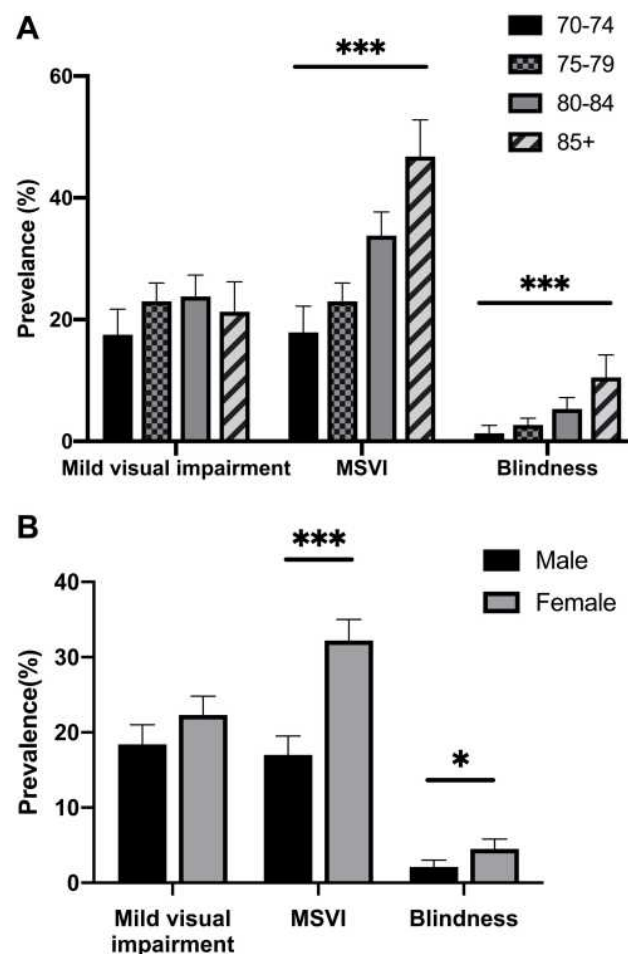**Abbreviation:** AMD, age-related macular degeneration.

Figure 2 The prevalence of presenting visual impairment using the World Health Organization standard. (**A**) The prevalence of MSVI and blindness increased with age. (**B**) The prevalence of MSVI and blindness was higher in female than those in male. *$p<0.05$; ***$p<0.001$.
Abbreviation: MSVI, moderate to severe visual impairment.

definitions, demographic makeup, socioeconomic level, sampling frame, and study time. In addition, the elderly population in China might be less likely to seek eye healthcare. The Chinese Health Statistical Yearbook 2019 reported that there were over 40,000 registered ophthalmologists in China, more than twice as many as in 2010.[24] However, in a study by Peng et al[25] nearly 90% of the Chinese rural population had never sought eye care services, for whom education to raise the awareness of eye diseases is needed to reduce visual impairment.

Cataract and uncorrected refractive errors were the main causes of visual impairment in the elderly population. This finding is similar to that of other population-based studies.[10,23] A novel finding in our study was that posterior capsular opacification was the fourth leading cause of visual impairment. This could be explained by the increasing cataract surgery rate promoted by the

Chinese government over decades.[26] Based on our study findings, a large proportion (81.7%) of visual impairment can be significantly improved by cataract surgery, refractive correction, or Nd:YAG laser capsulotomy. These results suggest that the prevention of visual impairment caused by cataract is well under way; however, further efforts are needed for the government and hospitals to increase cataract surgery coverage and postoperative follow-up, as well as provide spectacle-dispensing services for elderly people living in the rural areas in China.

Myopic maculopathy was the leading cause of retinal diseases, which is consistent with the findings in other eye studies in Asia.[27] The prevalence of myopic maculopathy-related visual impairment in Asians is higher than that in the Western population,[28] which requires further investigation.

We observed a high prevalence of vitreoretinal interface abnormalities leading to bilateral and monocular mild visual impairment (1.7% and 2.2%, respectively) and MSVI (2.2% and 4.4%, respectively), using OCT scan. OCT provides more sensitive and specific assessments of the vitreoretinal interface, compared with fundus photography.[29] However, the examination of the vitreoretinal interface in most population-based studies was limited to fundus photography. The prevalence of visual-impairing vitreoretinal interface abnormalities in our study (1.0%) was higher than that in the Hong Kong study (0.05%),[30] but lower than that in the UK Biobank Study (3.6%).[31] As the incidence of vitreoretinal interface abnormalities increase with age,[32] future population-based studies must include this as a potential cause of visual impairment among the elderly population.

The higher prevalence of visual impairment was associated with advanced age, female sex, self-reported visual impairment, and cognitive impairment, which is consistent with the results of previous studies.[8,28] Individuals with good cognitive function are more likely to seek eye care, while good vision helps mitigate age-related cognitive decline.[33] A higher educational level was associated with a lower risk of visual impairment. These findings may help to effectively identify interventional strategies to combat visual impairment.

The present study had several strengths. First, the large and representative study sample in this elderly population with a high response rate allowed us to obtain credible findings. Population-based studies in the elderly are usually limited by a high frequency of physical and cognitive disability. Our sample size (n=1914; response rate, 88.4%) was

Table 5 Logistic Regression Analysis for Factors Associated with Bilateral Visual Impairment (Presenting Visual Acuity < 6/12 in the Better Eye)

Variables	Univariate Odds Ratio (95% CI)[a]	p value	Multivariate Odds Ratio (95% CI)[b]	p value
Age (per year)	1.13 (1.11–1.16)	<0.001	1.09 (1.06–1.12)	<0.001
Female gender	2.49 (2.07–2.99)	<0.001	1.59 (1.18–2.15)	0.003
Married	0.62 (0.51–0.76)	<0.001	1.14 (0.90–1.44)	0.30
Education				
Less than primary	Reference		Reference	
Primary	0.40 (0.32–0.50)	<0.001	0.75 (0.56–0.99)	0.045
Secondary or higher	0.26 (0.21–0.34)	<0.001	0.53 (0.38–0.74)	<0.001
History of smoking	0.59 (0.47–0.73)	<0.001	1.12 (0.83–1.51)	0.45
History of alcohol	0.60 (0.49–0.73)	<0.001	0.84 (0.65–1.07)	0.15
Self-reported visual impairment	2.17 (1.77–2.67)	<0.001	1.91 (1.51–2.41)	<0.001
BMI (kg/m^2)				
Normal (18.0–23.9)	Reference		Reference	
Underweight (<18.0)	1.55 (0.95–2.54)	0.24	0.88 (0.48–1.61)	0.67
Overweight (24.0–27.9)	0.79 (0.65–0.97)	<0.001	0.79 (0.63–1.01)	0.059
Obese (≥28.0)	0.77 (0.57–1.05)	0.85	0.83 (0.57–1.19)	0.31
Systolic blood pressure (mmHg)	1.00 (1.00–1.00)	0.87		
Diastolic blood pressure (mmHg)	1.00 (0.99–1.00)	0.16		
Fasting blood glucose (mmol/L)	1.00 (0.95–1.05)	0.92		
Serum-HbA1c (%)	0.95 (0.86–1.04)	0.27		
Serum-Homocysteine (umol/L)	1.01 (1.00–1.02)	0.07		
Serum-cholesterol (mmol/L)	1.01 (0.93–1.11)	0.78		
Cognitive impairment[c]	2.24 (1.82–2.74)	<0.001	1.40 (1.11–1.76)	0.005

Notes: [a]The univariable logistic regression model was used to investigate the individual factors associated with bilateral visual impairment. [b]The multivariable logistic regression, including factors with association in the univariable analysis with a p value of <0.05, was used to investigate the factors associated with bilateral visual impairment. [c]Cognitive impairment was defined as Mini-Mental State Examination scores of ≤16 for illiterate, ≤19 for individuals with 1–6 years of education, and ≤23 for individuals with 7 or more years of education.
Abbreviations: CI, confidence interval; HbA1c, glycated hemoglobin; BMI, body mass index.

higher than those in other studies of this age group[17] and was well matched in terms of national gender ratio (female ratio in the age group of 70 years and older, 53.1% in national census versus 54.0% in the current study), which minimized the selection bias. Second, the use of standardized protocols as well as comprehensive ophthalmic examinations, including OCT scans, improved the accuracy of evaluations of visual impairment prevalence and causes.

This study has several limitations that should be addressed. First, the non-participants were older than the participants. As the rates of vision loss increase significantly with age, this might result in an underestimation of the true prevalence of visual impairment. Second, as cataract accounted for most cases of visual impairment, concurrent retinal diseases and glaucoma might have been masked by severe lens opacity among the elderly individuals. Third, the examinations were carried out without cycloplegia, which may have contributed to the failure to detect some conditions. Fourth, definitions of

visual impairment were limited to distance visual acuity, while near visual impairment and visual field were not assessed, which may have underestimated the prevalence of uncorrected refractive error, glaucoma or other optic atrophy. In addition, Given the cross-sectional nature of the study, our findings only suggested the associations between visual impairment and factors, but not a causative relationship.

Conclusion

In conclusion, RuLAS presented a high prevalence of visual impairment in an elderly Chinese population. Cataract and uncorrected refractive error remain the leading causes of vision loss, highlighting the significant challenges in popularizing cataract surgery and the use of spectacles for the elderly individuals living in rural areas. Myopic maculopathy, vitreoretinal interface abnormality, and posterior capsular opacification also contributed significantly to visual impairment. Strengthening the awareness of eye health

care should be listed as a high priority in health care services in rural areas in China, and specific focus should be placed on the eye health status of elderly women with low educational levels and cognitive impairment.

Abbreviations

AMD, age-related macular degeneration; BCVA, best-corrected visual acuity; BMI, body mass index; CI, confidence interval; MMSE, Mini-Mental State Examination; MSVI, moderate to severe visual impairment; OCT, optical coherence tomography; OR, odds ratio; PVA, presenting visual acuity; RuLAS, Rugao Longevity and Aging Study; WHO, World Health Organization.

Ethics Approval and Informed Consent

Obtained.

Disclosure

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