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ARTICLE

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

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Abstract

Objectives To assess the prevalence of and risk factors for refractive error (RE) in Han and Mongolian adults aged 40–80 years in Inner Mongolia in China and to identify ethnic differences in RE between these populations.

Methods Our cross-sectional study is part of the China National Health Survey (CNHS). The age-adjusted prevalence of RE in Han and Mongolian adults aged 40–80 in Inner Mongolia were compared. A multivariable logistic regression model was used to identify risk factors.

Results Among 2090 people, the age-adjusted prevalence of myopia (SE < −0.5D), hyperopia (SE > 0.5D), high myopia (SE < −6.0D) and astigmatism (cylinder ≥ 0.5D) were 29.4% (95% confidence interval (CI), 27.4–31.3%), 28.4% (95% CI, 26.4–30.5%), 3.6% (95% CI, 2.8–4.4%) and 65.9% (95% CI, 63.9–67.9%), respectively. The age-adjusted prevalence of myopia in the Han population was higher than that in the Mongolian population (31.8% vs. 23.0%, $p < 0.001$), but the prevalence of hyperopia was lower (25.8% vs. 35.3%, $p = 0.002$). In the multivariable logistic regression, ethnicity was associated with myopia ($p = 0.001$) and hyperopia ($p = 0.001$). Myopia was also associated with age, time spent in rural areas ($p < 0.001$) and middle/high school and undergraduate/graduate education levels ($p = 0.027$ and $p < 0.001$, respectively, compared with lower education levels). Additionally, age, height ($p = 0.015$) and pterygium ($p = 0.014$) were associated with hyperopia.

Conclusions Ethnicity is closely related to RE in Inner Mongolia in mainland China. Our study investigates differences in prevalence of and risk factors for RE between the Han and Mongolian populations, which could not be explained by differences in the risk factors investigated in this study.

Introduction

Refractive error (RE) is one of the most common ocular disorders. A review exploring the prevalence of RE between

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1990 and 2010 indicated that 108 million people worldwide are affected by RE [1]. According to a study in the United States from 1999 to 2002 that involved 13,265 people aged 12 years and older, RE accounts for nearly 80% of visual impairments [2]. RE is considered to be the fourth priority within the policies of VISION 2020 regarding combating visual dysfunction [3].

In the past few decades, environmental factors have been widely believed to be associated with the development of myopia [4, 5]. A number of single-nucleotide

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polymorphisms (SNPs) have been identified to be associated with myopia, but most of them are not conclusively related to myopia [6]. The prevalence of myopia varies worldwide [7]. It is unknown whether the different distributions of RE are the result of different racial genetic backgrounds or culture-specific environmental influences [8]. The Chinese population is composed of individuals of Han ethnicity (91.51%) and 55 ethnic minorities [9]. The Inner Mongolia Autonomous Region is located in Northern China, and Han and Mongolian individuals constitute 96% of the population in Inner Mongolia. As a typical nomadic people mainly living in Mongolia and northern China, Mongolians are critical in the culture and genetic admixture of modern Eurasia through the rapid expansion of the Mongolian Empire 1000 years ago [10]. The previous data of our health survey revealed that the risk of hypertension was higher in the Mongolian population than in the Han population in Inner Mongolia [11]. Other studies have suggested that in the Mongolian population, the risk of cardiovascular diseases is higher than in the Han population [12, 13], but the risk of stroke is lower [14]. Moreover, there is some evidence suggesting that the difference in the risk of diseases might be based on the genetic heterogeneity [15–17] and different lifestyles such as dietary habits [18] between the Han and Mongolian populations.

The Mongolian population in Inner Mongolia in Mainland China have the same ethnic background and similar lifestyles as people in Mongolia. A national health survey performed in Mongolia involving 1800 Mongolian people revealed that the prevalence of myopia (defined as a spherical equivalent (SE) $< -0.5D$) was 17.2%, which was much lower than that in other East Asian populations, such as Chinese Singaporeans, in whom the prevalence was 38.7% [19]. One article published in 2015 compared central corneal thickness and curvature between Han and Mongolian populations in Inner Mongolia, and no difference was found [20]. Until now, no study has compared the prevalence of and risk factors for RE between Han and Mongolian populations in the same region. Our study is the first a cross-sectional study to compare the prevalence of RE in Han and Mongolian populations in Inner Mongolia in mainland China and further investigate the risk factors for myopia and hyperopia.

Materials and methods

Study population

The China National Health Survey (CNHS) was conducted by the Chinese Academy of Medical Sciences to evaluate the Chinese Physiological Constant and Health Condition. The part we reported on in this study was conducted in the Inner Mongolia Autonomous Region in 2014. According to the level of urbanisation, four locations were randomly chosen for sampling, including a large city (Hohhot, 40.83°N), a midsize city (Jining District of Ulanqab League, 41.03°N), county seats (Wuyuan County of Bayannur City, 40.10°N; West Ujimqin Banner of Xilingol League, 44.58°N) and relevant rural sections. Sampling details can be found in the report of CNHS [21]. This study was conducted according to the tenets of the Declaration of Helsinki. Ethical approval was received from the Bioethics Committee at the Chinese Academy of Medical Sciences. Written informed consent was obtained from each participant after a full explanation of the nature and possible consequences of the study was provided.

Inclusion and exclusion criteria

The cluster sampling method was used in the CNHS. The ratio of Han to Mongolian participants was similar to the natural proportion of the population distribution in the Inner Mongolian Autonomous Region. As part of the National Health Survey, our study included 2222 participants aged 40–80 years old, and 2090 of them completed a questionnaire, a routine physical examination and eye examination. We only recruited people who had lived in their current residence for more than 1 year and excluded psychiatric patients, pregnant women and active-duty soldiers. Only participants with both Han parents or both Mongolian parents were included in our study.

Data collection

Questionnaire and routine physical examination

A questionnaire regarding demographic information and health history was administered during a comprehensive interview conducted by trained interviewers. The questionnaire collected information about age, sex, ethnicity, occupation, birthplace, current residence, migration date, education level, smoking and drinking history, occupational and leisure-time physical activity, and medical history, including hypertension and diabetes status. Routine physical examinations included assessments of height, weight, blood pressure, and fasting blood glucose. Height was measured to the nearest 0.1 cm using a fixed stadiometer, and weight was measured to the nearest 0.1 kg in a standing position via bioelectrical impendence analysis (BIA) with a commercially available body composition analyser (BC-420, TANITA, Japan) with the participants wearing light clothes. Systolic and diastolic blood pressure were measured with a digital automatic blood pressure monitor, and the average of three measurements was recorded. After fasting overnight for at least 8 h, blood samples were drawn, immediately processed, refrigerated,

transferred and assessed at the laboratory of the General Hospital of Chinese Peoples' Liberation Army in Beijing. Body mass index (BMI) was calculated using the formula weight (kg)/height (m)^2.

Ocular examination

Ocular examinations were performed by two well-trained ophthalmologists with no significant differences in the consistency testing performed in the preliminary study. Visual acuity was measured with a logarithm of the minimum angle of resolution E chart (Wehen Co., Ltd., Guangzhou, China) at 4 metres and recorded together with whether the corrective lenses were used. An Auto Ref/ Keratometer (ARK-510A, Nidek Co., Ltd., Tokyo, Japan) was used to measure noncycloplegic refraction and corneal curvature radius. The anterior segment of the eye was examined with a portable hand-held slit-lamp (KJ5S2, Suzhou Kangjie Medical Co. Ltd., Jiangsu, China).

Stratification standards

All participants were divided into 5 age groups (40–44, 45–49, 50–54, 55–59, and older than 60 years). Participants were divided into three groups based on education level, including primary school or less, middle/high school and undergraduate/graduate.

In terms of smoking history, participants were divided into never smokers and ever-smokers (which included current smokers and former smokers). Similarly, participants were divided into two categories regarding alcohol consumption: never-drinkers and ever-drinkers. Occupational and leisure-time physical activity were merged into activity level, which was categorised as three levels: low, moderate and high activity.

Definitions of RE

In our study, myopia was defined as $SE < -0.5D$, and hyperopia was defined as $SE > 0.5D$. Astigmatism was defined as ≥0.5D of the cylinder. Myopia was further divided into mild, moderate and high (mild and moderate: $SE \geq -6.0D$; high: $SE < -6.0D$).

Statistical analysis

There was a high correlation between right and left eyes (Spearman's correlation test, $p < 0.0001$, $r = 0.872$). Similar results between right and left eyes were found during the statistical analysis; thus, only the results from the right eye were reported for conciseness. The χ^2 test and Mann–Whitney U test were used to compare the demographic differences between Han and Mongolian populations. The χ^2 test was used to evaluate the differences in RE distributions between ethnicities among different age groups. The age-standardised prevalence was based on the Sixth National Population Census of the People's Republic of China. Multivariable logistic regression analysis was performed to identify the risk factors for RE. Multiple logistic regression models were developed with RE as a dichotomous dependent variable and relevant predictors as covariates. The potential risk or protective factors considered were ethnicity, age, sex, height, time spent in rural areas, education level, activity level, presence of pterygium and smoking habits. Indicators were chosen for the potential association with RE according to previous reports. Height has been indicated to be related to axial length [22–26]. It remains controversial whether nicotine intake is a protective factor or a risk factor for RE [27–29]. All coefficients were adjusted for other covariates that were included in the multiple logistic regression analysis. Analysis of all the participants was conducted first, and then separate analyses of Han and Mongolian populations were performed.

All probabilities were two-sided and were considered statistically significant at $p < 0.05$. Statistical analysis was performed using Stata/SE 15.1 (StataCorp, USA) and Statistical Analysis System (SAS) version 9.4; figures were created using Prism 7.0a (Graphpad Software Inc, USA).

Results

Characteristics of Han and Mongolian adults

According to the inclusion and exclusion criteria, 2090 participants aged 40–80 years were involved in the final analysis (Table 1). The age composition and height distribution were similar between the Han and Mongolian populations in both sexes. A greater percentage of Han individuals than Mongolian individuals were currently living (male, 90.80% vs. 84.81%, $p = 0.012$; female, 92.37% vs. 88.76%, $p = 0.043$) or were born (male, 46.99% vs. 17.30%, $p < 0.0001$; female, 47.55% vs. 26.33%, $p < 0.0001$) in an urban area.

Prevalence of RE in Han and Mongolian populations

The age-adjusted prevalence of myopia, hyperopia, high myopia and astigmatism were 29.4% (95% confidence interval (CI), 27.4–31.3%), 28.4% (95% CI, 26.4–30.5%), 3.6% (95% CI, 2.8–4.4%) and 65.9% (95% CI, 63.9–67.9%), respectively. The prevalence of different types of RE differed between Han and Mongolian populations. The age-adjusted prevalence of myopia and high myopia were higher in the Han population than in the Mongolian population (myopia, 31.8% vs. 23.0%,

Table 1 Characteristics of 2090 participants

	Male			Female		
	Han n = 598	Mongolian n = 237	P-value	Han n = 917	Mongolian n = 338	P-value
Age (y)	54.13 ± 9.50	53.61 ± 9.20	0.510	51.92 ± 9.14	51.72 ± 8.63	0.994
Age range			0.506			0.962
40–44	100 (16.72)	43 (18.14)		232 (25.30)	83 (24.56)	
45–49	125 (20.90)	47 (19.83)		213 (23.23)	84 (24.85)	
50–54	112 (18.73)	55 (23.21)		169 (18.43)	64 (18.93)	
55–59	98 (16.39)	38 (16.03)		110 (12.00)	37 (10.95)	
60+	163 (27.26)	54 (22.78)		193 (21.05)	70 (20.71)	
Height (cm)	169.53 ± 5.82	169.45 ± 6.46	0.773	157.55 ± 5.41	157.68 ± 5.71	0.635
Weight[a] (kg)	73.02 ± 11.82	75.81 ± 13.47	0.005	61.65 ± 9.38	63.93 ± 9.77	<0.0001
BMI[a] (kg/m^2)	25.37 ± 3.62	26.36 ± 4.05	0.001	24.82 ± 3.47	25.73 ± 3.88	<0.0001
Current residence			0.012			0.043
Urban	543 (90.80)	201 (84.81)		847 (92.37)	300 (88.76)	
Rural	55 (9.20)	36 (15.19)		70 (7.63)	38 (11.24)	
Birthplace			<0.0001			<0.0001
Urban	281 (46.99)	41 (17.30)		436 (47.55)	89 (26.33)	
Rural	317 (53.01)	196 (82.70)		481 (52.45)	249 (73.67)	
Time spent in rural areas[b] (y)	16.84 ± 20.22	26.88 ± 19.80	<0.0001	16.04 ± 19.12	22.59 ± 19.10	<0.0001
Education			0.004			<0.0001
Primary school or less	74 (12.37)	28 (11.81)		207 (22.57)	63 (18.64)	
Middle/high school	329 (55.02)	103 (43.46)		552 (60.20)	157 (46.45)	
Undergraduate/ graduate	195 (32.61)	106 (44.73)		158 (17.23)	118 (34.91)	
Hypertension	263 (43.98)	123 (51.90)	0.039	303 (33.04)	130 (38.46)	0.073
Diabetes[c]	77 (12.88)	30 (12.66)	0.932	70 (7.65)	15 (7.84)	0.046
Smoking status			0.011			<0.0001
Never	143 (23.91)	77 (32.49)		881 (96.07)	305 (90.24)	
Past or current	455 (76.09)	160 (67.51)		36 (3.93)	33 (9.76)	
Alcohol consumption			0.008			0.0005
Never	138 (23.08)	35 (14.77)		782 (85.28)	260 (76.92)	
Past or current	460 (76.92)	202 (85.23)		135 (14.72)	78 (23.08)	
Activity level			0.002			0.690
Light	14 (2.34)	0 (0.00)		25 (2.73)	8 (1.39)	
Moderate	489 (81.77)	215 (90.72)		848 (92.48)	310 (91.30)	
Heavy	95 (15.89)	22 (9.28)		44 (4.80)	20 (7.30)	

[a]Thirteen participants were missing weight and BMI data

[b]Fourteen participants were missing questionnaire data regarding relocation dates

[c]Three participants were missing blood glucose data; hypertension is marked when average systolic blood pressure ≥140 mmHg or average diastolic blood pressure ≥90 mmHg

The χ^2 test and Mann–Whitney test were used to evaluate the demographic differences between Han and Mongolian people

$p < 0.001$; high myopia, 4.4% vs. 1.5%, $p = 0.003$), but the prevalence of hyperopia was lower in the Han population than in the Mongolian population (25.8% vs. 35.3%, $p = 0.002$) (details in Supplemental Table 1).
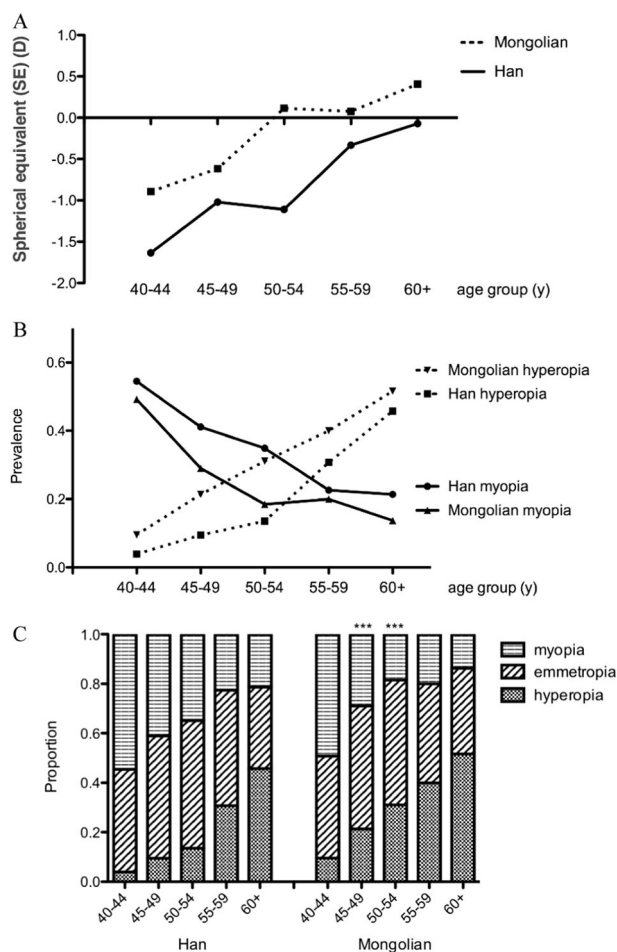
Distribution of RE in different age groups

Participants involved in the final analysis were divided into five age groups: 40–44, 45–49, 50–54, 55–59 and 60+ years old. The mean SE increased with age in both Han and Mongolian populations (Fig. 1a). The incidence of myopia decreased with age in both Han and Mongolian populations, while the incidence of hyperopia increased (Fig. 1b). The distribution of RE in the age groups from 45–49 ($p = 0.001$) and 50–54 years ($p < 0.001$) was different in Han and Mongolian participants (Fig. 1c).

Risk factors for RE in all participants

A multivariable logistic regression model was used to identify the risk factors for RE, and the results are presented in Table 2 and Fig. 2. Mongolian participants were less likely to have myopia than Han participants (odds ratio (OR), 0.63; 95% CI, 0.49–0.82; $p = 0.001$) after adjusting for age, sex, height, time spent in rural areas, education level, activity level, presence of pterygium in the same eye, and smoking habits. Participants aged 45–49 years (OR, 0.65; 95% CI, 0.49–0.87; $p = 0.003$), 50–54 years (OR, 0.47; 95% CI, 0.34–0.64; $p < 0.001$) and 55–59 years (OR, 0.46; 95% CI, 0.32–0.68; $p < 0.001$) had a lower risk of myopia than those aged 40–44 years. The length of time spent in rural areas (OR, 0.99; 95% CI, 0.98–0.99; $p < 0.001$) was identified as a protective factor against myopia. Conversely, a higher education level was found to be a risk factor for myopia. Compared with the ORs of participants with an education level of primary school or less, the OR for those with a middle/high school education level was 1.52 (95% CI, 1.05–2.20; $p = 0.027$), and the OR for those with an undergraduate/graduate education level reached 3.77 (95% CI, 2.47–5.75; $p < 0.001$).

Ethnicity was significantly associated with the onset of hyperopia. Mongolian participants were more likely to have hyperopia than Han participants (OR, 1.62; 95% CI, 1.23–2.13; $p = 0.001$) after adjustment for age, sex, height, time spent in rural areas, education level, activity level, presence of pterygium in the same eye, and smoking habits. Age was also related to the incidence of hyperopia, and elderly people tended to have hyperopia. Patients in all other age groups had a higher prevalence of hyperopia than those aged 40–44 years (45–49 years, $p = 0.016$; others $p < 0.001$). Height was identified as protective factors for hyperopia (OR, 0.97; 95% CI, 0.95–0.99; $p = 0.015$). Furthermore, we found that the presence of pterygium was a

Fig. 1 SE, prevalence and distribution of RE in different age groups in Han and Mongolian populations notes: **a** SE in different age groups in Han and Mongolian populations; **b** Prevalence of RE in different age groups in Han and Mongolian populations; **c** Distribution of RE in different age groups in Han and Mongolian populations. Chi-square tests were used to evaluate the differences in the distribution of the prevalence of RE between Han and Mongolian populations (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$)

risk factor and increased the prevalence of hyperopia (OR, 1.92; 95% CI, 1.14–3.23; $p = 0.014$).

Han versus Mongolian adults

Ethnicity was found to be consistently associated with the prevalence of myopia and hyperopia. Furthermore, multivariable logistic regression analyses were performed to evaluate participants with different ethnic backgrounds (Table 3).

Table 3a presents the results of the multivariable logistic regression analysis of risk factors for myopia in Han and Mongolian populations. The risk factors for myopia are generally similar in Han and Mongolian populations. Participants aged 45–49 years (Han OR, 0.70; 95% CI, 0.50–0.97; $p = 0.032$; Mongolian OR, 0.50; 95% CI,

Table 2 Multivariable regression analysis of the right eye in all participants

	Myopia (SE < −0.5D, n = 695)				Hyperopia (SE > 0.5D, n = 481)			
	Odds ratio	95% CI lower	95% CI upper	P-value	Odds ratio	95% CI lower	95% CI upper	P-value
Ethnicity (Mongolian/Han)	0.63	0.49	0.82	0.001	1.62	1.23	2.13	0.001
Age range (y)								
40–44	1.00				1.00			
45–49	0.65	0.49	0.87	0.003	1.87	1.12	3.11	0.016
50–54	0.47	0.34	0.64	<0.001	2.52	1.53	4.17	<0.001
55–59	0.46	0.32	0.68	<0.001	5.25	3.17	8.70	<0.001
60+	0.70	0.50	1.00	0.051	9.25	5.71	14.99	<0.001
Sex (female/male)	1.26	0.85	1.88	0.251	0.80	0.52	1.24	0.313
Height (cm)	0.99	0.97	1.01	0.248	0.97	0.95	0.99	0.015
Time spent in rural areas (y)	0.99	0.98	0.99	<0.001	1.00	0.99	1.01	0.801
Education								
Primary school or less	1.00				1.00			
Middle/high school	1.52	1.05	2.20	0.027	0.79	0.57	1.10	0.163
Undergraduate/graduate	3.77	2.47	5.75	<0.001	0.81	0.52	1.24	0.332
Activity level	0.77	0.55	1.08	0.131	0.92	0.63	1.34	0.658
Pterygium (with/without)	1.09	0.60	1.99	0.775	1.92	1.14	3.23	0.014
Smoking status (smokers/non-smokers)	1.12	0.80	1.56	0.508	1.17	0.82	1.66	0.398

A multivariable logistic regression model with nine indicators including ethnicity, age range, sex, height, length of time spent in rural areas, education level, activity level, presence of pterygium in the same eye and smoking status was used to assess the risk factors for myopia and hyperopia. The results for myopia and hyperopia were compared with those of emmetropic individuals

0.28–0.89; $p = 0.018$) and 50–54 years (Han OR, 0.50; 95% CI, 0.35–0.71; $p < 0.001$; Mongolian OR, 0.35; 95% CI, 0.18–0.67; $p = 0.002$) have a lower risk of myopia than those aged 40–44 years in both Han and Mongolian populations. Higher education level was a risk factor for myopia in both Han and Mongolian populations. The length of time spent in rural areas was found to be protective against myopia in the Han population (OR, 0.99; 95% CI, 0.98–0.99; $p = 0.001$) but not in the Mongolian population.

Table 3b presents the results of the multivariable logistic regression analysis of risk factors for hyperopia in the Han and Mongolian populations. Age was a risk factor that was significantly related to the occurrence of hyperopia in both Han and Mongolian populations. In the Han population, those aged 45–49 years had an increased risk of hyperopia compared to those aged 40–44 years (OR, 2.07; 95% CI, 1.04–4.11; $p = 0.038$). However, in the Mongolian population, the risk for hyperopia in those aged 45–49 or 50–54 years was not increased compared with that in those aged
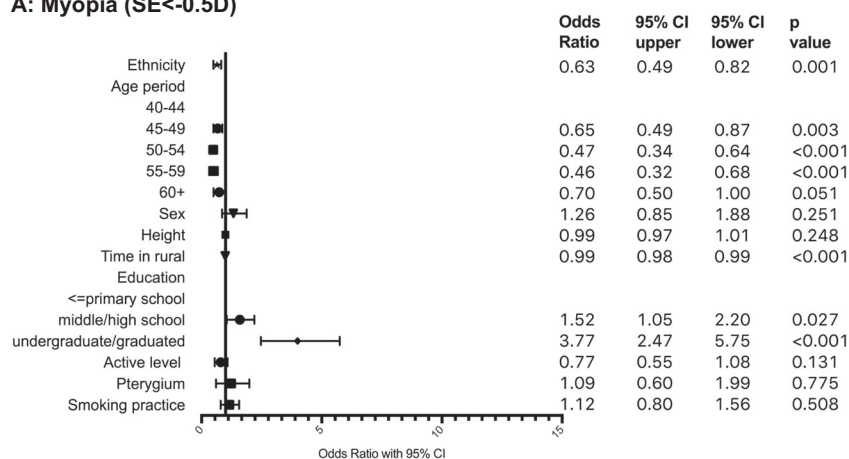
40–44 years (45–49 years, $p = 0.293$; 50–54 years, $p = 0.123$).
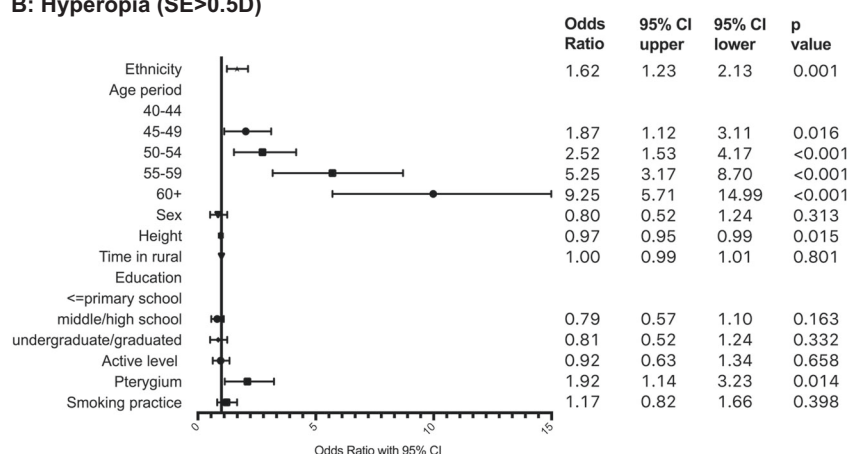
Discussion

Our cross-sectional study assessed the prevalence of and identified risk factors for RE in Han and Mongolian populations located in the same area, namely, the Inner Mongolian Autonomous Region in mainland China. Ethnicity is associated with myopia and hyperopia after adjustment for age, sex, height, length of time spent in rural areas, education level, activity level, presence of pterygium and smoking habits. The distribution of RE worldwide differs among different ethnicities and areas [8]. Pan et al. [30] investigated 10033 Chinese, Indian and Malay Singaporeans and found that the Chinese had the highest risk of myopia and lowest risk of hyperopia compared with the Malays and Indians. Our study found that in the same region in Inner Mongolia, Han ethnicity was a risk factor for

Fig. 2 Results of the multivariate logistic regression analyses for myopia and hyperopia notes: **a** Results of the multivariate logistic regression analysis of myopia; **b** Results of the multivariate logistic regression analysis of hyperopia. A multivariate logistic regression model with nine indicators including ethnicity, age range, sex, height, length of time spent in rural areas, education level, activity level, presence of pterygium in the same eye, and smoking status was used to assess risk factors for myopia and hyperopia. The myopia/hyperopia results were compared to emmetropic individuals. The OR of ethnicity was Mongolian/Han. The OR of sex was female/male. The OR of pterygium was eyes with pterygium/eyes without pterygium. The OR of smoking was smokers/never smokers

A: Myopia (SE<-0.5D)

	Odds Ratio	95% CI upper	95% CI lower	p value
Ethnicity	0.63	0.49	0.82	0.001
Age period				
40-44				
45-49	0.65	0.49	0.87	0.003
50-54	0.47	0.34	0.64	<0.001
55-59	0.46	0.32	0.68	<0.001
60+	0.70	0.50	1.00	0.051
Sex	1.26	0.85	1.88	0.251
Height	0.99	0.97	1.01	0.248
Time in rural	0.99	0.98	0.99	<0.001
Education				
<=primary school				
middle/high school	1.52	1.05	2.20	0.027
undergraduate/graduated	3.77	2.47	5.75	<0.001
Active level	0.77	0.55	1.08	0.131
Pterygium	1.09	0.60	1.99	0.775
Smoking practice	1.12	0.80	1.56	0.508

Odds Ratio with 95% CI

B: Hyperopia (SE>0.5D)

	Odds Ratio	95% CI upper	95% CI lower	p value
Ethnicity	1.62	1.23	2.13	0.001
Age period				
40-44				
45-49	1.87	1.12	3.11	0.016
50-54	2.52	1.53	4.17	<0.001
55-59	5.25	3.17	8.70	<0.001
60+	9.25	5.71	14.99	<0.001
Sex	0.80	0.52	1.24	0.313
Height	0.97	0.95	0.99	0.015
Time in rural	1.00	0.99	1.01	0.801
Education				
<=primary school				
middle/high school	0.79	0.57	1.10	0.163
undergraduate/graduated	0.81	0.52	1.24	0.332
Active level	0.92	0.63	1.34	0.658
Pterygium	1.92	1.14	3.23	0.014
Smoking practice	1.17	0.82	1.66	0.398

Odds Ratio with 95% CI

myopia, whereas Mongolian ethnicity was a risk factor for hyperopia. Apart from indicators included in our study, differences between Han and Mongolian populations have also been found in their genetic background [10, 15–17, 31], diet [18], alcohol consumption [32], sleeping habits [33, 34], body structure [35, 36] and morphological traits [37]. The differences in the prevalence of and risk factors for RE in the Han and Mongolian populations could not be explained by the differences in the risk factors investigated in this study.

In adults aged 40 years and older, the SE and the proportion of those with hyperopia increased, whereas the proportion of those with myopia decreased in both the Han and Mongolian populations. This result is consistent with the normal ageing process [38]. The age-adjusted prevalence of myopia in all participants in our study was 29.4% (95% CI, 27.4–31.3%), which was lower than the prevalence of myopia among Chinese Singaporeans (38.7%) [39], Malay Singaporeans (30.7%) [40] and Japanese located in Tajimi (41.8%) [41] (all participants aged 40+years; myopia was defined as an SE < -0.5D).

Wickremasinghe et al. [19] performed an epidemiological study involving 1800 Mongolian individuals aged 40 + years and showed that the prevalence of myopia (defined as an SE < -0.5D) was only 17.2%, the prevalence of hyperopia (defined as an SE >0.5D) was 32.9%, and the prevalence of high myopia (defined as an SE < -5D) was 2.7%. Moreover, the researchers pointed out that the prevalence of myopia in Mongolia is much lower than other East Asian populations but close to western countries [19]. Our study also noticed that the prevalence of RE in the Mongolian population in Inner Mongolia in mainland China was similar to that in the Mongolian population in Mongolia. Interestingly, Bai et al. [10] recently reported that Mongolians share a high level of genetic identity by descent with Europeans by whole-genome sequencing of Mongolians.

Ethnicity, age, length of time spent in rural areas, and education level were found to be associated with the occurrence of myopia in our study. In Beijing, Guo et al. [24] found that rural residency was associated with a decreased risk of myopia compared with urban residency

Table 3a Multivariable regression of myopia in Han and Mongolian populations

	Han (n = 541)				Mongolian (n = 154)			
	Odds ratio	95% CI lower	95% CI upper	P-value	Odds ratio	95% CI lower	95% CI upper	P-value
Age range (y)								
40–44	1.00				1.00			
45–49	0.70	0.50	0.97	0.032	0.50	0.28	0.89	0.018
50–54	0.50	0.35	0.71	<0.001	0.35	0.18	0.67	0.002
55–59	0.43	0.28	0.67	<0.001	0.56	0.26	1.22	0.146
60+	0.75	0.50	1.11	0.151	0.59	0.27	1.29	0.186
Sex (female/male)	1.38	0.86	2.22	0.179	0.96	0.45	2.05	0.925
Height (cm)	0.98	0.96	1.01	0.190	0.99	0.95	1.03	0.601
Time spent in rural areas (y)	0.99	0.98	0.99	0.001	0.99	0.97	1.00	0.079
Education								
Primary school or less	1.00				1.00			
Middle/ high school	1.45	0.96	2.19	0.074	1.75	0.70	4.39	0.234
Undergraduate/ graduate	3.90	2.40	6.33	<0.001	3.66	1.41	9.48	0.008
Activity level	0.71	0.49	1.03	0.069	1.33	0.58	3.04	0.504
Pterygium (with/ without)	1.01	0.50	2.03	0.979	1.43	0.43	4.76	0.557
Smoking status (smokers/non-smokers)	1.30	0.87	1.93	0.198	0.79	0.42	1.47	0.457

A multivariable logistic regression model with eight indicators including age range, sex, height, length of time spent in rural areas, education level, activity level, presence of pterygium in the same eye and smoking status was used to assess risk factors for myopia. The results were compared to emmetropic individuals

(OR, 0.17; $p < 0.001$). An Australian study involving 2367 children revealed that the prevalence of myopia in an inner city region was greater than that in an outer suburban region (17.8% vs. 6.9%) [42]. Birthplace and current place of residence were combined into one indicator in our study, namely, time spent in rural areas, which was found to be associated with a decreased risk of myopia ($p < 0.001$). Apart from the indicators controlled in our multivariable model, urban residency might also bring higher individual income, professional or office-related occupations, and more contact with electronic devices. It is widely accepted that higher education level increases the risk of myopia [7, 8, 43]. The mechanism of myopia as a complex of genetics and environmental factors is still unknown, and researchers think that an individual's genetic risk of myopia is significantly influenced by their education level [44]. Moreover, educational attainment is strongly influenced by genes and should not be solely considered as an environmental risk factor [45]. Outdoor activities have also been indicated to reduce the risk of myopia [46, 47]. Moreover, a recent study revealed that outdoor activities play a greater role in decreasing the risk of myopia than the young-age near-work activity model that was previously touted [6].

Our study found no influence of different activity levels on the risk of myopia ($p = 0.131$), which confirmed that it is "outdoor" rather than "activities" that really matters. Recent studies found that sunlight outdoors might increase the release of retinal dopamine which is protective from axial elongation in experimental myopia [47, 48].

In addition to an association with ethnicity, associations between hyperopia and age, height and the presence of pterygium were also noticed in our study. The prevalence of hyperopia increases with age. Moreover, when analyses were performed separately for the Han and Mongolian populations, the risk of hyperopia in the Han participants was already increased in those aged 45–49 years compared with those aged 40–44 years. In the Mongolian population, the risk of hyperopia increased only after individuals reached 55–59 years. The progression of hyperopia starts earlier in the Han population than in the Mongolian population. The Liwan Eye Study in Guangzhou, China suggested that the rates of hyperopia started to increase in those aged 60–69 years, which is similar to the Japanese but later than the Singaporean Chinese and white and black Baltimore populations [49]. Fewer studies investigate the prevalence of hyperopia, and the exact pattern of hyperopia

Table 3b Multivariable regression of hyperopia in Han and Mongolian populations

	Han (n = 310)				Mongolian (n = 171)			
	Odds ratio	95% CI lower	95% CI upper	P-value	Odds ratio	95% CI lower	95% CI upper	P-value
Age range (y)								
40–44	1.00				1.00			
45–49	2.07	1.04	4.11	0.038	1.53	0.69	3.36	0.293
50–54	2.87	1.46	5.64	0.002	1.85	0.85	4.05	0.123
55–59	6.89	3.56	13.31	<0.001	3.06	1.32	7.08	0.009
60+	13.81	7.32	26.03	<0.001	3.89	1.76	8.64	0.001
Sex (female/male)	0.98	0.55	1.76	0.951	0.55	0.27	1.10	0.089
Height (cm)	0.98	0.95	1.01	0.120	0.96	0.92	0.99	0.024
Time spent in rural areas (y)	1.00	0.99	1.01	0.894	1.00	0.99	1.01	0.955
Education								
Primary school or less	1.00				1.00			
Middle/ high school	0.73	0.49	1.08	0.113	0.99	0.54	1.82	0.969
Undergraduate/ graduate	1.09	0.63	1.90	0.750	0.56	0.27	1.17	0.123
Activity level	0.84	0.53	1.31	0.437	1.16	0.57	2.36	0.688
Pterygium (with/ without)	1.85	0.98	3.48	0.059	2.10	0.80	5.55	0.133
Smoking status (smokers/non-smokers)	1.27	0.79	2.04	0.322	1.11	0.64	1.92	0.712

A multivariable logistic regression model with eight indicators including age range, sex, height, length of time spent in rural areas, education level, activity level, presence of pterygium in the same eye and smoking status was used to assess risk factors for hyperopia. The results were compared to emmetropic individuals

with age is still unclear [50]. Our study also suggested that height is a protective factor against hyperopia. Previous studies [22–26] have indicated that body stature, especially height, is associated with axial length, which is a possible explanation of our finding. Similar to previous studies [51, 52], our study also found that the presence of pterygium was associated with an increased risk of hyperopia (OR, 1.92; $p = 0.014$). Eyes with myopia have a thinner cornea, thinner sclera and more redundant conjunctiva than eyes with hyperopia, which might be protective against the development of pterygium [53–55]. Moreover, pterygium is a type of eye disease that is related to old age [56]. Considering that old age is one of the risk factors for hyperopia, it can be speculated that age might contribute to the relationship between pterygium and hyperopia.

The strengths of our study include a relatively large sample size and reasonable response rate which is 94%. However, as a cross-sectional study, we were unable to establish a causal relationship between the various risk factors and RE. Cohort studies are needed in the future. Moreover, more detailed information, including daily outdoor time, nutritional intake, and sleeping habits, could be included in the questionnaire. Indices of ocular

biometric data, such as axial length, should be included in future studies to investigate the prevalence of refractive myopia and axial myopia in Han and Mongolian populations.

Conclusion

Our cross-sectional study is the first to investigate the prevalence of and risk factors for RE in Han and Mongolian adults living in the same area, namely, the Inner Mongolian Autonomous Region in mainland China. Mongolian ethnicity was a protective factor against myopia but a risk factor for hyperopia. Additionally, age, time spent in rural areas, and education level were found to be risk factors for myopia. Age, height and the presence of pterygium were found to be associated with hyperopia. Our study assessed the prevalence of and risk factors for RE among participants of different ethnicities living in the same region. We investigated the difference of prevalence of and risk factors for RE between the Han and Mongolian populations, which could not be explained by differences in the risk factors investigated in this study.

Summary

What was known before:

- Mongols are an East-Central Asian ethnic group native to Mongolia and China's Inner Mongolia.
- Mongolian in Mongolia have a lower prevalence of myopia compared to other East Asian areas.

What this study adds:

- Compared to Han population in the same area in Inner Mongolia of China, Mongolian population have a lower myopia risk and higher hyperopia risk.
- Age, time spent in rural areas, and education level were found to be risk factors for myopia. Age, height and the presence of pterygium were found to be associated with hyperopia.

Compliance with ethical standards

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