High Prevalence of Myopia and High Myopia in 5060 Chinese University Students in Shanghai

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Purpose. Myopia is an important cause of correctable visual impairment worldwide. Genetic and environmental factors contribute to its development. The population of Chinese university students consists of approximately 30 million young people characterized by academic excellence and similar ages. To date, little is known about their refractive status. Our study is designed to investigate the prevalence of myopia in this specific population.

Methods. This is a cross-sectional study of myopia among university students in Shanghai, China; 5083 students from Donghua University were enrolled. All participants first responded to a detailed questionnaire, including questions on ethnicity, birth date, and family history, and then undertook a standardized ophthalmologic examination, including visual acuity, a slit-lamp examination, and non-cycloplegic autorefraction.

Results. The mean spherical equivalent refraction (SER) of the university students was –4.1 diopters (D). Of the subjects 95.5% were myopic (SER $<$ –0.50 D), 19.5% were highly myopic (SER $<$ –6.0 D), and only 3.3% were emmetropic (–0.5 D $\leq$ SER $\leq$ 0.5 D). The postgraduates were more myopic than the undergraduates (96.9% and 94.9%, respectively). Being female (–4.1 ± 2.4 D in female versus –3.8 ± 2.4 D in male subjects), of Han ethnicity (–4.1 ± 2.4 D in Han versus –3.4 ± 2.2 D in minorities), and of older age were associated with a higher probability of myopia only in the undergraduate population.

Conclusions. The prevalence of myopia and high myopia in this university student population was high. The refractive status of this population deserves further attention. (*Invest Ophthalmol Vis Sci.* 2012;53:7504–7509) DOI:10.1167/iovs.11-8343

Myopia is an important cause of correctable visual impairment and preventable blindness worldwide.[1,2] It has been reported that the prevalence of myopia in populations in East Asia is much higher than in South Asia and western countries, and the lowest prevalence appears to be in Africa. This difference was distinct particularly when young people of industrialized areas, such as Japan, Taiwan, Hong Kong, and Singapore, were considered.[3–14] Among urban Chinese adolescents, the prevalence of myopia was 78.4% in the 15-year-olds,[14] while in rural parts of northern China this rate was 36.7% in male and 55% in female subjects of the same age.[15]

Genetic and environmental factors contribute to the development of myopia, such as more time spent on near work, less time spent on outdoor activities, Chinese origin, and family history of high myopia.[2,16,17] Several studies have found a definite correlation between higher educational level or higher academic achievements and higher prevalence of myopia.[18–21] In fact, educational level often is correlated with long time spent on reading and writing work in and after class during the school years. Therefore, education may be a reflection of long time of near work and less time outdoors. Meanwhile, people in urban regions of China usually have more chance to be educated than ones in rural regions because of resource inequality.[22,23] Perhaps the association also may reflect common genetic factors that may reflect intelligence and refraction.

In fact, groups of people from all walks of life may have their own specific features. University students are in late adolescence/early adulthood with similar ages (20.2 ± 2.8 years). This population is characterized by academic excellence, as selected by the college entrance examination, and they are particularly susceptible to myopia due to less time spent outdoors and the high level of prolonged near work during their school years. Refractive data on this specific population with their unique features have been reported in many countries in the world, but seldom in China. China is a huge country accommodating one fifth of the world's population. According to China's Ministry of Education, there were 29.79 million university students in China in 2009. This is higher than any other country in the world, and this number is expected to increase to 35.50 million in the year 2020. The high prevalence of myopia and high myopia in this high

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Table 1. Study Population

	Total	Percentage	Freshmen	Percentage	Postgraduate	Percentage	*P* Value
Subjects	5060		3625	71.6%	1435	28.4%	
Males	2222	43.9%	1534	42.3%	688	47.9%	<0.001
Females	2838	56.1%	2091	57.7%	747	52.1%	
Age, y	20.2 ± 2.8		18.8 ± 0.8		23.8 ± 2.8		<0.001
Range	14.5 to 42.2		14.5 to 23.8		19.7 to 42.2		
Refraction	−4.08 ± 2.42		−3.97 ± 2.40		−4.36 ± 2.46		<0.001
Range	−22.69 to 7.13		−22.69 to 7.13		−17.13 to 5.50		
Ethnicity							
Han	4805	95.0%	3402	93.8%	1403	97.8%	<0.001
Minorities	255	5.0%	223	6.2%	32	2.2%	
Family history of myopia							
No	3474	68.7%	2276	62.8%	1198	83.5%	<0.001
Yes	1586	31.3%	1349	37.2%	237	16.5%	

selected population poses a particularly important public health and social problem.

Therefore, we performed a cohort study of refractive error in Donghua University students in the city of Shanghai in eastern China. Refractive status and potential sociodemographic determinants of myopia were explored.

Methods

This is a cross-sectional cohort study of myopia among university students in Shanghai, China. Ethical approval was obtained from the Shanghai Jiaotong University School of Medicine Ethics Review Board and the Ethics Committee of Shanghai Ninth People's Hospital. Students were recruited from Donghua University (DHU), located in the downtown area in the Changning district of Shanghai. DHU is one of the state-key universities, and one of the 112 universities in the "Project 211" out of 742 universities in China, but not included in the top 39 universities in the "Project 985." It is a multidisciplinary university with a wide range of undergraduate and graduate degree programs across a vast range of disciplines, including engineering, economics, management, literature and art, laws, science, and education. It has 12 colleges and schools, over 30,000 enrolled students, among which there are 15,000 undergraduates and approximately 6700 postgraduates. This university's enrollment covers all of the 32 provinces in mainland China through the national unified college entrance examination. DHU was selected due to its typical student population in state-key universities. Using cluster sampling, all classes of first-year undergraduates and first-year Master's degree students were selected in this study.

The survey was done by three groups of researchers. Each group consisted of two qualified oculists, one ocular assistant, one optometrist, and two enumerators. Before the formal survey, a training course was conducted to ensure that every question would be asked using a standard format, and there was a standard format for recording responses. A pilot study of 200 subjects was conducted to assess interobserver correlation in the measurement of refractive error ($P < 0.001$).

All of the selected subjects from this university were registered by name, sex, and student ID number at the student affairs office. The fieldwork was done from September 2009 to October 2009 in the student activity center of DHU. Among the 5477 subjects selected, 5083 students participated in the study (response rate 92.81%), 20 students were excluded due to eye diseases that may have altered optical media, and 3 foreign students were excluded. All subjects participating in the study gave informed consent, according to the Declaration of Helsinki. Students selected first were interviewed face-to-face by an oculist to complete a questionnaire, which included questions on their nationality, birth date, history of myopia, history of other eye diseases, and family history of either myopia or hereditary diseases. A second oculist then performed a simple ocular examination of each subject using a slit-lamp, to exclude opacity of the optical media. Then, visual acuity was measured as uncorrected visual acuity (Snellen charts) at a distance of 5 meters. If uncorrected visual acuity was lower than 1.0, corrected visual acuity was measured with the subject's own glasses or with a subjective refraction. Optical biometry (Optical Biometry, IOL Master; Carl Zeiss Meditec AG, Jena, Germany) was performed to obtain a measurement of the axial length and radius of the corneal curvature, and the mean value of five repetitions was recorded. An automatic refractometer (Auto Refractometer, AR-600; Nidek Ltd., Tokyo, Japan) also was used to obtain a measurement of the refractive error without cycloplegia, and the average value of five repetitions was recorded. The data on axial length and radius of corneal curvature were not reported formally in this article.

Statistical analysis was performed using SPSS software (version 17.0; SPSS Inc., Chicago, IL). Spherical equivalent refraction (SER) was calculated as the spherical value of the refractive error plus half of the cylindrical value. The representative results presented here were from the right eye of each subject, as the two eyes were statistically highly correlated (Spearman correlation coefficient $r = 0.886$, $P < 0.001$). All of the numerical data are given as the mean ± SD. Myopia was defined as a SER < –0.5 diopters (D) and high myopia was defined as a SER < –6.0 D. Ethnicity was divided only into Han and minority groups. Independent *t*-tests were used to compare means. χ^2 tests were used to analyze enumeration data. All *P* values were two-sided and were considered statistically significant when the *P* values were < 0.05.

Results

Among the 5477 selected subjects, the total response rate was 92.8%. A total of 182 subjects could not be contacted or did not have time to attend the examinations during the study period and, therefore, did not complete the questionnaire, while 212 subjects completed the questionnaire, but did not undergo the ocular examination. Table 1 shows the study population of undergraduate and postgraduate subjects, while Table 2 shows a comparison of selected characteristics in the subjects who participated in the ocular examination and those who did not. There were no significant differences in sex, age, nationality, or family history of myopia between the participants and nonparticipants in the undergraduate and postgraduate populations ($P > 0.05$, Table 1).

Taking into account the entire study population, the mean SER was –4.1 ± 2.4 D (median –4.0 D, range –22.7–7.1 D). Of the subjects 95.5% (95% confidence interval [CI] 94.9%–96.1%)

Table 2. Selected Characteristics of Participants and Nonparticipants

	Freshmen			Postgraduate		
	Participants	**Nonparticipant**	***P* Value**	**Participants**	**Nonparticipant**	***P* Value**
Subjects	3625	121		1435	91	
Males/females	1534/2091	56/65	0.386	688/747	51/40	0.134
Age, y	18.8 ± 0.8	18.9 ± 0.8	0.246	23.8 ± 2.8	23.9 ± 2.5	0.673
Range	14.5 to 23.8	16.1 to 21.0		19.7 to 42.2	21.05 to 33.08	
Ethnicity						
Han	3402	112	0.564	1403	91	0.256*
Minorities	223	9		32	0	
Family history of myopia						
No	2276	89	0.080	1198	83	0.057
Yes	1349	32		237	8	

* Fisher exact test result was used.

were myopic (SER < –0.5 D), 19.5% (95% CI 18.4%–20.6%) were highly myopic (SER < –6.0 D), and only 3.3% (95% CI 2.8%–3.8%) were emmetropic (–0.5 D ≤ SER ≤0.5 D, see Fig.).

The Undergraduate Population versus the Postgraduate Population

Using an independent-samples *t*-test, the postgraduate population (–4.4 ± 2.5 D) was significantly ($P < 0.001$) more myopic than the undergraduate population (–4.0 ± 2.4 D) based on SER comparison. In the postgraduate population, 96.9% (95% CI 96.0%–97.8%) of the subjects were myopic and 23% (95% CI 20.8%–25.2%) were high myopic, while in the undergraduate population 94.9% (95% CI 94.2%–95.6%) of the subjects were myopic and 18.12% (95% CI 16.9%–19.4%) were high myopic. Using the χ^2 test, the undergraduate population was significantly ($P < 0.001$) different from the postgraduate population in terms of sex, age, ethnicity, and family history of myopia (Table 2).

Correlation of Mean Refractive Error with Age

The age range was 14.5 to 42.2 for the total university student population, 14.5 to 23.8 for the undergraduates, and 19.7 to 42.2 for the postgraduates. The mean refractive error correlated significantly with age in the total college student population (correlation coefficient $r = –0.048$, $P = 0.001$) and in the undergraduate population ($r = 0.041$, $P = 0.014$). Older subjects always were more myopic than younger ones, but this was not found in the postgraduate population ($r = 0.01$, $P = 0.711$).

Males versus Females

In the undergraduate population, male subjects (–3.8 ± 2.4 D) were significantly ($P = 0.007$) less myopic than female subjects (–4.1 ± 2.4 D) based on SER comparison. However, this difference was not found either in the total college student population ($P = 0.230$) or in the postgraduate population ($P = 0.142$, Table 3).

Correlation between the Mean Refractive Error and Ethnicity

In the total university student population, subjects from minority ethnic groups (–3.4 ± 2.2 D) were significantly less myopic than subjects of Han ethnicity (–4.1 ± 2.4 D) based on SER comparison ($P < 0.001$). Of the subjects of Han ethnicity 95.6% (95% CI 95.0%–96.2%) were myopic and 19.9% (95% CI 18.8%–21.1%) were high myopic, while 92.9% (95% CI 89.8%–96.1%) of subjects of minority ethnicity were myopic and only 11.4% (95% CI 7.5%–15.3%) were high myopic. Among the undergraduate population, subjects from minority ethnic groups were significantly ($P < 0.001$) less myopic than subjects of Han ethnicity. In the postgraduate population, this difference was not statistically significant ($P = 0.155$, Table 3).

In fact, among the total university student population, subjects of the Buyi (–1. 9 ± 2.9 D), Kazak (–2.4 ± 1.1 D), and Uighur (–1.8 ± 1.2 D) ethnic groups were significantly less

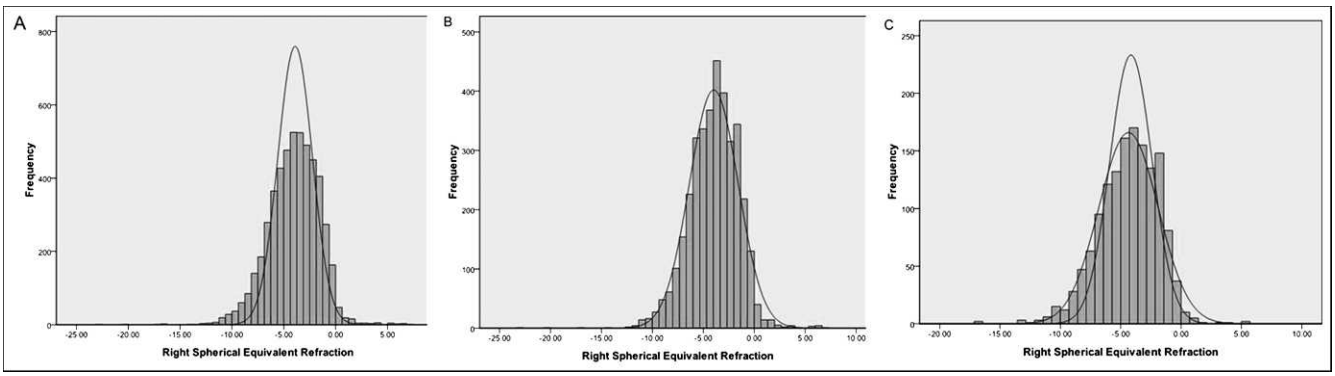

Figure. (**A**) The distribution of refractive error in the total college student population (mean –4.08, $n = 5060$). (**B**) The distribution of refractive error in the freshmen population (mean –3.97, $n = 3625$). (**C**) The distribution of refractive error in the postgraduate population (mean –4.36, $n = 1435$).

Table 3. Refractive Error (Diopters) and Miscellaneous Parameters in Stratified Subgroups

	Freshmen			Postgraduate			
	n	SER (D) Mean ± SD	*P* Value	*n*	SER (D) Mean ± SD	*P* Value	*P* Value
Sex group							
Males	1709	−3.79 ± 2.37	0.423	688	−4.46 ± 2.50	0.142	0.230
Females	3234	−3.85 ± 2.40		747	−4.27 ± 2.43		
Nationality							
Han	4699	−3.86 ± 2.40	<0.001	1403	−4.37 ± 2.46	0.155	<0.001
Minorities	244	−3.31 ± 2.12		32	−3.75 ± 2.72		
Family history of myopia							
No	2276	−3.59 ± 2.26	<0.001	1198	−4.20 ± 2.36	<0.001	<0.001
Yes	1349	−4.60 ± 2.48		237	−5.16 ± 2.81		

myopic than subjects of Han ethnicity (–4.1 ± 2.4 D, and $P = 0.016$, 0.030, and < 0.001, respectively). In the undergraduate population group, subjects of Kazak (–2.4 ± 1.1 D) and Uighur (–1.8 ± 1.2 D) ethnicity were significantly less myopic than subjects of Han (–4.0 ± 2.4 D, and $P = 0.040$ and < 0.001, respectively) ethnicity. Subjects from many other minority groups were too few to compute statistically.

A Family History of Myopia

In the total university student population, subjects with at least one myopic parent (–4.7 ± 2.5 D) were significantly more myopic than subjects with non-myopic parents (–3.8 ± 2.3 D) based on SER comparison ($P < 0.001$). Similar results were obtained in the undergraduate and postgraduate populations ($P < 0.001$, Table 3).

Discussion

To our knowledge this is the first study on myopia prevalence of a university student population in mainland China. A large number of subjects were enrolled with a high response rate of 92.8%. The 212 subjects who failed to participate in the ocular examination were not significantly different from the rest of the study population. However, the 182 students who did not finish the questionnaire may cause bias. We demonstrated high rates of myopia and high myopia in young adults exposed to high educational demands, though the sample investigated clearly is not representative of the population as a whole. The mean refractive error in this population was –4.1 D, and myopia was found in 95.5% of the subjects, with high myopia occurring in 19.5%. Students with emmetropia were very rare.

Population-based studies have provided comparative data on the prevalence of myopia in Chinese adolescents across different geographic locations. In the Shunyi Study conducted in a semirural area in northern China, 36.7% male and 55% female subjects were myopic at the age of 15.[15,24] In the Guangzhou Study, conducted in an urban city in southern China, 78.4% of the subjects were myopic at the same age,[14] while in the Yangxi Study, conducted in a rural county in southern China, the prevalence of myopia in subjects 17 years old was 53.4%.[9] In the Yongchuan Study, conducted on children aged 6 to 15 years in a rural county of western China, only 20.69% of the subjects were myopic.[25] Though a population-based survey cannot be compared directly to a university-based survey, which only has limited representativeness for a specific subgroup, the data are very helpful in conveying important information. Obviously, the very myopic university students we studied are derived from a population that always is very myopic by world standards. Besides, they demonstrated a distinct rural–urban difference on prevalence of myopia in children. Scholars substantially analyzed this difference, and believed that environmental factors, especially education, have a crucial role in myopia development, which is in accordance with many reports.[2,18,19,26,27]

University students comprise a specific population characteristic of academic excellence, thus the rates of myopia and high myopia probably are high. This idea was verified by our study. We found a high rate of myopia and high myopia in Chinese university students in DHU. Perhaps a high level of prolonged near work in and out of class for more than 10 years and less time outdoors is the main reason. Recent studies presented robust support to the importance of time spent outdoors on the incidence of myopia.[28–30] It has been reported for years that near work can be associated with myopia, though recent studies raised some doubts about this association.[21,31–33] We also found that the prevalence of myopia in postgraduates was higher than in undergraduates. The difference could be due to either continued myopia progression[34] or selection of more academic and more myopic students for postgraduate studies.[2]

Prevalence surveys on myopia in Chinese university students are very rare. A survey of students from a random sample of 90 primary and secondary schools in five provinces of China was reported in 2010. The prevalence of myopia in junior high school students was 42.9% and the prevalence in high school was 69.7%. The rates in coastal areas were higher than in inland regions, and those in developed regions were higher than in less developed regions[35] This was in accordance with a study by Pi et al., who reported a prevalence of only 13.7% in children of 6 to 15 years in a county of western China.[25] The rates of myopia in our study were higher than those in the aforementioned study. This perhaps is due to the different age. Subjects in our study were older, and have completed more education.

Several university-based surveys on myopia in other parts of the world may be taken for comparison. One of them was conducted on medical students at National Taiwan University. This 5-year longitudinal study showed a myopic prevalence increase from 92.8% to 95.8%, though the sample size was small.[36] A recent study with a large sample in this university reported similar results. The prevalence of myopia in freshmen was reported to be 91.3% in 1988 and 95.9% in 2005.[37] These rates are very similar to those in our study. Common points, like Chinese ethnicity, metropolitan cities, famous universities, and diligent students, probably could explain this similarity. Myopia was defined as a mean spherical equivalent of –0.25 D or less in the two studies from Taiwan. This cut-off level makes the rates higher. However, rates reported in western universities were much lower. Approximately 50% of the first-year

undergraduates in the Aston University and the University of Bradford in the United Kingdom were reported to be myopic,[38] while 66% of the third-year law students in the University of Pennsylvania were myopic.[39] The prevalence of myopia in first-year engineering students in the University of Trondheim in Norway was 48% in 1992, and increased to 65% after 3 years.[40,41] Rates in science students in the University of Minho in Portugal were 26% in 2002 and 32% in 2005.[42] The cut-off level in the Norway study also was a mean spherical equivalent of –0.25 D or less, and in other studies it was –0.5 D or less. The east–west difference may be attributed partly to ethnicity. It is important to mention that the prevalence of the British Asian group in the UK study was 53.4%, similar to and only a little higher than the prevalence of the white group. The data demonstrated that ethnicity may take a part, but cultural and environmental factors are rather important reasons.

In our study, we found that the mean refractive error correlated significantly with age only in the undergraduate population. Older students were more myopic than younger ones. This might be explained well by the 5-year longitudinal study in Taiwan University, and the 3-year longitudinal studies in Portugal and Norway. The investigators concluded that after the age of puberty, myopia can even progress, but at a slower rate than during childhood.[36,40,42] These longitudinal studies were better in showing this progression pattern than the cross-sectional design of our study. This correlation was not found in the postgraduate population, which partly was because of the varied age and experience. There are a considerable number of postgraduates going back to campus after years of working or travelling. The environmental factors are much more complicated.

Though studies on sex differences in myopia presented varied results before, most recent studies appear to reach a consensus on this issue. A significantly higher prevalence of myopia in female subjects usually was reported, inclusive of the national Taiwan University study.[3,9,18,20,37] We also found a slightly higher prevalence of myopia in female subjects in our study. It has been reported that female subjects spent more time at lectures, reading, and doing practical near-work.[41]

Our results indicated that, when taken together, the ethnic minority groups were less myopic than the Han group. Subjects of some minority subgroups, like Buyi, Kazak, and Uighur, and so forth, showed a tendency toward less myopia. These minorities were located mostly in remote areas in northwest China. Qian has reported that students of Han ethnicity in Shanghai were more myopic than Han students in Xinjiang. He attributed this difference to a different intensity of education. It also was reported that the Uygur students had a much lower rate of myopia than their Han classmates. Qian attributed this result to an ethnic explanation, for Uygur people had different race lineages as well as unique habits and customs.[43] Similar studies have been reported previously. In Australian schools, children of European Caucasian ethnicity had a lower prevalence of myopia than East Asian children.[44] In fact, ethnicity may have genetic and cultural connotations. The associations between ethnicity and myopia probably are not attributed to be genetic, but could reflect enduring patterns of behavior and cultural attitudes, such as higher levels of more intense near work and lower levels of outdoor activity. There are differences in exposure to the major risk factors between ethnic groups, even when they apparently are living in the same environment. The preferential enrollment criteria for some ethic minority students also should be considered as an important factor influencing the lower prevalence of myopia in our study.

It has been reported for years that people with myopic parents were more likely to be myopic than people with non-myopic parents.[33,39] This was verified by results obtained in our study. However, what is striking is that the students without a family history of myopia also were very myopic in our study.

As high myopia may be associated with myopic macular degeneration, cataracts or myopic glaucoma, and may induce vision impairments, understanding the prevalence of high myopia is vital. The prevalence of high myopia was 19.5% in our study, which is lower than the rates in the Taiwan University study. It was reported that 23.5% freshmen were high myopic in 1988, and this prevalence increased to 38.4% in 2005.[37] The cut-off level of this study also was –6.0 D, the same as ours. A population-based study has reported 10.9% rates for high myopia in children of 18 years in 1983 and 21% in 2000.[5] The difference probably may be explained by the theory that near work during education might cause late-onset myopia and myopia progression.[34] Meanwhile, to our knowledge university-based studies in western countries haven't shown data on high myopia.

Our study provided detailed data on the prevalence and associations of myopia and high myopia in a specific population of Chinese university students. We hope to get a better understanding of myopia, and help prevent myopia in young adults at risk. The obvious strength of our study was to explore a huge number of subjects with a standardized methodology. There were several limitations in our study. A big problem was the use of non-cycloplegic measurement, which led to overestimation of myopia and even greater underestimation of hyperopia. This combination led to even greater errors in the calculation of mean SER. Using –0.5 D as the cut-off level for myopia also may overestimate myopia. However, it is not really possible for the errors inherent in lack of cycloplegia to change the basic nature of the results—the levels of myopia and high myopia are exceptionally high, and the mean SER is exceptionally myopic. Another limitation of our study was that the parental myopia was obtained by questionnaire. We had not validated them, and this was another source of bias. Our study provided high rates of myopia and high myopia in Chinese university students. The refractive status of this specific population deserves further attention.

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