Journal of Clinical and Nursing Research, 2025, Volume 9, Issue 11
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

A Qualitative Study on Diagnosing Myopia Using the Ratio of Axial Length to Corneal Radius of Curvature

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Abstract: *Objective:* To investigate the influence of axial length (AL), corneal curvature (CR), and the ratio of axial length to corneal radius of curvature (AL/CR) on myopia in children, and to evaluate the accuracy and specificity of AL/CR in diagnosing myopia in children. *Methods:* A cross-sectional study was conducted. A total of 200 children (400 eyes) aged 6–12 years were recruited from the ophthalmology outpatient clinic of Fuling District People's Hospital from December 2022 to December 2023. AL, CR, and AL/CR were measured, and comprehensive optometry was performed under cycloplegia, with the results recorded in spherical equivalent (SE) form. *Results:* A total of 200 subjects (400 eyes) were included in this study, of which 330 eyes (82.50%) were myopic. No significant differences in CR were observed among different refractive groups, while significant differences were noted in SE, AL, and AL/CR. The AL and AL/CR ratios were higher in myopic eyes compared to emmetropic and hyperopic eyes. Using cycloplegia as the gold standard, SE in the myopia group was correlated with AL, AL/CR, and CR, with stronger correlations observed with AL and AL/CR. An AL/CR value > 3 demonstrated a sensitivity of 0.918, specificity of 0.786, misdiagnosis rate of 0.214, missed diagnosis rate of 0.082, and accuracy of 89.5% in diagnosing myopia. *Conclusion:* AL and AL/CR values are highly correlated with SE, with the strongest correlation observed in the myopia group. The AL/CR value exhibits high diagnostic value in determining myopia in children.

Keywords: Axial length; Corneal radius of curvature; Ratio of axial length to corneal radius of curvature; Myopia; Children

Online publication: Dec 5, 2025

1. Introduction

With the widespread use of electronic products and changes in human eye habits, the incidence of myopia is increasingly affecting younger populations and progressing at a faster rate, making it a primary cause of impaired eye health in children and adolescents [1]. According to 2023 data from China's National Health Commission, myopia affects over half (52.7%) of the nation's children and adolescents. The prevalence escalates with educational stages, starting at 14.3% among 6-year-olds and climbing to a striking 80.5% by senior high school [2]. According to the "2023 National Key Work Plan for Comprehensive Prevention and Control of Myopia in Children and Adolescents", the current focus of myopia prevention and control efforts remains on early diagnosis and timely intervention. The gold standard for clinically diagnosing myopia primarily involves examining uncorrected visual acuity, conducting retinoscopy and subjective refraction under cycloplegia, and using trial lenses. This standard offers high accuracy but has drawbacks such as cumbersome examination procedures and potential drug side effects. With advancements in ocular optical technology, parameters such as axial length (AL) and corneal radius (CR) can now be rapidly and accurately measured. Clinical studies have shown a correlation between the ratio of axial length to mean corneal radius (AL/CR) and myopia [3]. This study aims to investigate the impact of AL, CR, and AL/CR values on myopia status in children aged 6–12 years by performing cycloplegic refraction and measuring AL, CR, and AL/CR. Additionally, it will conduct a correlation analysis of the aforementioned data to evaluate the sensitivity, specificity, and clinical practicality of AL/CR in diagnosing myopia.

2. Materials and methods

2.1. Materials

A cross-sectional study was conducted. This study collected data from 200 children (400 eyes), aged 6–12 years, who visited the ophthalmology clinic at Fuling District People's Hospital from December 2022 to December 2023. Among them, 102 were male (51%) and 98 were female (49%), with an average age of 9.3 ± 2.85 years.

This study adhered to the Declaration of Helsinki, and consent was obtained from both the participants and their guardians, who signed informed consent forms. The study was approved by the hospital's ethics committee (Ethics Review No.: KY2022-015-01).

2.1.1. Inclusion criteria

(1) Children aged 6–12 years in primary school
(2) Ability to cooperate with ophthalmic examinations such as cycloplegic refraction and slit-lamp examination
(3) Signed informed consent

2.1.2. Exclusion criteria

(1) Concurrent ocular conditions such as amblyopia or strabismus
(2) History of ocular surgery or trauma
(3) Concurrent systemic diseases

2.2. Methods

In this study, basic information such as age and gender of the participants was collected through a questionnaire survey. Ocular biological parameters, including refractive diopter, axial length, and corneal curvature, were measured to establish refractive profiles. Volunteers participating in the study were instructed to instill 0.5% compound tropicamide eye drops (Shenyang Xingqi Ophthalmic Pharmaceutical Co., Ltd.; 230901; 5 mL: 5 mg tropicamide, 25 mg adrenaline hydrochloride) into both eyes, with 1–2 drops each time, every 5 minutes for a total of 4 times. Thirty minutes after the eye drops were administered, the degree of pupil dilation was examined using a laptop, followed by retinoscopy and trial lens examination. Relevant data were recorded in the refractive profiles [5]. Refractive status was expressed as spherical equivalent (SE). Participants were classified based on their SE values as follows: myopia (SE ≤ -0.50D), emmetropia (-0.50D < SE < +0.50D), and hyperopia (SE ≥ +0.50D). All subjects were grouped according to the refractive diopter of a single eye. AL and CR were measured using the IOL.Master 300 (Carl Zeiss, Germany) optical biometer, and the average values were automatically calculated by the computer. The axial length-to-corneal radius ratio (AL/CR ratio) was calculated as AL divided by CR. All the aforementioned procedures were performed by the same senior optometrist.

2.3. Observation indicators

2.3.1. Spherical equivalent

Calculated using the formula: SE = Sphere + 1/2 Cylinder.

2.3.2. Axial length

Measured using the IOL.Master 300 (Carl Zeiss, Germany) optical biometer, with the average value automatically calculated by the computer.

2.3.3. Corneal radius of curvature

Measured using the IOL.Master 300 (Carl Zeiss, Germany) optical biometer, with the average value automatically calculated by the computer.

2.4. Statistical analysis

Data management and statistical analysis were performed using SPSS 25.0. Quantitative data were described using mean ± standard deviation ($\overline{x} \pm s$), while qualitative data were described using frequency and percentage [n(%)]. Single-factor analysis of variance was employed to compare refractive parameters between groups. For quantitative data following a normal distribution, Pearson correlation analysis was conducted, and regression equations were fitted. The diagnostic value of AL and AL/CR was compared using the area under the ROC curve.

3. Results

3.1. Comparison of refractive factors among subjects in different refractive groups

While the corneal radius (CR) did not differ significantly across refractive groups, significant variations were found in spherical equivalent (SE), axial length (AL), and the AL/CR ratio. The AL of myopic eyes was higher than that of emmetropic and hyperopic eyes, with statistically significant differences ($p < 0.001$). The AL/CR ratio in the myopic group was higher than that in the emmetropic and hyperopic groups, with statistically significant differences ($p < 0.001$). See **Table 1** for details.

Table 1. Comparison of refractive factors among subjects in different refractive groups

Group	Eyes n (%)	SE (D)	AL (mm)	CR (mm)	AL/CR
Myopia	330 (82.50)	-1.71 ± 1.15	24.10 ± 0.77	7.76 ± 0.25	3.11 ± 0.10
Emmetropia	45 (11.25)	0.04 ± 1.16	23.10 ± 0.81	7.74 ± 0.23	2.98 ± 0.06
Hyperopia	25 (6.25)	+1.10 ± 0.96	22.24 ± 0.72	7.71 ± 0.22	2.89 ± 0.10
F-value		116.98	91.70	0.53	92.24
p-value		< 0.001	< 0.001	0.59	< 0.001

3.2. Correlation analysis of ocular parameters in the myopic group

The results indicated a significant correlation between SE and AL, AL/CR, and CR in the myopic group (r = -0.474, -0.747, 0.244, all $p < 0.001$). The linear relationships were as follows: SE = 15.24 - 0.7 × AL (see **Figure 1**), SE = 25.97 - 8.91 × AL/CR ratio (see **Figure 2**), and SE = -10.53 + 1.14 × CR (see **Figure 3**).

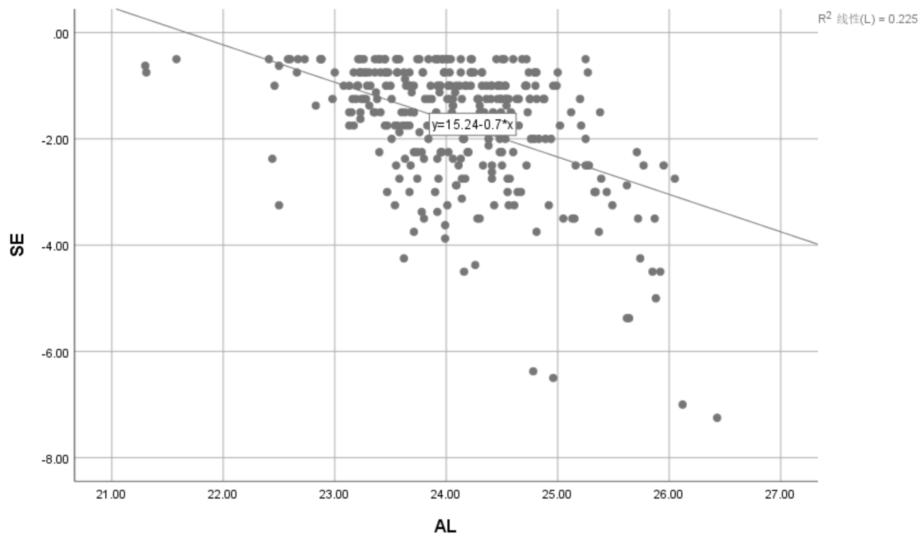

Figure 1. Linear regression analysis of SE and AL values in the myopic group (R^2: 0.22).

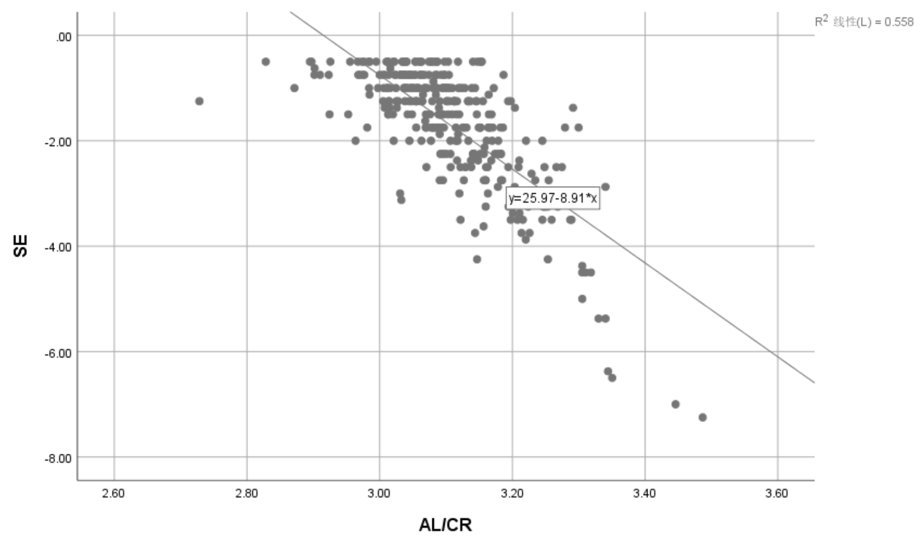

Figure 2. Linear regression analysis of SE and AL/CR values in the myopic group (R^2: 0.56).

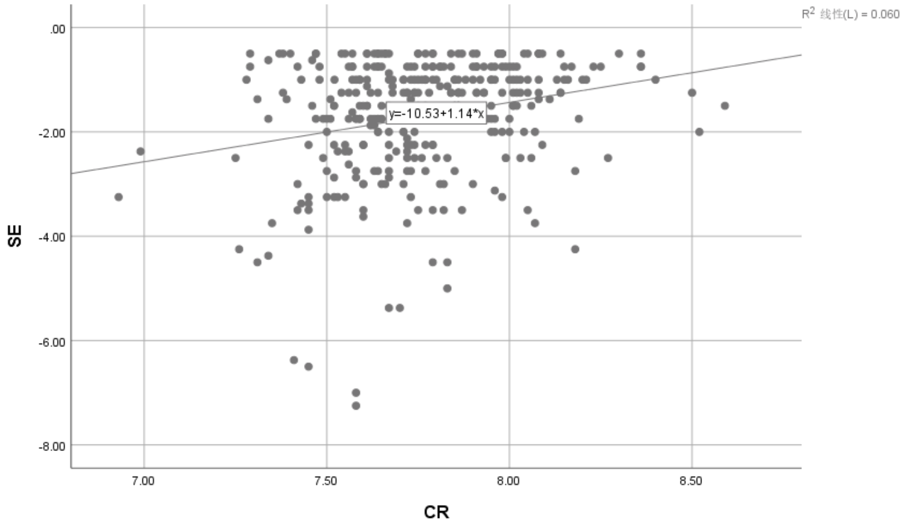

Figure 3. Linear regression analysis of SE and CR values in the myopic group (R^2: 0.06).

Pearson correlation analysis was used to analyze the three groups, revealing a strong correlation between SE and AL and AL/CR ratios in the myopic group (both $p < 0.01$). See **Table 2** for details.

Table 2. Correlation of SE, AL, and AL/CR ratio among different groups of examinees

Refractive group	Eyes (n)	AL (mm)		AL/CR ratio	
		r	*p*-value	r	*p*-value
Myopia	330	-0.474	< 0.001	-0.747	< 0.001
Emmetropia	45	-0.165	0.279	-0.130	0.394
Hyperopia	25	-0.405	0.045	-0.756	< 0.001

3.3. Reliability analysis

Using cycloplegic optometry-derived spherical equivalent (SE) as the reference standard, the diagnostic performance of the axial length-to-corneal radius (AL/CR) ratio for myopia was evaluated. The analysis demonstrated high diagnostic reliability, with a sensitivity of 0.918 and an accuracy of 89.5%. The specificity was 0.786, resulting in a false positive rate of 0.214 and a false negative rate of 0.082. Furthermore, the positive and negative predictive values were 0.953 and 0.671, respectively, while the positive and negative likelihood ratios were 4.285 and 0.104. Excellent agreement with the reference standard was confirmed by a Kappa coefficient of 0.659. See **Table 3** for details.

Table 3. Diagnosis of myopia using se from optometry under cycloplegia and AL/CR ratio

Spherical equivalent (SE)	AL/CR Ratio		Total
	Non-Myopic (Negative)	Myopic (Positive)	
Non-Myopic (Negative)	55	15	70
Myopic (Positive)	27	303	330
Total	82	318	400

Note: In this study, myopia was diagnosed when SE from optometry under cycloplegia was ≤ -0.50D and the AL/CR ratio was > 3.

Using the results of optometry under cycloplegia as the gold standard (reference line), the diagnostic performance of AL and AL/CR for myopia was analyzed using the ROC curve. The results showed that compared to AL, AL/CR had higher discriminatory power. The area under the ROC curve for AL was 0.863, with a standard error of 0.025 and a 95% confidence interval of 0.814–0.913; whereas the area under the ROC curve for AL/CR reached 0.904, with a standard error of 0.019 and a 95% confidence interval of 0.867–0.940. Regression analysis of AL, AL/CR, and SE revealed that for every 1-unit increase in the AL/CR ratio, myopia increased by 8.582D; for every 1mm increase in AL, myopia increased by 0.23D. Compared to the single AL indicator, an AL/CR ratio > 3 demonstrated a stronger correlation in reflecting changes in myopia in children. See **Figure 4** for details.

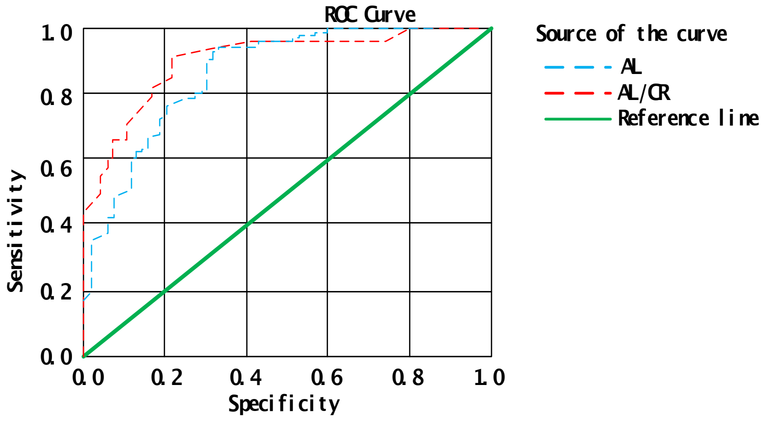

Figure 4. ROC curve of the model.

4. Discussion

The global prevalence of myopia is on the rise, with projections suggesting that by 2025, approximately 4.76 billion people worldwide will be affected by myopia, nearly one billion of whom will have high myopia [4]. The progression of myopia can lead to a variety of vision-impairing conditions, such as retinal degeneration, retinal tears, and vitreous opacities. Therefore, preventing the onset and progression of myopia is of paramount importance [5,6]. Myopia screening can aid in the early identification of children at high risk, enabling more timely and effective interventions to slow down the progression of myopia, thereby improving visual performance and enhancing quality of life [7]. Previous studies have indicated that childhood myopia is predominantly axial myopia, with the ratio of axial length (AL) to corneal radius (CR) being highly correlated with the degree of myopia [8]. In this study, 200 primary school students aged 6–12 years (400 eyes) were included, comprising 102 males (51%) and 98 females (49%). The average age was 9.3 ± 2.85 years. Among them, 45 eyes (11.25%) were emmetropic, 330 eyes (82.50%) were myopic, and 25 eyes (6.25%) were hyperopic. The proportion of myopic eyes significantly exceeded that of the other two groups, with findings similar to those of a study by Li Keran et al., which reported an 88.6% myopia rate in the 7–12-year-old primary school group among a 3–16-year-old population [9]. This indicates that myopia prevention and control remain a focal point in pediatric refractive clinics.

This study found statistically significant differences in AL, CR, and AL/CR values among different refractive groups by comparing these parameters in the subjects ($p < 0.01$). The hyperopic group had the shortest AL, while the myopic group had the longest AL. There was no statistically significant difference in CR among different refractive groups ($p > 0.05$). However, there were statistically significant differences in AL/CR values among different refractive groups, with the myopic group having the highest AL/CR value and the hyperopic group having the lowest. These findings are similar to those of a study by Du Qibo et al. on 340 adolescents aged 4–16 years [10]. Another study by Wang Hong et al. on 1011 individuals aged 3–17 years also demonstrated a high correlation between spherical equivalent (SE) and AL, AL/CR in the myopic group, with no statistically significant difference in CR [11]. Pearson correlation analysis of ocular parameters in the myopic group in this study revealed correlations between SE and AL/CR, CR, and AL (r = -0.474, -0.747, 0.244, respectively, all $p < 0.001$), with strong correlations observed between SE and AL/CR, AL. These findings suggest that the onset of myopia is associated with a disproportionate ratio of ocular biological parameters. As myopia progresses, AL gradually increases, while CR shows little variation, leading to an increase in the AL/CR ratio. Some scholars believe that AL/CR = 3 is the critical point for the compensatory limit of ocular biometric parameters, and AL/CR > 3 can be regarded as a sensitive indicator for diagnosing myopia [12–14]. He et al. argued that the optimal threshold for diagnosing myopia in children aged 6–12 is AL/CR > 2.99, but this conclusion only has a sensitivity of 83.05% [15].

Based on the strong correlation between SE and AL/CR, this study used an AL/CR value > 3 as the positive threshold for diagnosing myopia. By comparing it with the gold standard SE results under cycloplegia, the accuracy and diagnostic value of this parameter in diagnosing myopia in children aged 6–12 in the primary school group were evaluated. The AL/CR ratio demonstrated high diagnostic efficacy for myopia, with a sensitivity of 0.918 and an accuracy of 89.5%. The test's ability to rule in myopia was strong, as evidenced by a positive predictive value of 0.953 and a positive likelihood ratio of 4.285. This means that using a cutoff of AL/CR > 3 correctly identified 95.3% of myopic cases. However, its ability to rule out myopia was more moderate, with a negative predictive value of 0.671 and a negative likelihood ratio of 0.104, indicating a 67.1% probability of non-myopia when the ratio was below the cutoff. The possibility of correctly diagnosing myopia was 4.285 times that of incorrectly diagnosing it. The possibility of incorrectly diagnosing non-myopia was 0.104 times that of correctly diagnosing it. Under the criterion of AL/CR ratio > 3, the accuracy of correctly determining myopia in the 6–12 primary school group was 89.5%. The Kappa coefficient was 0.659, indicating moderate agreement. ROC curve analysis showed that compared with AL, AL/CR had the highest discriminatory power, with an area under the ROC curve of 0.863, a standard error of 0.025, and a 95% confidence interval of 0.814–0.913. This indicates that under the criterion of AL/CR > 3, the accuracy of diagnosing myopia is superior to that of AL. Simultaneously, regression analysis of AL, AL/CR, and SE revealed that for every unit increase in the AL/CR ratio, myopia will increase by 8.582D; for every 1 mm increase in AL, myopia will increase by 0.23D. Compared to the single AL indicator, AL/CR may be more sensitive in predicting the progression of myopia in children. The above indicates that AL/CR > 3 has a high diagnostic value in diagnosing myopia in children aged 6–12 in the primary school group.

Using ocular biometric instruments to assess AL, CR, and AL/CR values is an accurate, objective, and simple method for evaluating myopia. Compared with other methods, this approach is safe and convenient to operate, making it suitable for the professional classification of refractive status in children and adolescents. The measurement process for axial length (AL) and corneal radius (CR) is quick and easily accepted by children and adolescents. In scenarios involving large-scale population screenings or situations where effective cycloplegic refraction is not feasible, the AL/CR ratio can swiftly and efficiently diagnose myopia and predict its progression trends. However, this study has limitations, including a relatively small sample size and a cross-sectional design limited to a hospital-based population. It lacks large-sample random sampling studies in natural populations and does not include long-term follow-up observations of the study population. In the future, we will expand the scope of sample collection and establish a long-term dynamic follow-up process to provide more comprehensive data support for myopia assessment, thereby better utilizing the AL/CR ratio as a tool for evaluating myopia in clinical practice.

5. Conclusion

Based on the findings, it can be concluded that both axial length (AL) and the ratio of axial length to corneal radius (AL/CR) are strongly associated with spherical equivalent (SE), particularly among children with myopia. The AL/CR ratio, in particular, demonstrates high diagnostic value and can serve as a reliable indicator for detecting myopia in pediatric populations. This underscores its potential utility in clinical screening and myopia management strategies for children.

Funding

Chongqing Fuling District Science and Health Joint Medical Research Project (2022KWLH069)

Disclosure statement

The authors declare no conflict of interest.

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