Prevalence and Risk Factors of Refractive Error in Qinghai, China: A Cross-Sectional Study in Han and Tibetan Adults in Xining and Surrounding Areas

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Abstract

Background Our study aimed to explore the prevalence and risk factors of refractive error (RE) in Han and Tibetan population aged 50-79 years in Xining and surrounding areas in Qinghai Province on Qinghai-Tibet Plateau.

Methods As part of the China National Health Survey, our cross-sectional study compared the age-adjusted prevalence of RE in Han and Tibetan elder adults aged 50-79 years in Xining and surrounding areas. A multivariate logistic regression model was used to identify risk factors for myopia and hyperopia.

Results Among 769 Han participants and 476 Tibetan participants, the age-adjusted prevalence of myopia, hyperopia, high myopia and astigmatism were 28.56%, 22.82%, 2.80%, and 69.38%. Han population have higher age-adjusted prevalence of myopia (32.93% vs 21.64%, p<0.001), high myopia (3.93% vs 1.02%, p=0.001) and astigmatism (72.14% vs 64.94%, p=0.021) compared to Tibetan population. Being Tibetan is the protective factor of myopia compared to being Han (OR 0.58, 95%CI 0.42-0.79, p<0.001). Elder age (p=0.032), longer time length in rural area (p=0.048), undergraduate/graduate education level (p=0.031), lighter active level (p=0.007) and lower BMI index (p=0.015) are risk factors for myopia. Elder age (all p<0.001) and pterygium status of the same eye (p=0.013) also increases the hyperopia risk.

Conclusions Our study found an overall prevalence of myopia of 28.56% in Xining and surrounding areas in adults elder than 50 years. Han population has higher myopia risk than Tibetan population. More medical and social resources should be allocated to improve the vision and life quality of elder adults.

Background

Refractive error (RE) affects billions of people and uncorrected RE is the most important cause of the visual impairment worldwide(1). RE could decrease life quality massively and impose a heavy social and economic burden(2). Higher prevalence of myopia was reported in countries of East Asia including China, Japan and Korea compared to other regions. Social and economic factors are closely associated with the incidence of myopia(3). Pan CW summarized the worldwide patterns and trends for the myopia prevalence and found that the prevalence of myopia in children has been reported higher in Chinese ethnicity, while such racial difference is not so obvious in elder adult populations(4). Additionally, myopia, particularly high myopia, could considerably increase the risk of complications including myopic maculopathy(5), retinal detachment and open-angle glaucoma(6), of which the risk is even higher in elder adults(7).

Located on the Qinghai-Tibet Plateau, Qinghai is one of the widest provinces in China with average altitude higher than 3000 meters(8). No epidemiological study has investigated the prevalence of RE in adults in Qinghai. Tibetan is one of the largest ethnic minorities in China, mainly living on Qinghai-Tibet Plateau(9). Before the Chinese economic reform (1978), Tibetan population were less influenced by Eastern China politically and economically, and kept living in pastoral settings and small farming communities due to its remote and plateau location(9). In 1999, Dunzhu S et al. reported 2–3 folds higher prevalence of blindness and severe vision loss of Tibetans in Tibet compared to other Chinese areas in adults aged over 50 years(10). Considering that RE rarely causes blindness, this study did not further investigate the prevalence of RE in Tibet. In 2017, higher prevalence of blindness was again confirmed in Tibetan compared to Han population (2.2% vs 0.6% $p < 0.05$) in Kandze Tibetan Autonomous Prefecture in Sichuan Province. Moreover, 83% of early visual impairment could be avoided by providing refractive services according to this study(11). However, the specific prevalence and risk factors of RE is not investigated.

According to the most recent international population report, the distribution of people elder than 65 years would increase from 8.5% (617 million) in 2015 to 16.7% (1600 million) in 2050(12). More attention and more investigation should be paid to improve the medical care and health conditions of the elder adults. Limited epidemiological researches were related the prevalence of RE in Chinese elder adults and most of them were in eastern regions. The prevalence of myopia varies from 9.5% (Southern Harbin Eye Study, 2009, n = 4979, age ≥ 50y)(13) to 32.3% (Liwan Eye Study, 2009, n = 1269, age ≥ 50y) (14).

Our study is part of the China National Health Survey conducted by Chinese Academy of Medical Science. As the capital city of Qinghai Province, Xining is located on the plateau with the average altitude of 2261 meters(8). By investigating the prevalence and risk factors of RE in Tibetan and Han adults elder than 50 years in Xining and surrounding areas, our study aims to provide epidemiological data of Tibetan and Han elder adults in plateau areas.

Methods

Study population

To evaluate the physiological constant and health condition of Chinese, the Chinese Academy of Medical Sciences conducted the China National Health Survey (CNHS)(15). The part reported in this study was conducted in Qinghai Province in 2015. According to the level of urbanization, six locations were randomly chosen for sampling in this cross-sectional study, including two in a large city (Teaching hospital of Qinghai University and the Revenue Agency of Chengxi District in Xining), one in a medium city (Qiabuqia, the capital of Hainan State), two county seats (the County Hospitals of Guide County and Hualong County), and one relatively less developed location (the Town of Jiangxigou in Gonghe County). All these locations are within 160 km from Xining City. This study was conducted according to the tenets of the Declaration of Helsinki. The ethics approval was received from the bioethical committee of the Institute of Basic Medical Sciences, the Chinese Academy of Medical Sciences. After full explanation of the nature and possible consequences of the study, every participant gave their written informed consent.

Inclusive and exclusive criteria

Cluster sampling method was used in China National Health Survey. Only participants with both Han parents or Tibetan parents were included in our study. The ratio of participants of Han and Tibetan in our study is similar to the natural proportion of the population in Qinghai Province. Only people who had lived in their current residence for more than 1 year were included. Psychiatric patients, pregnant women and active duty soldiers were excluded. Of 1417

participants aged 50–79 years old included in our study, 1245 participants were included in the final analysis. Data of participants who failed to complete both questionnaire or eye examination and who have experienced cataract or myopic surgery was excluded.

Data collection

Questionnaire and routine physical examination

During a comprehensive interview by our well-trained interviewers, a questionnaire about demographic information and health history was collected. Information about age, sex, ethnicity of the participants and their parents, birthplace, current residence, migration date, education level, occupation, income per month, smoking and drinking practice, occupational and leisure-time physical activity, and medical history including hypertension and diabetes status were included in our questionnaire. An assessment of height, weight, blood pressure, and fasting blood-glucose was included in routine physical examinations. Height was measured to the nearest 0.1 cm using a fixed stadiometer and in a standing position by bioelectrical impendence analysis with a commercially available body composition analyzer (BC-420, TANITA, Japan) with participants in light clothes. Body mass index (BMI) was calculated using the formula weight (kg)/height $(m)^2$. A digital automatic blood pressure monitor was used after resting 10 minutes and the average of three measurements was recorded to measure systolic and diastolic blood pressure. Blood samples were drawn after fasting overnight for at least 8 hours, and then immediately processed, refrigerated, transferred and assessed in the lab in the General Hospital of Chinese Peoples' Liberation Army, Beijing.

Eye examination

Eye examinations on our participants were performed by well-trained ophthalmologists. A logarithm of the minimum angle of resolution E chart (Wehen Co., Ltd., Guangzhou, China) was used for visual acuity measurement at 4 meters. An auto ref-keratometer (ARK-510A, Nidek Co., Ltd., Tokyo, Japan) was used to measure noncycloplegic refraction and corneal curvature radium. The anterior segment of eyes was examined with a portable hand-held slit-lamp (KJ5S2, Suzhou Kangjie Medical Co. Ltd., Jiangsu, China).

Stratification Standard

All participants were divided into 4 age groups, which were 50–54, 55–59, 60–64, 65 and over years old. Education level was divided into three groups including primary school and lower, middle/high school, and undergraduate/graduate. Occupation information was divided into close-workers and non close-workers. Participants were divided into never-smokers and ever-smokers (including current smokers and former smokers) according to tobacco consumption. Additionally, participants were divided into never-drinkers and ever-drinkers (including current drinkers and former drinkers). We merged occupational and leisure-time physical activity into active level and regrouped it into low, moderate and high active level (16).

Definitions of RE

In our study, myopia was defined as spherical equivalent (SE) <-0.5D, and hyperopia was defined as SE > 0.5D. High myopia was defined as SE<-6.0D. Astigmatism was defined as > = 0.5D of the cylinder.

Statistics

High correlation between right and left eyes was found in our study (Spearman correlation test, $p < 0.001$, $r = 0.824$). We concluded similar statistical analysis results between right and left eyes and only reported results of the right eye for concision. Chi-square test and t test were used to compare the demographic differences between Han and Tibetan participants. Linear regression model was used to compare the SE and RE prevalence among different age groups. The difference of RE distributions between ethnicities among different age groups was tested with a chi-square test. The risk factors for RE were identified with multivariate logistic regression analysis. The age-standardized prevalence was based on the Sixth National Population Census of the People's Republic of China. A p value less than 0.05 was considered significant. Statistical analysis was done using Stata version 15.1, and figures were created using GraphPad Prism 7.0a.

Results

Characteristics of Han and Tibetan adults

1245 participants aged 50–80 years old, including 769 Han participants and 476 Tibetan participants were included in the final analysis (Table 1). The age composition was similar between Han and Tibetan population ($p = 0.658$). No difference was found in cigarette consumption ($p = 0.127$), hypertension ($p = 0.065$) and pterygium ($p = 0.395$) between Han and Tibetan population. However, Tibetan population have heavier weight and higher BMI compared to Han population (all $p < 0.001$). More participants of Tibetan ethnicity were born and now live in rural area and therefore have longer time length spent in rural areas (all $p < 0.001$). Moreover, more Han participants are influenced by diabetes (13.13% vs 8.61%, $p = 0.015$), and more participants of Han ethnicity are with moderate and heavy active level (light: 11.18% vs 17.23%; moderate: 73.86% vs 70.80%; heavy: 14.95% vs 11.97%; $p = 0.006$).

Table 1
Characteristics of Han and Tibetan participants

	Han n = 769	%	Tibetan n = 476	%	P value
Sex					0.035
Male	376	48.89	262	55.04	
Female	393	51.11	214	44.96	
Age (y)					0.658
50–54	359	46.68	207	43.49	
55–59	145	18.86	96	20.17	
60–65	136	17.69	94	19.75	
65+	129	16.78	79	16.60	
Height (cm)	162.37		163.00		0.205
Weight (kg)	63.99		68.34		< 0.001
BMI (kg/m^2)	24.22		25.62		< 0.001
Current Residence					< 0.001
Urban	528	68.66	200	42.02	
Rural	241	31.34	276	57.98	
Birth Place					< 0.001
Urban	167	21.72	28	5.88	
Rural	602	78.28	448	94.12	
Time spent in rural areas	33.48		47.48		< 0.001
Education					< 0.001
Primary school or lower	327	42.52	355	74.58	
Middle/high school	292	37.97	74	15.55	
Undergraduate/graduate	150	19.51	47	9.87	
Occupation					< 0.001
Non-close	420	54.62	361	75.84	
Close	349	45.38	115	24.16	
Income (¥)					< 0.001
< 800/month	273	35.50	285	59.87	
800–2000/month	165	21.46	88	18.49	
> 2000/month	331	43.04	103	21.64	
Hypertension	315	40.96	170	35.71	0.065
Diabetes	101	13.13	41	8.61	0.015
Smoking					0.127
Never	471	61.25	312	65.55	
Past/current	298	38.75	164	34.45	
Drinking					< 0.001
Never	360	46.81	291	61.13	
Past/current	409	53.19	185	38.87	
Activity level					0.006
Light	86	11.18	82	17.23	
Moderate	568	73.86	337	70.80	

	Han n = 769	%	Tibetan n = 476	%	P value
Heavy	115	14.95	57	11.97	
Pterygium	59	7.67	43	9.03	0.395

Prevalence of RE in Han and Tibetan population

The age-adjusted prevalence of myopia, hyperopia, high myopia and astigmatism in our study were 28.56% (95%CI 25.77%-31.35%), 22.82% (95%CI 20.13%-25.52%), 2.80% (95%CI 1.85%-3.74%), and 69.38% (95%CI 66.71%-72.06%), as presented in Table 2. Higher age-adjusted prevalence of myopia (32.93% vs 21.64%, p < 0.001), high myopia (3.93% vs 1.02%, p = 0.001) and astigmatism (72.14% vs 64.94%, p = 0.021) was found in Han population compared to Tibetan population. The age-adjusted prevalence of hyperopia is similar between Han and Tibetan populations (23.04% vs 22.48%, p = 0.313).

Table 2
Crude and age-adjusted prevalence of refractive error

	N	Crude rate	Age-adjusted rate	95%CI lower	95%CI upper	P value
Myopia						
Total	373	29.96%	28.56%	25.77%	31.35%	< 0.001
Han	274	35.63%	32.93%	29.28%	36.58%	
Tibetan	99	20.80%	21.64%	17.46%	25.82%	
Hyperopia						
Total	228	18.31%	22.82%	20.13%	25.52%	
Han	136	17.69%	23.04%	19.57%	26.51%	0.313
Tibetan	92	19.33%	22.48%	18.20%	26.75%	
High myopia						
Total	42	3.37%	2.80%	1.85%	3.74%	
Han	36	4.68%	3.93%	2.51%	5.35%	0.001
Tibetan	6	1.26%	1.02%	0.06%	1.98%	
Astigmatism						
Total	803	64.50%	69.38%	66.71%	72.06%	
Han	515	66.97%	72.14%	68.87%	75.40%	0.021
Tibetan	288	60.50%	64.94%	60.38%	69.49%	

Distribution of RE and SE in different age groups

Participants involved in the final analysis were divided into four age groups including 50–54,55–59、60–64, and 65 and over years old. The mean SE increases in Han population with aging (Linear regression: slope = 0.059, p = 0.011). The SE in Tibetan population shows an increasing trend with aging although without statistical significance (Linear regression: slope = 0.009, p = 0.807). The prevalence of hyperopia increases with aging in both Han and Tibetan participants (Han p = 0.047, Tibetan p = 0.046). No linear relationship was found in the prevalence of myopia with age. The U-shaped curve was noticed in the prevalence of myopia in different age groups in both Han and Tibetan population (Fig. 1A). Difference was found in the distribution of myopia, hyperopia and emmetropia in 50–54 and 55–59 age groups between Han and Tibetan ethnicity (50–54 p < 0.001, 55–59 p < 0.001) (Fig. 1B).

Risk factors of myopia and hyperopia

A multivariate logistic regression with 10 indicators was used to identify risk factors of myopia and hyperopia and results were presented in Table 3, Fig. 2 and Fig. 3. Ethnicity affects the risk of myopia and being Tibetan is the protective factor of myopia compared to being Han (OR 0.58, 95%CI 0.42–0.79, p < 0.001). However, Ethnicity is not the risk of hyperopia in Han population compared to Tibetan population (OR 0.93, 95%CI 0.65–1.33, p = 0.688).

Table 3
Results of multivariate logistic regression of refractive errors in Han and Tibetan

	Myopia				Hyperopia				High myopia				Astigmatism	
	Odds Ratio	95%CI lower	95%CI upper	P value	Odds Ratio	95%CI lower	95%CI upper	P value	Odds Ratio	95%CI lower	95%CI upper	P value	Odds Ratio	95%CI lower
Ethnicity	0.58	0.42	0.79	0.000	0.93	0.65	1.33	0.688	0.40	0.15	1.10	0.077	0.78	0.59
Sex	1.20	0.77	1.86	0.421	0.85	0.52	1.38	0.502	1.88	0.60	5.90	0.279	1.22	0.85
Age period														
50–54	1.00				1.00				1.00				1.00	
55–59	1.11	0.76	1.61	0.599	2.92	1.81	4.71	0.000	0.53	0.18	1.59	0.260	1.62	1.17
60–64	1.17	0.77	1.78	0.460	5.24	3.27	8.39	0.000	0.62	0.20	1.95	0.415	2.29	1.60
65+	1.60	1.04	2.45	0.032	6.46	3.92	10.65	0.000	0.53	0.15	1.86	0.322	4.29	2.80
Time in rural area	0.99	0.99	1.00	0.048	1.00	0.99	1.00	0.323	0.99	0.97	1.01	0.510	0.99	0.99
Education														
<=primary school	1.00				1.00				1.00				1.00	
middle/High school	0.99	0.66	1.48	0.965	1.34	0.85	2.13	0.209	0.34	0.10	1.15	0.082	1.01	0.71
undergraduate/graduate	1.82	1.06	3.13	0.031	0.77	0.33	1.79	0.547	0.57	0.14	2.30	0.431	1.05	0.63
Occupation	1.26	0.84	1.89	0.260	0.81	0.50	1.32	0.400	1.63	0.51	5.24	0.414	0.79	0.55
Active level	0.69	0.53	0.91	0.007	0.82	0.60	1.12	0.210	1.03	0.45	2.32	0.950	0.89	0.71
BMI	0.95	0.91	0.99	0.015	0.99	0.94	1.03	0.556	1.01	0.91	1.12	0.820	1.00	0.97
Pterygium	0.90	0.52	1.56	0.709	1.92	1.15	3.22	0.013	0.26	0.03	2.14	0.210	1.50	0.93
Smoking	1.16	0.75	1.80	0.496	0.98	0.60	1.61	0.942	0.41	0.11	1.53	0.187	1.33	0.92

Note: Multivariate logistic regression model with 10 indicators including ethnicity, sex, age period, rural level, education level, occupation, active level, BMI, pte of the same eye, and smoking practice was used to assess risk factors for myopia, hyperopia, high myopia and astigmatism. Myopia and hyperopia results v to emmetropic individuals. High myopia results were compared to individuals with light or moderate myopia. OR of ethnicity was Tibetan/Han. OR of sex wa OR of occupation was close-workers/non close-workers. OR of Pterygium was the eye with pterygium/eye without pterygium. OR of smoking was individual smoked/individual never smoked.

For myopia, compared to participants aged 50–54 years, those aged 65+ (OR 1.60, 95%CI 1.04–2.45, p = 0.032) years have higher risk of myopia. Longer time length in rural area is a protective factor for myopia (p = 0.048). Compared to those with primary school or lower education level, those with undergraduate or graduate education level have much higher possibility to be influenced by myopia (OR 1.82, 95%CI 1.06–3.13, p = 0.031). Myopia is also associated to active level (OR 0.69, 95%CI 0.53–0.91, p = 0.007) and BMI index (OR 0.95, 95%CI 0.91–0.99, p = 0.015).

Age is notably related to the incidence of hyperopia. Compared to those who aged 50–54 years, the elder who aged 55–59, 60–64, 65+ (all p < 0.001) years have much higher risk of hyperopia. Elder group have higher OR and the OR for age group 65 + years reaches 6.46 (95%CI 3.92–10.65). Moreover, the pterygium status of the same eye also increases the hyperopia risk (OR 1.92, 95%CI 1.15–3.22, p = 0.013).

Spectacle coverage rate

Among 373 participants of myopia in both Han and Tibetan in our study, only 67 of them wear glasses (17.96%). There are 274 Han participants with myopia, and 58 of them wear glasses (21.17%). However, only 9 of 99 Tibetan with myopia wear glasses (9.09%). The spectacle coverage rate of myopia participants in Han is particularly higher than that in Tibetan (p = 0.007).

Discussion

Myopia prevalence in elder adults of Han population in Qinghai and other areas

Our study is the first study investigating RE prevalence in elder adults in Qinghai. The age adjusted myopia prevalence is as high as 28.56% in Xining and surrounding area in Han and Tibetan population of 50–79 years old. The myopia prevalence in Han population is significantly higher than that in Tibetan population (32.93% vs 21.64%). Interestingly, studies in more developed areas in Eastern China and Southeastern Asia focusing on Han population found similar prevalence of myopia (Table 4). Up to now, there are limited number of epidemiological studies about RE in elder adults in China (13, 14, 17–23). The highest prevalence of myopia was observed in Liwan Eye Study in 2009, 32.3% in 1269 adults elder than 50 years(14), while the prevalence of myopia in Han population in our study is 32.93%. Although it is hard to compare the myopia prevalence among studies with massive variety in the age distribution of the participants and urban and rural settings, the prevalence of myopia we found in Han population in Xining and surrounding area is not low.

Table 4
Comparison of reported prevalence of RE in selected population-based studies nationally and internationally

Studies	n	Population	Age (y)	Myopia (%)	Myopia SE	High myopia (%)	High myopia SE	Hyperopia (%)	Hyperopia SE
CNHS Inner Mongolia Study, 2019(17)	2090	Chinese (Han/Mongolian)	40–80	29.4	<-0.5D	3.6	<-6D	28.4	> 0.5D
CNHS Yunnan Study, 2019(18)	1626	Chinese (Han/Yi)	40–80	26.4	<-0.5D	2.6	<-6D	19.9	> 0.5D
Handan Eye Study, 2009 (19)	6491	Chinese	30–86	26.7	<-0.5D	1.8%	<-5D	15.9	> 0.5D
Beijing Eye Study, 2006(20)	4319	Chinese	40–90	22.9	<-0.5D	2.6	<-6D	NR	NR
Liwan Eye Study, 2009(14)	1269	Chinese	≥ 50	32.3	<-0.5D	5.0	<-5D	40.0	> 0.5D
Shihpai Eye Study, 2003(21)	1361	Chinese	≥ 65	19.4	<-0.5D	2.4	<-6D	59.0	> 0.5D
Shanghai Eye Study, 2017(22)	6099	Chinese	≥ 50	22.8	<-0.5D	4.6	<-6D	48.5	> 0.5D
Suzhou Rural Eye Study, 2017(23)	4795	Chinese	≥ 60	23.5	<-0.5D	2.1	<-6D	NR	NR
Rural Southern Harbin Eye Study, 2009(13)	4979	Chinese	≥ 50	9.5	<-0.5D	NR	NR	8.9	> 0.5D
Tanjong Pagar Study, 2000(30)	1232	Chinese (Singapore)	40–79	38.7	<-0.5D	9.1	<-5D	28.4	> 0.5D
Singapore Longitudinal Aging Study, 2011(42)	1727	Chinese (Singapore)	55–85	30.8	≤-0.5D	NR	NR	41.1	≥ 1D
Chinese American Eye Study, 2017(48)	4144	Chinese (American)	≥ 50	35.1	<-0.5D	7.4	<-5D	40.2	> 0.5D
Tajimi Study, 2008(49)	3021	Japanese	≥ 40	41.8	<-0.5D	8.2	<-5D	27.9	> 0.5D
Hisayama Study, 2019(26)	2936	Japanese	≥ 40	45.8	<-0.5D	9.5	<-5D	NR	NR
Namil Rural Study, 2013(50)	1215	Korean	≥ 40	20.5	<-0.5D	1.0	<-6D	41.8	> 0.5D
Singapore Malay Eye Study, 2008(31)	2974	Malay (Singapore)	40–79	26.2	<-0.5D	3.9	<-5D	27.4	> 0.5D
Singapore Indian Eye Study, 2011(51)	2805	Indian (Singapore)	40–79	28.0	<-0.5D	4.1	<-5D	35.9	> 0.5D
Andhra Pradesh Eye Disease Study, 2009(52)	3642	Indian	40–92	34.6	<-0.5D	4.5	<-5D	18.4	> 0.5D
Indian Study of Age-related Eye Disease, 2018(53)	3267	Indian	≥ 40	35.6	≤-0.75D	2.0	≤-6D	30.3	≥ 0.5D
Meiktila eye study, 2008(54)	1863	Burmese	≥ 40	42.7	<-1D	6.5	<-6D	15.0	> 1D
Six Villages in Sumatra, 2002(32)	358	Indonesian	≥ 40	34.1	≤-0.5D	NR	NR	32.1	≥ 0.5D
Shahroud Eye Cohort Study, 2012(55)	4864	Iranian	40–64	30.2	≤-0.5D	1.9	<-6D	35.6	> 0.5D
Mongolian Eye Study, 2004(56)	1617	Mongolian	≥ 40	17.2	<-0.5D	NR	NR	49.9	> 0.5D
National Health and Nutrition Examination Survey, 2008(57)	7357	American	≥ 40	31.0	≤-1D	6.0	≤-5D	5.3	≥ 3D

NR = not reported

Studies	n	Population	Age (y)	Myopia (%)	Myopia SE	High myopia (%)	High myopia SE	Hyperopia (%)	Hyperopia SE
Multi-Ethnic Study of Atherosclerosis, 2013(58)	4430	American	45–84	25.1	≤-1D	4.6	≤-5D	38.2	≥ 1D
Los Angeles Latino Eye Study, 2006(59)	5927	Latinos (American)	≥ 40	16.8	≤-1D	2.4	≤-5D	NR	NR
Barbados Eye Study, 1999(60)	4709	Barbados-born Black adults	40–84	21.9	<-0.5D	NR	NR	46.9	> 0.5D
Victoria Visual Impairment Project, 1999(61)	4532	Australian	40–98	17.0	<-0.5D	2.1	<-5D	37.0	> 0.5D
NR = not reported									

Three potential reasons could lead to such similarity in the prevalence of myopia between our study and other studies in more developed areas. Firstly, located on the Qinghai-Tibet Plateau, residents in Xining and surrounding area experience severer ultraviolet exposure, which could lead to higher occurrence of cataract(24). The prevalence of age-related cataract in Lhasa, the capital city of Tibet with altitude of 4000 meters, is 60% higher than that in plain areas(25). Higher incidence of cataract due to high altitude could cause the myopia shift and therefore increase the prevalence of myopia. Secondly, the prevalence of myopia increases a lot in elder adults recently. The Hisayama Study in Japan noticed the significant increase of the myopia incidence in elder adults in Hasayama, from 37.7% in 2005 to 45.8% in 2017 (p for trend < 0.001). Moreover, the prevalence of high myopia increased from 5.8% in 2005 to 9.5% in 2017(26). Similarly, the Chinese Eye Study in Singapore also pointed out that the prevalence of myopia and high myopia increases dramatically in elder adults compared to that in Tanjong Pagar Survey 12 years earlier(27). With the constantly increasing prevalence of myopia in adolescent, it is reasonable to see higher prevalence of myopia in elder adults considering the aging of the population. The known prevalence of myopia as references in elder adults were collected years ago, which could have been already increased nowadays. Thirdly, with the China Western Development policy, the difference of social and economic environment between Western China and Eastern China, which is closely related to myopia occurrence, is getting much smaller. Moreover, Xining and surrounding areas are most developed region on Qinghai-Tibet Plateau, which might explain the similar prevalence of myopia in our study and in Eastern China. More medical resources should be paid to monitor the vision of local residents in Western China, and medical staff should be cautious of myopic complications considering the comparable prevalence of myopia.

The impact of ethnicity on the prevalence of RE

The prevalence of myopia, high myopia and astigmatism in Han population is significantly higher than that in Tibetan population. After adjusted by sex, age, time length in rural area, education level, occupation, active level, BMI, pterygium, and smoking condition, the risk of myopia in Han population is considerably higher than that in Tibetan population ($p < 0.001$). Our research group also found that in Inner Mongolia, the myopia risk is significantly higher in Han population than Mongolian population, which is one of the biggest ethnic minorities in China(17). After investigating 10333 Chinese, Indian and Malaysian in Singapore, Pan CW found that Chinese is easier to be affected by myopia, high myopia and astigmatism compared to Indian and Malaysian(27). The Chinese population in Singapore are mostly Han population. In our study, Han population have higher risk of myopia than Tibetan. However, considering that there are still many other factors such as genetic background, eating habit, and sleeping time length and so on(8), the difference of the myopia risk between Han and Tibetan population might be the results of genetic and environmental variance.

The prevalence of myopia is lower in Tibetan population but the incidence of the uncorrected myopia is much higher compared to Han population. Uncorrected refractive error is the most important reason of visual impairment worldwide(28). The incidence of uncorrected RE is excessive in elder population in China, and the incidence of uncorrected myopia is even higher(29). Therefore, to improve the visual quality and life quality of elder people, government and medical service provider should pay extra attention to the correction of RE in elder population.

The result of the multivariate logistic regression did not show any difference between the risk of hyperopia in Han and Tibetan population. The occurrence of hyperopia might be much more influenced by age, and could be similar among different ethnic populations.

The change of prevalence of myopia and hyperopia with aging

The distribution of myopia, hyperopia and emmetropia varies significantly in Han and Tibetan population aged 50–54 years and 55–59 years. However, in people elder than 60 years, no difference was noticed between these two ethnic populations. The prevalence of hyperopia increases massively with aging in both Han and Tibetan population. With aging process, the incidence of cataract and hyperopia increases and the effect of the refractive conditions in younger period of life would be less after 60 year. Higher odds ratio of hyperopia is found with elder age, which is correspond with normal process of aging (14).

Meanwhile, we noticed the U-shaped curve of the prevalence of myopia in people elder than 50 years in both Han and Tibetan population. Such U-shaped curve was similarly found in Tanjong Pajar study in Singapore(30), Malaysian Eye Study in Singapore(31), Handan Eye Study(19), and Sumatra Study in Indonesia(32). The risk of myopia first decreases with aging but started to increase after 65 years old. The prevalent nuclear and posterior subcapsular cataract are significantly associated with myopia(33). Therefore, the association between aging and myopia could be related to the myopic shift due to cataract(34).

Other risk factors of myopia and hyperopia

Shorter time length in rural area, higher education level, lighter active level and lower BMI are risk factors for myopia in our study. Similar study conducted by our team in Inner Mongolia of China also found that longer time length in rural area decrease the risk of myopia($p < 0.001$)(17). A study in Beijing with 681

students showed a much lower risk of myopia in rural area compared to that under urban settings (OR 0.17, $p < 0.001$)(35). Similarly, the risk of myopia in inner city region with higher population concentration was found to exceed that in outer suburban region in another study including 2367 Australian children(17.8% vs 6.9%)(36). The higher education level is widely considered to be related to higher incidence of myopia, which was proved again in our study. The excessive use of eyes might explain the higher risk of myopia in population with higher education level(1, 4, 17, 37). Terasaki H et al noticed the association between BMI and ocular length(38). The body structure especially the height is correlated to the ocular length(39–43). Lower BMI is the risk factor of myopia in our study, which might be explained by the influence of BMI on the ocular length.

Pterygium is another risk factor of hyperopia in our study apart from age, which was also found in the study conducted by our team in Inner Mongolia and Yunnan(17, 18). Eyes with hyperopia tend to have thinner cornea and sclera, but thicker conjunctiva, which might increase the risk of pterygium(44–46). Pterygium would also drag the cornea and make it flatter, which increase the occurrence of hyperopia. Meanwhile, the association between pterygium and aging(47) might also increase the association between pterygium and hyperopia.

Limitation

Our study was conducted mainly in Xining, the capital city of Qinghai, and surrounding areas, which cannot show the overall picture of the RE condition in plateau regions. As a cross-sectional study, our study cannot prove the causality between risk factors and RE. Therefore, more longitudinal studies including cohort study and prospective study are highly recommended in the future.

Conclusions

Located on the remote Qinghai-Tibet Plateau, Qinghai Province is mainly composed of Han and Tibetan population, with no previous epidemiological research about RE in elder adults. In our study, an overall prevalence of myopia of 28.56% was found in Xining and surrounding areas in adults elder than 50 years. Han population has higher myopia risk than Tibetan population. Elder age, shorter time length in rural area, lighter active level, and lower BMI are risk factors of myopia. Elder age and pterygium increase the risk of hyperopia. The myopia prevalence of elder adults in relatively developed regions in Western China was not as low as expected. More medical and social resources should be allocated to improve the vision and life quality of elder adults.

List Of Abbreviations

Body mass index: BMI

China National Health Survey: CNHS

Confidence interval: CI

Odds ratio: OR

Refractive error: RE

Spherical equivalent: SE

Declarations

Ethics approval and consent to participate: This study was conducted according to the tenets of the Declaration of Helsinki. Ethics approval was received from the bioethics committee of the Institute of Basic Medical Sciences, the Chinese Academy of Medical Sciences. Written informed consent was obtained from every participant after a full explanation of the nature and possible consequences of the study.

Consent for publication: Not applicable

Availability of data and material: Not applicable

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: MW analysed and interpreted the data and drafted the manuscript. LG, JC, TC, XW, YW, ZL, SC, AY, WL, GJ, and XH assisted with the acquisition of the data. GS, LP, YZ and JM designed the study. GS and HH helped develop the statistical method. LG, JM revised the final manuscript. All authors read and approved the final manuscript.

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References

1. Wojciechowski R. Nature and nurture: the complex genetics of myopia and refractive error. Clin Genet. 2011;79(4):301–20.
2. Charman WN, Radhakrishnan H. Peripheral refraction and the development of refractive error: a review. Ophthalmic Physiol Opt. 2010;30(4):321–38.

3. Foster PJ, Jiang Y. Epidemiology of myopia. Eye (London, England). 2014;28(2):202–8.
4. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. Ophthalmic Physiol Opt. 2012;32(1):3–16.
5. Bullimore MA, Brennan NA. Myopia Control: Why Each Diopter Matters. Optom Vis Sci. 2019;96(6):463–5.
6. Ikuno Y. Overview of the Complications of High Myopia. Retina. 2017;37(12):2347–51.
7. Fang Y, Yokoi T, Nagaoka N, Shinohara K, Onishi Y, Ishida T, et al. Progression of Myopic Maculopathy during 18-Year Follow-up. Ophthalmology. 2018;125(6):863–77.
8. Information encyclopedia on the development of western China. Beijing: China Planning Press; 2003.
9. Tabulation on the 2010 population cesus of the People's Republic of China. http://wwwstatsgovcn/tjsj/pcsj/rkpc/6rp/indexchhtm. 2010.
10. Dunzhu S, Wang FS, Courtright P, Liu L, Tenzing C, Noertjojo K, et al. Blindness and eye diseases in Tibet: findings from a randomised, population based survey. Br J Ophthalmol. 2003;87(12):1443–8.
11. Jiachu D, Jiang F, Luo L, Zheng H, Duo J, Yang J, et al. Blindness and eye disease in a Tibetan region of China: findings from a Rapid Assessment of Avoidable Blindness survey. BMJ Open Ophthalmol. 2018;3(1):e000209.
12. Schwartz M. Neuroprotection as a treatment for glaucoma: pharmacological and immunological approaches. European journal of ophthalmology. 2003;13 Suppl 3:S27-31.
13. Li Z, Sun D, Cuj H, Zhang L, Lju P, Yang H, et al. Refractive error among the elderly in rural Southern Harbin, China. Ophthalmic Epidemiol. 2009;16(6):388–94.
14. He MG, Huang WY, Li YT, Zheng YF, Yin QX, Foster PJ. Refractive Error and Biometry in Older Chinese Adults: The Liwan Eye Study. Invest Ophth Vis Sci. 2009;50(11):5130–6.
15. He H, Pan L, Pa L, Cui Z, Ren X, Wang D, et al. Data Resource Profile: The China National Health Survey (CNHS). Int J Epidemiol. 2018;47(6):1734–5 f.
16. Shan G, Wei D, Wang C, Zhang J, Wang B, Ma M, et al. Trends of overweight and obesity in Yi people between 1996 and 2007: an Yi migrant study. Biomed Environ Sci. 2011;24(5):467–74.
17. Wang M, Ma J, Pan L, Chen T, Wang HL, Wang YH, et al. Prevalence of and risk factors for refractive error: a cross-sectional study in Han and Mongolian adults aged 40–80 years in Inner Mongolia, China. Eye (London, England). 2019;33(11):1722–32.
18. Wang M, Cui J, Shan G, Peng X, Pan L, Yan Z, et al. Prevalence and risk factors of refractive error: a cross-sectional Study in Han and Yi adults in Yunnan, China. Bmc Ophthalmol. 2019;19(1):33.
19. Liang YB, Wong TY, Sun LP, Tao QS, Wang JJ, Yang XH, et al. Refractive errors in a rural Chinese adult population the Handan eye study. Ophthalmology. 2009;116(11):2119–27.
20. Xu L, Li J, Cui T, Hu A, Fan G, Zhang R, et al. Refractive error in urban and rural adult Chinese in Beijing. Ophthalmology. 2005;112(10):1676–83.
21. Cheng CY, Hsu WM, Liu JH, Tsai SY, Chou P. Refractive errors in an elderly Chinese population in Taiwan: the Shihpai Eye Study. Invest Ophthalmol Vis Sci. 2003;44(11):4630–8.
22. He J, Lu L, He X, Xu X, Du X, Zhang B, et al. The Relationship between Crystalline Lens Power and Refractive Error in Older Chinese Adults: The Shanghai Eye Study. Plos One. 2017;12(1):e0170030.
23. Xu C, Pan C, Zhao C, Bi M, Ma Q, Cheng J, et al. Prevalence and risk factors for myopia in older adult east Chinese population. Bmc Ophthalmol. 2017;17(1):191.
24. Modenese A, Gobba F. Cataract frequency and subtypes involved in workers assessed for their solar radiation exposure: a systematic review. Acta Ophthalmol. 2018;96(8):779–88.
25. Hu TS, Zhen Q, Sperduto RD, Zhao JL, Milton RC, Nakajima A. Age-related cataract in the Tibet Eye Study. Arch Ophthalmol. 1989;107(5):666–9.
26. Ueda E, Yasuda M, Fujiwara K, Hashimoto S, Ohno-Matsui K, Hata J, et al. Trends in the Prevalence of Myopia and Myopic Maculopathy in a Japanese Population: The Hisayama Study. Invest Ophthalmol Vis Sci. 2019;60(8):2781–6.
27. Pan CW, Zheng YF, Anuar AR, Chew M, Gazzard G, Aung T, et al. Prevalence of refractive errors in a multiethnic Asian population: the Singapore epidemiology of eye disease study. Invest Ophthalmol Vis Sci. 2013;54(4):2590–8.
28. Naidoo KS, Leasher J, Bourne RR, Flaxman SR, Jonas JB, Keeffe J, et al. Global Vision Impairment and Blindness Due to Uncorrected Refractive Error, 1990–2010. Optometry Vision Sci. 2016;93(3):227–34.
29. Kuang TM, Tsai SY, Liu CJ, Ko YC, Lee SM, Chou P. Seven-year incidence of uncorrected refractive error among an elderly Chinese population in Shihpai, Taiwan: The Shihpai Eye Study. Eye (London, England). 2016;30(4):570–6.
30. Wong TY, Foster PJ, Hee J, Ng TP, Tielsch JM, Chew SJ, et al. Prevalence and risk factors for refractive errors in adult Chinese in Singapore. Invest Ophthalmol Vis Sci. 2000;41(9):2486–94.
31. Saw SM, Chan YH, Wong WL, Shankar A, Sandar M, Aung T, et al. Prevalence and risk factors for refractive errors in the Singapore Malay Eye Survey. Ophthalmology. 2008;115(10):1713–9.
32. Saw SM, Gazzard G, Koh D, Farook M, Widjaja D, Lee J, et al. Prevalence rates of refractive errors in Sumatra, Indonesia. Invest Ophthalmol Vis Sci. 2002;43(10):3174–80.
33. Pan CW, Cheng CY, Saw SM, Wang JJ, Wong TY. Myopia and age-related cataract: a systematic review and meta-analysis. Am J Ophthalmol. 2013;156(5):1021-33 e1.
34. Pan CW, Cheng CY, Saw SM, Wang JJ, Wong TY. Myopia and Age-Related Cataract: A Systematic Review and Meta-analysis. American Journal of Ophthalmology. 2013;156(5):1021–33.

35. Guo Y, Liu LJ, Xu L, Lv YY, Tang P, Feng Y, et al. Outdoor Activity and Myopia among Primary Students in Rural and Urban Regions of Beijing. Ophthalmology. 2013;120(2):277–83.
36. Ip JM, Rose KA, Morgan IG, Burlutsky G, Mitchell P. Myopia and the urban environment: findings in a sample of 12-year-old Australian school children. Invest Ophthalmol Vis Sci. 2008;49(9):3858–63.
37. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. Lancet. 2012;379(9827):1739–48.
38. Terasaki H, Yamashita T, Yoshihara N, Kii Y, Sakamoto T. Association of lifestyle and body structure to ocular axial length in Japanese elementary school children. Bmc Ophthalmol. 2017;17(1):123.
39. Huang CY, Hou CH, Lin KK, Lee JS, Yang ML. Relationship of lifestyle and body stature growth with the development of myopia and axial length elongation in Taiwanese elementary school children. Indian J Ophthalmol. 2014;62(8):865–9.
40. Northstone K, Guggenheim JA, Howe LD, Tilling K, Paternoster L, Kemp JP, et al. Body Stature Growth Trajectories during Childhood and the Development of Myopia. Ophthalmology. 2013;120(5):1064-+.
41. Guo Y, Liu LJ, Xu L, Lv YY, Tang P, Feng Y, et al. Outdoor activity and myopia among primary students in rural and urban regions of Beijing. Ophthalmology. 2013;120(2):277–83.
42. Tan CS, Chan YH, Wong TY, Gazzard G, Niti M, Ng TP, et al. Prevalence and risk factors for refractive errors and ocular biometry parameters in an elderly Asian population: the Singapore Longitudinal Aging Study (SLAS). Eye (London, England). 2011;25(10):1294–301.
43. Saw SM, Chua WH, Hong CY, Wu HM, Chia KS, Stone RA, et al. Height and its relationship to refraction and biometry parameters in Singapore Chinese children. Invest Ophthalmol Vis Sci. 2002;43(5):1408–13.
44. Linke SJ, Steinberg J, Eddy MT, Richard G, Katz T. Relationship between minimum corneal thickness and refractive state, keratometry, age, sex, and. left or right eye in refractive surgery candidates. J Cataract Refract Surg. 2011;37(12):2175–80.
45. Jonas JB, Xu L. Histological changes of high axial myopia. Eye. 2014;28(2):113–7.
46. Mimura T, Usui T, Yamagami S, Funatsu H, Noma H, Toyono T, et al. Relationship between conjunctivochalasis and refractive error. Eye Contact Lens. 2011;37(2):71–8.
47. Chen T, Ding L, Shan G, Ke L, Ma J, Zhong Y. Prevalence and racial differences in pterygium: a cross-sectional study in Han and Uygur adults in Xinjiang, China. Invest Ophthalmol Vis Sci. 2015;56(2):1109–17.
48. Varma R, Torres M, McKean-Cowdin R, Rong F, Hsu C, Jiang X, et al. Prevalence and Risk Factors for Refractive Error in Adult Chinese Americans: The Chinese American Eye Study. Am J Ophthalmol. 2017;175:201–12.
49. Sawada A, Tomidokoro A, Araie M, Iwase A, Yamamoto T, Tajimi Study G. Refractive errors in an elderly Japanese population: the Tajimi study. Ophthalmology. 2008;115(2):363–70 e3.
50. Yoo YC, Kim JM, Park KH, Kim CY, Kim TW, Namil Study Group KGS. Refractive errors in a rural Korean adult population: the Namil Study. Eye (London, England). 2013;27(12):1368–75.
51. Pan CW, Wong TY, Lavanya R, Wu RY, Zheng YF, Lin XY, et al. Prevalence and risk factors for refractive errors in Indians: the Singapore Indian Eye Study (SINDI). Invest Ophthalmol Vis Sci. 2011;52(6):3166–73.
52. Krishnaiah S, Srinivas M, Khanna RC, Rao GN. Prevalence and risk factors for refractive errors in the South Indian adult population: The Andhra Pradesh Eye disease study. Clin Ophthalmol. 2009;3:17–27.
53. Joseph S, Krishnan T, Ravindran RD, Maraini G, Camparini M, Chakravarthy U, et al. Prevalence and risk factors for myopia and other refractive errors in an adult population in southern India. Ophthalmic Physiol Opt. 2018;38(3):346–58.
54. Gupta A, Casson RJ, Newland HS, Muecke J, Landers J, Selva D, et al. Prevalence of refractive error in rural Myanmar: the Meiktila Eye Study. Ophthalmology. 2008;115(1):26–32.
55. Hashemi H, Khabazkhoob M, Jafarzadehpur E, Yekta AA, Emamian MH, Shariati M, et al. High prevalence of myopia in an adult population, Shahroud, Iran. Optom Vis Sci. 2012;89(7):993–9.
56. Wickremasinghe S, Foster PJ, Uranchimeg D, Lee PS, Devereux JG, Alsbirk PH, et al. Ocular biometry and refraction in Mongolian adults. Invest Ophthalmol Vis Sci. 2004;45(3):776–83.
57. Vitale S, Ellwein L, Cotch MF, Ferris FL, 3rd, Sperduto R. Prevalence of refractive error in the United States, 1999–2004. Arch Ophthalmol. 2008;126(8):1111–9.
58. Pan CW, Klein BE, Cotch MF, Shrager S, Klein R, Folsom A, et al. Racial variations in the prevalence of refractive errors in the United States: the multi-ethnic study of atherosclerosis. Am J Ophthalmol. 2013;155(6):1129-38 e1.
59. Tarczy-Hornoch K, Ying-Lai M, Varma R, Los Angeles Latino Eye Study G. Myopic refractive error in adult Latinos: the Los Angeles Latino Eye Study. Invest Ophthalmol Vis Sci. 2006;47(5):1845–52.
60. Wu SY, Nemesure B, Leske MC. Refractive errors in a black adult population: the Barbados Eye Study. Invest Ophthalmol Vis Sci. 1999;40(10):2179–84.
61. Wensor M, McCarty CA, Taylor HR. Prevalence and risk factors of myopia in Victoria, Australia. Arch Ophthalmol. 1999;117(5):658–63.