Refractive Error and Biometrics of Anterior Segment of Eyes of Myopic Teenagers

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Research article

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Abstract

Background: To investigate the impact of refractive error and corneal parameters on myopic teenagers by using Pentacam and IOL Master 700.

Methods: Retrospective observational case series of 505 eyes from 268 children from 7 to 19 years old presenting with myopia. Clinical course, slit lamp photographs and pentacam and IOL Master 700 findings were the main outcomes.

Results: Assessment of the tomographic, topographic of corneal parameters of myopic children without any interventions revealed no statistically significant changes in terms of age based on sex. The mean Rf, Rs, K1 and K2 values of anterior and posterior corneal surface were 7.98±0.24mm, 7.73±0.30mm, 42.38±1.86 degrees, 43.55±1.91 degrees, 6.60±0.25mm, 6.21±0.26mm, -6.07±0.23 degrees, -6.42±0.65 degrees. Boys had higher Rf and Rs, but smaller in K1 and K2 than girls ($P<0.05$) of both anterior and posterior corneal surface. The Anterior chamber volume (ACV) had significant differences between sex ($P<0.05$). The Rf, K1 of anterior corneal surface did not show significantly different between ages, however, teenagers only in 7 to 9 age group increased significantly than 13 to 15-year-old group ($P=0.031$). Meanwhile, the Anterior chamber depth (ACD), Anterior chamber volume (ACV), Pupil diameter (PD), Spherical equivalent (SE) and Axial length (AL) had increasingly differenced in different age groups ($P=0.002$, 0.002, 0.036, 0.044, 0.002, <0.001). Model performance using $p< 0.05$ parameters as the predictive factors. SE=3.391+0.08×Age+2.307×Rs-0.094×ACD-0.001×ACV-0.951×AL.

Conclusions: Our findings may suggest a physiological nature for ocular changes during the development that may elucidate the special points during the process of myopia of adolescents. We also imitate a formula based on our data which may help to evaluate the myopia of children and the prognosis in clinic.

Our research conducted retrospectively registered.

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"The myopia boom" in East Asia witnessed an unprecedented rise to 90% of teenagers and young adults[1]. By 2050, nearly half of the world's population may be myopic, and 10% of them is highly myopic[2]. The prevalence of myopia increases with a tendency of age and at younger ages at the time of incidence [3]. Pathological changes caused by high myopia following with eye sight declining, myopia fast worsening, proptosis, poor dark adaption and finally goes to macular degeneration, retinal detachment and other diseases that leading to blindness. Thus, it is meaningful of preventing of myopia and high myopia for teenager eye healthy.

Genetic and environmental factors both affect the development of myopia. However, only 12% of the phenotypic variance due to the environmental components, more than 18 chromosomal regions responsible for the progress of myopia, nearly account for over 50% of myopic variance[4]. So, the parameters of cornea are the strong evidence of teenagers' myopia progress.

Human cornea is a prolate ellipse, not an ideal sphere, which is flatted from corneal apex to periphery. Ocular surface health is the backbone of teenager eye health. Unidentified need of wearing glasses for teenagers is the leading cause of reduced vision[5]. Myopia is a consequence of uncoordinated contributions of ocular components to the overall eye structure. Corneal shape and its correlation with anterior segment parameters are essential part conducted in ophthalmic clinics. Central corneal thickness (CCT), Thinnest corneal thickness (TCT), Apex corneal thickness (Apex CT), Corneal volume (CV), Anterior chamber depth (ACD), Anterior chamber volume (ACV) and Corneal astigmatism (CA), these parameters conducted precisely for prescribing ocular healthy in the treatment of myopia. Q value vary differently with the degree of ametropia. Biometric parameters like Axial length (AL), Corneal power (CP), Anterior chamber depth (ACD), lens thickness and so on, is associated with refractive status, which is important for preventing myopia.[6]

The aim of our study was to evaluate the parameters of myopic teenagers by using Pentecam. The information about mean parameters of teenagers provided in this study will be useful to researchers and clinicians for assessing the development of teenagers with the tendency to myopia and scheduling the effective treatment.

Methods

An observational cross-sectional study comprised of 505 eyes of 268 teenagers with age of 7-19 years old (mean±SD: 11.22±2.73) was conducted in the Refractive Center of Nanjing Medical University Afflicted Eye Hospital, China from 2018-2019. We had explained the nature of our study to each participant with inform consent from a parent or a legal guardian. The experiment of followed the tenets of the Declaration of Helsinki and was approved by the Research Ethics Committee of Mashhad University of Medical Sciences.

Participants with healthy anterior segment without contact lens usage, IOP of more than 21 mmHg, history of ocular surgery or any refractive surgery were included from our study. All enrolled teenagers underwent general physical evaluations like age, sex, ocular disease history and comprehensive examinations.

Each teenager in our study underwent detailed examinations including visual acuity, refraction, slit-lam biomicroscopy, corneal topography of Pentacam and fundus. Our reseatch team comprised by ophthalmologist and optometrists. An experienced ophthalmologist checks all enrolled participant by slit-lamp biomicroscopy for ocular anterior segment abnormalities. Noncontact tonometer for IOP measurement. Autorefraction was performed after compete cyctoplegia by Desktop Autorefractor. IOL Master was used for Axial Length (AL).

All of the Pentacam measurements were taken according to the manufacture's guidelines by a trained optometrist who was blinded to our study. All measurements were doing between 9:00 to 12:00 in a sufficient lighting ([illegible]300 lux)for at least three times for the most suitable mean value with an excellent repeatability. Teenagers were asked to put their chin in a chin rest and adjusted their heads still using a forehead strap to stare at the fixed light spot of the instrument without blinking during the examination. All data were accepted when the quality was "OK". We had taken these parameters in our study for statistical analysis. (1) ACD: the distance from corneal endothelium to the crystal. (2) ACV: the volume of anterior segment, about the ACD with a range of 12mm diameter centered on corneal apex. (3) Apex corneal angle

(ACA): the smaller angle values calculated in the horizontal direction. (4) corneal thickness (CCT and TCT): describe the corneal thickness and thinnest point. (5) PD: describe the nondilated pupil diameters. (6) flat and steep keratometry values(K). (7) SE: calculated as the spherical diopter plus half of the cylindrical diopter.

Statistical Analysis

Commercially SPSS (version 22.0) and GraphPad Prism software (version 6.0) were used in our study. Mean ± SD were described for all the data. The Kolmogorov-Smirnov test was used for normality of the distribution. Independent -sample t tests were used to investigate the difference of data with a normal distribution and variance homogeneity. The Kruskal-Wallis H test was performed to compare data incompatible with a normal distribution or variance homogeneity. Pearson correlation test was conducted for the associations between two variables. Multiple linear regressions were performed to characterize the effects of all parameters. All data difference was set at P 0.05 as significant, and estimates were presented with 95% confidence intervals.

Results

General Characterics

We analyzed 505 eyes from 268 children aged from 7 to 19 years completed the Pentacam examination after cycloplegia and had a completed data record for all the parameters (including age, sex, Rf, RS, K1, K2, Rper, Rmin, Q-val, TCT, ACD, ACV, ACA, CCT, TCT, and SE), with a mean age of 11.22 ± 2.73 years. 229 boys (45.35%) and 276 girls (54.65%) were included in the final analysis. There are 23 of high myopia (4.55%), and none of the eyes had complications associated with myopia. And the distribution of the refractive errors in boys and girls is shown in Fig. 1. Table 1 displays the general characteristics of the participants.

Table 1
General Characteristics of Anterior Eye Segment Parameters in Pentacam of 505 Teenagers

Parameters		**Total**		**Male**		**Female**		**Independent Samples *t* Test**
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
		n = 505		**n = 229**		**n = 276**		***P***
Anterior	Rf	7.98	0.24	8.04	0.25	7.92	0.22	<0.001*
	K1	42.38	1.86	41.94	1.17	42.76	2.22	<0.001*
	Rs	7.73	0.30	7.77	0.36	7.69	0.24	0.005*
	K2	43.55	1.91	43.10	2.32	43.90	1.37	<0.001*
	Rper	8.11	0.48	8.19	0.29	8.05	0.59	0.001*
	Rmin	7.64	0.28	7.71	0.24	7.59	0.30	<0.001*
	Q-val	-0.40	0.28	-0.39	0.13	-0.40	0.36	0.576
Posterior	Rf	6.60	0.25	6.67	0.23	6.54	0.25	<0.001*
	K1	-6.07	0.23	-6.00	0.21	-6.12	0.23	<0.001*
	Rs	6.21	0.26	6.27	0.25	6.16	0.25	<0.001*
	K2	-6.42	0.65	-6.39	0.25	-6.45	0.84	0.279
	Rper	6.67	0.23	6.71	0.23	6.63	0.23	<0.001*
	Rmin	6.03	0.40	6.08	0.43	5.98	0.36	0.003*
	Q-val	-0.34	0.16	-0.32	0.15	-0.35	0.16	0.032*
	TCT (μm)	549.91	43.25	550.14	55.02	549.72	30.31	0.917
	ACV (mm^3)	199.97	28.40	207.85	27.91	193.42	27.15	<0.001*
	ACA (deg.)	40.57	6.32	40.79	6.47	40.38	6.20	0.461
	ACD (mm)	3.34	1.34	3.34	0.30	3.34	1.80	0.997
	PD (mm)	3.17	0.65	3.21	0.55	3.14	0.72	0.233
	SE (D)	-3.10	1.50	-3.12	1.54	-3.09	1.46	0.811
	AL (mm)	24.97	0.95	25.28	0.92	24.72	0.90	<0.001*

Parameters	Total		Male		Female		Independent Samples *t* Test
	Mean	SD	Mean	SD	Mean	SD	
	n = 505		n = 229		n = 276		*P*

Values presented are mean and SD. Independent samples *t* test was used to investigate the difference between males and females.

ACA indicates anterior chamber angle; ACD, anterior chamber depth; ACV, anterior chamber volume; AL, axial length; TCT, thinnest corneal thickness; PD, pupil diameter; SE, spherical equivalent.

**P < 0.05*

A scatter plot of the refractive errors (ordinate) and AL (abscissa) is shown in Fig. 2, a scatter plot of the refractive errors (ordinate) and ACD (abscissa) is shown in Fig. 3, a scatter plot of the refractive errors (ordinate) and ACV (abscissa) is shown in Fig. 4, and a scatter plot of the refractive errors (ordinate) and PD (abscissa) is shown in Fig. 5.There were significant differences in the AL, ACD, which myopic teenagers have longer AL, deeper ACD.

Distribution of Related paramerers Among Sex and Age

As shown in Table 1, for all the children included in our study, the mean Rf, Rs, K1 and K2 values of anterior and posterior corneal surface were 7.98 ± 0.24 mm, 7.73 ± 0.30 mm, 42.38 ± 1.86 degrees, 43.55 ± 1.91 degrees, 6.60 ± 0.25 mm, 6.21 ± 0.26 mm, -6.07 ± 0.23 degrees, -6.42 ± 0.65 degrees, respectively. Boys had higher Rf and Rs, but smaller in K1 and K2 than girls (P < 0.05, Table 1) of both anterior and posterior corneal surface. Also, the Axial length (AL) and Anterior chamber volume (ACV) had significant differences between sex (P < 0.05, Table 1**)**. The correlations between the refractive error and the ACA, and TCT were not significant (Fig. 6).

Because of the small number of children aged 7 to 19-years old, we forming 4 groups for the ranges 7 to 9 years, 10 to 12 years, 13 to 15 years, and 16 to 19 years, to reduce the differences in the number of children between groups see in Table 2 **(at the end of article)**. The Rf, K1 of anterior corneal surface did not show significantly different between ages, however, teenagers only in 7 to 9 age group increased significantly than 13 to 15-year-old group (P = 0.031). Meanwhile, the TCT, ACD, ACV, PD, SE and AL had increasingly differenced in different age groups (P = 0.002, 0.002, 0.036, 0.044, 0.002, < 0.001).

Table 2
Distributions of Anterior Eye Segment Parameters in Pentacam of 268 Teenagers

Parameters	Age groups(y)		7 to 9	10 to 12	13 to 15	16 to 19	*P*
Anterior	Rf	Mean	7.95	7.97	8.01	8.01	0.146
		SD	0.25	0.24	0.24	0.21	
	K1	Mean	42.62	42.37	42.15	42.17	0.156
		SD	2.68	1.29	1.26	1.08	
	Rs	Mean	7.73	7.70	7.75	7.76	0.333
		SD	0.26	0.37	0.26	0.26	
	K2	Mean	43.61	43.58	43.47	43.35	0.853
		SD	1.28	2.69	1.36	1.21	
	Rper	Mean	8.07	8.13	8.14	8.12	0.644
		SD	0.73	0.29	0.29	0.28	
	Rmin	Mean	7.64	7.61	7.67	7.68	0.267
		SD	0.23	0.35	0.25	0.23	
	Q-val	Mean	-0.43	-0.40	-0.36	-0.33	0.063
		SD	0.45	0.13	0.13	0.14	
Posterior	Rf	Mean	6.60	6.66	6.59	6.59	0.984
		SD	0.23	0.24	0.30	0.21	
	K1	Mean	-6.06	-6.06	-6.07	-6.08	0.965
		SD	0.22	0.22	0.25	0.20	
	Rs	Mean	6.23	6.19	6.21	6.20	0.378
		SD	0.23	0.27	0.27	0.27	
	K2	Mean	-6.42	-6.39	-6.44	-6.48	0.869
		SD	0.24	1.03	0.27	0.28	
	Rper	Mean	6.67	6.67	6.66	6.68	0.976
		SD	0.21	0.25	0.24	0.21	
	Rmin	Mean	6.07	6.02	6.01	5.90	0.118
		SD	0.25	0.27	0.47	0.89	
	Q-val	Mean	-0.32	-0.35	-0.33	-0.34	0.298
		SD	0.14	0.19	0.13	0.15	

Parameters	Age groups(y)		7 to 9	10 to 12	13 to 15	16 to 19	*P*
	TCT	Mean	545.49	547.14	562.63	540.78	0.002*
		SD	35.73	56.41	29.11	31.98	
	ACA	Mean	39.95	41.25	40.95	38.79	0.073
		SD	6.34	6.20	4.68	10.27	
	ACD	Mean	3.23	3.28	3.34	4.14	0.002*
		SD	0.20	0.20	0.37	4.94	
	ACV	Mean	196.51	198.57	204.59	207.19	0.036*
		SD	24.94	28.46	30.68	32.70	
	PD	Mean	3.13	3.11	3.25	3.39	0.044*
		SD	0.59	0.53	0.68	1.13	
	SE	Mean	-2.87	-3.12	-3.16	-3.90	0.002*
		SD	1.21	1.51	1.58	2.01	
	AL	Mean	24.67	24.94	25.27	25.52	<0.001*
		SD	0.73	0.99	0.98	1.03	
	N		168	178	123	36	

Values presented are mean and SD

*P < 0.05

Other Factors Associated With anterior segment parameters

The Pearson correlation tests showed that age, Rs of anterior cornea were closely associated with each other, but showed weak relationship with ACA, ACD, AL and SE. Multiple linear regression analyses were performed with the refractive error as dependent variable and the 24 anterior eye segment parameters (Rf, K1, Rs, K2 et al) as the independent variables. Applying different correlation models to each age using variables that are difficult to measure. An analysis was therefore performed to quantify the teenager’s myopia with pentacam measurements information. However, not every parameters had closed relationship with SE. Thus, model performance using P < 0.05 parameters as the predictive factors in the model.

$$SE = 3.391 + 0.08 \times Age + 2.307 \times Rs - 0.094 \times ACD - 0.001 \times ACV - 0.951 \times AL$$

Conclusion

In the current study, we observed a changing pattern toward teenager’s myopia, the corneal topographic and biomechanical parameters were significantly different compared with that of initial measurements. Many studies were taken focus on the differences in the values of anterior segment parameters of myopic and emmetropic eyes, or conducted on older individuals. However, the prevalence of myopia is known to vary and high in young age, therefore, it is important evaluating structural changes associated with myopia to develop strategies preventing progression of myopia and its complications.

In the present study, ACD, ACV, ACA, TCT, PD, AL and SE were measured in myopia teenagers and their relationships with refraction, age and gender investigated. Our results showed that age and gender have no difference of included myopia teenagers. Sex has a significant effect on corneal parameters in our study: Boys had higher Rf and Rs, but smaller in K1 and K2 than girls of both anterior and posterior corneal surface. Also, the Anterior chamber volume (ACV) and Axial length (AL) had significant differences between sex. However, there was no difference in ACD of gender, which means boys' cornea is flatter than girls. Thus, flatted corneas in boys may reduce the prevalence of myopia than girls. Given the significant effects of gender on corneal parameters of myopia teenagers, as shown in this study, we speculate that kid' behaviors of sex may contribute to the discrepancy across studies. These results highlight the importance of paying different attentions to girls and boys even at the same ages when controlling myopia development. The flatter cornea and deeper anterior chamber would reduce the refractive error. A flatter cornea has lower refractive power and the overall refractive power of the eye will be lower, the light will focus on a point farther from the cornea. Deeper anterior chamber means the distance between the cornea and crystalline lens increases because the summed power of two lens is equal to their sums minus the distance between the lens divided by the index of refraction of the medium. The relationship between the corneal corneal thickness and myopia is contradictory[7], some reports decline the correlation with corneal thickness and myopia. However, there are some studies report that corneal thickness has positive correlation with myopia[8]. In our results, the correlation was positively, the significant correlation was seen in multiple regression analysis.

In addition to sex, another important finding of this study is age weight on myopia development. As indicated by previous data analysis in Table 1, subjects in 7 to 9 age group increased significantly of Rf and K1 of anterior corneal surface than 13 to 15 age group. Sharply increasingly of corneal shape in the early age indicate 7 to 9 age is the key period of controlling myopia, especially the dream time for Orthokeratology using. Hyman investigate younger baseline age was the strongest factor independently related to faster myopic children, children aged 6 to 7 years have the fastest progression in all age groups[9]. Hiraoka et al follow up 10-years of overnight orthokeratology found thar long-term efficacy and safety of OK lens wear in reducing myopia progression in schoolchildren[10]. Elder children wearing orthokeratology for controlling myopia have weaken effects for the stable of anterior corneal surface development. Q-val of anterior and posterior corneal surface increased significantly without age. However, according to the result of Zhang's study[11] that coincidence with the current of myopia development. Q-value represents the spherical aberration with positive relation of refractive error. In the emmetropia eyes, central cornea become flatter with age increasing and peripheral cornea grow slowly, while, with the development of myopia in children, with obviously rise of AL and ACD, peripheral cornea become steep followingly. Meanwhile, the PD had increasingly differences in different age groups (P = 0.003, 0.029). The change of PD may have relations with age and refractive degree of myopia. Pupil size has impact on the amount of penetrating light by more peripheral rays penetrating through larger pupils than smaller ones. In some studies, children with larger pupils have less myopia progression than those smaller pupils wearing orthokeratology[12]. This phenomenon may make an explanation of AL prolonged in myopia group. To the best of our knowledge, this is the innovative study to analyze the trend of myopia development in teenagers and the effects of these parameters on myopia. The use of a relatively large sample size of children with a narrow range of SE and age range allowed our study to provide a more detailed examination of whether there are age differences in ocular parameters in teenager than has been performed previously.

Analyses identified corneal parameters as the predominant predictor of teenager's myopia. The cut point that the trend of myopia in teenagers need to be identified by bio-parameters as objective indicators. This predictive model should enable clinicians and scientists to evaluate the risk for myopia in teenager using simple, feasible measures. As the large number of children with myopia, we should take myopia in teenagers as a usual phenomenon in the development. So, the model should be beneficiated for monitoring teenager's myopia by optometrists and ophthalmologists to plan children' eye examination therapy individually. Based on the data analyzed previously, we found the age, Rs, ACD, ACV, AL corelated tightly than other parameters, the cut point of spherical equivalent refractive error for optimized prediction, which is the best predictor of future myopia in teenagers.

There are some limitations of our study. First, our included population was relatively small compared with other studies. Second, a cross-sectional study at one time point, we need a prospective longitudinal study is needed to determine the anatomical changes of myopia in teenagers.

Abbreviations

ACA	Apex corneal angle
Apex CT	Apex corneal thickness
ACD	Anterior chamber depth
ACD	Anterior chamber depth
ACV	Anterior chamber volume
ACV	Anterior chamber volume
AL	Axial length
CCT	Central corneal thickness
CA	Corneal astigmatism
CP	Corneal power
CV	Corneal volume
PD	Pupil diameter
SE	Spherical equivalent
TCT	Thinnest corneal thickness

Declarations

- **Ethics approval and consent to participate**

The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of The affiliated Eye hospital of Nanjing Medical University. Written informed consent was obtained from individual or guardian participants.

- **Consent for publication**

Not applicable.

- **Availability of data and materials**

All data generated or analysed during this study are included in this published article.

- **Competing interests**

The authors declare that they have no competing interests.

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- **Authors' contributions**

HG: data acquisition, data analysis, manuscript revision, and final approval. SX: data acuquisition, analysis and manuscript revision. ZY: data acuquisition, analysis and manuscript revision. QJ: design of the work, data acquisition, data analysis, manuscript redaction, manuscript revision, and final approval.

All the authors have read and approved the final version. All the authors take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors have read and approved the manuscript.

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Not applicable.

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Figures

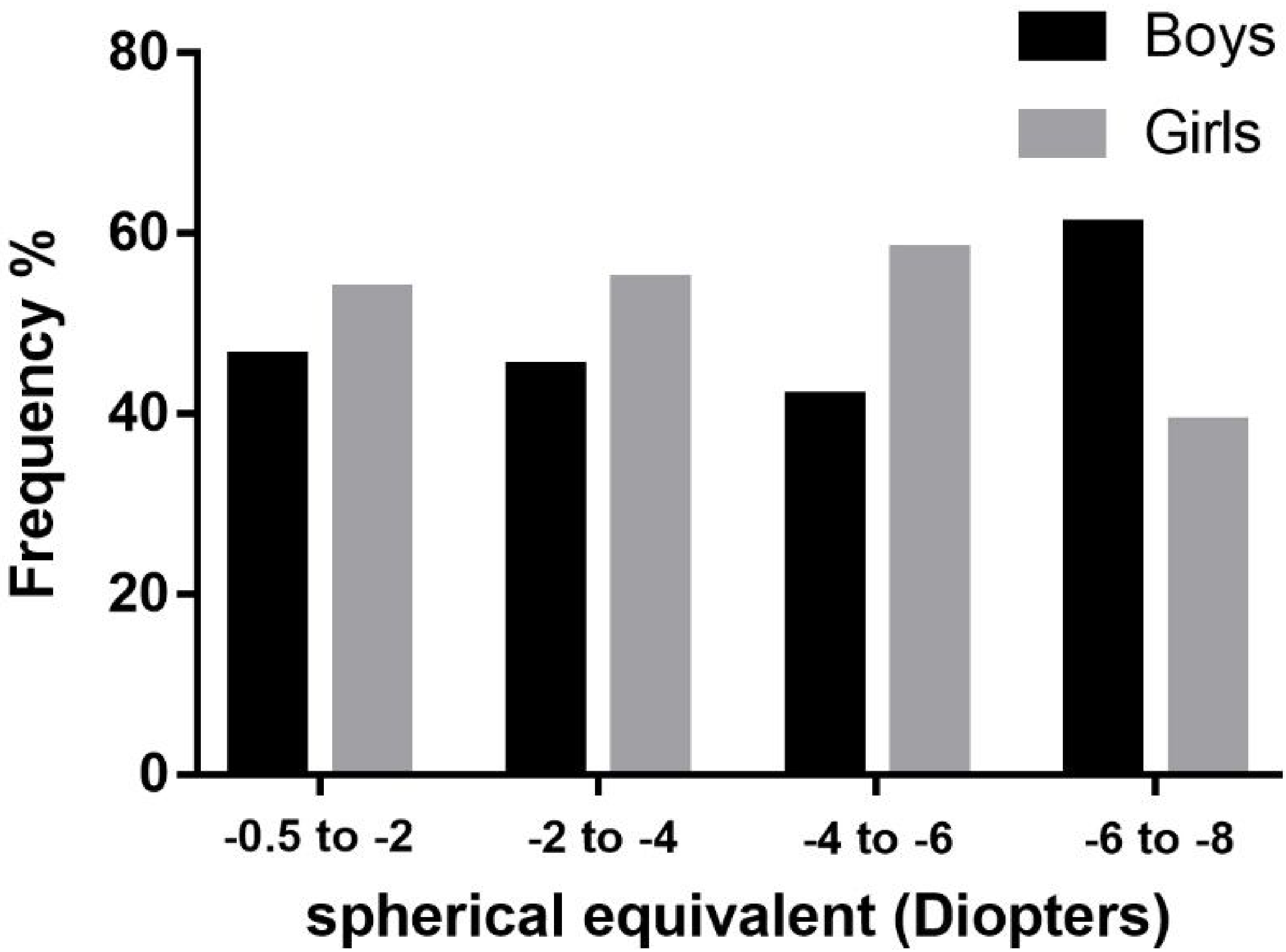

Figure 1

Histogram showing frequency (%) of refractive error in the boys and girls. The difference between boys and girls was not significant (P=0.811).

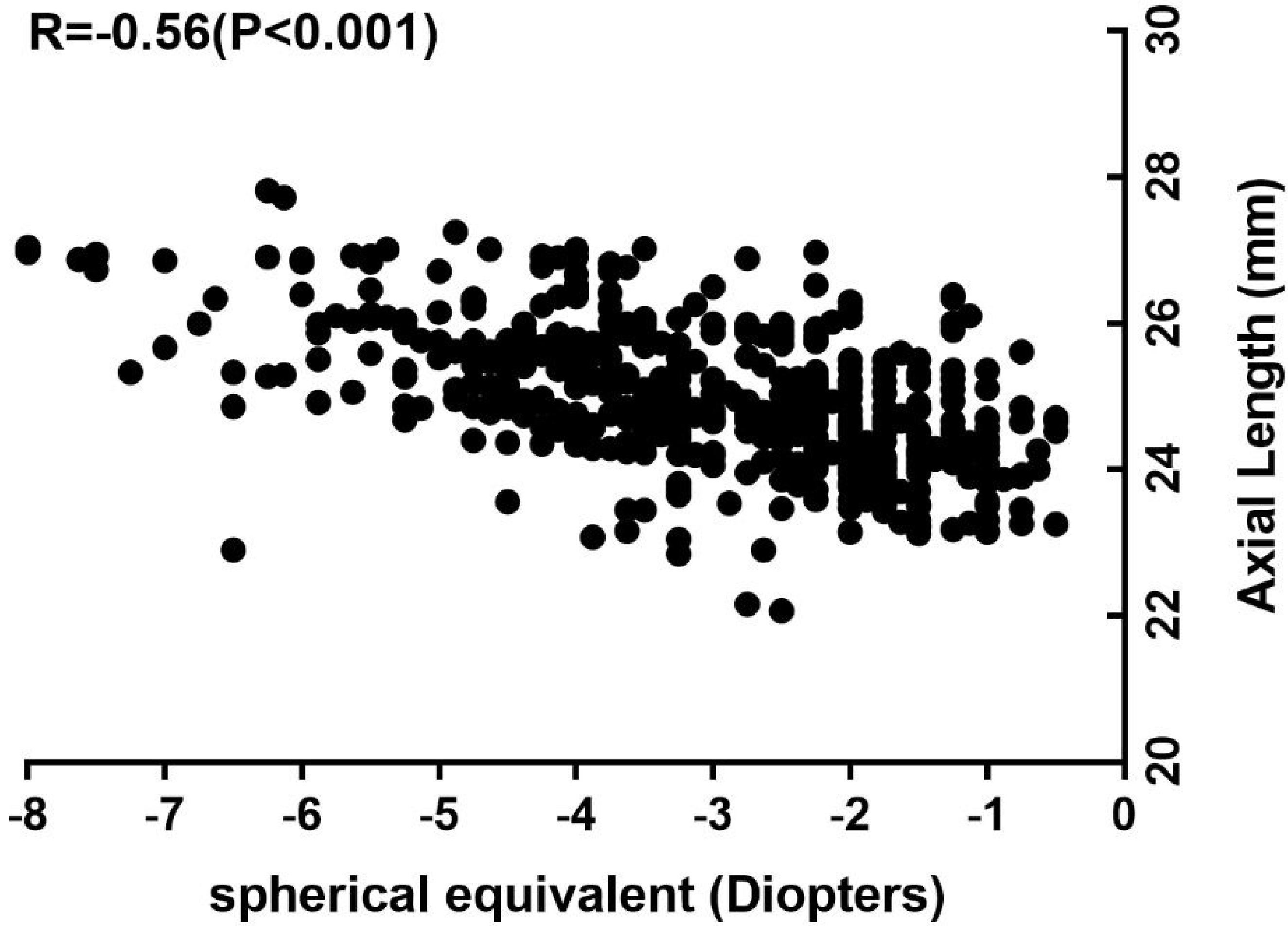

Figure 2

Scatterplots showing the relationship between the refractive error (spherical equivalent) and the axial length. The refractive error is significantly correlated with the axial length (R=-0.56, P<0.001).

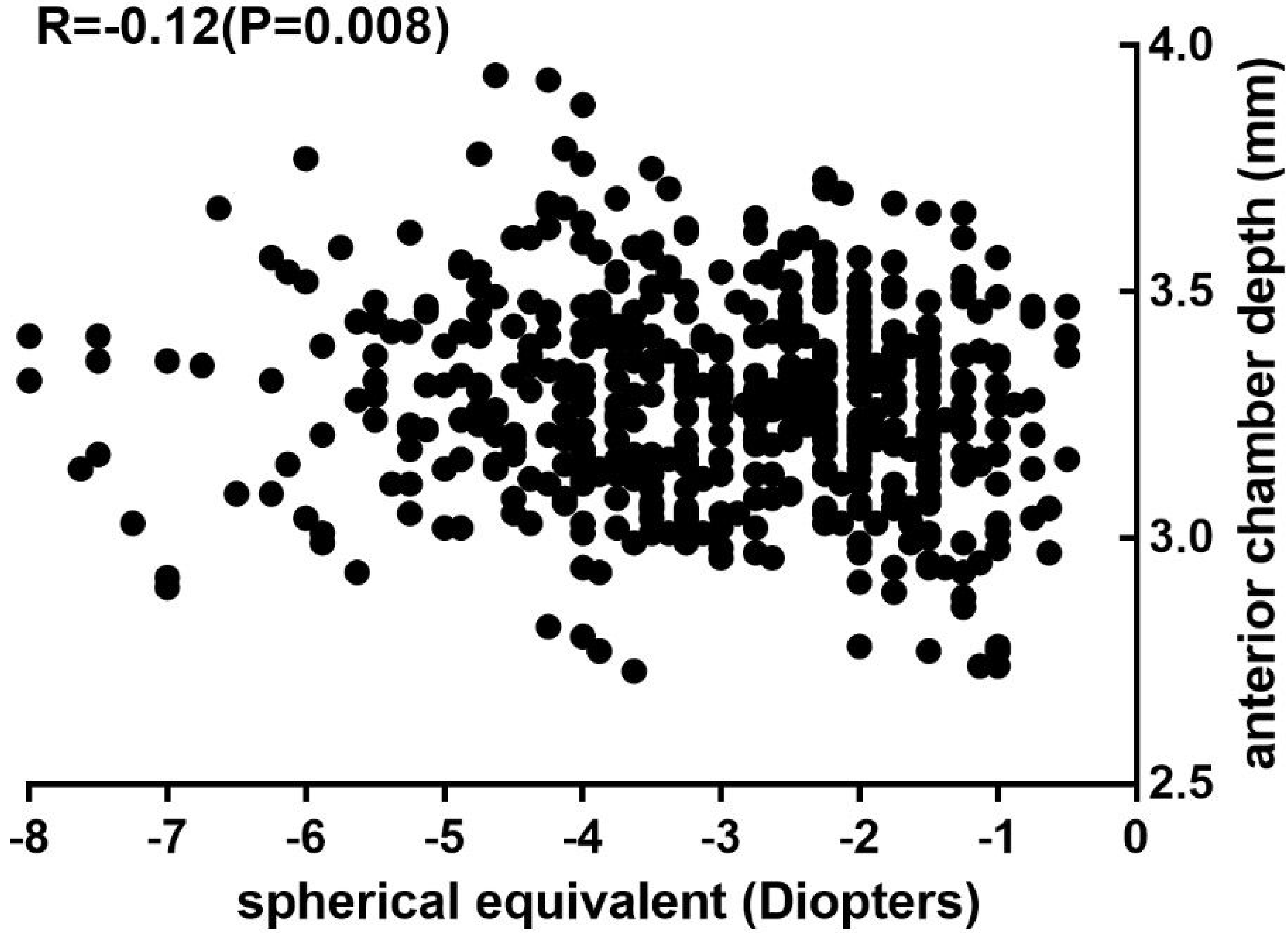

Figure 3

Scatterplots showing the relationship between the refractive error (spherical equivalent) and the anterior chamber depth. The refractive error is significantly correlated with the anterior chamber depth (R=-0.12, P=0.008).

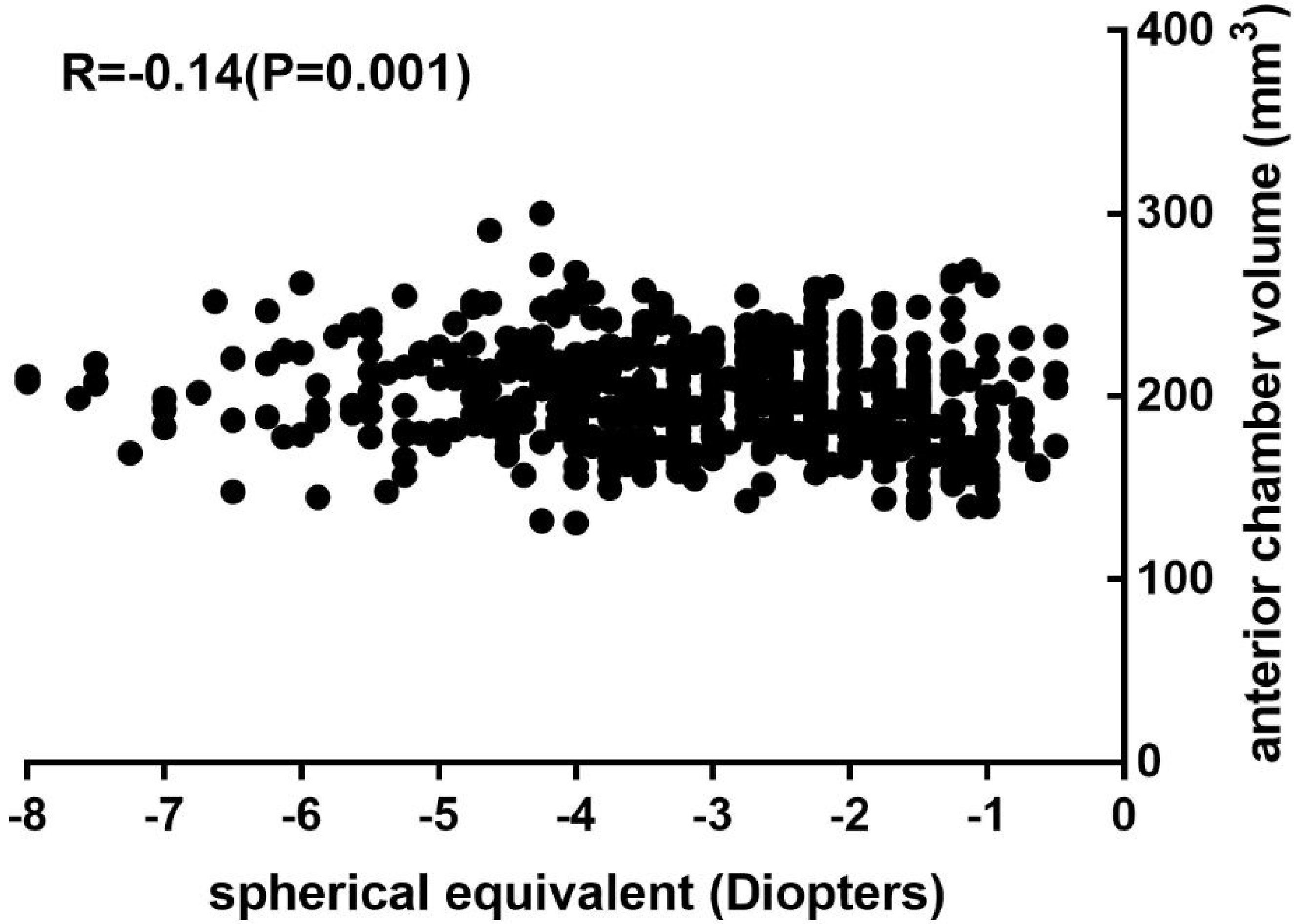

Figure 4

Scatterplots showing the relationship between the refractive error (spherical equivalent) and the anterior chamber volume. The refractive error is significantly correlated with the anterior chamber depth (R=-0.14, P=0.001).

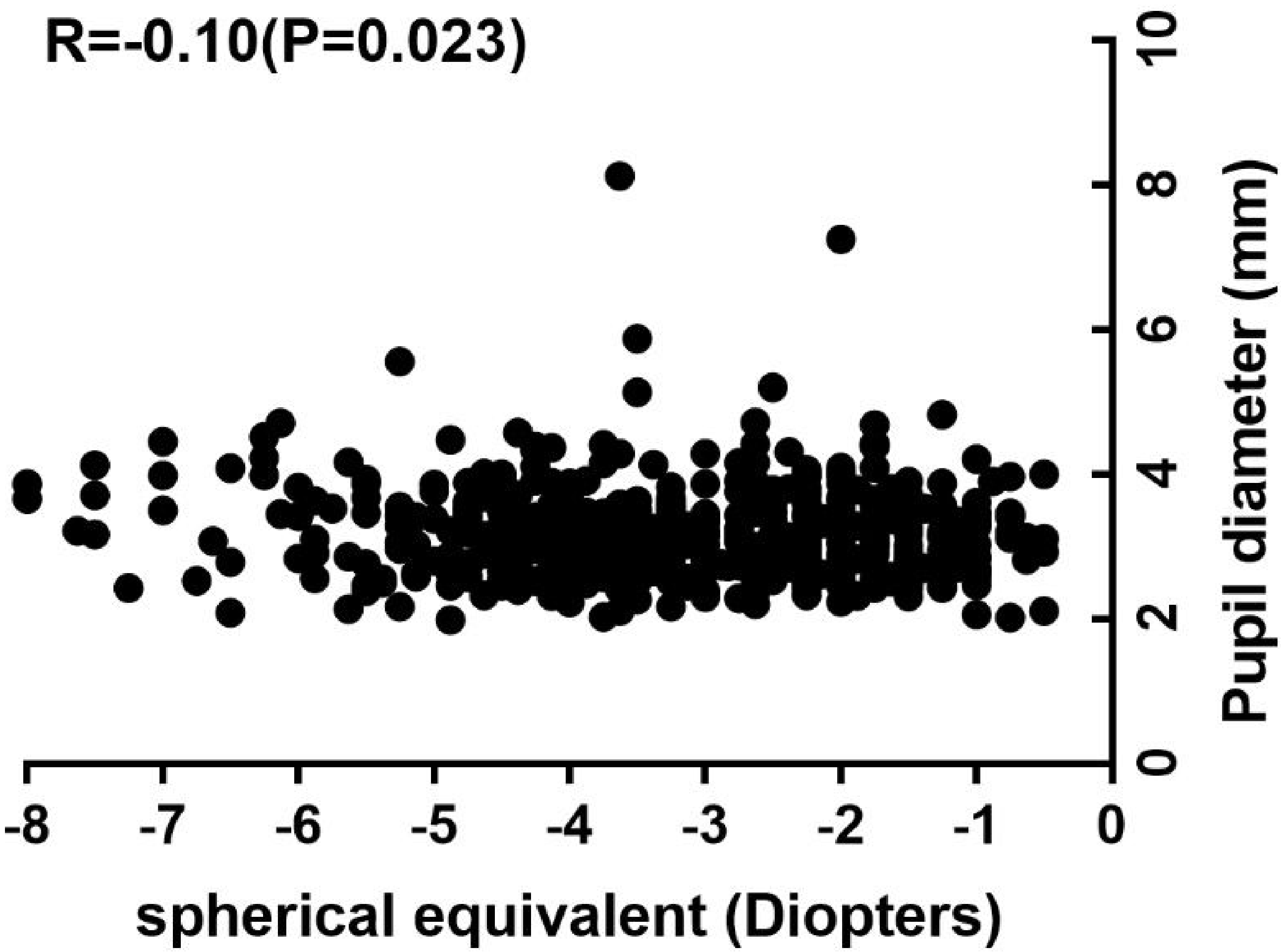

Figure 5

Scatterplots showing the relationship between the refractive error (spherical equivalent) and the pupil diameter (mm). The refractive error is significantly correlated with the anterior chamber depth (R=-0.10, P=0.023).

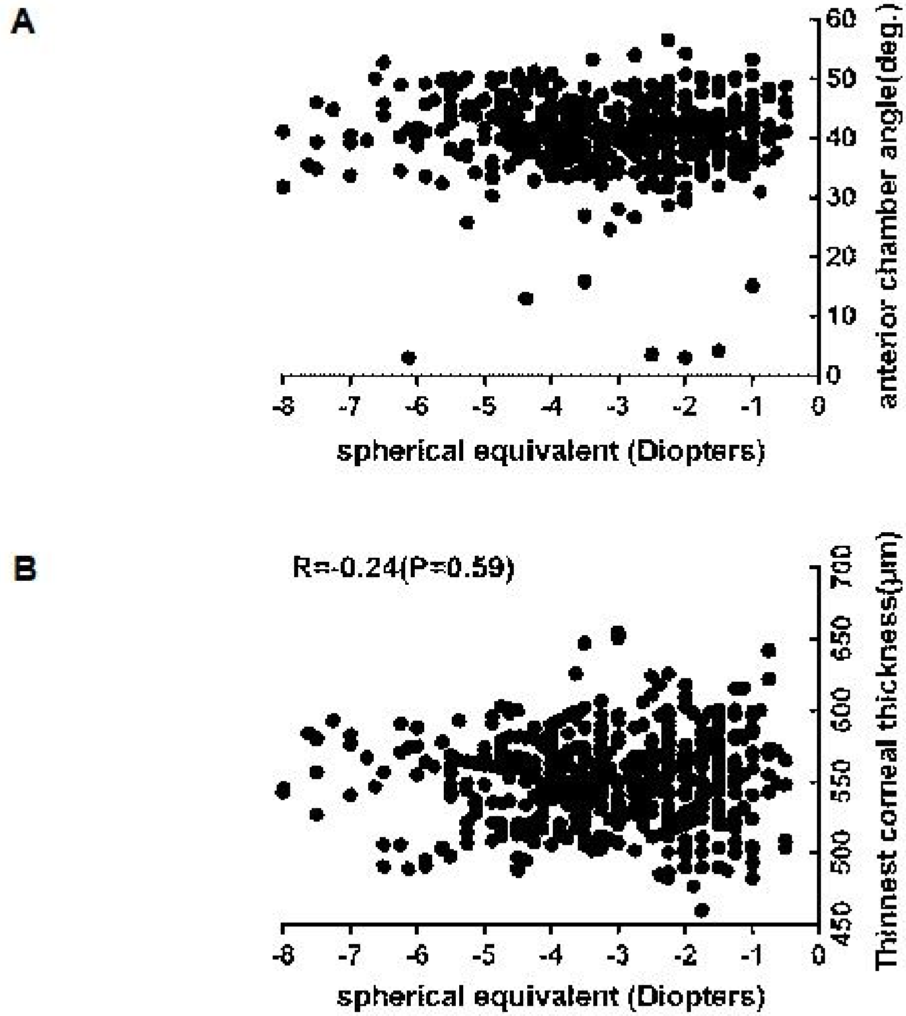

Figure 6

Scatterplots showing the relationship between the refractive error (spherical equivalent) and the anterior chamber angle, thickness corneal thickness and pupil diameter (A and B). The refractive error is not significantly correlated with the ACA and TCT (P>0.01).