·Investigation·

Prevalence and causes of visual impairment and blindness in Sichuan province of China

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Abstract

• AIM: To describe the prevalence and causes of low vision and blindness in a population within Sichuan province in southwestern China.

• METHODS: A stratified, multi-phased and cluster probability sampling design was employed to enumerate 125641 participants from 40351 households within 38 counties/cities. 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.

• RESULTS: Population-weighted prevalence of blindness was 0.77% (95%CI: 0.72-0.82, *n*=966) and low vision was 1.22% (95%CI: 1.14-1.27, *n*=1513). Overall, the prevalence of visual disability was 1.40% in the urban population, and 2.22% in the rural population (*P*<0.01). Cataract was the leading cause of visual disability (55.7%, *n*=1381), and was of similar frequency in both urban and rural populations. Retinal disease was the second leading cause(9.7%, *n*=236), but was more common in urban than in rural participants (34.3% *vs* 2.7%, *P*<0.01). Corneal disease accounted for 6.5% (*n*=161) of cases of visual disability, and was more common in the rural population (7.2% *vs* 3.9%, *P*=0.006).

• CONCLUSION: We estimate that 1.72 million people suffer from visual disability within Sichuan province, of which 525000 are blind, the focus of blindness prevention should be in rural area.

• KEYWORDS: low vision; blindness; visual impairment; blindness prevention
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INTRODUCTION

Visual impairment remains a major global public health challenge, with an estimated 314 million people with visual impairment [1]. Knowledge of the regional epidemiology of visual impairment and its causes is needed before planning effective interventions and strategies to reduce avoidable blindness, in line with the Vision 2020: the Right to Sight' global initiative [2]. The People's Republic of China has a population of more than 1.3 billion people, and a land area of 9.6 million square kilometers. The majority of estimates of blindness and visual impairment within Mainland China have been based in urban centers [3-8], with little sampling of rural regions, despite up to 70%-80% of the population residing in rural areas in some provinces. There are scarce relevant ophthalmic epidemiological data relating to Sichuan province, and so the second China national survey on disability afforded the opportunity to evaluate the causes of visual impairment and blindness in the population resident in urban and rural regions of Sichuan province within the context of this general disability survey.

MATERIALS AND METHODS

Subjects Residents of Sichuan province were selected randomly using a stratified, clustered, sampling technique with probabilities proportionate to the size of the population in each cluster. Sichuan is located in southwestern China and has a total area of 480 000 square kilometers [9] and a population of 87.5 million in 2005. The Sichuan survey sampled 38 counties/cities, 152 towns, and 304 communities, leading to 40351 households.

Methods In line with the survey protocol, 40 ophthalmologists with more than 5 years' clinical experience from Sichuan were selected and offered special training, and then took part in the sampling survey for visual disabilities of Sichuan province from April 1 to May 31 of 2006 with the cooperation and support of the Disabled People's Association of Sichuan Province. One of the study authors (MW) led the visual disability group protocol for the project.

The survey enumerators visited each of the sampled households, interviewing, screening and assessing participants. Those who were identified as having disability were then referred to the medical survey teams for further assessment. Participants under the age of 6 years underwent primary assessment by the medical teams, and then further assessment of disabilities where appropriate. Leaders of each investigating/enumerating team rechecked the questionnaires and examinations at the end of each working day for any manual data entry errors prior to electronic data entry.

All participants in the survey received complete eye examinations. The examination protocol included uncorrected, best-corrected and presenting visual acuity measurements; manifest, subjective and cycloplegic refraction, color vision test; Schiotz tonometry; lensometry; examination of the external eye, anterior segment, media, and fundus. An interview was also conducted relating to demographic characteristics, past history of eye diseases, eye trauma, diabetes mellitus, hypertension, and any ophthalmological care the participant received. The examiners were not masked to the demographic details of the subjects.

Visual acuity was determined by using a chart projector with tumbling E letters at a distance of 2.5 meters. The participants' visual acuity without correction was measured separately for each eye and presenting acuity was measured. Then visual acuity was tested with best spectacle correction. Visual acuity was recorded as the smallest line in which the patient could read at least 3 of the four letters correctly. If the person was unable to read the largest E letters in the chart (20/200 E letter) at 2.5 meters, then the participant was requested to walk forward till he/she could read the largest line E (20/200), and visual acuity was calculated as [VA=0.1 × distance/2.5] (e.g. at 2 meters, VA=0.1 × 2/2.5=0.08). If the participant could not read 20/200 E letter at 0.5 meters, counting finger (CF) was performed. If this was visible then VA was documented as CF. If counting of digits was not possible, then the examiner slowly waved his/her hand in front of the participant's eyes and asked the participant if he/she could see the hand moving. If the participant responded positively, "hand motion (HM)" was recorded on the examination form. If the participant could not see the examiner's hand, a penlight was held in front of the participant's eye and he/she was asked if he/she could tell when the light was on. If the participant could correctly identify when the light was on, "light perception (LP)" was recorded on the examination form. If the participant was unable to see the light "no light perception (NLP)" was recorded. Children's visual acuity was measured with objects appropriate to their age.

A visual acuity of less than 20/400 (3/60) in the better eye with the best correction was considered blindness. Low vision has been defined as a best-corrected visual acuity of less than 20/60 (6/18) but not less than 20/400 in the better eye [10]. For the purposes of data analysis, blindness or visual impairment was defined according to the best-corrected visual acuity for the best eye. Visual field analysis was also performed utilising a special visual field card consisting of 2 rings. The card was placed in front of the participant at a distance of 33cm, and eyes were examined monocularly. If at least one eye could see both the small ring and big ring, (a visual field diameter >10°), this was defined as no visual field disability'. If the small ring could not be seen by both eyes, (a visual field diameter<5°), this was defined as visual impairment category 4 according to ICD-10 definition of visual impairment [11]. If at least one eye could identify the small ring but not the big ring, this equated to a visual field of 5° <visual field diameter<10°, and was defined as ICD-10 visual impairment category 3.

An ophthalmologist determined the cause of visual disability. Using clinical judgment, the ophthalmologist determined one cause for each eye as the principal cause of visual impairment or blindness. When multiple disorders were present, the ophthalmologist attempted to identify the disorder causing the greatest limitation of vision. If there were any other contributory causes, the ophthalmologist specified that as a second cause. In cases with different causes of visual reduction in a participant's two eyes, the diagnosis in the less affected eye was used [12]. When two causes appeared to have an equal contribution to visual impairment the primary cause was assigned to the one that was more amenable to treatment to restore vision. Cataract was regarded as the main cause of severe low vision if the fundus was obscured by lens changes, or if no evident fundus abnormalities were observed in eyes with significant cataract.

If no obvious morphological eye abnormality was found responsible for the visual disability, it was considered as visual impairment of unknown origin, including amblyopia. Glaucoma as reason for visual impairment/blindness was defined by advanced glaucomatous optic nerve damage as evaluated on the optic disc examination and IOP. Degenerative myopia was defined by a myopic refractive error of at least -6 diopters and a typical myopic maculopathy with stretching of the macula. Retinal disease encompassed diabetic retinopathy, retinal vascular disease and age-related macular degeneration (AMD). Diabetic retinopathy was present if the macula showed cystoid macular edema, hard exudates, intraretinal hemorrhages, and

Table 1 Prevalence of visual impairment and blindness in different locations

Region	Sample			Low vision			Blindness		
	n	M (%)	*F*	*n*	%	95%CI	*n*	%	95%CI
Urban	38125	18642 (48.9)	19483	374	0.99	0.88-1.10	159	0.42	0.35-0.49
Rural	87516	44093 (50.4)	43423	1139	1.30	1.22-1.38	807	0.92	0.86-0.99
Rural and urban	125641	62735 (49.9)	62906	1513	1.22	1.14-1.27	966	0.77	0.72-0.82

microaneurysms. Retinal branch vein occlusion was defined as edematous and hemorrhagic changes or partially occluded vessels with or without collaterals. Central retinal vein occlusion was characterized by edematous and hemorrhagic changes in the entire fundus, with dilated and engorged retinal veins. In contrast to diabetic retinopathy, there were not many hard exudates. AMD was characterized by degeneration or dystrophy of macular retina without any other causes such as diabetic or hypertensive retinopathy. Corneal pathology included all types of infectious keratitis, corneal degenerations and ulcers. Optic neuropathy encompassed optic neuritis, optic atrophy, papillitis and papilledema. Hereditary/congenital conditions were those diagnosed from birth or within one year of age, or with a family history. Trachoma was diagnosed according to the WHO grading system [13]. Intoxication referred to cases related to drug or chemical ingestion leading to visual disability.

The study adhered to the Declaration of Helsinki, and ethics approval was obtained from the National Survey Ethics Committee. The Survey aims were explained to all subjects prior to enrollment and written informed consent was obtained from all participants where possible. Verbal consent was obtained for any illiterate participants. After completion of enumeration and recheck in all sampled provinces, autonomous regions and municipalities directly under the Central Government, 99 sampling areas were selected randomly for re-enumeration in accordance with the Post Survey Quality Check Measures. The results of this quality assurance check revealed that the omission rate of the resident population was 1.31 per thousand, the omission rate of the disabled population was 1.12 per thousand, and the permitted error of proportion of the disabled population to the total national population is 0.97 per thousand, all within the permissions of the survey design. An evaluation on the survey procedures and data quality shows that the survey is successful and the data are reliable. Sichuan province did not show any significant deviations from this error rate.

Statistical Analysis Statistical analysis was performed using SPSS software version 11 (SPSS, Inc., Chicago, IL). Age- and gender-standardized prevalence of low vision or blindness and 95% confidence intervals were estimated via direct standardization of the study sample to the overall Sichuan province population provided by 2000 China Census.

RESULTS

Within Sichuan province, 38 counties/cities were sampled, 152 towns, 304 communities, and 40351 households, comprising a total of 125641 participants. The response rate was over 99%, potential participants who were not available in the household at the time of the enumerator's visit were re-visited at a time convenient to them to ensure maximal response. Local government and councils were also active in promoting participation in this national Chinese Government Survey. The urban population comprised 38125 participants (30.3%), and 87516 participants were sampled within the rural regions. The ethnic breakdown was as follows: Han nationality 118859 (94.6%), Yi nationality 3418 (2.72%), Tibetan 1052 (0.84%), other minority nationalities comprised 2312 (1.84%). The urban-rural age distribution and gender breakdown of the sample is shown in Table 1. The age and sex distribution of participants was different from the population of the province. People over 50 years of age were overrepresented in the sample. People between the ages of 20-29 of both sexes were under-represented in the sample in comparison to the province population. This is likely to be related to the exclusion of the police force and army personnel from the survey who falls within this age group. In addition there is likely to be economic migration of young people of working age to other provinces/cities such as Beijing, Shanghai, Guangzhou and Shenzhen.

The prevalence of visual disability (i.e. low vision and blindness combined) was 1.97% (95%CI: 1.90-2.05) (n= 2479). The prevalence of low vision was higher in the rural population (1.30%) compared to the urban population (0.99%, P<0.01). In addition, a higher prevalence of blindness was seen in the rural population compared to the urban population (0.92% *vs* 0.42%, P<0.01). Overall, visual disability was 1.40% in the urban population, and 2.22% in the rural population (P<0.01). The prevalence of visual impairment and blindness increased with increasing age in both genders (Table 2). The overall age-adjusted prevalence of visual impairment was 0.81% in males, and 1.12% in females (P <0.01). The age-standardized prevalence of blindness was 0.46% in males and 0.76% in females (P<0.01). The most marked disparities in blindness prevalence and visual impairment prevalence between the

Table 2 Prevalence of visual and impairment and blindness, by age and gender*

Gender	Age (yr)	Sample	Visual impairment *n* (%)	95%CI	Blind *n*(%)	95%CI
M	0-9	8407	6(0.07)	0.02-0.15	2(0.02)	0.002-0.08
	10-19	10020	14 (0.14)	0.07-0.23	2(0.02)	0.002-0.07
	20-29	4592	12(0.26)	0.14-0.46	8(0.17)	0.07-0.34
	30-39	10597	21(0.20)	0.12-0.30	20(0.19)	0.11-0.29
	40-49	8329	58(0.70)	0.53-0.90	27(0.32)	0.21-0.47
	50-59	9971	120(1.20)	0.99-1.44	53(0.53)	0.40-0.69
	60-69	6414	155(2.41)	2.05-2.82	68(1.06)	0.82-1.34
	70+	4405	279 (6.33)	5.63-7.09	198(4.49)	3.90-5.15
	Total *	62735	665(0.81)	0.78-0.84	378(0.46)	0.43-0.49
F	0-9	7446	4(0.05)	0.01-0.14	2(0.03)	0.003-0.09
	10-19	9242	8(0.09)	0.03-0.17	7(0.08)	0.003-0.15
	20-29	5477	7(0.13)	0.05-0.26	6(0.11)	0.04-0.23
	30-39	11325	27(0.23)	0.16-0.35	11(0.10)	0.04-0.17
	40-49	8765	57(0.65)	0.49-0.84	20(0.23)	0.14-0.35
	50-59	9742	134(1.38)	1.15-1.62	51(0.52)	0.39-0.67
	60-69	5873	191(3.27)	2.81-3.74	104(1.77)	1.44-2.14
	70+	5036	420(8.34)	7.59-9.14	387(7.68)	6.96-8.46
	Total*	62906	848(1.12)	1.09-1.23	588(0.76)	0.73-0.79
M & F	0-9	15853	10(0.06)	0.03-0.11	4(0.03)	0.007-0.06
	10-19	19262	22(0.11)	0.07-0.17	9(0.05)	0.02-0.08
	20-29	10069	19(0.19)	0.11-0.29	14(0.14)	0.07-0.23
	30-39	21922	48(0.22)	0.16-0.29	31(0.14)	0.10-0.20
	40-49	17094	115(0.67)	0.5-0.80	47(0.27)	0.20-0.37
	50-59	19713	254(1.29)	1.13-1.45	104(0.53)	0.43-0.63
	60-69	12287	346(2.82)	2.53-3.12	172(1.39)	1.20-1.62
	70+	9441	699(7.40)	6.89-7.95	585(6.19)	5.72-6.70
	Total*	125641	1513(0.96)	0.94-0.98	966(0.60)	0.58-0.62

* Standardized by age and gender to the China National Census of 2000, Sichuan population

genders were after the age of 60 years. In those aged 60-69, and those >70 years, the blindness and VI prevalence was higher in females than males (P<0.05 for all categories, data not shown). Overall, the age and gender-standardized prevalence of visual impairment was 1.22% (95%CI: 1.14-1.27), and of blindness was 0.77% (95% CI: 0.72-0.82). Overall, cataract was the cause of visual disability for over half the population (55.7%), with very similar proportions affected in both rural and urban areas. Retinal disease was the second leading cause of visual disability, however there was a significant disparity between rural and urban populations, accounting for 34.3% of visual disability in urban areas, and 2.7% in rural areas (P<0.01). Corneal pathology was the third leading cause of visual disability, and was more common in rural than urban populations (7.2% *vs* 3.9% , P =0.006). Optic neuropathy and hereditary/congenital eye diseases were the fourth and fifth leading causes respectively. The prevalence of glaucoma was similar in both urban and rural communities. Degenerative myopia was had a higher prevalence in the urban population (5.4% *vs* 2.6% , P=0.001). Trachoma accounted for 1.9% of all cases of visual disability (Table 3).

Table 3 Causes of visual disability *n*(%)

Cause	Overall	Urban	Rural
Cataract	1381 (55.7)	295 (55.3)	1086 (55.5)
Retinal disease	236 (9.5)	183 (34.3)	53 (2.7)[b]
Corneal pathology	161 (6.5)	21 (3.9)	140 (7.2)[b]
Optic neuropathy	149 (6.0)	38 (7.1)	111 (5.7)
Hereditary/congenital	117 (4.7)	23 (4.3)	94 (4.8)
Glaucoma	96 (3.9)	20 (3.8)	76 (3.9)
Degenerative myopia	79 (3.2)	29 (5.4)	50 (2.6)[b]
Trauma	66 (2.7)	19 (3.6)	47 (2.4)
Miscellaneous	65 (2.6)	7 (1.3)	58 (3.0)[a]
Trachoma	46 (1.9)	9 (1.7)	37 (1.9)
Amblyopia	43 (1.7)	13 (2.4)	30 (1.5)
Unknown	33 (1.3)	6 (1.1)	27 (1.4)
Intoxication	7 (0.3)	0	7 (0.4)
Total	2479	533	1946

[a]P<0.05, [b] P<0.01 *vs* Urban

DISCUSSION

The Second China National Sample Survey on Disability afforded an opportunity to estimate the prevalence of and causes of blindness within the Sichuan province population. In comparison to other population-based studies within China, and indeed compared to other international studies, this Survey enumerated a very large number of participants, both within rural and urban populations. The response rate was high, and all participants underwent full ophthalmic examinations by experienced ophthalmologists. This survey found the population-weighted prevalence of blindness was 0.77%, a prevalence higher than other provinces/cities of China, such as Beijing 0.49%, Shanghai 0.43%, Jiangsu 0.49%, Tianjin 0.31%, Jilin 0.22%, Guangzhou 0.20%, Shandong 0.31%, Yunnan 0.57%, Anhui 0.69%, Guangxi 0.53%. The low vision prevalence is this population was 1.22%, also higher compared to other Chinese regions such as Shandong 0.62%, Jiangsu 0.70%, Yunnan 0.66%, Jilin

0.47%, Guangxi 0.47%, and Beijing Shunyi county 0.99%. 115167 people in Shandong province were enumerated for a study that included a full ophthalmic examination by ophthalmologists, and sampled rural (83.3%) and urban populations. The prevalence of unilateral blindness in this population was similar to this study at 0.65%, but the prevalence of VI was lower at 0.64%. Cataract was the leading cause of visual disability (in rural and urban populations) followed by corneal pathology and retinal disease. The First China National Sample Survey on Disability was conducted in 1987 and permits some analysis of temporal trends of the causes of visual impairment in Sichuan: in 1987 trachoma was ranked as the second most common cause of visual disability (after cataract), and has now fallen to 9th position. Retinal disease is now the second most common cause of visual disability, having previously been ranked 5th in the First Survey. These findings are likely to relate to improved sanitation and hygiene in general across the province, however trachoma still accounts for around 2% of visual disability in both the rural and urban populations in this study.

The prevalence of VI and blindness was higher in the rural population compared to the urban population. This disparity has been noted in other population-based studies in China [4,8], however the magnitude of difference between urban and rural populations and the actual prevalence figures are highest within Sichuan. This may be partly explained by the large rural population within the province, who largely reside within agricultural environments. In the last 60 years, the economy of Chengdu (capital city of Sichuan) has developed far more rapidly than its surrounding rural areas. As a result of economic development, the accessibility and the relative affordability of eye care services is superior in the metros of Chengdu than within in rural areas. For example, there are 7 tertiary general hospitals located in the Chengdu city areas, compared with only 13 in the entirety of Sichuan County. The majority of the causes of visual disability in the study population are treatable. This may suggest that there are issues relating to lack of eye care services, or inaccessibility (or both) among rural Chinese, especially for those aged 60 years and older who are likely to require more eye care services than the younger population. Cataract was the leading causes of visual disability in both rural and urban areas, however retinal disease was far more common in the urban population, and corneal pathology was more prevalent within the rural population. It is not possible within the confines of a cross-sectional study to identify definite reasons for this, but the higher prevalence of retinal disease such as diabetic retinopathy, AMD and retinal vascular occlusive disease could be related to the differing diets and lifestyles of those who live within urban areas. Corneal pathology may be more prevalent in the rural areas due to the majority of occupations being related to agriculture, and possibly increasing the likelihood of infectious corneal disease. In addition, trachomatous corneal scarring is likely to account for some cases. A population-based study of rural and urban populations within the Beijing area [4], did not detect any difference in the frequency of cataract or glaucoma between the two populations (as in this study), but and also did not detect the differences in retinal and corneal pathology as seen within this study population. The prevalence of VI and blindness was higher in females, both before and after age-standardization. This finding is in agreement with a meta-analysis of global population-based prevalence surveys where the age-adjusted odds ratio of blind women to men was 1.4 in Asia. Literacy (as a proxy marker for education) has been found to be an important predictor of whether females in rural settings can access cataract surgery services [14], and further work is indicated to assess the association of gender with visual disability, after adjusting for education/literacy and socieconomic circumstances. The disparity in blindness prevalence was most marked after the age of 60 years, and suggests that potential intervention programs should particularly target elderly females.

There are limitations to the present study. The characteristics of the Survey participants are likely to be comparable with the general Sichuan population, however institutionalized populations (e.g. prisons and targeted schools for the blind) were not sampled. This population may have a higher prevalence of ophthalmic disease, and thus the overall estimate may have been underestimated. The age-gender breakdown of the Survey population compared to the Sichuan population revealed that people over 50 years of age were overrepresented in the sample and people between the ages of 20-29 of both sexes were under-represented (Table 2). This selection bias could mean the prevalence of VI and blindness has been over-estimated as the under-represented 20-29 age group is likely to be relatively healthy, and the older age groups that are over-represented, are more likely to have ophthalmic disease. Cataract accounted for the largest number of cases of visual disability. However, severe lens opacities may have prevented detection of any co-existent retinal or optic nerve pathology. Thus, there may have been under-detection of diabetic retinopathy, AMD, and glaucoma. The case definition for this study meant that the primary cause of visual disability was assigned to the cause that was more amenable to treatment to restore vision, and this is likely to

have been cataract surgery in many cases.

Based upon the data obtained from this study, it is estimated that 1.72 million people suffer from visual disability within Sichuan province, of which 525 000 are blind. Cataract was the leading cause of visual disability within this population, and this study suggests that within Sichuan more than 950 000 people have visual disability due to cataract. The number of cataract surgeries within the entire province in 2006 was 43 000, and estimated at approximately 50 000 to 60 000 cases annually in 2007-2008 [15]. The national CSR was estimated at 380 in 2006, and at 676 in 2008[16]. The Sichuan CSR was 491 in 2006. However, the large rural population of Sichuan means that an increase of the CSR is likely to be still necessary. Community-based measures have been shown to increase the CSR in China, but the sustainability of these activities has yet to be determined. This study highlights the need to target intervention programs for prevention of visual impairment towards the rural population, and particularly in relation to provision of and accessibility to cost-effective cataract surgery services.

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