

WORLD VIEW

Blindness and eye diseases in Tibet: findings from a randomised, population based survey

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Background: Public health officials of the Tibet Autonomous Region (TAR) of China requested a survey of blindness, eye diseases, and eye care service utilisation to assist the development of a 10 year blindness prevention and treatment plan. The objective of the survey was to determine the prevalence of blindness and visual impairment, as well as cataract surgical coverage and surgical outcome in the TAR.

Methods: The Tibet Eye Care Assessment was a cross sectional prevalence study of three of the seven prefectures (provinces) of the TAR (Lhoka, Nakchu, and Lingzhr) selected to represent its three main environmental regions. The survey sample was selected using a random multistage cluster method. Two teams conducted the survey in a standardised fashion in each prefecture, Lhoka during May and Nakchu during June 1999, and Lingzhr during May 2000. Visual acuity, cause of vision loss, trachoma, and vitamin A deficiency were included in the clinical examination.

Results: Among the 15 900 people enumerated, 12 644 were examined for an overall response rate of 79.6%. The crude prevalence of blindness (presenting better eye visual acuity of less than 6/60) was 2.3%; age and sex adjusted blindness prevalence was 1.4% (95% CI 1.3 to 1.5). Visual impairment (better eye presenting visual acuity of 6/24 to 6/60) was found in 10.9% (95% CI 10.5 to 11.2) of the population (age and sex adjusted). Cataract was the primary cause of blindness (50.7%), followed by macular degeneration (12.7%) and corneal opacity (9.7%).

Conclusion: Blindness is a serious public health problem in Tibet, with prevalence higher than in similar studies in eastern China. As elsewhere in the world, women have an excess burden of blindness compared to men. About 75% of blindness in Tibet can be either prevented or treated. Eye care planning for Tibet must focus on cataract, particularly among women.

The Tibet Autonomous Region (TAR) of the People's Republic of China, with 1.2 million square kilometres, forms one of the highest and harshest human habitations on earth. Approximately 80% of its 2.4 million people live in rural settings, either in small farming communities at elevations around 4000 metres or as semi-nomadic herders at higher elevations.

Following centuries of isolation, Tibetans have faced several decades of unprecedented exposure to foreign political and economic influence. At the same time, a growing percentage of Tibetans have moved to urban areas. An ageing Tibetan population has greatly increased demand for health care services, particularly services for the "diseases of ageing" such as stroke, diabetes, cancer, and cataract.

The high prevalence of age related cataract blindness among Tibetans is perhaps due to high altitude ultraviolet light exposure. Particular concern about this issue emerged in 1987, following the findings from a population based cataract survey of Duilong-Deqing County adjacent to Lhasa.¹ Hu *et al* reported a strikingly elevated cataract prevalence of 12-18/1000 (11.8% among people over 40 years of age). The prevalence of cataract among the Tibetans near Lhasa (altitude 4000 metres) was 60% higher than an age and sex matched population concurrently surveyed in a county near Beijing (altitude 50 metres).

Hu *et al* raised important questions regarding the prevalence of cataract among Tibetans of a relatively young age. However, the researchers sampled only a small portion of the Tibetan population and studied only cataract prevalence.

Public health officials in the TAR, who recognise the significant need for eyecare services, requested that a survey

of blindness, eye diseases (including trachoma and vitamin A deficiency), and use of eyecare services be undertaken in their region. Their goal was to use the findings in the creation of a 10 year plan aimed at addressing the primary blinding conditions of Tibet, a worldwide initiative to eliminate avoidable blindness by the year 2020. In response, the Tibet Eye Care Assessment (TECA) protocol was developed to measure blindness and visual impairment, trachoma and vitamin A deficiency, as well as cataract surgical coverage and surgical outcome in the TAR. Cataract surgical coverage and outcome will be reported separately.

METHODS

Study site

TECA was a cross sectional prevalence study of three of the seven prefectures (provinces) of the Tibet Autonomous Region, selected to represent its three main environmental regions. Lokha (population 281 738 in the 1990 census) is characterised by a lower elevation (around 3000 metres) farming communities and plains. Lingzhr (population 110 616) is at similar elevation to Lokha but with farming communities and forests. Nakchu (population 296 023) is an area of high elevation, primarily populated by nomadic herders. Each prefecture is divided into counties (about 20 000 population); counties are divided into townships ("xiangs"); and xiangs are divided into villages.

Sampling plan

The study population was selected using a random multistage cluster sampling method. The first stage of randomisation used a population proportional to size (PPS) method to select

Table 1 Prevalence of blindness (visual acuity <6/60) by prefecture

Prefecture	Age adjusted		Age and sex adjusted	
	% (95% CI)		% (95% CI)	
	Men	Women		p Value*
Lokha	0.97 (0.95 to 0.98)	1.53 (1.51 to 1.55)	1.25 (1.23 to 1.26)	0.02
Nakchu	1.44 (1.35 to 1.53)	2.09 (1.91 to 2.21)	1.75 (1.63 to 1.86)	0.13
Lingzhr	0.98 (0.95 to 1.01)	1.18 (1.10 to 1.26)	1.06 (1.01 to 1.11)	0.28
Total	1.11 (1.06 to 1.16)	1.60 (1.49 to 1.71)	1.39 (1.31 to 1.47)	<0.01

*Indicates comparison of men versus women

xiangs: 23/147 xiangs in Lokha, 25/146 in Nakchu, and 24/177 in Lingzhr. The 23 xiangs selected in Lhoka were spread over nine of 12 counties, the 25 xiangs selected in Nakchu were spread over eight of 11 counties, and the 24 xiangs selected in Lingzhr were spread over all seven counties. Within each xiang, one village (again using PPS) was selected. Forty households from each selected village (randomly sampled from village household lists) were invited to participate in the survey. With an average number of household members of five, a sample of 5000 people of all ages was anticipated from each prefecture.

Sample size

The sample size was calculated in order to estimate the prevalence of blindness (defined as better eye presenting vision of <6/60) for the adult population over 50 years of age. The a priori assumption of blindness prevalence was taken as 5% among people 50 years of age or older, based on the earlier cataract survey in which the population prevalence of blindness was estimated at 1%, and at least 5% among those 50 years of age and over. Based upon these assumptions, 455 people over 50 years of age were needed from each prefecture. Approximately 18% of the TAR population is over age 50, resulting in a total sample of at least 2528. This sample size was doubled to 5000 in each prefecture to compensate for the multistage (as opposed to a simple random sampling) method. This larger sample size also improved the assessment of use of eye care services, cataract surgical coverage, and outcome of surgery at the prefectural level; and also accommodated anticipated non-response. Overall, a total of 15 000 individuals were to be enrolled in the TECA.

Survey teams

Two teams conducted the survey in each prefecture, Lhoka during May 1999, Nakchu during June 1999, and Lingzhr during May 2000. Each team consisted of two ophthalmologists (one Tibetan trained in "Western" or allopathic medicine at a medical school in China, and the other "foreign" trained in Western medicine in India, the United States, or Canada); a "five senses" doctor (the Tibetan equivalent of a specialist in eye, ear, nose, and throat problems) who conducted visual acuity testing; a nurse who primarily acted in a clerical role; an interviewer; two enumerators; and two xiang/village assistants. The teams also included an overall team leader in charge of protocol; and two representatives, one from the prefecture health bureau, and one from the Tibet Development Fund who organised communication, transportation, and accommodation.

One of the authors (CT) acted as the lead ophthalmologist, maintaining quality control and conducting clinical examinations during the survey in all three prefectures. The same Tibetan ophthalmologists, five senses doctors, and enumeration team leaders performed the survey in all three prefectures. The nurses, interviewers, and some of the enumerators were different personnel in Lingzhr prefecture during the second year.

Field procedures

Enumeration

Under the protocol, the enumeration team was to precede the clinical team by one day. In practice, however, this arrangement varied, particularly in the more sparsely populated and geographically difficult terrain found in Nakchu. Enumerators recorded total population, number of households,

Table 2 Prevalence of blindness by age and sex by prefecture

	Nakchu	Lingzhr	Lokha	Three prefectures
	No (%)	No (%)	No (%)	No (%)
Men				
<20 years	1 (0.19)	2 (0.45)	2 (0.35)	5 (0.33)
20-29	0	2 (0.73)	1 (0.43)	3 (0.39)
30-39	1 (0.31)	0	1 (0.40)	2 (0.23)
40-49	2 (1.12)	1 (0.65)	5 (2.46)	8 (1.49)
50-59	4 (2.05)	3 (2.14)	2 (1.11)	9 (1.74)
60-69	9 (6.82)	4 (3.51)	3 (2.07)	16 (4.09)
70+	24 (33.33)	10 (12.05)	11 (18.03)	45 (20.83)
Overall	41 (2.45)	22 (1.48)	25 (1.53)	88 (1.84)
Women				
<20 years	0	1 (0.20)	1 (0.16)	2 (0.13)
20-29	0	0	1 (0.27)	1 (0.10)
30-39	1 (0.34)	0	2 (0.52)	3 (0.29)
40-49	2 (1.17)	2 (0.87)	3 (1.10)	7 (1.04)
50-59	7 (4.43)	4 (1.99)	6 (2.72)	17 (2.93)
60 to 69	9 (6.08)	4 (3.36)	12 (6.35)	25 (5.48)
70+	36 (33.33)	25 (21.37)	33 (27.73)	94 (27.32)
Overall	55 (3.33)	36 (1.98)	58 (2.68)	149 (2.64)

Table 3 Prevalence of visual impairment (visual acuity 6/24 to 6/60) by prefecture

Prefecture	Age adjusted % (95% CI)		Age and sex adjusted % (95% CI)	
	Men	Women		p Value*
Lokha	6.8 (6.7 to 6.9)	7.6 (7.4 to 7.7)	7.2 (7.1 to 7.3)	0.81
Nakchu	17.0 (16.9 to 17.1)	15.8 (15.6 to 15.9)	16.6 (16.5 to 16.7)	0.61
Lingzhr	7.7 (3.8 to 11.6)	9.9 (6.5 to 13.3)	8.7 (5.7 to 11.7)	0.85
Total	11.0 (10.6 to 11.3)	10.9 (10.5 to 11.4)	10.9 (10.5 to 11.2)	0.70

*Indicates comparison of men versus women.

distance to nearest eye care services (village, county, or prefectural doctor), sanitation and service (electricity) infrastructure, subsistence activities, and transportation options. Elevation was recorded for each village based upon available maps.

The enumerators selected 40 households from the village register book using random number cards, and developed the list of household members from the village census list. The enumerators then visited each selected household, obtained consent, and completed a household form which included further details on access to piped water, cooking facilities, latrine, electricity, and primary occupation or income generating activity of household. All household members were enumerated directly when present, or indirectly by means of questioning the people available. Empty houses were revisited. Each household received a referral slip with time and place for clinical examination. As often as possible, the enumerated individuals were escorted to the clinical examination site.

Clinical examination

Clinical examination usually occurred in a central village building. Visual acuity testing, clinical examination, and interviewing all occurred at the central site.

A five senses doctor tested presenting visual acuity separately in each eye using a "Tumbling E" chart at a distance of 6 metres. If the person was wearing glasses (for distance vision), then his/her visual acuity was measured again without glasses. If the presenting visual acuity was <6/18 in either eye, pinhole visual acuity was assessed.

Ophthalmologist examination

Ophthalmologists conducted basic eye examinations, which included visual inspection of the lid and globe, and ophthalmoscopic examination of the cornea, anterior chamber, and lens, using a slit lamp. Trachoma was graded according to the WHO simplified system.² Clinical evidence of vitamin A deficiency included assessment of Bitot spots, night blindness, conjunctival xerosis, and corneal xerosis. Ophthalmologists dilated the pupils if visual acuity was <6/18 and not the result of corneal disease or phthisis bulbi, and assessed the cause of vision loss with retinoscopy. In all cases of cataract surgery the eye was assessed for cause of a failure to reach 6/18 or better.

Training, pilot testing, and quality control

The TECA survey was preceded by 1 month of training and pilot testing (1999) and reliability testing (repeated in 2000). The lead ophthalmologist instructed the clinical team, while epidemiologists trained the interviewers, enumerators, and data managers. Before pilot studies, 2 days of field practice occurred in a village close to Lhasa where approximately 100 villagers were enumerated and examined.

Inter-rater reliability was tested between the two five senses doctors sequentially and independently in separate pilot tests in each year, 1999 and 2000. The five senses doctors achieved 92% or higher agreement on major categorisation for presenting vision in the better eye: vision 6/18 or better; 6/24 to 6/60; and vision less than 6/60. Additional training and testing occurred in the second year.

In each year, diagnostic accuracy of the ophthalmologists was tested against the senior ophthalmologist through independent examination of 50 patients with low vision and blindness. Agreement was tested for: (1) the principal cause of low vision or blindness; (2) the presence of significant cataract (causing visual acuity <6/18); and (3) the presence of trachoma and signs of vitamin A deficiency.

During the first year, reliability testing (among 50 residents) occurred in a village in Lokha prefecture, not selected for the survey. The ophthalmologists achieved 100% agreement for the basic clinical examination. They agreed in 88.2% of cases that cataract was the principal cause of low vision or blindness. The two cases where the teams disagreed were resolved through discussion. For Lingzhr, a similar test was conducted and agreement was comparable.

Accuracy was determined by observation of interviews. Inter-rater agreement was evaluated by discussion following each pilot study day.

The senior ophthalmologist (CT) actively supervised all survey teams for a week at the start of the survey in all three prefectures. Enumeration data were compared with more detailed questions asked by the interviewers for utilisation of eye care services, completed for individuals with visual impairment.

Data analysis and reporting

For data analysis and reporting, we sorted individuals into three categories according to better eye presenting visual

Table 4 Causes of blindness (visual acuity <6/60) by prefectures (% of total blindness)

Prefecture	No of blind	Cataract, not operated	Aphakia, not corrected	Corneal opacity	Macular degeneration	Glaucoma	Refractive error	Globe	Others
Lokha	84	51.2%	6.1%	10.7%	15.5%	2.4%	4.8%	6%	3%
Nakchu	96	59.0%	3.6%	9.6%	18.1%	1.2%	6.0%	0%	2.5%
Lingzhr	81	42.0%	3.7%	8.6%	13.6%	3.7%	3.7%	11.1%	13.6%
Total	261	50.7%	4.7%	9.7%	15.7%	2.5%	4.8%	5.7%	6.2%

Table 5 Comparison of blindness prevalence (visual acuity <6/60) age 50 and older, Tibet prefectures versus Shunyi and Zhongshan regions

Prefecture	Age adjusted % (95% CI)		Age and sex adjusted % (95% CI)
	Men	Women	
Lokha	4.0 (3.3 to 4.7)	8.7 (7.5 to 9.9)	6.7 (5.7 to 7.7)
Nakchu	11.2 (9.4 to 13.0)	19.2 (16.1 to 22.3)	15.5 (13.0 to 18.0)
Lingzhr	4.1 (1.8 to 6.4)	6.3 (5.2 to 7.4)	5.2 (4.5 to 5.9)
Total	7.5 (6.6 to 8.4)	14.2 (12.0 to 16.4)	10.9 (9.3 to 12.5)
Shunyi ⁵	1.7	3.5	2.8 (2.4 to 3.1)
Zhongshan ⁴	2.9	3.5	4.4 (3.8 to 4.9)

acuity: vision 6/18 or better; 6/24 to 6/60; and vision less than 6/60. Blindness was defined as a presenting visual acuity (in the better eye) of less than 6/60 (<20/200 or <0.10) according to Chinese Ministry of Public Health guidelines. Visual impairment was defined as a presenting visual acuity (in the better eye) of 6/24 to and including 6/60.

Prevalence estimates were calculated, with 95% confidence intervals, for the three major visual acuity categories, as well as for the most common causes of blindness and low vision: cataract, corneal opacities, refractive error, and disorganised globe. Prefecture specific and overall prevalence estimates were calculated. Tibet census data were used to adjust the overall prevalence estimates for age and sex. We used Mantel-Haenzel χ^2 test to evaluate age and sex differences in blindness prevalence.³

The cataract blindness prevalence estimates include operated and unoperated individuals. Unoperated cataract blind were defined as bilaterally blind individuals with cataract as the principal cause of blindness in at least one eye. Operated cataract blind patients were assumed bilaterally blind at the time of operation if both eyes had undergone surgery, or if the unoperated eye was blind at the time of surgery.

RESULTS

Population sampled, enumerated, and examined

All randomly selected clusters were identified and examined in Lhoka and Nakchu, 23 and 25 clusters, respectively. However, in remote areas in both prefectures, a degree of substitution of villages occurred because the survey team faced considerable difficulty identifying individual villages by name. In Lingzhr, the survey team substituted three of the seven counties (constituting 43% of the sampled population) because of heavy rains and poor road conditions. They substituted randomly selected clusters from the remaining available areas to achieve the targeted number of enumerated people.

Of the 15 900 enumerated people, 12 644 were examined for an overall response rate of 79.6%; highest in Nakchu (81.4%) and lowest in Lingzhr (76.9%). The response was highest among women (82.7%) than men (75.7%), and 86% among people over age 50 years.

Blindness and visual impairment

The crude prevalence of blindness (presenting visual acuity of less than 6/60) was 2.3%. The age and sex adjusted prevalence of blindness shown in Table 1 was 1.39% (95% CI 1.31 to 1.47). As expected, blindness increased with age; as shown in Table 2, residents over 70 years of age accounted for 58.6% of all blindness (51% for men and 63% for women). If the three selected prefectures are representative of Tibet's 2.4 million residents, there are approximately 27 600 who are blind. Using the WHO definition of blindness (<3/60 or <20/400, or <0.05), the age and sex adjusted prevalence of blindness was 0.89% (95% CI 0.84 to 0.94). Women had a significantly higher prevalence of blindness, at 1.02% (95% CI 0.95 to 1.09) than men, at 0.76% (95% CI 0.72 to 0.80).

Visual impairment (better eye presenting visual acuity of 6/24 to 6/60), was found in 10.9% (95% CI 10.5 to 11.2) of the population (age and sex adjusted). It was significantly higher in Nakchu compared to other prefectures (Table 3).

Causes of blindness

Cataract was the most common cause of blindness, accounting for 50.7% of all cases. The second leading cause of blindness was macular degeneration (15.7%), followed by corneal opacity (9.7%) (Table 4). Treatable causes of blindness (cataract, uncorrected aphakia, and refractive error) accounted for approximately 60% of the total cases. Preventable causes of blindness (most corneal opacities and globe related conditions such as phthisis bulbi) accounted for approximately 16% of the total. As there is no practical treatment for macular degeneration, we estimate that

Table 6 Comparison of visual impairment (visual acuity 6/24–6/60) prevalence age 50 and older, Tibet prefectures versus Shunyi and Zhongshan regions

Prefecture	Age adjusted % (95% CI)		Age and sex adjusted % (95% CI)
	Men	Women	
Lokha	39.6 (38.6 to 40.6)	36.9 (36.1 to 37.8)	38.1 (37.5 to 38.8)
Nakchu	76.9 (71.0 to 83.0)	67.1 (61.0 to 73.0)	72.8 (70.0 to 76.1)
Lingzhr	27.5 (21.6 to 33.4)	42.1 (39.4 to 44.8)	42.1 (38.3 to 45.9)
Total	49.9 (47.0 to 52.8)	47.5 (44.2 to 50.8)	48.5 (46.1 to 50.9)
Shunyi ⁵	16.0	20.0	18.2
Zhongshan ⁴	NA	NA	25.5

NA = data not available.

about 75% of blindness in Tibet could be either prevented or treated.

In the working age population (age 15–50), 25 individuals were found to be blind, of whom 36% were blind due to cataract, 20% due to refractive error, 16% due to corneal opacity, 8% due to globe, and 20% due to other causes. Among the 2080 children under 15 years of age only eight, 0.39% (95% CI 0.17 to 0.76) were blind, four due to cataract, two due to corneal opacity, and one each due to disrupted globe and others. Based on TECA findings, approximately 1100 children in Tibet are blind, among whom one half could have been or could be corrected with cataract surgery.

There were only 34 children (0.3%) with evidence of clinical vitamin A deficiency (Bitot spots, night blindness or corneal xerosis). Vitamin A deficiency was similar in all three prefectures. We found no clinical cases of trachoma, either active or cicatricial.

Cataract was defined as a white or grey pupil and a visual acuity of $<6/18$ without a central corneal opacity, in a person who was examined with a retinoscope. For the purposes of this study, a patient with a history of cataract surgery in either or both eyes was also defined as a cataract patient. The prevalence of cataract was 5.2% overall and 13.8% for people over age 50.

DISCUSSION

The prevalence of blindness found in Tibet is higher than that reported for other regions of China, Zhongshan (Guangdong Province)⁴ and Shunyi (Beijing Province).⁵ Comparing people 50 years of age and older, blindness prevalence in the TAR is about three times that of these provinces (Table 5). In all three studies, women over age 50 had about twice the prevalence of blindness as men, similar to survey findings from other settings.⁶

The two surveys from Zhongshan⁴ and Shunyi³ also provided visual impairment findings, for people over age 50 years. The prevalence of visual impairment in the TAR is about twice that found in the Zhongshan and Shunyi studies (Table 6).

Unoperated cataract accounted for half of all blindness in Tibet, similar to the studies in Zhongshan (61.5%) and Shunyi (45.7%). The higher prevalence of cataract in Tibet¹ is likely to be the primary reason for the higher blindness prevalence in Tibet compared to Shunyi or Zhongshan. Cataract prevalence for people over age 40 is 9.6%, which is slightly less than the prevalence reported by Hu *et al* of 11.8%.

Because cataract prevalence increases with age, the number of blind and visually impaired people is likely to increase in the TAR as life expectancy rises, unless specific interventions are implemented to address the problem.

Nakchu, the highest and most remote prefecture, was found to have the highest prevalence of blindness and visual impairment, compared to Lokha and Lingzhr. The cause of this increased prevalence remains unclear from the TECA data. The prevalence of cataract (both operated and unoperated) was higher in Nakchu than in Lokha and Lingzhr, but this was not statistically significant. The lack of statistical significance is likely to be a reflection of insufficient study power to detect the small differences between prefectures.

There is little clinical evidence of vitamin A deficiency. However, our sample of children was inadequate to provide reliable estimates. Since isolated instances of vitamin A deficiency were found, further investigation is warranted in certain districts. Current vitamin A deficiency interventions (nutrition education and vitamin A capsule distribution) should continue. Although reported by Tibetan colleagues as a leading cause of eye disease, trachoma related corneal disease is not a cause of blindness in Tibet. This does not

preclude the possibility of small foci of disease. It should be noted that the WHO simplified grading of trachoma, not generally practised in China, is more restrictive than the Chinese grading system.

Several limitations may affect the reliability of our study. Approximately 80% of the enumerated sample were examined ($>85\%$ in the 50+ age group). Under-represented were people living in the most inaccessible terrain and/or at the extremes of altitude. These people may have a high prevalence of eye diseases and visual impairment. Also under-represented were younger men working away from their village at the time of enumeration. Family members provided what were considered to be reliable estimates of the visual function of these absentee household members: almost all were (reasonably) considered not to have significant visual impairment. In a number of villages in Lokha, it was suggested that there had been some substitution of households, thus breaking randomisation. However, follow up enumeration and examination of individuals in these villages during the following year did not substantiate broken randomisation concerns.

In summary, blindness and visual impairment are significant public health problems in the TAR, with the most elderly having rates of blindness between 12% (Lingzhr men) and 33% (Nakchu men and women). As recognised in many settings,⁶ women in Tibet bear two thirds of the burden of blindness. Excess prevalence was not related to age, as women in all older (50+ years) age groups had a higher prevalence of blindness compared to men.

Based in part on the TECA findings, in June 2002 the TAR Health Bureau launched a master plan to increase the quality and quantity of eye care services in the TAR for the next 10 years. Focusing first on cataract, the master plan follows the framework outlined in both the World Health Organization's Vision 2020 "The Right To Sight", and the Chinese national "Blindness Prevention and Eye Care" documents. Targets have been set and funds directed, largely from foreign agencies working in Tibet, to improve the skill of Tibetan eye care professionals through further training and supervision. In addition, community based educational and promotion programmes are planned to improve knowledge and use of services, particularly by women.

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