The Impact of Parental Myopia on Myopia in University Students: A Cross-Sectional Study from Shanghai, China

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Abstract

Background: To evaluate the effect of parental myopia on Chinese university students with a high prevalence of myopia in Shanghai.

Methods: A cross-sectional study of university students in Shanghai, China. All participants responded to a detailed questionnaire, including questions about age, ethnicity and family history. They underwent a standardized ophthalmological examination, including visual acuity, a slit lamp examination and non-cycloplegic auto-refraction. Generalized linear model was used to identify risk factors for myopia.

Results: Of the 11,977 total subjects, 91.55% were myopic (spherical equivalent refraction [SER] ≤ -0.75 D), 20.18% were highly myopic (SER ≤ -6.0 D) and only 6.94% were emmetropic (-0.75 D $\leq$ SER ≤ 0.75 D). The mean age of the myopic participants (19.7 ± 2.4) was higher than that of the emmetropic participants (19.3 ± 1.9 , $p < 0.001$). 10391 (91.8%) of Han students were myopic, which exhibited greater myopia than minority students (91.5%, $p < 0.001$). Among the students from families with two myopic parents, 97.9% had myopia. Only 93.7% of students had myopia where only one parent was myopic, and among the students without myopic parents, 90.7% had myopia ($p < 0.001$). Female students whose parents were myopic (8.0%) were more likely to have myopia than male students whose parents were myopic (7.5%) ($p < 0.001$). Students with two myopic parents (mean difference: -2.04, 95% CI: -2.21, -1.86) were at a high risk of myopia compared with students with no myopic parents ($p < 0.001$).

Conclusions: This study showed that the refractive status of children in a population with a high prevalence of myopia was related to the status of parents. Increased severity of parental myopia led to a greater risk of myopia in their children.

Background

Myopia, one of the most prevalent refractive errors, has become a major public health issue worldwide [1–3]. There are approximately 1950 million people with myopia worldwide (28.3% of the global population) [4]. However, the prevalence of myopia varies across the world. According to current surveys, the prevalence is higher in Asian countries such as China (73.1%) [5], Korea (70.6%) [6] and Singapore (79.3%) [7] than in countries such as Norway (35.0%) [8], the UK (26.9%) [9], the United States (33.1%) [10] and Australia (11.9%) [11]. An increase in the myopia rate has resulted in an increase in the prevalence of high myopia. High myopia is associated with severe ocular issues, including myopic maculopathy, choroidal neovascularization, macular holes, myopic retinoschisis, retinal detachment and open-angle glaucoma [12–15]. Based on the growing prevalence of refractive errors and high myopia, it is increasingly important to find ways to reduce myopia rates among the younger generation in East and Southeast Asia [16].

Myopia is thought to have a multifactorial etiology, including intensive education [17], lifestyle [18–20], parental myopia [21, 22] and a lower serum 25-hydroxyvitamin D (25[OH]D) concentration [6]. The association between genetic factors and myopia has been extensively analyzed [23–28]. The myopia

status of children is reported to be closely related to the status of their parents. Only two studies did not find an association between parental and juvenile myopia [29, 30]. Our research focused mainly on the relationship between hereditary factors and myopia in a Shanghai university student population with a high prevalence of myopia.

Methods

Participants

This was a cross-sectional study of the characteristics of ocular biometry in university students in Shanghai, China [31]. The students were recruited from Donghua University (DHU), located in the Changning district of Shanghai, and Shanghai University of Medicine & Health Sciences (SUMHS). Study participants were recruited using cluster sampling; all first-year undergraduates and first-year Master's degree students were selected. The fieldwork was carried out during September 2009 and October 2010. Each student's name, sex, and student ID number were registered at the student affairs office. Among the 12,711 subjects selected, 11,977 students participated in the study (response rate of 94.23%). Students who had had corneal or scleral surgery or any other eye disease that would damage their visual acuity were excluded.

All participants received detailed information about the study before being enrolled. Informed consent was obtained according to the Declaration of Helsinki. The Shanghai JiaoTong University School of Medicine Ethics Review Board and the Ethics Committee of Shanghai Ninth People's Hospital approved the study.

Questionnaire And Ophthalmic Examination

Students were selected by an ophthalmologist to complete a questionnaire, which included questions about their date of birth, nationality, history of myopia, history of other eye diseases and family history of either myopia or hereditary diseases. In detail, the parents' refractive status was filled in by students with emmetropia, low myopia, moderate myopia and high myopia. Next, a second ophthalmologist performed a simple ocular examination using a slit lamp to exclude opacity of the optical media. Visual acuity was then measured as uncorrected visual acuity (UCVA) (Snellen charts) at a distance of 5 m. An automatic refractometer (Auto Refractometer, AR-600; Nidek Ltd., Tokyo, Japan) was used to obtain a measurement of the refractive error without cycloplegia, and the average value of five repetitions was recorded. If the UCVA was < 1.0 , the corrected visual acuity was measured by subjective refraction.

Statistical Analysis

All data were entered into Epidata (version 3.1) and statistical analyses were performed using SPSS software (version 22.0; IBM Corp., Armonk, NY, USA). Spherical equivalent refraction (SER) was calculated as the spherical value of the refractive error plus half of the cylindrical value. All of the numerical data are

given as the means $\pm$ standard deviation (SD). Myopia was defined as an SER < -0.75 diopters (D), and these cases were further categorized into three subgroups based on the magnitude of the SER: low myopia ($-3.00\text{D} \leq \text{SER} < -0.75\text{D}$), moderate myopia ($-6.0\text{D} \leq \text{SER} < -3.0\text{D}$), and high myopia ($\text{SER} < -6.0\text{D}$). Emmetropia was taken as an SER score between -0.75D and $+0.75\text{D}$; an SER value $> 0.75\text{D}$ was regarded as hyperopia. Means were compared by independent t -tests. Chi-squared tests were used to analyze the enumeration data. Generalized linear model was used in multivariate analyses. All p -values were two-sided and were considered statistically significant at $p < 0.05$.

Results

Participants' characteristics

Among the 12,711 selected subjects, the response rate was 11,977 (94.2%), of which 4,191 (35.0%) were male and 7,786 (65.0%) were female. According to Fig. 1, only 54 students were hypermetropic, and the number of emmetropia was 777. 5218 Students who were moderate myopic counted most (43.6%). There were 3511 and 2417 students with low myopia and high myopia, respectively. Table 1 showed that the mean age of the participants was 19.7 ± 2.4 years, and the mean age of the myopic participants was higher than that of the emmetropic participants ($p < 0.001$). Interestingly, when we divided the age of students into freshmen and postgraduate students, the difference between myopia and non-myopia students had no statistical significance. The 11,977 participants included 11,273 Han Chinese and 704 from other minorities. The Han Chinese students had higher rates of myopia than the minority students ($p < 0.001$). There was no difference in the prevalence rates of myopia according to birth season ($p = 0.100$) and sex ($p = 0.404$). Among the participants with myopia, 2,270 (20.7%) had a mother with myopia and 2,201 (20.07%) had a father with myopia. Among the students from families with two myopic parents, 97.9% had myopia. Of the students with only one myopic parent, 93.7% had myopia, compared with 90.7% of the students without myopic parents ($p < 0.001$). These results indicated that parents with myopia tend to have children with myopia.

Table 1
Characteristics of the 11,977 study participants ^a

Characteristics	Total	Myopia		p-value ^b
		No	Yes	
No. of participants	11,977 ^a	1,012	10,965	–
Age, years	19.7 ± 2.4	19.3 ± 1.9	19.7 ± 2.4	< 0.001
Freshmen		18.8 ± 1.2	18.9 ± 2.7	0.477
Postgraduate		22.4 ± 3.8	23.0 ± 3.2	0.116
Sex				
Male	4191 (35.0)	342 (8.2)	3849 (91.8)	0.404
Female	7786 (65.0)	670 (8.6)	7116 (91.4)	
Ethnicity				
Han	11273 (94.1)	882 (7.8)	10391 (92.2)	< 0.001
Minorities	704 (5.9)	130 (18.5)	574 (81.5)	
Birth season				
Spring	2640 (22.0)	231 (8.8)	2409 (91.3)	0.100
Summer	2908 (24.3)	273 (9.4)	2635 (90.6)	
Fall	3414 (28.5)	294 (8.0)	3140 (92.0)	
Winter	3015 (25.2)	234 (7.8)	2781 (92.2)	
Parental myopia status	2384 (19.9)	114 (4.8)	2270 (95.2)	< 0.001
Maternal myopia	9593 (80.1)	898 (9.4)	8695 (90.6)	
Yes				
No				
Paternal myopia	2307 (19.3)	106 (4.6)	2201 (95.4)	< 0.001
Yes	9670 (80.7)	906 (9.4)	8764 (90.6)	
No				
Parental myopia status				

^a The data are means ± SD or n (proportion, %).

^b p-values were obtained using the *t*-test or chi-squared test, as appropriate.

Characteristics	Total	Myopia		p-value ^b
		No	Yes	
Neither	8161 (68.1)	810 (9.9)	7351 (90.1)	< 0.001
Mother or father	2941(24.6)	184(6.3)	2757(93.7)	
Both	875 (7.3)	18 (2.1)	857 (97.9)	
^a The data are means ± SD or n (proportion, %).				
^b p-values were obtained using the <i>t</i> -test or chi-squared test, as appropriate.				

Characteristics of college students according to their parental myopia status

As shown in Table 2, 1,868 female students had only one myopic parent, accounting for 26.3% of the total number of females, and only 889 male students were myopic if they had one parent with myopia, accounting for only 23.1% of the total number of males. Similarly, among the students whose parents were myopic, the myopia rate in female students (8.0%) was higher than that in males (7.5%). Table 2 also shows that Han students whose parents were myopic were more likely to have myopia (7.7%) than minority students with myopic parents (7.5%) ($p = 0.013$).

Table 2
Characteristics of the 11,977 students according to their parental myopia status

Parental myopia status (mother, father)	Myopia (male students)	Myopia (female students)	Han	Minorities
	n (proportion)	n (proportion)	n (proportion)	n (proportion)
(-, -)	2671 (69.4)	4680 (65.8)	6966 (66.8)	424 (72.2)
(+, -) or (-, +)	889 (23.1)	1868 (26.3)	2658 (25.5)	119 (20.3)
(+, +)	289 (7.5)	568 (8.0)	799 (7.7)	44 (7.5)
p-value ^a	< 0.001		0.013	
^a p-values were obtained using the Mann-Whitney test				

The association between parental myopia status and the refractive error (diopters) among students (Tables 3–4, Figure 2–3)

Table 3

Generalized linear model analysis of parental myopia status and the refractive error (Diopters) among 11,977 Chinese university students

		Parental myopia status ^a				P for trend ^d
		0	1	2	3	
Model 1 ^b	Father	0 (Ref.)	-0.83 (-1.01, -0.66) ^e	-0.98 (-1.14, -0.81)	-1.38 (-1.64, -1.13)	< 0.001
	Mother	0 (Ref.)	-0.79 (-0.96, -0.63)	-1.00 (-1.17, -0.84)	-1.77 (-2.01, -1.53)	< 0.001
Model 2 ^c	Father	0 (Ref.)	-0.86 (-1.03, -0.68)	-1.00 (-1.16, -0.84)	-1.41 (-1.66, -1.15)	< 0.001
	Mother	0 (Ref.)	-0.83 (-1.00, -0.66)	-1.04 (-1.20, -0.87)	-1.81 (-2.05, -1.57)	< 0.001
^a 0: Hypermetropia and emmetropia; 1: Low myopia; 2: Moderate myopia; 3: High myopia.						
^b Model 1 was a crude model without adjustment.						
^c Model 2 was adjusted for age and ethnicity.						
^d Tests for a linear trend were performed by entering parental myopia status as a continuous variable for all of the models.						
^e Mean difference (95% Wald confidence interval) was estimated using the model.						

Table 4

The association (mean difference [95% CI]) between the joint classification of parental myopia status and the refractive error (Diopters) among 11,977 college students

	Parental myopia status (mother, father) ^a			p for trend ^d
	(-, -)	(+, -)/(-, +)	(+, +)	
Model 1 ^b	0 (Ref.)	-1.03 (-1.14, -0.93) ^e	-1.98 (-2.15, -1.80)	< 0.001
Model 2 ^c	0 (Ref.)	-1.06 (-1.16, -0.96)	-2.04 (-2.21, -1.86)	< 0.001
^a -: Not myopic; +: Myopic.				
^b Model 1 was a crude model without adjustment.				
^c Model 2 was adjusted for age and ethnicity.				
^d Tests for a linear trend were performed by entering parental myopia status as a continuous variable for all of the models.				
^e Mean difference (95% Wald confidence interval) was estimated using the model.				

To further analyze the influence of hereditary factors on the offspring according to the degree of myopia in their parents, the SER of students was used as the dependent parameter and age, sex, ethnicity and parental myopia status as the independent variables in the first step of a generalized linear model analysis. In the multivariate analysis, age and ethnicity were adjusted for, and the remaining parameters that were significantly associated with myopia in a stepwise fashion in the univariate analyses were included.

The results in Table 3 showed that students with fathers with high myopia had a SER of 1.41D less than students without a myopic father (mean difference: -1.41, 95% CI: -1.66, -1.15, $p < 0.001$), and students with a mother with high myopia were more likely to be myopic compared with students without a myopic mother (mean difference: -1.81, 95% CI: -2.05, -1.57, $p < 0.001$). It can be analyzed that the higher the degree of myopia of father, the lower the SER of the child. The same went for mother's results (Table 3, Fig. 2). As shown in Table 4, students with two myopic parents were at a high risk of myopia (mean difference: -2.04, 95% CI: -2.21, -1.86, $p < 0.001$) (Table 4, Fig. 3). Tables 3 and 4 both showed that the SER in college students was strongly related to the myopia status of their parents ($p < 0.001$).

Discussion

In this study, we found that the myopia status of children in a population with a high myopia prevalence was associated with the myopia status of their parents. Although four of five myopic students didn't have myopic parents, the influence of parents' myopia could still be seen. Increasing severity of parental myopia may lead to an increased risk of myopia in children.

As shown in Table 5, comparable results have been reported previously. For instance, an epidemiological survey from China showed that children with a single parent with myopia were twice as likely to have myopia as their non-myopic counterparts, and those with both parents with myopia were three times as likely to have myopia as their non-myopic counterparts [28]. A study conducted by Ip et al. [23] identified the odds of childhood myopia at 2.3 (95% CI 1.8–2.9) when one parent was myopic and 7.9 (95% CI 5.0–12.4) when both parents were myopic after adjusting for environmental and demographic factors, compared with children whose parents were not myopic. In another population-based cross-sectional study in Korea, the prevalence rate ratio (PRR) for children's myopia and high myopia with myopic parents were 1.34 (95% CI 1.24–1.45) and 3.11 (95% CI 1.93–5.01), respectively. The PRR of myopia and high myopia in children increased significantly to 1.37 (95% CI 1.04–1.81) and 11.41 (95% CI 6.24–20.88), as the degree of parental myopia increased ($p < 0.001$, respectively). Children with two myopic parents were more myopic than those with only one myopic parent ($p < 0.001$, respectively) [26]. An American study conducted on children aged 13.7 ± 0.5 years showed that among children in families with two parents with myopia, 32.9% had myopia compared with 18.2% of children in families in which only one parent was myopic and 6.3% of children in families with no parents with myopia [27].

Table 5
Association between parental myopia and refractive status of the offspring

Sum	Author	Year	Country	Sample size	Prevalence of myopia (%)	Result
1	Pärssinen [48]	1983–1984	Finland	240	/	Yes
2	Wu[49]	2012	China	43, 771	34.39(F) 29.4(M)	Yes
3	Mutti[27]	1991–1996	USA	366	18.3	Yes
4	Jones[50]	1989–2001	USA	514	21.6	Yes
5	Zhang[51]	1950–2013	Asia, Europe, USA, Australia	31,677	8,393	Yes
6	Zadnik[29]	1989–2010	USA	4,512	/	No
7	Lim[26]	2008–2012	Korea	3,862	2495(64.6)	Yes
8	Pärssinen [52]	1983–1984	Finland	240	/	Yes
9	Xiang[53]	2000	China	1,567	57.7	Yes
10	Lee[54]	2010–2011	China	5,187	86.1	Yes
11	Greene[55]	2015	USA	165	38.5	Yes
12	Liao[56]	2006–2017	China (Guangzhou)	1,831	/	Yes
13	Hsu[57]	2013–2016	China (Taiwan)	11,590	36.4	Yes
14	Kurtz[58]	1997–1998	USA	232	/	Yes
15	Ip[23]	2003–2005	Australia	2,353	/	Yes
16	Jones-Jordan [59]	1989–2010	USA	2,158	/	Yes
17	Lam[26]	1998–2000	China (Hong Kong)	7,560	/	Yes
18	Edwards[30]	1991–1996	China (Hong Kong)	123	53%	No

Although the above studies were conducted in different decades and regions, all showed that the myopia status of the children was related to parental myopia. The subjects of this study had a comparatively high prevalence of myopia and were relatively well educated.

However, two studies concluded that there was no association between parental myopia and the refractive status of the offspring [29, 30]. There are several possible reasons for this discrepancy. First, we speculated that the subjects differed considerably between our study and those two prior studies in terms of age, ethnicity, academic pressure, and life-style. Second, the social status and educational level of parents potentially influence the association between their myopia status and that of their children. Finally, the discrepancy could be due to differences in the sensitivity and specificity of the statistical methods used.

The prevalence of myopia identified in this study was higher than those in previous reports. For example, a prevalence of 29.1% was reported in children of Chinese ethnicity in Singapore [32], 47.9% in Saudi Arabian college students [33], 30.6% in adults across Europe [34], and 21.1% in north Indian schoolchildren [35]. However, the prevalence of myopia in this study was similar to those reported in male Taiwanese military members (86.1%) [21], Chinese students aged 17–18 years (74.2%) [36], and teenaged high-school students in Singapore (73.9%) [37]. The discrepancy may be due to differences in environmental factors and educational pressures between East Asian (especially Chinese) and Western students [38, 39]. The educational pressure on East Asian students is greater than that on students in other countries [1]. We analyzed the prevalence of myopia in students from two universities in Shanghai, China. Due to the higher educational level of these students, they spent more time on near work in order to achieve good marks and get chance to study in university. This may explain their higher prevalence of myopia compared with the rates reported in other epidemiological studies [39–41].

This study found that age and ethnicity were closely associated with myopia ($p < 0.001$), which is largely in agreement with previous studies [25, 34, 42]. After adjusting for age and ethnicity, parental myopia was still an independent risk factor associated with the occurrence of myopia in the multivariate analysis. Our results thus suggest a familial predisposition for myopia.

This study has some limitations. First, compared with previous studies, this survey focused mainly on the relationship between myopia and heredity. However, in the myopia progression process, factors such as lifestyle, long-term and close distance learning and outdoor activities have not been ruled out, so our results may have been influenced by these factors. Second, data on parental myopia were self-reported by the participants. The self-reported measures of parental myopia may have overestimated the proportion of parents who wear spectacles to correct refractive problems other than myopia. Moreover, as our sample was limited to Chinese undergraduates, comparative studies should be undertaken of the hereditary differences in other nationalities to further explore myopia, which is a multifactorial disease. Finally, this study only investigated the relationship between parental refraction and that of their children; the additional measurement of the relationship between parental axial length and that of their offspring would enhance our understanding of the heritability of myopia.

Previous studies identified an association between myopia and MMP-2, TIMP-2, TGF- β , miRNA-328, PAX6, miR-29a and miR-let-7i [43–47]. Using genetic data, an analysis of the correlation between parental genes and those of their children and refractive status would enable more accurate and efficient treatments for myopia, including molecular targeted therapies.

Abbreviations

UCVA

Uncorrected Visual Acuity

SER

Spherical Equivalent Refraction

SD

Standard Deviation

PRR

Prevalence Rate Ratio

Declarations

Ethics approval and consent to participate:

The Shanghai JiaoTong University School of Medicine Ethics Review Board and the Ethics Committee of Shanghai Ninth People's Hospital approved the study and the study was performed in accordance with the Declaration of Helsinki. All patients signed an informed consent form.

Consent for publication:

Not applicable.

Availability of data and materials:

The datasets for the analysis of the current study are readily available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

WL, PX participated in the design of the study. WL, PX collected and analyzed the data. All authors interpreted the data. WL wrote the article. PX critically revised the article. CC and JZ reviewed the literature. All authors read and approved the final manuscript.

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Figures

Figure 1

Composition ratio of refractive state among 11,977 Chinese university students Hypermetropia: 54 (0.5%); emmetropia: 777 (6.5%); low myopia: 3511 (29.3%); moderate myopia: 5218 (43.6%); high myopia: 2517(20.2%).

Figure 2

Generalized linear model analysis of parental myopia status and the refractive error (Diopters) among 11,977 Chinese university students X-Axes: Parental myopia status (Hypermetropia and emmetropia; low myopia; moderate myopia; high myopia). Y-Axes: Refractive error of students (Diopters).

Figure 3

The association (mean difference [95% CI]) between the joint classification of parental myopia status and the refractive error (Diopters) among 11,977 college students X-Axes: Parental myopia status (neither myopic, either myopic, both myopic). Y-Axes: Refractive error of students (Diopters).