Original Article

Ocular Biometry Characteristics and its Relationship with Age, Gender, Spherical Equivalent in Turkish Children

O Dayi, E Bulut[1], M Karadağ[2], H Bulut[3]

Department of Ophthalmology, Beylikduzu State Hospital, [1]Department of Opticianry, Vocational School of Health Services, Gelisim University, Istanbul, [3]Department of Child Development, Vocational School of Health Services, Gelisim University, Istanbul, [2]Department of Biostatistics and Medical information, Hatay Mustafa Kemal University Faculty of Medicine Hatay, Turkey

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Abstract

Background: Studying ocular biometric parameters in different populations and determining the relationship with personal characteristics can provide valuable information about ocular growth and help provide a better understanding of refractive errors. **Aims:** To describe distributions of ocular biometry and to evaluate its associations with age, gender, spheric equivalent in Turkish children. **Patients and Methods:** In this prospective study 344 children aged 3-14 years were evaluated. Parameters studied included axial length (AL), anterior chamber depth (ACD), and mean corneal radius (CR) measured with optical biometry. Cycloplegic refraction values were obtained using autorefractometer. The change of biometric parameters according to age and gender were evaluated. The relationship between ocular biometry parameters with refraction and age was analyzed by linear regression. **Results:** Mean spherical equivalent (SE), AL, ACD and AL/CR observed to be lowest in the preschooler group ($P < 0.001$). SE reduced with age, and a weak correlation observed between SE and age ($r = -0.333$). AL and ACD had moderate and weak positive correlations with age respectively ($r = 0.511$; $r = 0.304$). There were negative correlations between SE with AL, ACD and AL/CR ($r = -0.826$; $r = -0.540$; $r = -0.886$). The strongest correlation with SE among these parameters was identified for AL/CR. AL and ACD were higher in boys, while the CR was lower in girls ($p < 0.001$). **Conclusion:** While AL in children in late schooler group is higher than European countries, it shows similar characteristics in early schooler group. In addition AL is lower in all age groups than Asian population sexcept preschooler group. With age AL increases, SE decreases and AL plays a key role in refractive development.

Keywords: *Children, ocular biometry, refractive error*

Introduction

With the growth of ocular structures in the childhood period, they display continuous change and development. Visual system maintains refraction in the normal range by compensatory mechanisms known as emmetropization.[1] In their animal study, Smith and colleagues showed that myopic defocus causes slowing in axial elongation and hyperopic defocus causes acceleration in axial elongation.[2] Additionally, it is known that myopic overcorrection causes myopic shifting in humans.[3] This information supports that retina plays critical role in eliminating refractive errors. Previous studies have shown that corneal power reduces with age in the development process in children; as axial length increases, with reduction in lens power.[4,5] With this change, hyperopia and astigmatism observed at high rates in the first years of life reduce with advancing age.[6] Studies have shown that this process of change does not always result in emmetropia and refractive errors may occur.[7] Refractive errors are still the most important cause of visual impairment in children at

Address for correspondence: Dr. O Dayi, Department of Ophthalmology, Beylikduzu State Hospital, Pinartepe Mah. Yavuz Sultan Selim Bulv, 253 Sok, No: 8, Pınartepe, Büyükçekmece, 34500, Istanbul, Turkey. E-mail: ozlemkuru_uutf@hotmail.com

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present and a clear increase in the prevalence of myopia in the world is encountered as a significant public health problem.[8] The distribution of refractive error varies according to age, gender and ethnic background.[4] Çaça *et al*.[5] screened 21,062 children and identified 3.2% had myopia, 5.9% had hyperopia and 14.3% had astigmatism. This study emphasized that myopia increased with age and was more commonly observed in the female sex and those with high education level. Understanding the relationship between the ocular biometry components in children with age, gender and refractive errors may explain the prevalence differences for refractive errors between different populations. Many studies have been performed assessing the distribution of ocular biometric parameters and relationship with refraction, with these studies completed for different ethnic backgrounds.[4,7] In the current literature, there is no clinical study assessing refractive and biometric parameters in children in the Turkish population. As a result, in our study we aimed to assess the distribution of biometric parameters among in the Turkish pediatric population, the variation in these parameters according to age and gender, and additionally the relationship between biometric parameters and refraction

Material and Methods

Patient data collection and exclusion criteria

This prospective study included sequential children aged 3-14 years attending routine ophthalmologic examination in Beylikdüzü State Hospital Ophthalmology clinic. The parents of all participants provided written consent after detailed explanations of the study procedure. Cases had axial length (AL), anterior chamber depth (ACD), and mean corneal radius (CR) values measured with optical biometry (AL-Scan Nidek, Japan). cycloplegic refraction values were obtained using autorefractometer (Topcon KR 800 Tokyo, Japan) after cyclopentolate 1% drops were administered 3 times at 5-minute intervals and then 30 minutes wait time. All measurements were completed by the same experienced technician. Cases also had history, visual acuity test, and detailed eye examination including biomicroscopic and dilated fundus examination performed. Cases with corneal disease, cataract, vitreous opacity, retina disease, nystagmus, previous ocular surgery and trauma history were excluded. Spherical equivalent was obtained by adding the spherical value to half of the cylindrical value. According to spherical equivalent (SE) values, cases with $-0.50 < SE < +0.50$ were accepted as emmetropia, those with $SE \leq -0.50$ had myopia and those with $SE \geq +0.50$ had hyperopia. Children included in the study were divided into 4 groups as preschooler for those younger than 6 years, early schooler from 6-9 years, late schooler from 9-13 years and adolescent above 13 years.

Statistical analysis

All analyses conducted with the right eye because of the high correlation between the fellow eyes. Normal distribution of data was tested with the Shapiro Wilk test. Comparison of 2 independent groups with normal distribution used the Student t test, while the Mann Whitney U test was used for comparison of 2 independent groups without normal distribution. Additionally, comparison of more than 2 independent groups with numerical data used the one-way analysis of variance (ANOVA) and LSD multiple comparison test for those with normal distribution, while the Kruskal Wallis test and Dunn multiple comparison tests were used for those without normal distribution. Correlations between numerical variables were tested with the Spearman correlation coefficient. Beta (β) coefficients were estimated with linear regression analysis. Descriptive statistics are given as mean ± standard deviation for numerical variables and number and % for categoric variables. Statistical analyses were completed using the SPSS Windows version 24.0 and $P < 0.05$ was accepted as statistically significant.

Ethical statement

The present study was approved by University of Health Sciences, Istanbul Training and Research Hospital Ethics Committee dated 29.03.2019 and numbered 1768. The study procedure adhered to the Declaration of Helsinki.

Results

The study included a total of 344 eyes, of 157 male (44.6%) and 187 (54.4%) female subjects. Mean age of subjects was 8.61 ± 2.70 years. Among the subjects, 136 (39.5%) had hyperopia, 27 (7.8%)

Table 1: Number of examined children by age, gender and spherical equavalent

Group	Number
Age mean±sd	8,61±2,70
Gender *n* (%)	
Boys	157 (44.6)
Girls	187 (54.4)
Groups according to spheric equavalent *n* (%)	
Hyperopia	136 (39.5)
Emmetropia	27 (7.8)
Myopia	181 (52.6)
Groups according age *n* (%)	
Preschooler	72 (20.9)
Early Schooler	124 (36.0)
Late schooler	132 (38.3)
Adolescent	16 (4.6)

(*n*=344)

Table 2: Refractive and biometric characteristics as a function of age and gender

	Min	25%	Median	75%	Max	Mean	sd	*P	†P
SE									
Age groups									
Preschooler	-6.5	0.56	1.38	1.88	7.13	A1.08	2.12	<0.001	<0.001
Early schooleer	-6.13	-1.00	0.88	2.13	5.88	A0.65	2.19	0.030	
Late schooler	-6.63	-2.50	-0.5	1.38	5.88	B -0.42	2.56	0.064	
Adoloscent	-5.63	-2.56	-1.56	0.19	3.5	C-1.36	2.02	0.767	
Myopia	-6.63	-3.00	-2.13	-1.25	-0.5	A-2.31	1.33	<0.001	<0.001
Emmetropia	-0.38	-0.13	0.25	0.38	0.5	B0.19	0.28	0.061	
Hyperopia	0.63	1.13	1.75	2.75	7.13	C2.09	1.25	<0.001	
Boys	-6.63	-1.88	0.50	1.88	7.13	0.12	2.49	0.004	0.263
Girls	-6.13	-1.38	0.75	1.88	5.88	0.33	2.36	0.001	
Total	-6.63	-1.69	0.69	1.75	7.13	0.18	2.42	0.002	
AL									
Age groups									
Preschooler	19.91	21.60	22.11	22.60	25.57	A 22.21	1.04	0.003	<0.001
Early schooleer	20.29	22.16	22.83	23.45	26.18	B 22.89	0.98	<0.001	
Late schooler	20.91	22.81	23.64	24.42	26.19	C 23.63	1.15	0.150	
Adoloscent	22.64	23.20	23.98	24.56	25.79	C 23.98	0.90	0.235	
Myopia	21.52	23.51	24.08	24.72	26.19	A 24.15	0.88	0.009	<0.001
Emmetropia	21.45	22.68	23.17	23.70	24.63	B 23.22	0.76	0.248	
Hyperopia	19.91	21.81	22.30	22.86	24.40	C 22.32	0.77	0.133	
Boys	19.91	22.55	23.26	24.13	26.18	23.34	1.13	0.051	<0.001
Girls	20.11	21.97	22.78	23.65	26.19	22.90	1.20	<0.001	
Total	19.91	22.22	23.04	23.93	26.19	23.13	1.19	0.014	
ACD									
Age groups									
Preschooler	2.69	3.34	3.54	3.68	4.04	B 3.49	0.29	0.016	<0.001
Early schooleer	2.93	3.42	3.60	3.84	4.38	A 3.62	0.27	0.221	
Late schooler	2.82	3.50	3.73	3.89	4.46	C 3.70	0.31	0.114	
Adoloscent	3.20	3.65	3.84	4.02	4.22	C 3.81	0.27	0.311	
Myopia	3.09	3.67	3.82	3.99	4.46	A 3.83	0.22	0.039	<0.001
Emmetropia	3.08	3.45	3.76	3.89	4.29	B 3.72	0.28	0.044	
Hyperopia	2.69	3.30	3.49	3.64	4.26	C 3.48	0.26	0.278	
Boys	2.69	3.53	3.72	3.91	4.46	3.71	0.31	0.013	<0.001
Girls	2.75	3.40	3.57	3.78	4.26	3.58	0.28	0.532	
Total	2.69	3.45	3.66	3.85	4.46	3.65	0.30	0.907	
CR									
Age groups									
Preschooler	7.30	7.56	7.71	7.91	8.37	7.74	0.23	0.082	0.157
Early schooleer	7.18	7.63	7.78	7.95	8.37	7.77	0.22	0.103	
Late schooler	7.23	7.64	7.78	7.98	8.46	7.79	0.25	0.108	
Adoloscent	7.45	7.51	7.78	7.96	8.17	7.76	0.23	0.022	
Myopia	7.23	7.61	7.77	7.89	8.37	7.75	0.22	0.440	0.197
Emmetropia	7.30	7.64	7.79	8.04	8.33	7.81	0.26	0.109	
Hyperopia	7.18	7.62	7.77	7.97	8.46	7.78	0.24	0.133	
Boys	7.29	7.66	7.80	7.99	8.46	7.82	0.23	0.344	<0.001
Girls	7.18	7.56	7.75	7.90	8.37	7.74	0.23	0.066	
Total	7.18	7.61	7.78	7.95	8.46	7.78	0.24	0.328	
AL/CR									
Age groups									
Preschooler	2.59	2.80	2.87	2.94	3.18	A 2.87	0.12	0.220	<0.001
Early schooleer	2.65	2.85	2.93	3.03	3.28	B 2.95	0.13	0.020	
Late schooler	2.64	2.93	3.04	3.14	3.37	C 3.03	0.14	0.234	
Adoloscent	2.78	3.02	3.12	3.18	3.37	C 3.09	0.14	0.269	

Contd...

Table 2: Contd...

	Min	25%	Median	75%	Max	Mean	sd	*P	†P
Myopia	2.84	3.04	3.12	3.17	3.37	A 3.12	0.09	0.164	<0.001
Emmetropia	2.80	2.94	2.99	3.02	3.08	B 2.97	0.06	0.003	
Hyperopia	2.59	2.81	2.88	2.93	3.15	C 2.87	0.09	0.090	
Boys	2.61	2.88	2.98	3.10	3.37	2.99	0.15	0.128	0.031
Girls	2.59	2.86	2.95	3.07	3.32	2.96	0.14	0.019	
Total	2.59	2.86	2.97	3.09	3.37	2.97	0.15	0.056	

†Comparison within groups, Within variables row, different letters (A, B, C) in superscript indicate significant differences ($P<0.05$) according to Kruskal wallis post hoc test (Dunn test), sd: Standard Deviation, * P value was obtained from Shapiro Wilk test ($P<0.05$). SE: spherical equivalent AL: axial length ACD: anterior chamber depth CR: corneal radius

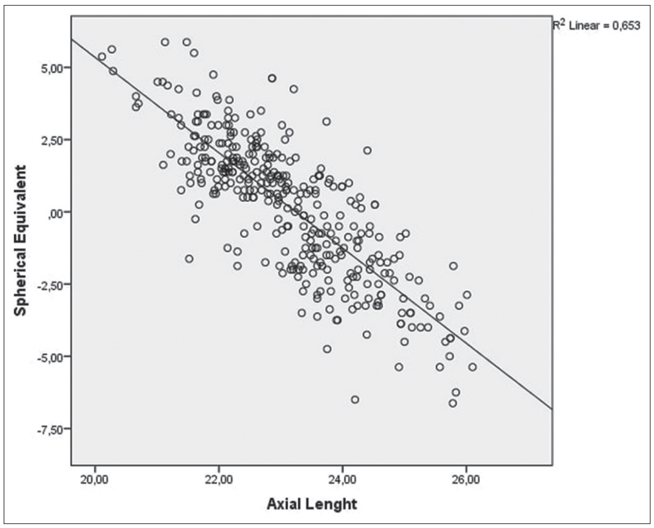

Figure 1: Regression line of the AL and SE. SE = 38,33 AL = -1,65 ($r = 0,808$ $R^2 = 0,653$, $P < 0,001$)

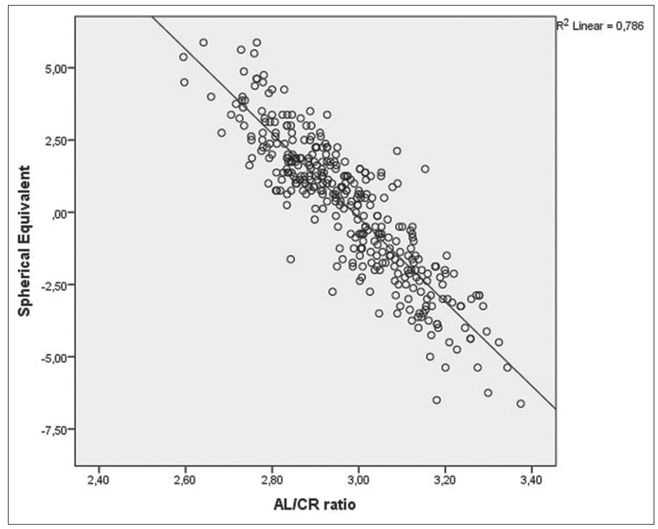

Figure 2: Regression line of the AL/CR ratio and SE. SE = 43,5 AL/CR = -14,56 ($r = 0,886$, $R^2 = 0,786$, $P < 0,001$)

had emmetropia and 181 (52.6%) had myopia observed [Table 1].

Table 2 shows the detailed analysis of SE and biometric parameters according to age and refractive groups. Mean SE was similar in the preschooler and early schooler groups, and higher than the late schooler and adolescent groups ($p < 0.001$). AL, ACD and AL/CR were observed to be lowest in the preschooler group ($p < 0.001$). CR did not show significant difference between age groups or refractive groups ($p = 0.157$, $P = 0.197$). When biometric parameters are assessed according to refractive groups, AL and ACD were higher in myopic individuals and lower in hyperopic individuals ($p < 0.001$). When differences between the genders are examined, AL and ACD were higher in boys, while the CR was lower in girls; in other words, girls were observed to have steeper corneas ($p < 0.001$).

Table 3 presents the correlations between SE, age and biometric parameters. Accordingly, SE reduced with age, with a weak correlation observed between SE and age ($r = -0.333$). AL and ACD had moderate and weak positive correlations with age respectively ($r = 0.511$; $r = 0.304$). There were negative correlations between SE with AL, ACD and AL/CR ($r = -0.826$; $r = -0.540$; $r = -0.886$). The strongest correlation with SE among these parameters was identified for AL/CR.

According to linear regression analysis shown in Figures 1 and 2, 65.3% of the variation in SE can be explained by AL alone ($R^2 = 0.653$), while 78.6% can be explained by AL/CR alone ($R^2 = 0.786$). 1 mm change in AL value was observed to cause a 1.65 D in SE value. Varying 0, 1 unit in AL/CR ratio caused the corresponding SE to change by 1,45 D.

Table 4 shows the correlation pattern according to age and refractive groups. Accordingly, the correlation between SE with AL and AL/CR increases in the preschooler early schooler and late schooler groups but reduces in the adolescent group. When assessed according to refractive errors, the correlation between SE with AL and AL/CR were observed to be weaker for emmetropic values.

Discussion

Refractive errors are the most important cause of preventable vision loss in the world.[9] According to

Table 3: Ocular biomertry correlation with SE and age

	Age	SE
SE		
r	-0,333*	
P	<0,001	
AL		
r	0,511*	-0,826*
P	<0,001	<0,001
ACD		
r	0,304*	-0,540*
P	<0,001	<0,001
AL/CR		
r	0,492*	-0,886*
P	<0,001	<0,001

*Correlation is significant at the 0.01 level, *r*: Sperman Correlation Coefficient. SE: spherical equivalent AL: axial length ACD: anterior chamber depth CR: corneal Radius

previous studies, increase in the incidence and severity of refractive errors in children, has become an important public health problem in worldwide.[10,11] Refractive status is determined by biometric parameters like AL, CR, ACD and lens thickness. Mismatch between these parameters results in refractive errors. From this aspect, optical biometry has gained importance in recent years for investigation of refractive development characteristics and early identification of refractive errors.[12] This study is the first to assess ocular biometry parameters in Turkish children as a function of age, gender and refractive errors. The gender differences in biometric parameters of children in the Turkish population from 3-14 years is consistent with previous reports.[13,14] Males typically have longer AL and deeper ACD values. In males, the AL value was observed to be mean 0.44 mm longer than in females. This difference can be explained by boys being taller than girls.[14] The variation pattern of AL with age does not show differences between the two gender and older children have longer AL values. With the increase in age, corneal power both girls and boys showed a stable course, but girls had steeper cornea. Many studies have emphasized that girls have higher corneal power.[15,16] Hashemi *et al*.[14] reported that males had mean 0.82 D higher keratometry than females in studies assessing children from 9-12 years of age. The most important reason for the steeper and more powerful cornea in girls is associated with girls having shorter axial length compared to boys.[17] Thus, the visual system ensures to keep refraction in normal intervals with the emmetropization mechanism.

According to the results of our study, the lowest mean AL value was 22.34 ± 1.03 in the preschooler group, with significantly higher frequency of hyperopia in the preschooler group consistent with the shortness of AL values. The study of preschool children by Guo *et al*.[7] identified mean AL value as 22.39 ± 0.68 mm. As stated in previous studies, hyperopia is observed frequently in the preschool period independent of ethnic origin.[18] In contrast AL value was found to be lower in early schooler group aged 7-9 years than the study by He *et al*.[19] This may be explained by the higher myopia prevalence in school-age children in the Chinese population.[20] A study in Iran by Hashemi is consistent with our results for AL values in children aged 7-9 years.[14] When Rudnicka *et al*.[21] assessed according to ethnic origin, children aged 9-12 years had AL of 23.01 in the white European 23.25 in black Africans and 23.43 in south Asians. In our study, mean AL value in children in the late schooler group was 23.63 which was observed to be higher than the values reported in Europe for similar age groups. Studies in Asian countries reported higher values in similar age groups.[22,23] Additionally, the most pronounced variation in AL and SE values in our country was linked with increase in developing myopia prevalence occurs in the late school period. The reason for this may be associated with the increased intensity of close work activities by children at higher school/educational levels. CR has more stable course with age.[19] In our study, mean CR was 7.78 ± 0.30 and there was similar distribution in all age groups, with no significant correlation observed between age and CR. Different from our study, Scheiman *et al*.[24] observed significant flattening in CR in a longitudinal study of children from 6-12 years. Li *et al*. compared 7-year-old children with 14-year-old children and stated CR was similar.[23] ACD increased progressively in all age groups with the most pronounced change in the late schooler group similar to AL and SE. Previous studies have reported that ACD reduces with age and explained this situation as due to growth of the sclera and tension applied by the posterior ciliary muscle to posterior zonular fibrils pulling the lens backward and causing deepening of the ACD.[25]

Different studies have assessed the correlation between optical biometry parameters and refractive status and according to the results of these studies, AL is the most important parameter determining refractive status.[14,26] Myopic eyes have longer axial length compared to emmetropic eyes, while hyperopic eyes have shorter axial length.[4] A study by Fiona *et al*. stated there was a strong correlation between AL and SE in all age groups and all refractive errors. Additionally, a 1 mm change occurring in axial length was shown to have greater effect on refractive error in those with low myopia compared to high myopia (3.13 D refraction change in low myopia, while -1.72 D variation in high myopia).[27] He *et al*.[19] in a study of children from 6-12 years of age identified a correlation of -0.657 between AL and SE

Table 4: Linear regression analysis for SE dependent variable in groups

	AL			AL/CR		
	β (SE)	Correlation Cofficent	R^2	β (SE)	Correlation Cofficent	R^2
Miyopia	-0,824 (0,108)	-0,524*	0,317	-9,587 (0,902)	-0,697*	0,473
Emmetropia	-0,083 (0,085)	-0,254	0,028	-2,455 (0,978)	-0,350	0,160
Hyperopia	-0,839 (0,100)	-0,482*	0,284	-8,655 (0,733)	-0,625*	0,438
Preschooler	-1,712 (0,179)	-0,615*	0,611	-15,875 (1,313)	-0,779*	0,716
Early schooler	-1,764 (0,131)	-0,762*	0,597	-15,116 (0,758)	-0,853	0,765
Late schooler	-1,801 (0,104)	-0,815*	0,678	-15,821 (0,647)	-0,892*	0,808
Adoloscent	-1,613 (0,494)	-0,566*	0,432	-13,982 (1,340)	-0,858*	0,886

SE: spherical equivalent AL: axial length CR: corneal Radius

and a 1 mm change in AL was shown to cause a 1.01 D variation. In the current study, similarly, there was a very strong, negative correlation observed between spherical equivalent and axial length. Additionally, a 1 mm increase in AL was concluded to cause a 1.65 D reduction in SE. Many studies in recent years have stated there is a better correlation between AL/CR ratio and SE.[28] Consistent with these studies, AL/CR ratio showed higher correlation with SE than with only AL in our study. The correlation between SE and AL displays progressive increase between age groups, with a reduction observed in the adolescent period. The correlation between SE and AL/CR shows progressive increase up to the adolescent period. The group with highest correlation between SE with AL and AL/CR is the late schooler group compassing children from 9-13 years. Additionally, the correlation between SE with AL and AL/CR is not linear but was weaker at emmetropic values. This situation may be explained by compensation due to other optical parameters. He *et al.*[19] showed the AL/CR ratio explained 65.7% of the total variance in SE, while AL alone only explained 43.1% of the variance in SE. Another study stated these rates were 31% and 16%, respectively.[29] In our study, these rates were higher, AL explaining 65.3% of the variation in SE while AL/CR ratio explained 78.6% of the variation. Previous studies showed that anterior chamber depth was correlated with refractive errors. Myopia is known to be associated with deeper, while hyperopia is associated with shallower anterior chamber.[30] Similarly, in this study, myopic eyes had deeper anterior chamber, while hyperopic eyes had shallower anterior chamber compared to emmetropic eyes and a negative and strong correlation was observed between ACD and SE. Another refractive component of CR was emphasized to be steeper in myopic eyes compared to emmetropic eyes, and flatter in hyperopic eyes in many studies. In contrast, CR did not display differences in myopic, emmetropic or hyperopic eyes. Accordingly, in children in the Turkish population, CR does not display significant change as a part of the emmetropization process.

In conclusion, our study presents descriptive data about the refractive and ocular biometry characteristics of children in the Turkish population. Axial length was shorter compared to children in the Asian population in all age groups, while there was a clear increase in AL values in the late schooler group with AL longer than studies reporting from European countries. AL alone shows strong correlation with refraction errors. The CR had homogeneous values in all groups and did not display significant variation as part of the emmetropization process in myopic eyes or hyperopic eyes. AL/CR explained the total variance in SE better than AL alone. Accordingly, assessment of AL/CR may be used as reference for refractive development. Along with the age increase, increasing AL creates a myopic shift.

Limitations

The most important limitation in our study is the cross-sectional design. Longitudinal studies may provide more robust results on the changes of refractive and biometric parameters with age. Another point is limited number of subjects in the study. In this respect it is not clear that the results are representative of the general population.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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