• Investigation •

Prevalence and inconformity of refractive errors and ocular biometry of 3573 medical university freshman students for 4 consecutive years

Hui-Juan Gao[1,2], Hong-Mei Zhang[1], Wei-Yu Dang[1], Lin Liu[1], Yun Zhu[3], Qing He[1], Xin Wang[1], Yan-Hui Chen[4], Fei Gao[1], Qing-Xin Wang[1], Hua Rong[1], Shu-Ling Niu[2], Rui-Hua Wei[1]

[1]Tianjin Key Laboratory of Retinal Functions and Diseases, Tianjin Branch of National Clinical Research Center for Ocular Disease, Eye Institute and School of Optometry, Tianjin Medical University Eye Hospital, Tianjin 300384, China
[2]Tianjin Third Central Hospital-Branch, Tianjin 300300, China
[3]Department of Epidemiology and Biostatistics, Tianjin Medical University, Tianjin 300384, China
[4]Tangshan Eye Hospital, Tangshan 063016, Hebei Province, China

Co-first authors: Hui-Juan Gao and Hong-Mei Zhang
Correspondence to: Rui-Hua Wei. Tianjin Medical University Eye Hospital, 251 Fukang Road, Nankai District, Tianjin 300384, China. rwei@tmu.edu.cn
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Abstract

● **AIM:** To evaluate the prevalence of refractive errors and ocular biometry in 3573 freshman students at Tianjin Medical University for 4 consecutive years.

● **METHODS:** In this university-based, cross-sectional study, comprising 3573 students, visual acuity (VA), slit-lamp examination, non-cycloplegic auto-refraction, and ocular biometry were recorded.

● **RESULTS:** The prevalence of myopia increased annually, from 2017 to 2020 were 93.5%, 94.5%, 95.9%, and 96.2%, respectively (P=0.03), and the prevalence of high myopia was 25.7%, 26.9%, 28.6%, and 28.6%, respectively. Males tended to have a higher percentage of total astigmatism than females, with astigmatism ≥0.75 and ≥1.0 D criteria. The percentage of with-the-rule astigmatism, against-the-rule astigmatism, and oblique astigmatism was 90.3%, 5.8%, and 3.9%, respectively, with astigmatism ≥1.00 D criteria. The mean spherical equivalent, axial length (AL), central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), corneal radius (CR), and lens position (LP) were 4.37±2.52 D, 25.28±1.24 mm, 539.49±34.98 μm, 3.31±0.34 mm, 3.47±0.21 mm, 7.8±0.28 mm, and 5.04±0.32 mm, respectively. With diopter increase in myopia, the AL became longer, CR became steeper, ACD became deeper, LT became thinner, and LP became more posterior (all P<0.01). Females had a shorter AL, thinner CCT, smaller CR, shallower ACD, thicker lens, and more anterior LP than males (P<0.01). The 64% of high myopia had AL≥26 mm, meanwhile, 5.8% mild myopia and 21.1% moderate myopia had AL≥26 mm. With AL≥26 mm, mild and moderate myopia compared to high myopia, AL was shorter (26.51±0.46 *vs* 26.87±0.70 mm), CR was larger (8.10±0.3 *vs* 7.85±0.23 mm) and LT was thinner (3.39±0.19 *vs* 3.45±0.19 mm, P<0.001).

● **CONCLUSION:** The prevalence of myopia and high myopia is significantly high in freshman students. The majority of astigmatism is with-the-rule. Inconformity of refractive errors and ocular biometry existed in some students. Attention should be paid to the ocular biometry of myopia.

● **KEYWORDS:** refractive errors; myopia; prevalence; ocular biometry; astigmatism

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INTRODUCTION

Myopia has become a global public health problem. Recent Meta-analyses have suggested that by 2050, approximately 49.8% of the world population will have myopia, and 9.8% of the world population will have high myopia[1]. In developed countries in Southeast and East Asia, the prevalence of myopia is currently 80%-90% in children completing secondary schooling (age 17-18y)[2]. In China, Sun *et al*[3] reported that in Dong Hua University in Shanghai, 19.5% and 95.5% of freshman students had high myopia and myopia, respectively, and Wang *et al*[4] reported that approximately 90% and 26% of high school students in eastern China had

myopia and high myopia, respectively. Lv and Zhang[5] reported that the prevalence of myopia in medical university students increased from 78.5% to 84.1% over a 2-year follow-up period. Adolescent myopia, particularly among university students[3,6], has become a marked public health problem. Astigmatism is a common type of refractive error, defined as the difference between the two principal meridians of the eyeball in refractive error[7-8].

Ocular biometric parameters are important for the evaluation of myopia. There is a strong association between ocular biometric parameters and refraction[9-10]. Based on refractive status and sex, for the main ocular biometric parameters in young adults, Sun *et al*[11] provided a range of reference values. However, data on ocular biometry remain scarce in medical university students. Axial length (AL) contributes to the variance in spherical equivalent (SE)[12]. High myopia is usually defined as an AL≥26.0 mm or an SE more than 6.0 D[13]. High myopia associated with cataracts, myopic glaucoma, or myopic macular degeneration is one of the leading causes of blindness, particularly in European and East Asian countries[14-15].

This study investigated the prevalence of refractive errors and determined the distribution of ocular biometric parameters in freshman students at Tianjin Medical University.

SUBJECTS AND METHODS

Ethical Approval This study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Tianjin Medical University Eye Hospital (No.2021KY-16). Before the study, all participating students signed an informed consent form.

Study Population This study was conducted at Tianjin Medical University, China. From 2017 to 2020, 3895 freshman students were invited to participate in this study. Students originated from all provinces of mainland China. Undergraduates who unwilling to cooperate with examination, without successful biometric measurements (n=299), glaucoma (n=2), undergone retinal detachment surgery (n=6) or refractive surgery (n=15) were excluded. Eventually, effective ocular biometric data were obtained for 3573 (91.73%) students in this study.

Ocular Examination The examination included distant visual acuity, ocular biometry, and non-cycloplegic refraction. An optical biometer (LENSTAR LS900, i8.2.2.0, Haag-Streit, Koeniz, Switzerland) was used to measure the central corneal thickness (CCT), AL, keratometry power (K), anterior chamber depth (ACD), and lens thickness (LT). Five repeated measurements were taken, and the average value was calculated for each parameter. Non-cycloplegic refraction was measured using an automatic refractometer (model KR 8900; Topcon, Tokyo, Japan) by professional optometrists, and after three measurements, refractive errors [spherical (S), cylinder (C), axis (A)] were recorded.

Definitions Refractive errors were classified according to SE. The SE was calculated using the following equation: SE=S+C/2. Emmetropes were defined as SE between -0.5 and +0.5 D. Myopia was defined as an SE<-0.50 D, whereas hyperopia was defined as an SE>0.50 D. Myopia was also classified into high, moderate, and mild myopia, based on an SE of <-6.00, -3.00 to -6.00, and -0.50 to -3.00 D, respectively. Different criteria were also used to define the extent of astigmatism (cylinder powers 0.50-<0.75, 0.75-<1.00, and ≥1.00 D). Total astigmatism (TA) refers to the astigmatism of the eye as a complete ocular system. TA was the combined outcome of internal astigmatism (IA) and corneal astigmatism (CA). TA and CA were obtained from the measurement of automatic refractometer and lenstar, using the following formula IA=TA-CA. A cylinder axis of 90°±30° was defined as against-the-rule (ATR) astigmatism, a cylinder axis of 180°±30° was defined as with-the-rule (WTR) astigmatism, and cylinder axis of 31°-59° or 121°-149° was defined as oblique astigmatism. The cylinder power was expressed in the form of a negative. Corneal radius (CR) was extracted from the K value using the formula CR (mm)=1000×0.3375/K (D). The ACD was defined as the distance from the anterior lens to the corneal endothelium. The corrected lens position (LP) was defined as the sum of half of the LT, and the ACD[16].

Statistical Analysis Statistical Package for the Social Sciences (SPSS) statistical package version 20.0 (IBM Corporation, Armonk, NY, USA) was used to perform statistical analysis. There was no significant difference in the number, sex, and age in each year; thus, freshman students' data from 4 consecutive years were analyzed together. For continuous variables, data are presented as mean±standard deviation (SD). Categorical variables were compared for the different groups using the Chi-squared test. Continuous variables were assessed using the analysis of variance and compared using an independent t-test. Only the right eye was analyzed. P-values were two-sided and considered significant at P<0.05.

RESULTS

Prevalence of Myopia and High Myopia This study comprised 3573 [1312 (36.7%) males and 2261 (63.3%) females] students. The mean age was 18.22±0.67y (range: 15-23y). The total prevalence of hyperopia, emmetropia, myopia was 1.3%, 3.7%, 95%, and prevalence of mild myopia, moderate myopia, high myopia was 23.9%, 43.6%, and 27.5%. There was no statistically significant difference between males and females. The prevalence of myopia from 2017 to 2020 were 93.5%, 94.5%, 95.9%, and 96.2%, respectively (P=0.03). The prevalence of high myopia was 25.7%, 26.9%, and 28.6%, respectively. The prevalence of high myopia increased in the first 3 years, while the difference was not statistically significant (P=0.45; Table 1).

Table 1 Prevalence of refractive errors in 3573 freshman students *n* (%)

Refractive errors	Total	Gender		*P*	Year				*P*
		Male	Female		2017	2018	2019	2020	
Total	3573	1312 (36.7)	2261 (63.3)		895	891	917	870	
Hyperopia	46 (1.3)	19 (1.4)	27 (1.2)	0.52	13 (1.5)	17 (1.9)	6 (0.7)	10 (1.1)	0.12
Emmetropia	132 (3.7)	51 (3.9)	81 (3.6)	0.64	45 (5.0)	32 (3.6)	32 (3.5)	23 (2.6)	0.06
Myopia	3395 (95)	1242 (94.7)	2153 (95.2)	0.46	837 (93.5)	842 (94.5)	879 (95.9)	891 (96.2)	0.03
Mild	855 (23.9)	325 (24.8)	530 (23.4)	0.37	216 (24.1)	226 (25.4)	200 (21.8)	213 (24.5)	0.33
Moderate	1559 (43.6)	569 (43.4)	990 (43.8)	0.81	391 (43.7)	376 (42.2)	417 (45.5)	375 (43.1)	0.55
High	981 (27.5)	348 (26.5)	633 (28)	0.34	230 (25.7)	240 (26.9)	262 (28.6)	249 (28.6)	0.45

Table 2 Percentage of total astigmatism, corneal astigmatism, and internal astigmatism

Astigmatism	*n*	0.50-<0.75 D			0.75-<1.00 D			≥1.00 D		
		n (%)	95%CI (%)	*P*	*n* (%)	95%CI (%)	*P*	*n* (%)	95%CI (%)	*P*
Total astigmatism										
All	3573	2314 (64.8)	63.2-66.3		1537 (43)	41.4-44.6		990 (27.7)	26.2-29.2	
Male	1312	873 (66.5)	64.0-69.1		596 (45.4)	42.7-48.1		406 (30.9)	28.4-33.4	
Female	2261	1441 (63.7)	61.7-65.7	0.09	941 (41.6)	39.6-43.7	0.027	584 (25.8)	24.0-27.6	0.001
Corneal astigmatism										
All	3573	3147 (88.1)	87.0-89.1		2659 (74.4)	73.0-75.9		2097 (58.7)	57.1-60.3	
Male	1312	1138 (86.7)	84.9-88.6		940 (71.6)	69.2-74.1		761 (58)	55.3-60.7	
Female	2261	2009 (88.9)	87.6-90.2	0.06	1719 (76)	74.3-77.8	0.004	1336 (59.1)	57.1-61.1	0.525
Internal astigmatism										
All	3573	2100 (58.8)	57.2-60.4		1319 (36.9)	35.3-38.5		705 (19.7)	18.4-21.0	
Male	1312	706 (53.8)	51.1-56.5		428 (32.6)	30.1-35.2		218 (16.6)	14.6-18.6	
Female	2261	1394 (61.7)	59.6-63.7	<0.001	891 (39.4)	37.4-41.4	<0.001	487 (21.5)	19.8-23.2	<0.001

CI: Confidence interval.

Table 3 Percentage of different types of astigmatism ≥1.00 D

Gender	*n*	WTR		ATR		Oblique		*P*
		n (%)	95%CI (%)	*n* (%)	95%CI (%)	*n* (%)	95%CI (%)	
All	990	894 (90.3)		57 (5.8)		39 (3.9)		
Male	406	377 (92.9)	90.3-95.4	15 (3.7)	1.9-5.5	14 (3.4)	1.7-5.2	
Female	584	517 (88.5)	85.9-91.1	42 (7.2)	5.1-9.3	25 (4.3)	2.6-5.9	0.05

WTR: With-the-rule astigmatism; ATR: Against-the-rule astigmatism; oblique: Oblique astigmatism; CI: Confidence interval.

Percentage and Classification of Astigmatism Males tended to have a higher percentage of TA than females with astigmatism 0.75-<1.00 and ≥1.0 D, females tended to have a higher percentage of CA and IA with astigmatism ≥0.75 D (Table 2).

Astigmatism was generally set at 1.00 D as a clinically significant threshold. The most common type of TA was WTR (90.3%), followed by ATR (5.8%) and oblique astigmatism (3.9%). However, there were no significant differences between males and females (Table 3).

Ocular Biometric Parameters With diopters increase in myopia, the AL became longer, LT became thinner, CR became steeper, ACD became deeper, and LP became posterior (all $P<0.01$). CCT did not change statistically significantly ($P=0.10$). Females were found to have a shorter AL, thinner CCT, smaller CR, shallower ACD, thicker lens, and more anterior LP than males ($P<0.01$). SE was not statistically significant between males and females ($P=0.11$; Table 4).

Distribution of Myopia Stratified by Axial Length and Spherical Equivalent According to AL, individuals with myopia were divided into two groups: AL≥26 mm and AL<26 mm. The 36% of high myopia had AL<26 mm, 78.9% moderate myopia, and 94.2% mild myopia had AL<26 mm. The 64% of high myopia had AL≥26 mm. Meanwhile, 5.8% mild myopia and 21.1% moderate myopia had AL≥26 mm (Figure 1).

Comparison of ocular Biometric Parameters Between Mild to Moderate Myopia and High Myopia, with Different Axial Length For myopic subjects with AL<26 mm, the group with high myopia had a longer AL, lower CCT, and

Table 4 Ocular biometric characteristics of freshman students

Parameters	Total	Hyperopia (*n*=46)	Emmetropia (*n*=132)	Myopia			*P*	Gender		*P*
				Mild (*n*=855)	Moderate (*n*=1559)	High (*n*=981)		Male (*n*=1312)	Female (*n*=2261)	
SE (D)	-4.37±2.52	1.75±1.05	0.00±0.25	-1.83±0.72	-4.37±0.83	-7.47±1.36	<0.001	-4.29±2.53	-4.43±2.51	0.11
AL (mm)	25.28±1.24	22.98±1.90	23.50±1.03	24.43±0.94	25.29±0.87	26.33±0.96	<0.001	25.63±1.23	25.07±1.20	<0.001
CCT (μm)	539.49±34.98	543.67±45.52	536.89±45.79	540.8±37.60	540.32±32.70	537.20±33.79	0.10	544.26±34.92	536.73±34.72	<0.001
CR (mm)	7.8±0.28	7.89±0.49	7.87±0.38	7.87±0.33	7.80±0.25	7.75±0.25	<0.001	7.89±0.27	7.76±0.28	<0.001
ACD (mm)	3.31±0.34	2.97±0.42	3.01±0.34	3.26±0.33	3.33±0.32	3.36±0.32	<0.001	3.37±0.34	3.27±0.33	<0.001
LT (mm)	3.47±0.21	3.58±0.33	3.60±0.28	3.47±0.21	3.46±0.21	3.46±0.20	<0.001	3.46±0.21	3.48±0.21	<0.01
LP (mm)	5.04±0.32	4.76±0.34	4.81±0.30	4.99±0.32	5.06±0.31	5.10±0.31	<0.001	5.10±0.32	5.01±0.31	<0.001

SE: Spherical equivalent refraction; AL: Axial length; CCT: Central corneal thickness; CR: Corneal radius; ACD: Anterior chamber depth; LT: Lens thickness; LP: Lens position.

Table 5 Comparison of ocular biometric parameters between mild to moderate myopia and high myopia, stratified by AL

Parameters	AL<26 mm (*n*=2749)		*P*	AL≥26 mm (*n*=1089)		*P*
	Mild to moderate (*n*=2035)	High (*n*=353)		Mild to moderate (*n*=379)	High (*n*=628)	
SE (D)	-3.29±1.42	-6.91±0.93	<0.001	-4.41±1.28	-7.80±1.46	<0.001
AL (mm)	24.70±0.78	25.38±0.49	<0.001	26.51±0.46	26.87±0.70	<0.001
CCT (μm)	539.83±33.75	531.28±32.62	<0.001	544.03±38.20	540.52±34.00	0.13
CR (mm)	7.77±0.25	7.59±0.19	<0.001	8.10±0.30	7.85±0.23	<0.001
ACD (mm)	3.28±0.32	3.30±0.31	0.28	3.43±0.32	3.40±0.32	0.10
LT (mm)	3.48±0.21	3.49±0.23	0.42	3.39±0.19	3.45±0.19	<0.001
LP (mm)	5.02±0.32	5.04±0.31	0.17	5.13±0.31	5.12±0.31	0.81

SE: Spherical equivalent refraction; AL: Axial length; CCT: Central corneal thickness; CR: Corneal radius; ACD: Anterior chamber depth; LT: Lens thickness; LP: Lens position.

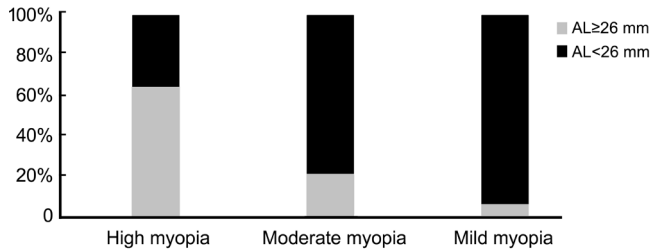

Figure 1 Distribution of myopia stratified by axial length and spherical equivalent in 3395 myopia students.

steeper CR than the group with mild to moderate myopia. For myopic subjects with AL≥26 mm, the group with mild to moderate myopia had shorter AL, flatter CR, and thinner LT than the group with high myopia (Table 5).

DISCUSSION

This work describes refractive errors prevalence and ocular biometry in 3573 freshman students at Tianjin Medical University for 4 consecutive years. Our results showed that the prevalence of myopia and high myopia increased annually. Huang *et al*[17] reported that myopia prevalence among university students in Nanjing was 86.8%. Sun *et al*[3] conducted a cross-sectional study on 5060 students in Donghua University in Shanghai, a developed city in China, and observed the mean refractive error was -4.1 D and the prevalence of myopia and high myopia was 95.5% and 19.5%, respectively. Lv and Zhang[5] reported that the prevalence rate of myopia increased significantly from 78.5% to 84.1% in students in Weifang Medical College, with a mean age of 18.27y over a 2-year follow-up study in 2008 and 2010. The prevalence of myopia was 70.5% and 69.2% at Inner Mongolia Medical University in 2011 and 2013, which was an underdeveloped inland city in North China[18]. Our results were consistent with Donghua University in Shanghai and Nanjing but were significantly higher than those in Weifang Medical College and Inner Mongolia Medical University. Probably because myopia is associated with economic levels[19-20].

CA refers to astigmatism on the anterior surface. IA is difficult to measure, thus, it is usually considered to be the difference between TA and CA[21]. The percentage of those with TA≥0.50 D (64.8%) was lower than that of those with CA (88.1%), which is consistent with Chen *et al*'s[22] results because IA usually has a compensatory association with CA. Males tended to have a higher percentage of TA than females with astigmatism ≥0.75 D and ≥1.0 D; however, females tended to have a higher percentage of CA and IA with astigmatism ≥0.75 D. WTR astigmatism was the main type of astigmatism.

In our study, AL (25.28±1.24 mm) was longer than university students in Shanghai (male: 25.10±1.55 mm, female: 24.74±1.49 mm)[23] and Anyang (24.78±1.21 mm)[11]. In our

opinion, this was associated with higher diopter. Females had a shorter AL, thinner CCT, smaller CR, shallower ACD, thicker lens, and more anterior LP than males, which was consistent with previous studies results of young adults[11], children[24]. With the diopters increase in myopia, the AL became longer, CR became steeper, ACD became deeper, LT became thinner, and LP became posterior, which was consistent with Anyang study results.

CR is the main clinical endophenotype of the refractive status. A more negative or myopic refractive error is associated with a steeper CR. Approximately 35%-95% inter-individual CR variation is associated with genetic factors[25]. In line with our results, among the adult Egyptian population with myopia, with the increase of myopic diopter, the cornea became steeper[26]. The LT is changing in one's life. Children with myopia first showed a pattern of lens thinning, between the age of 10 and 11.5y, the lens reaching thinnest, after 18 years old, it becomes thicken until 75 years old[27]. The increase in LT could cause myopia drift. For example, in patients with diabetes, glucose may accumulate in the lens, with an increase in curvature and thickness and a shift toward myopia[28]. Shih *et al*[29] reported that a thinner LT can have an emmetropization effect and may be associated with increased AL, possibly playing a role in myopia progression. However, in 6-18-year-old teenagers, course myopia and lens thickening and thinning association was considered coincidental[30]. CCT is highly hereditary and is associated with complex eye diseases, such as glaucoma and keratoconus[31]. Chen *et al*[32] and Sun *et al*[11] reported that CCT was an independent factor, and was not associated with CR, ACD, AL, or refractive error. In our study, the CCT difference was not statistically significant, which was consistent with the results of Chen *et al*'s[32] study.

We divided students into groups according to AL. In 3395 students with myopia, 64% of high myopia had AL≥26 mm, but we also found that 5.8% of mild myopia and 21.1% of moderate myopia had AL≥26 mm. In myopia students with AL≥26 mm, mild and moderate myopia compared to high myopia, AL was shorter (26.51±0.46 *vs* 26.87±0.70 mm), CR was larger (8.10±0.30 *vs* 7.85±0.23 mm) and LT was thinner (3.39±0.19 *vs* 3.45±0.19 mm; $P<0.001$). The larger CR and thinner LT neutralize the longer AL and manifest mild or moderate myopia. It is known that the longer the AL, the higher the risk of fundus lesions. The axial elongation has been associated with maculopathies and resulted in degenerative changes in the retina, such as macular holes[33], posterior staphyloma[34], retinal pigment epithelium atrophy, and choroidal neovascularization[35-36]. The prevalence rate of myopic macular degeneration in subjects with an AL≥26 mm was higher than that in subjects with an AL<26 mm[37]. Therefore, inconformity of refractive errors and ocular biometry existed in some students. Therefore, attention should be paid to the ocular biometry of myopia.

This study had some limitations. First, we may overestimate the prevalence of myopia without cycloplegia, a study showed that a mean 0.4±0.5 D hyperopic shift after cycloplegia aged 10-40y[38]. Hence, future studies regarding cycloplegia should be conducted. Second, the subjects were recruited from one medical university. Thus, the generalization of our findings to Chinese young adults should be cautious.

In summary, the prevalence rates of myopia, high myopia were significantly high among freshman students at Tianjin Medical University. Inconformity of refractive errors and ocular biometry existed in some students. More attention should be paid to the ocular biometry of mild and moderate myopia.

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