• Clinical Research •

Correlation between ocular biological parameters and cycloplegic refractive shift in pediatric myopia

Zhi-Hui Li[1,2], *Jing Lin*[2], *Jie Li*[2], *Cheng-Yu Ji*[2], *Yan Guan*[2], *Run-Yu Zhu*[1,2], *Lan Hu*[2,3]

[1]Dalian Medical University, Dalian 116000, Liaoning Province, China

[2]Department of Pediatric Ophthalmology and Strabismus, Shenyang He Eye Specialist Hospital, Shenyang 110000, Liaoning Province, China

[3]School of Visual Sciences, He University, Shenyang 110163, Liaoning Province, China

Correspondence to: Lan Hu. Department of Pediatric Ophthalmology and Strabismus, Shenyang He Eye Specialist Hospital; School of Visual Sciences, He University, Shenyang 110000, Liaoning Province, China. hulan@hsyk.com.cn

Received: 2025-07-24 Accepted: 2026-03-18

Abstract

● **AIM:** To analyze the correlation between ocular biometric parameters and cycloplegic refractive shift (ΔSE) and to provide evidence for clinical decision-making regarding cycloplegic refraction in pediatric myopia management.

● **METHODS:** This retrospective study enrolled myopic patients aged 5-17y between July 2022 and November 2023. Data collected included age, gender, pre-cycloplegic spherical equivalent (SE_1), axial length (AL), average corneal curvature (K), lens thickness (LT), anterior chamber depth (ACD), central corneal thickness (CCT), positive relative accommodation (PRA), negative relative accommodation (NRA), and post-cycloplegic spherical equivalent (SE_2). Only right eyes were analyzed. Participants were divided into three groups by ΔSE: Group A (ΔSE≤0.25 D), Group B (0.25<ΔSE<0.75 D), and Group C (ΔSE≥0.75 D). Based on SE_2, subjects were classified into pre-myopia (−0.50<SE_2≤+0.75 D), low myopia (−3.00<SE_2≤−0.50 D), and moderate myopia (−6.00<SE_2≤−3.00 D).

● **RESULTS:** A total of 996 myopic patients (455 boys, 541 girls) with a mean age of 9.97±0.83y were included. Groups A, B, and C comprised 544, 284, and 168 eyes, respectively. Post-cycloplegic stratification identified 94 pre-myopic eyes, 797 low myopic eyes, and 105 moderate myopic eyes. Significant inter-group differences were observed in AL, CCT, ACD, LT, NRA, and axial length/corneal radius (AL/CR; all *P*<0.05). LT was positively correlated with ΔSE (*P*=0.003), while NRA was negatively correlated with ΔSE (*P*=0.049). AL/CR showed the strongest negative association (*P*<0.001). ROC curve analysis yielded area under the curve (AUC) values of 0.551 for LT, 0.447 for NRA, and 0.441 for AL/CR. For LT, the optimal cutoff was 3.39 mm, with 65.4% sensitivity and 44.2% specificity. Mean LT was 3.438±0.168 mm in the 5-7-year group, significantly thicker than in 8-10y (3.360±0.145 mm), 11-13y (3.353±0.158 mm), and 14-17y (3.336±0.155 mm; all *P*<0.001). Median AL/CR ratios were 3.02 (2.95, 3.08) in pre-myopia, 3.10 (3.06, 3.14) in low myopia, and 3.21 (3.15, 3.28) in moderate myopia. Linear regression produced the model: AL/CR=3.025-0.051×SE_2 (R^2=0.462, *F*=854.081, *P*<0.001). Receiver operating characteristic (ROC) analysis for moderate myopia detection showed an AUC of 0.851 with an optimal AL/CR cutoff of 3.15.

● **CONCLUSION:** In myopic patients aged 5-17y, ΔSE is negatively correlated with NRA and positively correlated with LT. Cycloplegic refraction is recommended when LT exceeds 3.39 mm, but interpretation must account for age-related variations in lens thickness. Using the formula AL/CR=3.02-0.05×SE_2, cycloplegic refraction is advised when a marked discrepancy exists between pre-cycloplegic refraction and AL/CR.

● **KEYWORDS:** myopia; cycloplegic refraction; lens thickness; axial length/corneal radius; children

DOI:10.18240/ijo.2026.06.15

Citation: Li ZH, Lin J, Li J, Ji CY, Guan Y, Zhu RY, Hu L. Correlation between ocular biological parameters and cycloplegic refractive shift in pediatric myopia. *Int J Ophthalmol* 2026;19(6):1140-1148

INTRODUCTION

In recent years, the widespread prevalence of myopia among children and adolescents has emerged as a critical public health concern. In China, the myopia rate in this population reached 52.7% by 2020[1]. Since active accommodation in children may interfere with subjective refraction, cycloplegic refraction plays an essential role in pediatric examinations and is considered as the gold standard for clinical refractive assessment. The Chinese Expert Consensus on Cycloplegic Refraction and Safe Medication Use in Children (2019)[2]

recommends routine cycloplegic refraction for children under 12y old, particularly first-time spectacle wearers. However, the decision to perform cycloplegia for follow-up visits currently relies primarily on clinicians' experience. Cycloplegic refractive shifts (ΔSE) are influenced by multiple complex factors[3]. At the biological level, excessive axial length (AL) elongation is recognized as a hallmark of myopia progression, but numerous studies have found no correlation between AL changes and ΔSE. Lens thickness (LT) is a key indicator of accommodative function, has shown significant association with hyperopic shift after cycloplegia. The influences of other parameters such as corneal curvature (K) and anterior chamber depth (ACD) on cycloplegic refraction outcomes require further investigation. From an environmental and behavioral perspective, accommodative spasm caused by prolonged near work may amplify refractive differences before and after cycloplegia[4], which may also accelerate myopia onset and progression. Although existing studies have examined these factors in isolation, the multifactorial interactions and their unique manifestations in pediatric populations remain insufficiently understood.

This study collected pre-cycloplegic ocular biometric parameters, positive relative accommodation/negative relative accommodation (PRA/NRA) measurements, and demographic characteristics from myopic children and adolescents. By analyzing the correlation between these factors and ΔSE, we aimed to identify key determinants influencing ΔSE, so as to provide evidence-based guidance for clinical decision-making regarding cycloplegic refraction, address challenges such as long duration of cycloplegia and children's non-compliance, and offer a theoretical basis for developing personalized myopia management strategies.

PARTICIPANTS AND METHODS

Ethical Approval This study was approved by the Ethics Committee of Shenyang He Eye Specialist Hospital [IRB (2025) K006.01], which was adhered to the tenets of the Declaration of Helsinki, and the informed consent has been waived through the ethics review committee.

Participants This study enrolled myopic children and adolescents who visited the Pediatric Ophthalmology and Strabismus Clinic at He Eye Specialist Hospital from July 2022 to November 2023, with complete data on refractive status before and after cycloplegia, ocular biometric parameters, and accommodation parameters. The right eye was designated as the study eye. Based on event per variable (EPV) rule, incidence rate of ΔSE>0.25 D was 50% in preliminary experiment. EPV was set to 20, so a minimum of 20 samples per independent variable was needed. This study incorporated 12 independent variables, including gender, age, AL, average K, LT, ACD, central corneal thickness (CCT), PRA, NRA, pre-cycloplegic spherical equivalent (SE_1), post-cycloplegic spherical equivalent (SE_2), and axial length/corneal radius (AL/CR). The sample size formula is:

$$Sample\ Size=\frac{Number\ of\ Variables\times EPV}{Incidence\ Rate}$$

$$=\frac{12\times 20}{0.5}=480$$

Consequently, a minimum sample size of 480 cases was required.

Inclusion criteria 1) Aged 5-17y, gender not limited; 2) corrected visual acuity ≥1.0; 3) $-6.00<SE_1\leq-0.50$ D or astigmatism ≥-1.5 D; 4) cycloplegic refraction, pre-cycloplegic visual function examination and ocular biometric parameter measurements were conducted; 5) cycloplegic refraction, visual function examination and IOLmaster700 biometric measurements were performed on the same day; 6) complete patient data were available in our hospital information system.

Exclusion criteria 1) Patients with other diseases affecting refractive examination, such as congenital cataracts, corneal opacity, keratoconus, lens dislocation, uveitis and abnormal lens morphology; 2) Children with history of intraocular surgery, such as congenital cataract extraction, glaucoma, vitrectomy, *etc*.; 3) Wearing orthokeratology or rigid gas permeable (RGP) within 3mo before data collection date, or soft contact lenses within 1wk; long-term use of low-concentration atropine eye drops within 3mo, or undergoing visual function training within recent 3mo; 4) Patients with inaccurate measurement results due to nystagmus, large-angle strabismus or non-compliance; 5) Other issues considered by investigators that may affect study results.

Methods

Examination methods 1) Demographic and biological information: Basic information including gender and age was collected from outpatient records of myopic children and adolescents. 2) Pre-cycloplegic refraction: Pre-cycloplegic autorefraction results were obtained using an automatic refractometer (ARK-1, NIDEK Co., Japan). Recorded data represented the average of three measurements, including pre-cycloplegic spherical power (DS_1) and cylindrical power (DC_1). 3) PRA and NRA: Data on PRA and NRA were extracted from outpatient records. PRA measurement: Using a phoropter (CV-500, TOPCON Co., Japan) with full binocular correction and near pupillary distance (PD), patients viewed a 40 cm target (one line above best-corrected acuity) under near illumination. Meanwhile, -0.25 D spherical lenses were successively added to both eyes until the target became blurred. The cumulative minus lens power added represented the PRA. NRA measurement: Same setup as PRA, gradually adding +0.25 D lenses until the target became blurred. The maximum plus lens power added represented

Table 1 Comparison of gender distribution among different diopter difference groups

Group	Male (n=455)	Female (n=541)	χ^2	P
Group A (n=544)	249 (45.8%)	295 (54.2%)	3.498	0.174
Group B (n=284)	139 (48.9%)	145 (51.1%)		
Group C (n=168)	67 (39.9%)	101 (60.1%)		

the NRA. 4) Ocular biometric parameters: K1, K2, AL, LT, ACD, and CCT were measured three times using IOLMaster 700 (Carl Zeiss Meditec AG, Germany), with averaged values recorded. 5) Post-cycloplegic refraction: Post-cycloplegic autorefraction results were obtained using an automatic refractometer (ARK-1, NIDEK Co., Japan). The recorded data represented the average of three measurements, including post-cycloplegic spherical power (DS_2) and cylindrical power (DC_2). The cycloplegic agents were administered as follows: children aged 5-7y received 0.1 mL per dose for 1% atropine sulfate ophthalmic gel (Dishan, Shenyang Xingqi Eye Pharmaceutical Co., China) and three times daily for three consecutive days, with refraction performed on the fourth day; children aged 8-10y received 0.05 mL per dose for 1% cyclopentolate hydrochloride eye drops (Cyclogyl, Alcon, USA) and administered three times at 10-minute intervals, followed by refraction 30min later; and children aged 11-17y received 0.05 mL per dose for 1% compound tropicamide eye drops (Mydrin-P, Santen Pharmaceutical Co., China) and administered four times at 5-minute intervals, followed by refraction 20min later. 6) Data calculations: $SE_1=DS_1+1/2DC_1$; $SE_2=DS_2+1/2DC_2$; $\Delta SE=SE_2-SE_1$; $AL/CR=AL\times K/337.5$.

All examinations were performed by dedicated, experienced clinicians and optometrists to ensure consistency.

Grouping methods According to the national standard "Optical Glasses Products-Part 1: Spectacle Frames and Lenses" (GB10810.1-2003), the national standards for lens error are as follows: the relative error should not exceed 0.125 D, and the absolute error should not exceed 0.25 D. All patients were divided into three groups based on different ΔSE: Group A ($\Delta SE\leq0.25$ D), Group B ($0.25<\Delta SE<0.75$ D), and Group C ($\Delta SE\geq0.75$ D). Additionally, patients were classified into three groups according to SE_2: pre-myopia ($-0.5<SE_2\leq0.75$ D), low myopia ($-3.00<SE_2\leq-0.50$ D), and moderate myopia (-6.00 $SE_2\leq-3.00$ D).

Statistical Analysis Statistical analysis was performed using SPSS 26.0 software. Quantitative data were tested for normal distribution using Q-Q plots. Normally distributed data were expressed as mean±standard deviation, and comparisons between groups were conducted using one-way ANOVA. Categorical data were analyzed using the Chi-square test. For non-normally distributed data, median (interquartile range) was used for description, and the Kruskal-Wallis rank-sum test was employed for intergroup comparisons. A multiple linear regression model was applied to analyze factors influencing diopter difference before and after cycloplegia. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the accuracy of relevant parameters in predicting the magnitude of post-cycloplegic refractive change, with sensitivity, specificity, and Youden index as evaluation metrics. $P<0.05$ was considered statistically significant.

RESULTS

This study included 996 myopic patients aged 5-17y with a mean age of 9.97±0.83y, consisting of 455 boys (455 eyes) and 541 girls (541 eyes). Group distribution was as follows: Group A: 544 eyes; Group B: 284 eyes; Group C: 168 eyes. Post-cycloplegia classification showed 94 eyes with pre-myopia, 797 eyes with low myopia, and 105 eyes with moderate myopia. Q-Q plot analysis confirmed normal distribution for Age, AL, K, LT, ACD, CCT, PRA, NRA, SE_1, and AL/CR (Figure 1).

Comparison of Gender, Age, and Ocular Biometric Parameters Results showed no statistically significant difference in gender distribution among the groups (P=0.174; Table 1). No statistically significant differences were found among groups for age, K, PRA, and SE_1 ($P>0.05$). Statistically significant differences were observed for AL, CCT, ACD, LT, NRA, and AL/CR ($P<0.05$; Table 2).

Analysis of Factors Influencing the ΔSE Based on the results of one-way ANOVA, this study incorporated factors with $P<0.05$ as independent variables (ACD, CCT, LT, NRA, AL, and AL/CR), with the SE difference as the dependent variable. The final constructed multiple linear regression model was statistically significant (F=14.634, $P<0.001$). The variance inflation factor (VIF) values of the above independent variables are all less than 10, indicating no significant multicollinearity. The regression diagnosis employs the Shapiro-Wilk test, and the P value of the residuals is greater than 0.05, indicating normality. LT had a significant positive correlation with ΔSE (P=0.003), NRA showed a negative correlation with ΔSE (P=0.049). AL/CR demonstrated the most significant negative correlation with ΔSE ($P<0.001$). AL, ACD, and CCT showed no significant correlation with ΔSE (P=0.395, 0.405, 0.137).

ROC Curve in Predicting ΔSE and Analysis on the Optimal Cut-off Value Using the criteria of $\Delta SE\leq0.25$ D (assigned value=1) versus $\Delta SE>0.25$ D (assigned value=2), ROC curve analysis was performed for LT, NRA, and AL/CR as test variables. Area under the curve (AUC) were 0.551 (P=0.006),

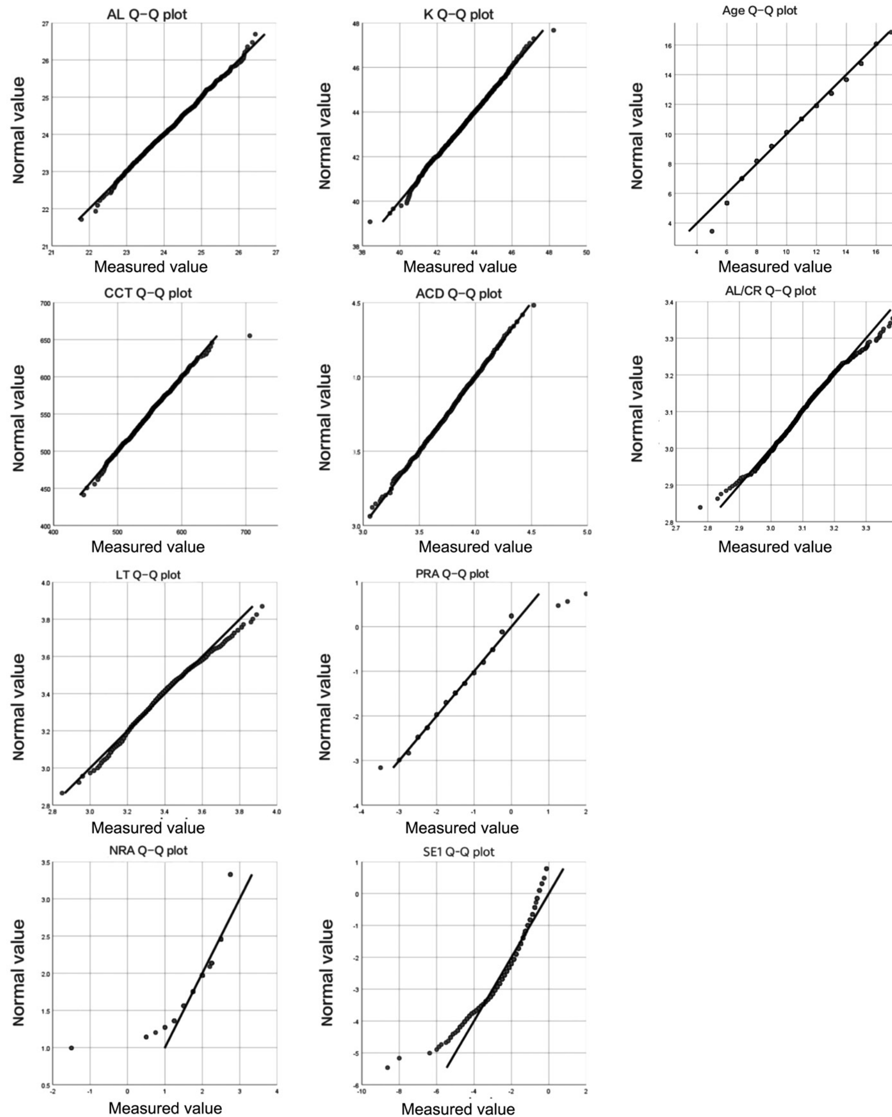

Figure 1 Q-Q plots analysis AL: Axial length; K: Average corneal curvature; CCT: Central corneal thickness; ACD: Anterior chamber depth; AL/CR: Axial length/corneal radius; LT: Lens thickness; PRA: Positive relative accommodation; NRA: Negative relative accommodation; SE_1: Pre-cycloplegic spherical equivalent.

Table 2 Comparison of age and ocular biometric parameters among different diopter difference groups

Group	Age (y)	AL (mm)	K (D)	CCT (μm)	ACD (mm)	LT (mm)	PRA (D)	NRA (D)	SE_1 (D)	AL/CR
Group A (*n*=544)	9.000±2.064	24.283±0.752	43.362±1.359	551.410±32.459	3.768±0.217	3.353±0.140	-1.172±0.554	2.238±0.342	-2.038±0.967	3.117±0.791
Group B (*n*=284)	10.170±2.110	24.195±0.742	43.457±1.305	542.580±31.664	3.758±0.214	3.365±0.160	-1.258±0.667	2.130±0.432	-2.112±1.043	3.113±0.749
Group C (*n*=168)	9.980±2.391	23.946±0.830	43.264±1.276	546.689±36.667	3.689±0.258	3.414±0.182	-1.264±0.638	2.111±0.468	-2.179±1.278	3.068±0.980
F	1.717	12.484	1.145	6.829	8.008	10.027	2.649	4.469	1.315	24.736
P	0.180	<0.001[a]	0.319	0.001[a]	<0.001[a]	<0.001[a]	0.071	0.012[a]	0.269	<0.001[a]

AL: Axial length; K: Average corneal curvature; CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; PRA: Positive relative accommodation; NRA: Negative relative accommodation; SE_1: Pre-cycloplegic spherical equivalent; AL/CR: Axial length/corneal radius. [a]Statistically significant difference.

0.447 (*P*=0.158), and 0.441 (*P*=0.001), respectively. Since both NRA and AL/CR showed AUC values below 0.5, only LT was further analyzed for its predictive capability. The specificity of LT was 0.442, the sensitivity was 0.654, and the Youden index (Youden index=sensitivity+specificity-1) was 0.096. The optimal cutoff value was 3.39 mm that corresponded to Youden index 0.096 (Figure 2).

Table 3 showed statistically significant differences in LT across different age groups. The 5-7y group exhibited the thickest mean LT, with pairwise comparisons against the other three groups yielding statistically significant differences (*P*<0.001). In contrast, pairwise comparisons among the remaining three age groups showed no statistically significant differences (*P*=0.513, 0.231, 0.407). Consistent findings were observed

Table 3 Comparison of LT among different age group, using the criteria of ΔSE ≤0.25 D versus ΔSE>0.25 D

Age (y)	Total (*n*=996)	Group A (*n*=544)	Group B+C (*n*=452)	*t*	*P*
5-7	3.438±0.168 (135)	3.398±0.136 (74)	3.487±0.190 (61)	-3.172	0.002
8-10	3.360±0.145 (472)	3.354±0.136 (264)	3.368±0.156 (208)	-1.061	0.289
10-13	3.353±0.158 (327)	3.340±0.148 (172)	3.367±0.168 (155)	-1.538	0.125
14-17	3.336±0.155 (62)	3.314±0.135 (34)	3.362±0.174 (28)	-1.190	0.240
F	11.798	3.923	9.124		
P	<0.001[a]	0.009	<0.001[a]		

[a]Statistically significant difference. LT: Lens thickness; ΔSE: Cycloplegic refractive shifts.

in subgroups stratified by ΔSE (ΔSE≤0.25 D or >0.25 D). In Group A, 5-7y group had the thickest mean LT; pairwise comparisons with the other three groups were statistically significant (*P*=0.017, 0.003, 0.004), whereas no significant differences were noted among the other three groups (*P*=0.323, 0.116, 0.312). In Group B+C, 5-7y group also displayed the thickest mean LT, with significant differences in pairwise comparisons against the other three groups (*P*=0.000, 0.000, 0.001), while no significant differences existed among the other three groups (*P*=0.946, 0.843, 0.873). These results suggest that age should be considered when predicting ΔSE depending on LT. Additionally, Table 3 showed that 5-7y children were sensitive to accommodation, in the subgroup of ΔSE>0.25 D, LT was significantly increased (*P*=0.002), whereas no statistically significant differences were observed in other age groups (*P*=0.289, 0.125, 0.240).

Comparison of AL/CR among Pre-myopia, Low Myopia and Moderate Myopia Groups Based on SE_2, the subjects were divided into three groups: pre-myopia (94 eyes, $-0.5<SE_2\leq0.75$ D), low myopia (797 eyes, $-3.00<SE_2\leq-0.50$ D), and moderate myopia (105 eyes, $-6.00<SE_2\leq-3.00$ D). Levene's test for AL/CR showed *P*<0.000, indicating heterogeneity of variance, so Kruskal-Wallis *H* test was performed. The median and interquartile ranges were: 3.02 (2.95, 3.08) for pre-myopia, 3.10 (3.06, 3.14) for low myopia, and 3.21 (3.15, 3.28) for moderate myopia. The results demonstrated that AL/CR increased with worsening myopia severity. The distribution of AL/CR values among the three groups showed highly statistically significant differences (*H*=136.408, *P*<0.001).

Linear Regression Analysis of AL/CR with SE_2 and ROC Curve Analysis for Myopia Severity Diagnosis The Pearson correlation analysis between AL/CR and SE_2 showed a significant negative correlation (*r*=-0.68, *P*<0.001). Using AL/CR as the dependent variable and SE_2 as the independent variable, the linear regression model was established as: $AL/CR=3.025-0.051\times SE_2$ (*F*=854.081, *P*<0.001; Table 4). ROC curve analysis was performed with $SE_2\leq-3.00$ D assigned as 1 and $SE_2>-3.00$ D as 2, using AL/CR as the test variable. The AUC was 0.851 (*P*<0.001), with an AL/CR cutoff value of 3.15.

Table 4 Linear regression analysis of SE2 and AL/CR

Parameters	*B*	Standard error	*T*	*P*
Constant	3.025	0.003	874.976	*P*<0.001
SE_2	-0.051	0.002	-29.225	*P*<0.001
R^2		0.462		
F		*F*=854.081, *P*<0.001		
D-W		1.808		

SE2: Post-cycloplegic spherical equivalent; AL/CR: Axial length/corneal radius.

At AL/CR=3.15, the sensitivity, specificity, and Youden index for determining the moderate myopia threshold (SE=-3.00 D) were 79%, 79.6%, and 0.58, respectively (Figure 3).

DISCUSSION

Influence of Gender and Age on ΔSE Table 1 shows no statistically significant gender differences among diopter difference groups (*P*>0.05). While gender correlates with myopia prevalence[5-6], its association with ΔSE remains unclear. Sanfilippo *et al*[7] reported significant ΔSE (0.36±4.41 D) in 13-year-old versus minimal changes (0.06±0.50 D) in 25-year-old, suggesting marked variations under age 20. Although our study found no age-related differences (*P*>0.05), uneven age distribution may introduce bias, which cannot demonstrate a clear correlation between ΔSE and age. For adolescents aged 13 to 20y, even though their accommodative ability decreases with age, they may still develop pseudomyopia caused by accommodative spasm due to prolonged or intensive near work, resulting in significant changes in refractive error before and after cycloplegia.

Influence of K, CCT, LT, and ACD on ΔSE In the comparison among groups with different ΔSE, the variation in K showed no statistical significance (*P*>0.05). ΔSE demonstrated no significant correlation with corneal curvature. This finding aligns with the conclusion of Autrata *et al*'s[8] study. Another study[9] also indicated no significant difference in corneal curvature measurements using the same instrument before and after cycloplegia. Therefore, we conclude that corneal curvature has no notable influence on ΔSE and cannot serve as an indicator to predict or assess these changes.

The mean CCT showed statistically significant differences among groups A, B, and C, but no clear pattern or linear

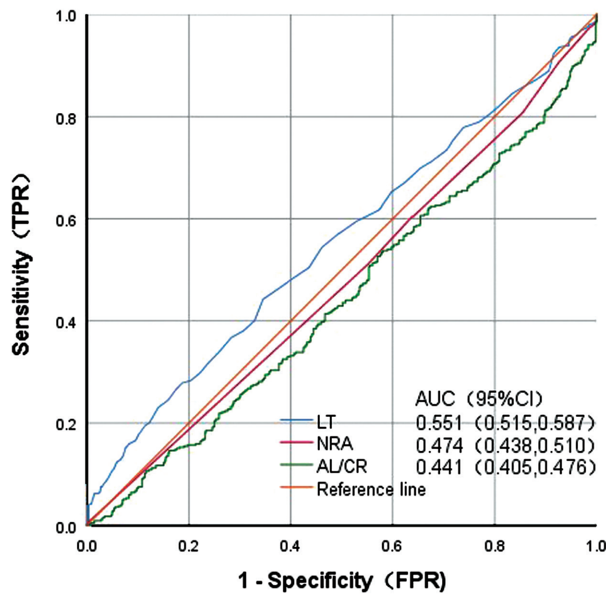

Figure 2 ROC curve analysis of LT for predicting ΔSE>0.25 D ROC: Receiver operating characteristic; TPR: True positive rate; AUC: Area under the curve; LT: Lens thickness; NRA: Negative relative accommodation; AL/CR: Axial length/corneal radius; FPR: False positive rate.

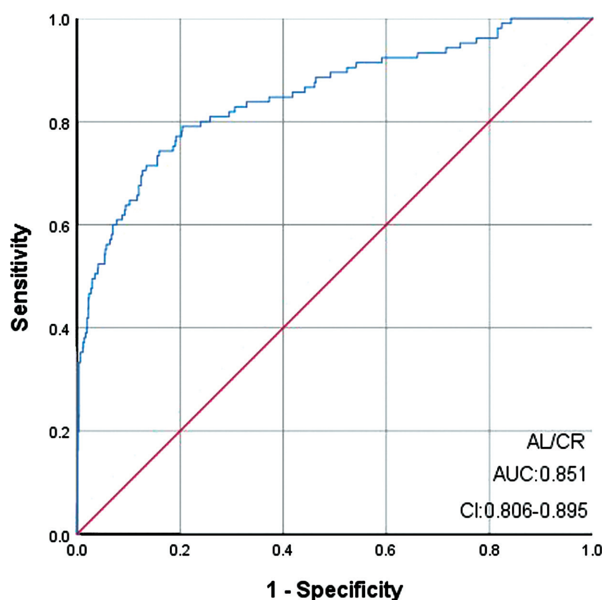

Figure 3 ROC curve analysis of AL/CR for predicting moderate myopia AL/CR: Axial length/corneal radiuss; AUC: Area under the curve; CI: Confidence interval.

correlation was observed across the groups. Some research suggests[10] that CCT increases after cycloplegia, possibly because the administration of cycloplegic drugs typically requires children to keep their eyes closed. This may indirectly prevent the corneal epithelium from absorbing oxygen from the air, leading to localized increases in carbon dioxide and lactic acid levels in the cornea, resulting in epithelial edema and consequently thicker CCT. Although CCT may change after cycloplegia, no studies have proven a relationship between this change and refractive error changes. Moreover, pre-cycloplegic CCT cannot determine whether a patient has pseudomyopia or serve as an indicator for the necessity of cycloplegic refraction.

The mean LT showed statistically significant differences among groups A, B, and C. Multiple linear regression analysis revealed P=0.004, indicating statistical significance. These findings demonstrate a significant positive correlation between LT and ΔSE. When children and adolescents engage in prolonged near work, the crystalline lens becomes thicker and more convex due to accommodation. A thicker LT may indicate excessive accommodation or accommodative spasm, leading to a greater increase in myopic refractive power. Although this study did not investigate LT changes before and after cycloplegia, multiple studies have shown that LT decreases significantly in children and adolescents after cycloplegic administration. Bao *et al*[11] studied 132 children aged 5-15, including both myopic and non-myopic subjects, and observed that LT decreased from 3.47±0.20 to 3.41±0.20 mm in non-myopic children and from 3.30±0.17 to 3.27±0.16 mm in low myopia children after cycloplegia. This indicates that LT undergoes significant changes after cycloplegia in both myopic and non-myopic children and adolescents, consistent with our conclusion that LT may significantly influence ΔSE. Therefore, we propose that LT can serve as an indicator to determine whether cycloplegic refraction is necessary.

Based on the ROC curve results, the AUC for LT was 0.551 (P=0.006). Using the Youden index 0.096 calculated from sensitivity and specificity, the optimal cutoff value for LT was determined to be 3.39 mm. Studies have shown that LT changes are related to age but do not correlate with myopia progression, exhibiting no clear linear relationship[12]. Lu *et al*[13] found that the mean LT in children aged 11.03±2.84y was 3.30±0.16 mm. Wang *et al*'s[14] research reported mean LT values of 3.69±0.26 mm in children aged 3-6, 3.37±0.14 mm in those aged 7-12, and 3.38±0.16 mm in adolescents aged 13-17. In our study, the mean LT in 5-7y group was 3.438±0.168 mm, thicker than 8-10y (3.360±0.145 mm), 11-13y (3.353±0.158 mm) and 14-17y (3.336±0.155 mm) group (P<0.001). Consistent findings were observed in subgroups stratified by ΔSE (ΔSE≤0.25 D or >0.25 D). These results suggest that age should be considered when predicting ΔSE depending on LT. Additionally, Table 3 showed that 5-7y children were sensitive to accommodation, in the subgroup of ΔSE>0.25 D, LT was significantly thicker (P=0.002), whereas no statistically significant differences were observed in other age groups. So children under 7 years old, cycloplegic refraction should be recommended to exclude influence of accommodation. For children and adolescents aged 8-18, cycloplegic refraction is considered when LT is thicker than 3.39 mm.

The mean ACD showed statistically significant differences among groups A, B, and C. The group exhibiting larger refractive changes after cycloplegia has shallower ACD. Mitsukawa *et al*[15] also observed a significant increase in ACD after cycloplegia. However, multiple linear regression analysis yielded a *P*-value of 0.405 for ACD indicating no statistical significance and no correlation with diopter difference before and after cycloplegia. This may be due to insufficient sample size or low predictive power of the model.

Influence of PRA and NRA on ΔSE PRA represents the maximum accommodative capacity, reflecting the eye's accommodative reserve. It's the most variable parameter during near work[16]. Low PRA values indicate poor accommodative ability, making individuals more prone to visual fatigue during near work or faster myopia progression, while higher values suggest stronger accommodative capacity and sufficient reserve. NRA reflects the ability to relax accommodation. Lower NRA value indicates poor eye relaxation ability, making the eyes prone to fatigue and accommodative spasm, which can lead to pseudomyopia.

NRA showed statistically significant differences among groups A, B, and C in this study. Multiple linear regression analysis indicated a negative correlation between NRA and ΔSE. Poor eye habits, such as excessive near work may lead to accommodative spasm, where ciliary muscle contraction causes zonular relaxation and increased lens curvature, thereby augmenting myopic refractive power. Cycloplegic drugs can relax the ciliary muscle, tense the zonules, and thin the lens, reducing myopic refractive power and resulting in greater ΔSE. This explains why LT correlates with ΔSE, suggesting NRA may be an indicator for cycloplegic refraction. However, the AUC for NRA was 0.447 in this study, indicating insufficient accuracy for prediction based on specificity, sensitivity, and Youden index. Studies will be necessary to expand the sample size to further clarify the relationship between NRA and ΔSE.

PRA showed no significant differences among groups A, B, and C. In patients with accommodative dysfunction, reduced PRA is a common manifestation of accommodative insufficiency. The study[17] shows myopes typically have lower PRA. Although PRA reduction correlates with rapid myopia progression, it rarely causes pseudomyopia. Thus, this study found no clear association between cycloplegic refractive changes and PRA, making it unsuitable as an indicator for cycloplegic refraction.

Influence of AL, AL/CR, and Pre-Cycloplegic SE_1 on ΔSE AL is a key factor influencing refractive status, with myopic progression showing a clear positive correlation with AL elongation. Most myopia in children and adolescents is attributed to axial elongation. Meng *et al*[18] reported that AL undergoes a period of accelerated growth in children between the ages of 6 and 12 among 6364 Shandong children aged 4-18, suggesting that AL progressively increases with age. Clinically, each 1 mm AL increase corresponds to approximately 2.5-3.0 D myopic shift[19], making AL a useful myopia indicator. However, AL alone does not determine refractive status. Recent studies show refractive status correlates more strongly with AL/CR than AL alone[20-23], making AL/CR a preferred clinical indicator. Liu *et al*[24] found AL/CR cutoff values vary with age among children and adolescents aged 3-18, but the diagnostic predictive value of AL/CR for myopia is age-independent. Li *et al*[25] reported an optimal AL/CR cutoff of 3.01 for myopia diagnosis, with sensitivity and specificity exceeding 90%.

In this study, the mean SE_1 in groups A, B, and C was -2.038±0.967, -2.112±1.043, and -2.179±1.278 D, respectively (P=0.269), indicating no statistically significant intergroup differences. The mean AL in groups A, B, and C was 24.283±0.752, 24.195±0.742, and 23.946±0.830 mm, respectively (P<0.01), demonstrating significant intergroup variation. However, multiple linear regression analysis revealed a *P*-value of 0.395 for AL, suggesting no statistically significant association between AL and ΔSE.

Notably, the mean AL/CR values in groups A, B, and C were 3.117±0.791, 3.113±0.749, and 3.068±0.980, respectively (P<0.001), demonstrating statistically significant intergroup differences. Multiple linear regression analysis further confirmed a significant negative correlation between AL/CR and cycloplegic refraction shift (P<0.001). However, since all AUC values for AL/CR were below 0.5, indicating low validity and poor predictive performance, this study did not evaluate AL/CR's predictive capability for cycloplegic refraction changes, focusing instead on its relationship with refractive status. The study established different mean AL/CR values for pre-myopia, low myopia, and moderate myopia: 3.02 (2.95-3.08), 3.10 (3.06-3.14), and 3.21 (3.15-3.28), respectively, with statistically significant differences among groups (P<0.01). These findings align with Jong *et al*'s[26] research, which reported mean AL/CR values of 3.46±0.10 for high myopia versus 3.16±0.07 for low myopia (P<0.05), with statistically significant differences among groups (P<0.05). For children aged 5-17y, we derived the linear regression equation: $AL/CR=3.025-0.051\times SE_2$, showing a negative correlation between SE2 and AL/CR, every 1.00D decrease in SE corresponded to a 0.05 increase in AL/CR. The cut-off point for predicting moderate myopia with AL/CR is 3.15. These findings are consistent with previous studies. Wang *et al*'s[27] research similarly demonstrated a negative correlation between SE_2 and AL/CR, establishing the linear regression formula $AL/CR=2.99-0.06\times SE_2$ for children aged 3-14y, indicating that every 0.06 increase in AL/CR corresponds to a 1.00 D

reduction in refractive error. The conclusion drawn by Mu *et al*[28] is that for every 0.06 increase in AL/CR, refractive errors decrease by 1.00 D. Additionally, Hu *et al*[29] identified 3.199 as the diagnostic threshold for AL/CR, showing its clinical value in detecting moderate myopia.

The study revealed while mean SE_1 values progressively decreased (reflecting increasing myopia severity) across groups A to C, AL/CR showed an opposite trend. This discrepancy suggests potential inaccuracies in pre-cycloplegic refraction. Group C's mean SE_1 should theoretically correspond to AL/CR=3.12 (calculated *via* $AL/CR=3.025-0.051\times SE_2$), yet the measured mean value was 3.06. As Harrington *et al*[30] believes, combining AL/CR with non-cycloplegic SE can achieve better myopia discrimination. So when significant disparities exist between AL/CR-predicted refraction and pre-cycloplegic SE in young myopes, clinicians should suspect large ΔSE and perform cycloplegic refraction to eliminate the effects of accommodation or measurement inaccuracies to obtain true refractive status.

In summary, this study found no significant correlation between ΔSE and gender, K, AL, CCT, PRA, or pre-cycloplegic refractive status in myopic children and adolescents aged 5-17y. The ΔSE showed a negative correlation with NRA and a positive correlation with LT. Cycloplegic refraction is considered when LT exceeds 3.39 mm, but clinical application should be comprehensively judged in combination with age because normal range of LT varies among different age groups. Clinical application of the formula $AL/CR=3.025-0.051\times SE_2$ suggests that cycloplegic refraction should be performed when significant discrepancy exists between pre-cycloplegic refraction and AL/CR. The limitation of this study is the lack of measurement of biological parameters of the eyeball after pupil dilation. Future research should focus on ocular biometric parameters changes most with cycloplegia, and then appropriately examine how those changes relate to cycloplegic shift. In addition, there is selection bias in this study, as all the selected samples are adolescents and children from the Shenyang area. Future research should expand the sample size to multiple regions to enhance the representativeness of the study. However, establishing precise correspondence between AL/CR ratios and expected refraction values, which would enhance clinical decision-making regarding cycloplegia and provide clinical reference for determining the necessity of cycloplegic refraction.

ACKNOWLEDGEMENTS

Foundation: Supported by Liaoning Science and Technology Program (No.2023-MSLH-078).

Conflicts of Interest: Li ZH, None; **Lin J,** None; **Li J,** None; **Ji CY,** None; **Guan Y,** None; **Zhu RY,** None; **Hu L,** None.

REFERENCES

1 Optometry group of Chinese ophthalmological society, *et al*. Expert consensus on myopia management white paper (2022). *Chinese Journal of Optometry Ophthalmology and Visual Science* 2022;24(9):641-648.
2 Chinese association for pediatric ophthalmology and strabismus. Chinese expert consensus on cycloplegic refraction and safe medication use in children (2019). *Chinese Journal of Ophthalmology* 2019;55(1):7-12.
3 Wang JW, Ding W, He HW, *et al*. Correlation between diopter and some biological parameters of eye in school-age children and adolescents. *Chinese Journal of Strabismus & Pediatric Ophthalmology* 2023;31(1):29-32.
4 Qin LW, Tian CY, Li N, *et al*. Observation study on the accommodative parameters of myopic children and adolescents aged 6 to 14 years old. *Journal of Clinical Ophthalmology* 2021;29(5):428-431.
5 Czepita M, Czepita D, Safranow K. Role of gender in the prevalence of myopia among Polish schoolchildren. *J Ophthalmol* 2019;2019:9748576.
6 Fu AC, Watt K, M Junghans B, *et al*. Prevalence of myopia among disadvantaged Australian schoolchildren: a 5-year cross-sectional study. *PLoS One* 2020;15(8):e0238122.
7 Sanfilippo PG, Chu BS, Bigault O, *et al*. What is the appropriate age cut-off for cycloplegia in refraction? *Acta Ophthalmol* 2014;92(6):e458-e462.
8 Autrata D, Chrapek O, Drahorád S. The effect of pharmacological pupil dilation on intraocular lens power calculation in patients indicated for cataract surgery. *Czech Slovak Ophthalmol* 2021;77(4):192-200.
9 Wu SQ, Chen G, Xiao YS. Clinical studies on the changes of intraocular pressure and keratometry before and after pupil dilation in children and teenagers. *Journal of Kunming Medical University* 2022;43(1):102-106.
10 Wang W, Zhang JQ, Gu XX, *et al*. Effect of high myopia on dynamic changes of anterior angle after pharmacologic mydriasis in cataract patients: a SS-ASOCT study. *Trans Vis Sci Tech* 2021;10(6):25.
11 Bao YL, Zhang ZR, Cao J, *et al*. Changes in the thickness of the crystalline lens components before and after cycloplegia in children with different refractive errors. *J Optom* 2025;18(1):100539.
12 Zhang JQ, Jin L, Chen QY, *et al*. Changes in lens thickness and power before and after myopia onset. *Invest Ophthalmol Vis Sci* 2025;66(3):36.
13 Lu TL, Song JK, Wu QX, *et al*. Refractive lens power and lens thickness in children (6-16y old). *Sci Rep* 2021;11:19284.
14 Wang YH, Zhong J, Li XM. Age-related changes of lens thickness and density in different age phases. *Int J Ophthalmol* 2022;15(10):1591-1597.
15 Mitsukawa T, Suzuki Y, Momota Y, *et al*. Effects of 0.01% atropine instillation assessed using swept-source anterior segment optical coherence tomography. *J Clin Med* 2021;10(19):4384.
16 Chen YY, Ding CL, Li X, *et al*. Short-term effects of various contact lenses on accommodative function in myopic children. *Eye Contact Lens Sci Clin Pract* 2025;51(6):254-260.
17 Zhuang CC, Zhang L, Pan SS, *et al*. Accommodation and binocular vision in children with myopic anisometropia. *J Ophthalmol* 2024;2024:6525136.

18 Meng WH, Butterworth J, Malecaze F, *et al*. Axial length of myopia: a review of current research. *Ophthalmologica* 2011;225(3):127-134.

19 He XG, Zou HD, Lu LN, *et al*. Axial length/corneal radius ratio: association with refractive state and role on myopia detection combined with visual acuity in Chinese schoolchildren. *PLoS One* 2015;10(2):e0111766.

20 Chen SY, Mu JY, Tan XY, *et al*. Prediction of myopia based on biometric parameters of 500, 000 children and adolescents aged 3-18y. *Front Public Health* 2025;13:1563305.

21 González-Jiménez R, Povedano-Montero FJ, Bernárdez-Vilaboa R, *et al*. The distribution of ocular normative parameters in a Spanish school population. *J Clin Med* 2025;14(7):2507.

22 Tang T, Zhao H, Wang K, *et al*. Age-specific distribution of oculometric parameters and myopia in children aged 8-12y. *Int J Ophthalmol* 2024;17(10):1887-1897.

23 Yin Y, Li L, Wang T, Lin S, Wang J, Wang H, Jiang M, Ma Y, Zhu J. Establishment of noncycloplegic methods for screening myopia and pre-myopia in preschool children. *Front Med (Lausanne)* 2023;10:1291387.

24 Liu S, Chen J, Wang JJ, *et al*. Cutoff values of axial length/corneal radius ratio for determining myopia vary with age among 3-18y old children and adolescents. *Graefes Arch Clin Exp Ophthalmol* 2024;262(2):651-661.

25 Li T, Yu R, Zhang FY, *et al*. Analysis of refractive parameters and theirs correlation with spherical equivalent in preschool children aged 3 to 6y. *Guoji Yanke Zazhi (Int Eye Sci)* 2023;23(7):1189-1195.

26 Jong M, Sankaridurg P, Naduvilath TJ, *et al*. The relationship between progression in axial length/corneal radius of curvature ratio and spherical equivalent refractive error in myopia. *Optom Vis Sci* 2018;95(10):921-929.

27 Wang LN, Yan CN, Liang T, *et al*. Efficiency comparison of the Dem with axial length to corneal radius ratio in predicting refractive state of 3-14y old children. *Guoji Yanke Zazhi (Int Eye Sci)* 2024;24(12):1975-1981.

28 Mu JF, Zeng D, Fan JJ, *et al*. The accuracy of the axial length and axial length/corneal radius ratio for myopia assessment among Chinese children. *Front Pediatr* 2022;10:859944.

29 Hu J, Chen ZY, Zhang Y, *et al*. Diagnostic value of axial to corneal curvature ratio in children with low myopia and moderate myopia. *Hans J Ophthalmol* 2020;9(1):89-94.

30 Harrington S, Moore M, Loughman J, *et al*. Optimising non-cycloplegic screening strategies for early detection of pre-myopia and myopia in young children. *Ophthalmic Physiol Opt* 2025;45(5):1080-1089.