Purpose. To determine the prevalence of myopia and ocular biometry in population-based samples of ethnic Yi and Han people living in an inland rural community in China.

Methods. A random cluster sampling strategy was used to select ethnic Han and Yi adults aged 50 years or older living in Yunnan. Refractive error was determined by subjective refraction and ocular biometric parameters, including axial length (AL), anterior chamber depth (ACD), vitreous chamber depth (VCD), and lens thickness (LT), which were measured using an Echoscan.

Results. Adults of Yi ethnicity had lower prevalence of myopia (10.3% vs. 8.1%; \( P = 0.02 \)) and high myopia (2.3% vs. 1.6%; \( P = 0.10 \)) than their counterparts of Han ethnicity. The prevalence of myopia increased with age (\( P \) for trend < 0.05), whereas the mean AL did not differ significantly among age groups in both ethnic groups (both \( P \) for trend > 0.05). In multivariate analysis, time spent outdoors was associated with myopia (\( P = 0.003 \)) and AL (\( P < 0.001 \)) but not high myopia (\( P = 0.33 \)). No interaction effect was detected between ethnicity and other risk factors on myopia (all \( P > 0.05 \)). Adjustment for lens nuclear opacity score reduced the excess prevalence of myopia in Han ethnicity by 37.5%.

Conclusions. There was little evidence showing that ethnic disparities existed in the prevalence and risk factors between the major and minor ethnic groups living in the same communities in rural China. The “cohort effect” on myopia observed in many other populations was not seen in this study.

Keywords: myopia, axial length, epidemiology, ethnicity

Myopia is a global health concern associated with a wide range of ocular complications\(^1\)\(^–\)\(^3\) and health-related quality of life.\(^4\) Multiethnic population-based studies have identified significant interethnic disparities in the prevalence of myopia among different ethnic groups. For example, in Singapore, a highly urbanized city state in Southeast Asia with a widely recognized “epidemic” of myopia, people of Chinese ethnicity had a higher age-matched prevalence of myopia together with a longer axial length (AL) than other ethnic groups.\(^5\)\(^–\)\(^6\) It has often been asserted that people of Chinese ethnicity are thought to be more susceptible to myopia than the other ethnic groups, but previous studies in Chinese individuals also reported low prevalence estimates.\(^7\)\(^–\)\(^8\) In contrast to these low estimates in Chinese individuals, some higher prevalence estimates have been reported in other ethnic groups, such as Malay,\(^9\) Indian,\(^10\) Japanese,\(^11\)\(^–\)\(^12\) or Korean individuals.\(^13\)\(^–\)\(^14\) In addition, the epidemic of myopia was not only observed in Chinese people. Early evidence on Inuit populations showed that myopia prevalence had increased spectacularly between generations of migrants.\(^15\)\(^–\)\(^17\) It is still debatable whether Chinese individuals are intrinsically more myopic than other ethnic groups. Therefore, it is important to understand how prevalent myopia is in poorly educated Chinese people.

China is the world’s most populous country and the second largest economy, with a multiethnic population including Han ethnicity and 55 other ethnic minorities. Han ethnicity is the major ethnic group, which accounts for approximately 90% of the entire population in China. Genetically, Han Chinese is a heterogeneous ethnic group, with significant differences between northern and southern populations in China. The north Chinese have greater genetic affinities with Japanese and Korean populations, and south Chinese are more closely linked to the populations in Southeast Asia and the Pacific Islands.\(^18\) However, the genetic difference may be relatively smaller among different ethnic groups living in the same areas compared with that among ethnic groups as defined in the United States, the United Kingdom, or other countries with major migrant populations, such as Australia, Canada, and Singapore.\(^19\) The epidemiology of myopia in adults has been well defined with a large number of population-based studies in different parts of China.\(^7\)\(^–\)\(^8\)\(^,\)\(^20\)\(^,\)\(^21\) However, the study participants were predominantly of Han ethnicity, and there were few studies addressing the issues of ethnic minorities in China.
Thus, whether myopia is more common in Han ethnicity or other specific ethnic minorities and whether the ethnic disparities in myopia are related to a difference in environmental exposures, such as education level, time outdoors, or other myopia-related factors, remains uncertain. Understanding the ethnic variations in prevalence and associated risk factors for myopia is essential to guide future eye health care and clinical management in China.

Yunnan province, located at the southwest part of China, is a major population center for ethnic minorities in China. Besides the Han Chinese, 25 ethnic minorities are reported to reside in Yunnan province according to the 2010 census data, which provides unique opportunities to investigate the ethnic variations in the patterns, predictors, and burdens of myopia and other ocular disorders in China. The Yi ethnicity is one of the major ethnic minorities in China, including approximately 7 million people. In this article, we describe the ethnic differences in prevalence of myopia and ocular biometry in population-based samples of ethnic Yi and Han people living in an inland rural community in Yunnan province and examine risk factors that may account for possible ethnic differences in prevalence.

METHODS

Study Population

The Yunnan Minority Eye Studies (YMES) are a series of population-based studies in different ethnic groups including Han ethnicity and other ethnic minorities in different areas in Yunnan province from 2010. The aims of the YMES are to estimate the burden and impact of visual impairment and major age-related eye diseases in ethnic minorities and to compare the ethnic variability in eye disease prevalence, risk factors, and availability of health care among Han ethnicity and other ethnic minorities living in Yunnan province. Considering the difference in residence for each ethnic group, we recruited study participants of different ethnic groups in different areas to ensure a sufficient sample size within each ethnic group. All the studies were conducted using the same study protocols for data collection to facilitate the comparisons among ethnic groups. In the previous reports, we have described the detailed methodology of the YMES and some major findings in the Bai ethnicity living in Dali.22-24 The current study focused on the Han and Yi ethnic groups, which were recruited in an inland rural community with a relatively lower socioeconomic status. In brief, a random cluster sampling strategy was adopted to select ethnic Han and Yi aged 50 years or older living in Shilin. Each village with a population of approximately 1000 was considered as a cluster. Villages with a population of less than 750 were combined and those of more than 1500 were divided and regrouped. Subsequently, 10% of the total clusters were randomly selected using a computer-assisted program, and all the adults of Han and Yi ethnicity aged 50 years or older living in the selected clusters were invited to the clinics for a detailed eye examination and a face-to-face questionnaire interview. Finally, 2205 ethnic Han and 2208 ethnic Yi adults participated in this study with a response rate of 82.0% for Han and 80.5% for Yi ethnicity, respectively. There were no age and sex differences between study participants and nonparticipants (all P > 0.05) in both ethnic groups.

All studies were approved by the Kunming Medical University Institutional Review Board and the conduct of the studies adhered to the Declaration of Helsinki.

Assessment of Refractive Error and Axial Length

Noncycloplegic autorefraction was performed using an autorefractor (RM-8000; Topcon Corp., Tokyo, Japan). Noncycloplegic refraction might have overestimated the prevalence of myopia and cycloplegic refraction is suggested to be the gold standard for epidemiological studies of myopia, not only in children but also in adults up to the age of 50.25 but this issue seems to be marginal in this study because our study subjects were older than 50 years. Refraction was subjectively refined until the best visual acuity was obtained. Spherical equivalent (SE) was defined as sphere plus half cylinder and myopia and high myopia were defined as SE of less than −0.5 diopter (D) and −6.0 D, respectively. Ocular biometric parameters including AL, anterior chamber depth (ACD), vitreous chamber depth (VCD), and lens thickness (LT) were measured using an Echoscan (US-800; Nidek Co., Ltd., Tokyo, Japan).

Risk Factors Assessment

Information regarding participants’ educational level, socioeconomic status, lifestyle-related factors (time spent outdoors per day in childhood, smoking, alcohol drinking), disease history, and medication intake was collected using a detailed questionnaire by trained research assistants. Height was measured in centimeters using a wall-mounted measuring tape after removing shoes. Weight was measured in kilograms after taking off heavy clothing. Systolic blood pressure, diastolic blood pressure, and pulse rate for all participants were recorded using a standardized mercuric-column sphygmomanometer, and one of four cuff sizes (pediatric, regular adult, large, or thigh) was selected based on the circumference of the participant’s arm. Slit-lamp examination (model SL-1E; Topcon) was performed after pupil dilation by trained study ophthalmologists and included a clinical grading of cataract according to the Lens Opacities Classification System (LOCS) III.26

Statistical Analyses

Participants with prior cataract or refractive surgery were excluded from the analyses related to myopia. As the correlation coefficients for SE (r = 0.92) and ocular biometric parameters (r = 0.95 for AL) in the left and right eye were high and the results of analysis in both eyes were similar, only the results for right eyes are presented. All probabilities quoted were considered statistically significant if P value was less than 0.05 and all data analyses were performed using SPSS (PASSW Statistics 18; SPSS, Inc., Chicago, IL, USA).

The prevalence of myopia, high myopia, and mean ocular biometric parameters were estimated for each ethnic group adjusting for age and sex and were compared based on χ² test or Ftest, as appropriate. For risk factors, variables of interest were first assessed in univariate models. For multivariate analysis, only age, sex, and factors that were significantly different in univariate comparisons (P < 0.10) or factors of scientific importance were retained in the model. To determine whether ethnicity modified associations, a logistic regression model was fitted with interaction terms between ethnicity and each potential risk factor, and a likelihood ratio test was performed on the interaction terms.

To evaluate the extent that myopia-related risk factors may explain the excess prevalence of myopia in adults of Han ethnicity compared with those of Yi ethnicity, we estimated the percentage reduction in odds associated with adjustment for these risk factors based on the following formula: (Ra − Rb)/(Ra − 1) × 100, where Ra is the odds ratio (OR) of myopia in the Han ethnicity compared with the Yi ethnicity, adjusted for age and sex only (reference model), and Rb is the OR in models after additional adjustment.

RESULTS

Table 1 compares the characteristics of the Han and Yi ethnic groups in the YMES. Compared with the Han ethnic group, the
Yi ethnic group was shorter ($P = 0.001$) and lighter ($P < 0.001$), had higher systolic blood pressure ($P = 0.01$), and lower lens nuclear opacity score ($P < 0.001$). The samples from these ethnic groups showed no differences in the distributions of age, sex, educational level, or time spent outdoors per day ($P > 0.05$).

After excluding participants with previous cataract or refractive surgery, 1763 (80.0%) adults of Han ethnicity and 1836 (83.2%) adults of Yi ethnicity with refraction data in the right eye contributed to the analyses related to the myopia and high myopia. Table 2 compares the crude and age-sex–adjusted prevalence of myopia ($SE < −0.5$ D), high myopia ($SE < −6.0$ D), and mean ocular biometric parameters between the two ethnic groups. Adults of Yi ethnicity had lower prevalence of myopia (10.3% vs. 8.1%; $P = 0.02$) and high myopia (2.3% vs. 1.6%; $P = 0.10$) than their counterparts of Han ethnicity. The mean AL was slightly longer (23.04 vs. 22.95 mm; $P = 0.06$) and ACD was deeper (2.98 vs. 2.86 mm; $P < 0.001$) in people of Yi ethnicity compared with those of Han ethnicity after adjusting for the effect of age and sex. Vitreous chamber depth and LT were not significantly different between the two ethnic groups ($P > 0.05$).

The age-specific prevalence of myopia ($SE < −0.5$ D) was 2.6%, 6.3%, 15.9%, and 18.2% in adults of Yi ethnicity aged 50 to 59, 60 to 69, 70 to 79, and older than 80 years and it was 5.0%, 9.6%, 16.7%, and 22.2% in adults of Han ethnicity for the same age groups. The prevalence of myopia increased with age groups in both ethnic groups (both $P$ for trend $< 0.05$). The mean AL did not differ significantly among age groups in both ethnic groups (both $P$ for trend $> 0.05$), whereas the lens nuclear opacity score increased significantly in both ethnic groups (both $P$ for trend $< 0.05$) (Figs. 1–5).

Multivariate logistic or linear regression analyses were performed to evaluate the association between prevalence of myopia, high myopia, AL, and factors of interest, while...
adjusting for confounders (Table 3). Higher lens nuclear opacity score ($P < 0.001$) and less time spent outdoors per day in childhood ($P = 0.003$) were significantly associated with the presence of myopia. Younger age ($P < 0.001$) and higher lens nuclear opacity score ($P < 0.001$) were significantly associated with the presence of high myopia. However, time spent outdoors per day was not significantly associated with high myopia ($P = 0.33$). Male sex ($P < 0.001$), taller stature ($P < 0.001$), and less time spent outdoors in childhood ($P < 0.001$) were associated with a longer AL. No interaction effect was detected between ethnicity and other risk factors on myopia, high myopia, or AL (all $P > 0.05$).

In addition, we estimated the reduction in odds of myopia associated with adults of Han ethnicity compared with Yi ethnicity with additional adjustment of myopia-related factors. Adjustment for environmental exposures, such as time outdoors per day in childhood, or educational level did not lead to significant reduction in the excess prevalence of myopia in Han ethnicity. On the contrary, adjustment for lens nuclear opacity score reduced the excess prevalence of myopia in Han ethnicity by 37.5%. The prevalence of myopia in Han ethnicity was also reduced by 37.5% when all myopia-related factors were adjusted for (Table 4).

**DISCUSSION**

In this multiethnic population of Han and Yi ethnicity residing in an inland rural community, we reported relatively low prevalence estimates of myopia and high myopia compared with the results reported in other population-based studies in China, Japan, South Korea, and neighboring countries, such as Japan, South Korea, and East Asia. We found little evidence showing that ethnic disparities existed in the prevalence and risk factors between the major and minor ethnic groups living in the same communities in rural China. In addition, these data also suggested that the prevalence of myopia in Chinese individuals with poor education could be low, in contrast to a common view that Chinese individuals are more susceptible to myopia compared with other ethnic groups. Chinese individuals may not be intrinsically more myopic than other ethnic groups.

Although we found that the prevalence of myopia is somewhat higher in adults of Han ethnicity as compared with Yi ethnicity, the magnitude of difference was small and did not reach statistical significance in multivariate analysis. In addition, 40% of the observed differences were explained by...
difference in lens nuclear opacity score. Therefore, we believed that the variation in the burden of myopia was insignificant between the two ethnic groups. This is largely because these two ethnic groups are living in the same small town with no major differences in environmental exposures, such as schooling system, population density, expectation for academic achievement from parents in childhood, and other unknown factors that may be related to myopia. The insignificance of differences in myopia prevalence and AL between the two ethnic groups reemphasizes the importance of environmental exposures on the onset and development of myopia.

The prevalence of myopia in elderly people of Chinese ethnicity has been widely reported previously, both in and outside the mainland of China. To minimize the effect of cataract on refraction, we compared the prevalence in adults aged 50 to 59 years. Our study reported an extremely low prevalence estimate in adults aged 50 to 59 years (2.6% and 5.0% for adults of Yi and Han ethnicities, respectively), in contrast to the values reported to be 31% in Guangzhou,20 20% in Beijing,21 12% in Handan,8 and 8% in Harbin.7 Participants in these studies were predominantly of Han ethnicity, which is the major ethnic group in China and accounts for approximately 90% of the total population in China. In Han Chinese living outside the mainland, myopia prevalence was reported to be 26% in Singapore28 and 40% in Hong Kong29 for the same age groups. Our study suggested that there is little evidence supporting an intrinsically higher prevalence of myopia or a greater susceptibility to environmental risk factors in populations of Chinese ethnicity. Area-level social economic status may be a major determinant for the burden of myopia in a specific area.

We observed a major increasing trend of myopia and high myopia with increasing age but a relatively stable trend in AL in

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Myopia, &lt; 0.5 D</th>
<th>High Myopia, &lt; -6.0 D</th>
<th>AL, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Han</td>
<td>OR 95% CI P</td>
<td>OR 95% CI P</td>
<td>Beta 95% CI P</td>
</tr>
<tr>
<td>Yi</td>
<td>0.79 0.61–1.02 0.07</td>
<td>0.68 0.41–1.12 0.13</td>
<td>0.14 –0.04–0.32 0.18</td>
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<td>Age, y</td>
<td></td>
<td></td>
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<tr>
<td>50–59</td>
<td>0.91 0.60–1.38 0.67</td>
<td>0.51 0.27–0.98 0.04</td>
<td>–0.05 –0.16–0.05 0.34</td>
</tr>
<tr>
<td>60–79</td>
<td>1.15 0.73–1.81 0.55</td>
<td>0.29 0.13–0.64 0.002</td>
<td>–0.11 –0.25–0.04 0.11</td>
</tr>
<tr>
<td>≥80</td>
<td>0.86 0.46–1.59 0.63</td>
<td>0.18 0.06–0.60 0.005</td>
<td>–0.02 –0.18–0.15 0.78</td>
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<tr>
<td>Sex</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Men</td>
<td>0.99 0.97–1.02 0.86</td>
<td>0.98 0.94–1.02 0.30</td>
<td>0.02 0.01–0.03 &lt;0.001</td>
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<tr>
<td>Women</td>
<td>1.00 0.70–1.44 0.99</td>
<td>1.09 0.54–2.20 0.81</td>
<td>–0.22 –0.35 to –0.11 &lt;0.001</td>
</tr>
<tr>
<td>Height, per cm increase</td>
<td>0.99 0.97–1.02 0.86</td>
<td>0.98 0.94–1.02 0.30</td>
<td>0.02 0.01–0.03 &lt;0.001</td>
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<td>Educational level</td>
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<tr>
<td>No formal education</td>
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<td>Reference</td>
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<tr>
<td>Primary education</td>
<td>1.00 0.73–1.36 1.00</td>
<td>1.06 0.60–1.87 0.84</td>
<td>–0.02 –0.11–0.08 0.72</td>
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<tr>
<td>Secondary education or higher</td>
<td>1.21 0.74 1.97</td>
<td>0.78 0.29–2.11 0.63</td>
<td>–0.00 –0.21–0.10 0.43</td>
</tr>
<tr>
<td>Lens opacity, LOCS III, per unit increase</td>
<td>2.19 1.93–2.50 &lt;0.001</td>
<td>2.11 1.70–2.63 &lt;0.001</td>
<td>0.14 –0.10–0.24 0.61</td>
</tr>
<tr>
<td>Time spent outdoors per day in childhood, per hour increase</td>
<td>0.92 0.84–0.98 0.003</td>
<td>0.95 0.80–1.28 0.33</td>
<td>–0.22 –0.33 to –0.11 &lt;0.001</td>
</tr>
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CI, confidence interval.

<table>
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<tr>
<th>Model</th>
<th>OR* 95% CI P</th>
<th>% Reduction Excess Prevalence†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.40 1.09–1.78 0.02</td>
<td>Reference</td>
</tr>
<tr>
<td>2</td>
<td>1.39 1.09–1.78 0.01</td>
<td>2.5</td>
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<tr>
<td>3</td>
<td>1.38 1.08–1.77 0.02</td>
<td>5.0</td>
</tr>
<tr>
<td>4</td>
<td>1.25 0.97–1.62 0.08</td>
<td>37.5</td>
</tr>
<tr>
<td>5</td>
<td>1.25 0.97–1.62 0.08</td>
<td>37.5</td>
</tr>
</tbody>
</table>

* Odds ratio (95% confidence interval) of myopia, comparing adults of Yi and Han ethnicities, adjusted for the following variables:
Model 1: age and sex;
Model 2: age, sex, and educational level;
Model 3: age, sex, and outdoor time per day in childhood;
Model 4: age, sex, and lens nuclear opacity score;
Model 5: age, sex, outdoor time per day in childhood, educational level, and lens nuclear opacity score.
† Percentage reduction in excess prevalence defined by the formula: (Ra – Rb)/(Ra – 1), where Ra is the OR of myopia in Han ethnicity versus the Yi ethnicity adjusted for age and sex only (Model 1, reference) and Rb is the OR after additional adjustment for the variables in Models 2 to 5.
both ethnic groups. This age-related pattern of myopia was different from other studies in East Asia. For example, in the Korean National Health and Nutrition Examination Survey, myopia was more prevalent in adults aged 50 to 59 years (34%) compared with those of 30 years or older (16%).3,4 Our study site, the site was located at the altitude of approximately 1,500 meters and is famous for prolonged daylight hours and increased exposure to sunlight, resulting in an intensive exposure to ultraviolet radiation, which is a known risk factor for cataract.50 It has been well established that nuclear cataract or sclerosis could result in a myopic shift, reflecting the increased power of the more sclerotic lens rather than increased AL.51–53 Thus, the change in AL would be more informative than SE in understanding of the age-related patterns of myopia, as it is not related to nuclear cataract or sclerosis. The observations in our study indicated that the age-related changes in refractive status in our study are mainly due to increasing nuclear sclerosis of the lens with age, leading to a myopic shift in refraction. The “cohort effect” on myopia prevalence, namely the increased prevalence of myopia observed in later birth cohorts, which was found in many other population-based studies,5,5–11,54,55 was not observed in our study. The possible explanation for this result is that the study participants were poorly educated and more than half of them did not receive formal education. In addition, the study area is an inland rural town located in the southwest part of China and has not experienced a dramatic change in social and environmental factors during the past few decades as compared with many metropolises in China and other countries in East Asia.

Myopia is well known to be affected by genetic and environmental exposures. In familial studies and twin studies, linkage analysis using microsatellite marker has identified 19 loci for myopia: MYP1 to MYP19.56 Although many genes in these loci were evaluated as candidate genes for myopia or high myopia, most genes were found not to be involved in the pathogenesis of myopia or high myopia. Two large recent genome-wide association studies have reported more than 30, partially overlapping, genetic loci associated with refractive phenotypes.57–58 These identified genetic variants can be linked to known visually triggered signaling pathways, or novel genetic pathways in the development of myopia.59–44 However, genetic factors only account for a small proportion of the variation in refraction and changes in them cannot explain the rapid increase in myopia prevalence observed in East and Southeast Asia in the past few decades, as genes pools do not change that fast. On the other hand, time spent outdoors in childhood is found to be the most consistent environmental exposure related to myopia.45 We found that environmental exposures such as time spent outdoors per day in childhood are related to myopia and AL but not high myopia. A traditional view supporting this finding is that genetic factors might have greater impact on high or extreme myopia, whereas environmental factors may play a more important role in mild or moderate myopia.46 However, recent evidence demonstrated a significant increase in the prevalence of high myopia, with approximately 20% of the younger cohort in East Asia being affected,47,48 indicating that environmental factors also may be important for the development of high myopia. However, considering the low education level of the participants in our study, it is unlikely that high myopia was triggered by environmental exposures in this study. In addition, we did not detect any interaction effect between ethnicity and any of the risk factors for myopia, indicating that the impact of environmental exposures on myopia may be equally important to each ethnic group.

The strengths of the study included a large and population-based sample, reasonable response rates, and standardized refraction and ocular biometry assessment. We collected the data using the same study protocols in the two ethnic groups so that interethnic comparison should be valid. There are also some limitations for this study that should be acknowledged. First, information bias may have happened during the data collection for myopia-related environmental exposures, such as time spent outdoors in childhood, considering the age range of the study participants. In addition, the cross-sectional design is limited to establish a temporal relationship and cannot determine any casual relationships between risk exposures and health outcomes. Finally, although we found no differences in age and sex distributions between responders and nonresponders, the prevalence of myopia in nonresponders may still be different from those participating in this study, leading to an overestimation or underestimation in myopia prevalence.

In conclusion, this multiethnic population-based study of adults older than 50 years in a rural community in China reported relatively lower prevalence rates of myopia and high myopia compared with the results of other studies on Chinese ethnicity reported previously. There was little evidence showing that ethnic disparities existed in the prevalence and risk factors between the major and minor ethnic groups living in the same communities in rural China, providing further insights into the role of social and environmental impacts on the risk of myopia. These study results in different ethnic groups in the same area are important for China and other countries to address the vision-related health inequalities or inequities among different ethnic groups.

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References
Ethnic Variations in Myopia in China


