ORIGINAL ARTICLE

The Relationship Between the Axial Length to Corneal Radius of Curvature Ratio and Refractive Status in Young Malay Adults

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ABSTRACT

Background: Myopia is increasing worldwide and is closely linked to structural changes in the eye. While axial length (AL) and corneal radius (CR) are commonly measured in clinical practice, evaluating their relationship provides a more complete understanding of refractive status. The ratio between AL and CR reflects the balance between eye elongation and corneal shape. This study aimed to evaluate the relationship between the AL to CR ratio and spherical equivalent refraction (SER) in young Malay adults. **Methods:** A cross-sectional study was conducted involving 94 young Malay adults (86.2% female) aged between 20 and 30 years. Participants were included if they were emmetropic or myopic and had no history of ocular disease, surgery, or recent myopia control treatment. AL was measured using the Haag-Streit Lenstar LS900 optical biometer, while corneal radius of curvature (CR) was measured using the Oculus Keratograph 5M (OK5M). The AL to CR ratio was calculated by dividing AL by CR. Refractive error was determined through objective and subjective refraction, and spherical equivalent refraction (SER) was calculated accordingly. Pearson correlation and linear regression analyses were used to examine the relationship between the AL to CR ratio and SER. **Results:** The mean SER was −3.64±2.35 dioptres, and the mean AL to CR ratio was 3.23±0.16. A very strong negative correlation was found between the AL to CR ratio and SER ($r=-0.902$, $p<0.001$). Linear regression analysis showed that the ratio explained 81.3% of the variation in refractive error ($R^2=0.813$, $p<0.001$), indicating that higher ratios were associated with greater levels of myopia. **Conclusion:** The AL/CR ratio serves as a robust structural indicator strongly associated with the refractive status in young Malay adults. These findings highlight its utility as an objective biometric marker for clinical assessment and screening, particularly in environments where cycloplegic refraction is restricted.

INTRODUCTION

Refractive errors represent an emerging domain in ophthalmology, with growing recognition of their importance and impact on vision (Cruickshank & Logan, 2018; Marinescu et al., 2025). Myopia is the refractive error with the most rapidly increasing prevalence (Marinescu et al., 2025; Baird et al., 2020; Holden et al., 2016). The World Health Organization projects that 52% of the world's population will be myopic by 2050 (Holden et al., 2016; World Health Organization-Brien Holden Vision Institute, 2015). Data from Asian countries highlight a substantial challenge (Zhang et al., 2023). For instance, research has shown that myopia was reported in over 91% of first-year university students in Taiwan as early as 2005 (Wang et al., 2009). In another study, 96% of army recruits in South Korea had myopia, of which over 20% were classified as high myopia (Jung et al., 2012).

High myopia is a well-established risk factor for sight-threatening pathologies, including myopic macular degeneration and retinal detachment (Du et al., 2021; Wang et al., 2021; Zhang et al., 2024). Crucially, even low levels of myopia can significantly elevate these risks, emphasising the need for early identification of at-risk individuals through robust biometric monitoring (Haarman et al., 2020; Bullimore et al., 2021). An eye with a refractive error of −3.00 dioptres (D) has a threefold higher risk of retinal detachment compared to an eye with −1.00 D, a risk level closely associated with progressive changes in ocular biometric ratios (Marinescu et al., 2025; Haarman et al., 2020). Myopic macular degeneration remains the leading cause of blindness among myopic patients (Fricke et al., 2018). Another chronic disease associated with myopia is primary open-angle glaucoma, for which the risk is 2.26 times higher than in the general population (Wu et al., 2021; Choquet et al., 2022).

During normal ocular development, a process known as emmetropization maintains clear vision by balancing axial elongation with corresponding changes in corneal

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curvature and crystalline lens power (Grosvenor, 1988; He et al., 2015). This coordinated growth helps ensure that images remain focused on the retina despite ongoing structural changes within the eye (He et al., 2015). During myopic progression, axial length (AL) increases, and compensatory corneal flattening may occur (Marinescu et al., 2025; Grosvenor, 1988). However, when axial elongation exceeds the eye's ability to compensate through these refractive adjustments, the focal point shifts anterior to the retina, resulting in myopia (Marinescu et al., 2025). Recent research has focused on the ratio of AL to corneal radius of curvature (AL/CR) as a valuable biometric parameter (He et al., 2015; Jong et al., 2018; Omoto et al., 2020). The AL/CR ratio provides a structural assessment of the eye by indicating the proportionality between AL and corneal curvature (Mu et al., 2022; Fan et al., 2024).

Previous studies have shown that the AL/CR ratio increases with myopia severity. Emmetropic eyes typically exhibit ratios close to 3.0, whereas myopic eyes generally demonstrate higher ratios (Grosvenor, 1988; Ojaimi et al., 2005; Scheiman et al., 2016). The AL/CR ratio has been reported to be more strongly associated with refractive error than AL alone (He et al., 2015; Ojaimi et al., 2005). Although AL remains the gold standard for monitoring axial elongation, the AL/CR ratio provides additional information regarding the structural status of the eye (Cruickshank & Logan, 2018). Recent studies have further highlighted the clinical utility of the AL/CR ratio as an indicator of refractive status and myopia risk (Chen et al., 2025; Marinescu et al., 2025; Wang et al., 2026). However, data on the association between the AL/CR ratio and refractive status in young Malay adults remain limited. Furthermore, evidence from the Malaysian population is scarce. Therefore, this study aimed to determine the relationship between the AL/CR ratio and spherical equivalent refraction (SER) among young Malay adults in Malaysia.

MATERIALS AND METHODS

This study utilised a cross-sectional methodology to investigate the biometric profiles of young adults. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the International Islamic University Malaysia Research Ethics Committee (Reference: IIUM/504/14/11/2/IREC-2025-191).

Participants

A total of 94 young Malay Malaysian adults were included in the final analysis, comprising 13 males (13.8%) and 81 females (86.2%). This gender distribution likely reflects the demographic profile of the student population from which participants were recruited via purposive sampling from the International Islamic University Malaysia (IIUM) community in Kuantan, Pahang. Inclusion criteria were age between 20 and 30 years, spherical equivalent refractive error (SER) of emmetropia (0.00 to −0.25 D) and myopia (SER≤−0.50 D) in both eyes, generally healthy, and willingness to undergo a comprehensive ocular examination. Written informed consent was obtained from all participants prior to their enrolment in the study. Participants were excluded if they presented with a history of ocular surgery or trauma, active ocular disease, or current use of myopia control treatments (e.g., orthokeratology and atropine) within the previous year.

Ocular Measurements

Ocular biometry was performed to evaluate the primary structural variables of the eye. The AL was measured using the Haag-Streit Lenstar LS900 optical biometer (Haag-Streit AG, Köniz, Switzerland), and the mean of five consecutive automated measurements was used for analysis (Lal et al., 2024). The CR was measured using the OCULUS Keratograph 5M corneal topographer (OCULUS Optikgeräte GmbH, Wetzlar, Germany), which employs a Placido ring-based system to obtain corneal curvature measurements (Zhang et al., 2025). For each eye, three consecutive scans were obtained, and the average keratometry value was used for statistical analysis. The AL to CR ratio (Equation given below) was subsequently calculated by dividing AL (mm) by the average corneal radius of curvature (mm) (Marinescu et al., 2025).

$$\mathrm{AL/CR} = \frac{Axial\ length\ of\ the\ eye\ (AL\!-\!measured\ in\ mm)}{Corneal\ curvature\ radius\ (CR\!-\!measured\ in\ mm)} \quad (1)$$

Refractive status was determined through objective and subjective refraction. Refraction (Rx) was performed without cycloplegia, as the study sample comprised adults aged 20 to 30 years and the study aimed to evaluate the relationship between refractive status and ocular biometric parameters under routine clinical conditions. Cycloplegic refraction was therefore not considered essential for achieving the study objectives. Spherical equivalent refraction (SER) was calculated as the spherical power plus half of the cylindrical power. Participants were classified as emmetropic or myopic based on their refractive status.

Statistical analysis was conducted using SPSS version 27 (IBM Corp., Armonk, NY, USA). The normality of the data was verified using the Shapiro–Wilk test (Shapiro & Wilk, 1965). Descriptive statistics were generated for all biometric and refractive parameters. Pearson's correlation coefficient was computed to evaluate the strength of the relationship between the AL/CR ratio and SER (Mukaka, 2012). A linear regression analysis was also performed to determine the predictive capacity of the AL/CR ratio for SER (Roustaei, 2024).

RESULTS

The normality of the study variables was assessed using the Shapiro–Wilk test to ensure the appropriateness of subsequent parametric analyses. Results indicated that SER demonstrated a statistically significant deviation from normality ($p=0.019$), whereas the AL/CR ratio was normally distributed ($p=0.685$). Despite the deviation from normality in SER values, parametric analyses were employed due to the sufficient sample size ($n=94$) and the inherent robustness of these tests for continuous ocular biometric data (Ghasemi & Zahediasl, 2012; Ashby, 1991). Consequently, parametric tests were used for all subsequent statistical analyses.

Table 1 summarises the demographic and refractive characteristics of the study population. A total of 94 young Malay Malaysian adults were included in the final analysis, comprising 13 males (13.8%) and 81 females (86.2%). The overall mean age was 21.32±1.29 years (range: 20–27 years). Male participants were significantly older than female participants; however, this difference was not clinically meaningful, with mean ages of 22.46±1.20 years and 21.14±1.18 years, respectively ($t(92)=-2.81$, $p=0.006$). All participants were either emmetropic or myopic, with SER errors ranging from 0.00 D to −9.25 D and a mean of −3.64±2.35 D. Comparison of mean SER between genders showed no statistically significant difference ($t(92)=-0.14$, $p=0.895$). The AL/CR ratio was also comparable between males and females.

As shown in Table 2, the mean AL was 25.03±1.20 mm, while the mean CR was 7.75±0.23 mm. The population had a mean AL/CR ratio of 3.23±0.16, ranging from 2.87 to 3.62.

Pearson correlation analysis demonstrated a very strong negative correlation between the AL/CR ratio and SER ($r=-0.902$, $p<0.001$), as shown in Table 3 and Figure 1. This indicates that an increase in the AL/CR ratio is directly correlated with a decrease in SER values, reflecting a higher degree of myopia (Figure 1). The strength of this correlation suggests a robust linear relationship between the structural AL/CR ratio and refractive status.

Linear regression confirmed that the AL/CR ratio is a robust predictor of refractive status, explaining 81.3% of the variance in spherical equivalent ($R^2=0.813$, $p<0.001$). The model yielded a significant negative coefficient ($\beta=-13.25$, $p<0.001$), indicating that a one-unit increase in the AL/CR ratio results in a 13.25 D myopic shift. This relationship is mathematically defined by the regression equation: SER=39.19 - 13.25x (AL/CR ratio).

Table 1: Demographic and refractive characteristics of the study population

Characteristic	Male (n=13)	Female (n=81)	Overall (n=94)	t(df)	p-value
Age (years)	22.46±1.20	21.14±1.18	21.32±1.29	−2.81 (92)	0.006
SER (D)	−3.98±2.99	−3.79±2.23	−3.64±2.35	−0.14 (92)	0.895

Table 2: Descriptive statistics of study variables

Variable	Mean±SD	Minimum	Maximum
SER (D)	−3.64±2.35	−9.25	0.00
AL (mm)	25.03±1.20	22.76	28.40
CR (mm)	7.75±0.23	7.06	8.44
AL/CR ratio	3.23±0.16	2.87	3.62

Table 3: Correlation between AL/CR ratio and SER

Variable Pair	r (Pearson)	p-value
AL/CR ratio vs SER	−0.902	<0.001

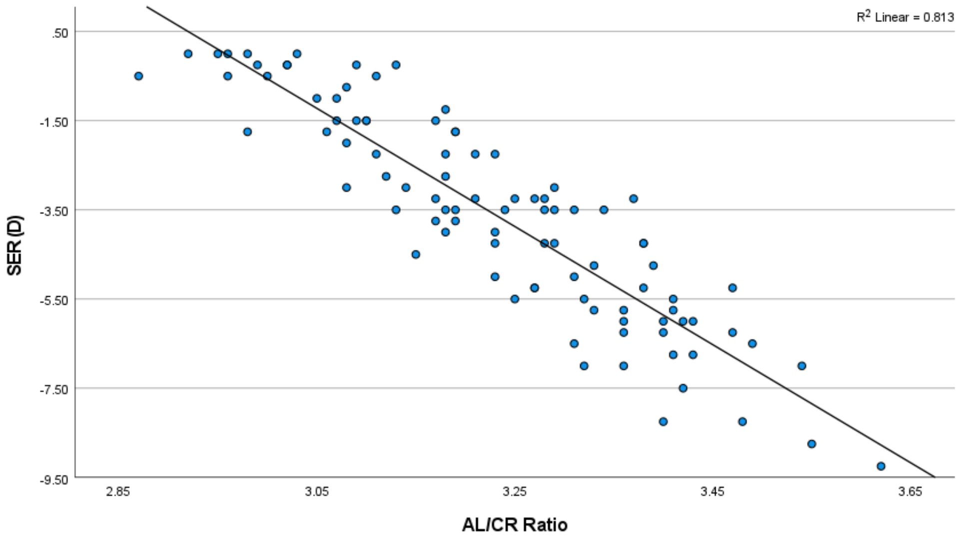

Figure 1: Correlation Between AL/CR Ratio and SER in Young Malay Adults

DISCUSSION

The primary objective of this study was to evaluate the relationship between the AL/CR ratio and spherical equivalent refraction in a sample of young Malay adults in Malaysia. The results demonstrated a very strong negative correlation (r=−0.902) between these two parameters, confirming that the AL/CR ratio is a highly reliable structural indicator of refractive status. This finding aligns with established literature suggesting that the AL/CR ratio provides a more comprehensive assessment of the eye's refractive state than AL alone (He et al., 2015; Foo et al., 2016).

The mean AL (25.03±1.20 mm) and mean CR (7.75±0.23 mm) observed in this study are consistent with the structural characteristics typically found in myopic eyes. Although both measurements fall within clinically expected ranges, the relatively longer AL reflects the axial elongation commonly associated with myopia development (Grosvenor, 1988; Marinescu et al., 2025). Grosvenor (1988) proposed that emmetropic eyes exhibit a balanced relationship between AL and CR, resulting in an AL/CR ratio of approximately 3.0. In contrast, the mean AL/CR ratio observed in the present study was 3.23±0.16, which is consistent with the predominantly myopic refractive profile of the study population. This finding supports the concept that myopia is associated with disproportionate axial elongation relative to corneal curvature, leading to an increase in the AL/CR ratio beyond the emmetropic threshold (Grosvenor, 1988; Cruickshank & Logan, 2018; Marinescu et al., 2025). Recent studies have further demonstrated that the AL/CR ratio is more strongly associated with refractive status and myopia risk than AL alone, highlighting its value as a robust biometric marker for the detection and monitoring of myopia progression (Chen et al., 2025; Wang et al., 2026).

The exceptionally strong correlation observed in the present study (r=-0.902) exceeds the r=-0.817 reported by Hashemi et al. (2013). This discrepancy may be attributed to the ethnic homogeneity and narrow age range of this Malay sample, which reduces biometric variance compared to more diverse populations.
Linear regression analysis revealed that the AL/CR ratio accounted for 81.3% of the variance in spherical equivalent refraction. This high R^2 value (0.813) demonstrates the strong association between the AL/CR ratio and SER within the study population. Given the cross-sectional design of the present study, these findings should be interpreted as reflecting a structural relationship between ocular biometry and refractive status rather than a causal or predictive association. In clinical environments where pharmacological cycloplegia is contraindicated or impractical, the AL/CR ratio may serve as a useful adjunctive measure for assessing refractive status (Marinescu et al., 2025). The regression equation derived in this study provides a mathematical framework for estimating refractive error based on biometric data. This is particularly relevant as the AL/CR ratio serves as a useful indicator of the relationship between axial elongation and corneal curvature. In emmetropic eyes, these components remain proportionally balanced to maintain retinal focus. However, when axial elongation exceeds the compensatory influence of corneal curvature, the AL/CR ratio increases, resulting in the development of myopia (Marinescu et al., 2025; Grosvenor, 1988; He et al., 2015).

Interestingly, no statistically significant gender differences were observed in the AL/CR ratio or SER, despite males being statistically significantly older than females in this sample. This suggests that the structural relationship between AL and CR remains relatively stable during early adulthood (He et al., 2015; Hashemi et al., 2013). However, the high prevalence of moderate to high myopia (63.9%) in this university-aged population reflects the growing trend of myopia in Southeast Asia (Holden et al., 2016; Wang et al., 2021). Such a trend necessitates the use of robust biometric markers, such as the AL/CR ratio (Cruickshank & Logan, 2018; Grosvenor, 1988; He et al., 2015), to monitor structural changes that increase the risk of sight-threatening pathologies (Holden et al., 2016; Haarman et al., 2020; Wu et al., 2021).

Several limitations must be acknowledged. The cross-sectional nature of the study precludes the determination of causal relationships over time. In addition, the sample exhibited a marked gender imbalance, with females accounting for 86.2% of participants. This distribution likely reflects the demographic profile of the student population at the International Islamic University Malaysia Kuantan campus, from which the purposive sample was recruited. Although no significant differences in the AL/CR ratio or SER were observed between males and females, the relatively small number of male participants (n = 13) may limit the generalisability of gender-specific findings. Furthermore, the use of non-cycloplegic refraction introduces the potential for residual accommodation; however, the high level of agreement between the subjective refraction and the purely structural biometric ratio suggests that the influence of accommodation was minimal in this adult cohort (Hashemi et al., 2013). Future longitudinal studies should be conducted to determine how the AL/CR ratio changes over time during myopic progression in this specific demographic (Marinescu et al., 2025). Nevertheless, the findings highlight the clinical utility of the AL/CR ratio as a key metric for optometrists and ophthalmologists in assessing myopic risk (Cruickshank & Logan, 2018; Marinescu et al., 2025).

CONCLUSION

In conclusion, the AL/CR ratio demonstrates a strong association with SER and serves as a reliable structural indicator of refractive status in young Malay adults. These findings highlight its potential utility as an objective biometric marker for clinical assessment and screening, particularly in settings where cycloplegic refraction may not be feasible. However, the cross-sectional nature of this study precludes conclusions regarding causality or prediction. Future longitudinal studies are warranted to further evaluate the role of the AL/CR ratio in monitoring refractive changes over time.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the author used ChatGPT by OpenAI to assist in polishing the English language, improving sentence structure, and enhancing academic writing clarity. All generated content was carefully reviewed, revised, and approved by the author, who accepts full responsibility for the final version of the manuscript.

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