Research Square

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Comparative biometric analysis in high axial anisomyopia

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Abstract

Purpose

High myopia is a public health burden and is commonly associated with a longer eyeball. Mechanisms governing ocular growth are not clearly known yet. By leveraging anisomyopia as a unique natural model, this study provides insights into the biometric determinants of ocular growth. This study compares the contributions of ocular biometric components to axial length (AL) in highly myopic eyes versus low- or non-myopic eyes in individuals with high anisomyopia

Design:

A hospital-based case–control study

Subjects:

Biometric data from 181 individuals with high myopia in a single eye (axial length [AL] > 26.00 mm in the case eye and < 24.5 mm in the fellow control eye), without pathological or visual complications was acquired.

Methods

Detailed biometric measurements included AL, central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), posterior segment length (PSL), and derived ratios (PSL:AL, ASL:AL, and PSL:ASL).

Outcome measures:

Correlations among these biometric components were compared between case and control eyes, and the relative contribution of each feature to AL was assessed using random forest analysis.

Results

PSL showed the strongest correlation with AL in both myopic (r = 0.89) and control eyes (r = 0.87). However, random forest analysis revealed a greater relative difference in the feature importance of anterior segment length (ASL) between the two groups, with a 53% lower contribution in case eyes. LT demonstrated a larger difference in its contribution to AL between case and control eyes compared with ACD.

Conclusion

While PSL appears to be the primary determinant of axial length, anterior segment parameters—particularly LT—exhibit distinctive contributions between the two eyes of individuals with high anisomyopia. Further longitudinal studies in paediatric cohorts during periods of active ocular elongation are recommended to provide deeper insights into ocular biometric interactions.

Introduction

Myopia is an emerging global public health issue and has reached epidemic proportions.[1,2] It can be broadly classified into two categories: low myopia (− 0.50 to − 5.75 diopters [D]) and high myopia (≤-6.00D).[3–5] Pathological myopia is a severe form of myopia and can impair vision irreversibly.[1,6] During emmetropization, the hyperopic eyeball increases axially along with changes in optics of the eye (largely cornea and lens) to achieve emmetropia, where the image is focused directly onto the retina. After reaching emmetropia, eye growth should ideally stop so that images continue to focus accurately. However, abnormal elongation or a mismatch between the structures and optics of the eyeball further lead to myopia.[7–10]

AL comprises corneal thickness (CT), anterior chamber depth (ACD), lens thickness (LT), and vitreous chamber depth (VCD). During myopia progression, the distinction between axial and refractive myopia becomes more apparent, as AL and its components can be monitored using basic biometric techniques. High axial myopia is generally defined as an AL > 26.00 mm.[3] A prior study of 60 adult eyes with high myopia reported continued axial elongation of 0.03–0.06 mm per year over six years of adulthood. This finding is clinically significant, as ongoing axial elongation is considered a risk factor for the development of pathological myopia and subsequent vision loss. However, the factors determining the evolution of ocular biometry during the emmetropization phase remain unclear.[11]

Our previous work suggested that highly myopic eyes exhibit disproportionate growth with poor interrelationships among the various components of AL.[12] Subsequently, we analysed biometric data from 214 myopic eyes and identified a potential biometric pivot—specifically, the ratio of vitreous chamber depth to AL—that may drive myopic eye growth, based on univariable correlation analyses among AL components.[7] However, in both studies, genetic and environmental factors were not accounted for, raising the possibility of unrecognized confounding factors that potentially weakened the evidence.[7,12]

High anisomyopia provides a unique clinical model for studying ocular growth because two eyes of the same individual are exposed to largely similar genetic and environmental influences while exhibiting markedly different refractive errors and axial elongation. A previous cross-sectional study of 202 eyes from 101 subjects aged 10–40 years with anisometropia ≥ 1.00 D compared biometric parameters, including AL, keratometry (K), ACD, and CCT, between fellow eyes and reported that interocular

differences were significantly correlated only with variations in ACD.[13] Therefore, comparing fellow eyes within the same individual may provide better insight into the mechanisms of asymmetric ocular growth.

We hypothesize that the intraocular components of AL contribute differently to overall eye length between the two eyes of individuals with high anisomyopia. The present study aimed to investigate the contribution of components of AL to ocular elongation in high anisomyopia.

Methods

This retrospective, hospital-based case–control study adhered to the tenets of the Declaration of Helsinki. The study protocol was reviewed and approved by the institutional review board, which provided ethical clearance (LEC-BHR-R-08-2025-248). The required data were extracted from the electronic medical records (EMR) database. Prior to ophthalmic examination, all individuals provided written informed general consent permitting the use of their data for research purpose.

Records of individuals diagnosed with high myopia and available ocular biometry were screened from period of July 2021 to August 2024. High myopia was defined as a spherical equivalent (SE) refractive error of ≤ − 6.00 diopters (D) with an associated axial length AL ≥ 26.00 mm. A total of 915 records with available biometric data were identified using this search strategy. Patients with pathological myopia or those with a refractive error worse than − 2.00 D in the fellow eye were excluded to maintain a clear distinction between groups. Ultimately, data from 181 patients were included in the analysis. Eyes with an AL ≥ 26.00 mm and SE ≤ − 6.00 D were included as case eyes, while fellow eyes with an AL < 24.5 mm were considered control eyes. The control eyes achieved a best corrected visual acuity (BCVA) of 20/20 following optical correction, while the cases had range of visual acuity from 20/20 to 20/400.

Ocular biometry measurements were obtained using either the Lenstar LS 900 (Haag-Streit, Jena, Switzerland) or the IOLMaster 700 (Carl Zeiss Meditec, Germany). The same instrument was used for both eyes of each participant. Both devices have a measurement resolution of 0.01 mm and have been reported to demonstrate good agreement and comparable repeatability across various ocular biometric parameters. From the biometric records, data on AL, CT, mean keratometry (K), ACD, LT, WTW, and posterior segment length (PSL; vitreous chamber depth) were extracted. Anterior segment length (ASL) was defined as the sum of ACD and LT. Posterior segment length, or vitreous chamber depth, was calculated as the distance from the posterior surface of the lens to the retina. Ratios of PSL:AL, ASL:AL, and PSL:ASL were also calculated.

Statistical analysis:

Elementary analysis was performed using descriptive statistics tools of Microsoft Excel 2018, (Microsoft Corporation, Redmond, USA). The normality of data for each feature was assessed using the Shapiro-Wilk test. A paired t-test and Mann–Whitney U test were performed for a within-subject comparison of the case and control eye variables depending on normality of data distribution (supplementary table 1). Pearson’s correlation matrix was generated to assess the relationship between AL and other biometric

parameters. Univariate and multivariate regression analyses were conducted to identify significant predictors of AL. Due to multicollinearity between variables (Fig. 1,2), a random forest algorithm was then employed to enhance predictive modelling and address limitations of linear regression. The algorithm uses advanced machine learning technique employing multiple decision trees. It thus solves classification and regression problems by handling complex, non-linear relationships between variables to reduce the risk of overfitting of statistical models. Feature importance scores were calculated within the random forest model. Feature importance scores determine importance of an input variable for predicting another variable. In our case it identified the importance of ocular biometry in predicting AL. A p-value < 0.05 as identified as statistically significant.

Results

The study included both eyes of 181 individuals, with high myopic eyes as cases and the fellow eye as controls, mean age being 28.13 ± 17.23 years. There were 109 males (60.2%) and 72 (39.8%) females. The mean spherical equivalent refractive error for the cases and control eyes was − 10.15 ± 3.23D and − 0.48 ± 0.30D respectively; corresponding values for the axial length were 27.42 ± 0.95 mm and 23.18 ± 0.64 mm respectively. Eighty individuals (44%) had visual acuity below 20/40 in the highly myopic eye attributable to anisometropic amblyopia.

Correlation of AL with ocular biometry

While the mean ASL was slightly higher in highly myopic eyes (7.31 +/- 0.38 vs. 7.19 +/-0.36), the PSL was much higher in them as compared to controls (19.6 +/- 1.0 vs. 15.5 +/-0.7). Detail of other variable have been presented in Fig. 1 (Box Plots).

In the eyes with high myopia (cases), PSL showed a strong positive correlation with AL (r = 0.89). A strong correlation was also noted between LT & ASL (r = 0.70). PSL:ASL showed moderate positive correlation with AL (r = 0.53). Moderate negative correlation was noted between ASL: AL & AL (r=-0.51) (Fig. 2). Akin to the case eyes, there was a strong correlation between AL and PSL in the control eyes (r = 0.87), and a moderate correlation was observed between PSL:AL and AL (r = 0.50). Similarly, a moderate positive correlation was found in LT with ASL (r = 0.67) (Fig. 3). However, in contrast to the case eyes, the control eyes manifested a better and moderate correlation between ASL and PSL (-0.47 vs. -0.29), thus indicating a stronger relation between the two in the control eyes as compared to the myopic eyes.

Linear relationship Models (Univariate and Multivariate)

PSL was the strongest univariate predictor of AL in case eyes, with a high R square value and regression coefficient (Coeff = 0.81, R^2 = 0.7954) as well as for the controls (Coeff = 0.76, R^2 = 0.7584). The three variables LT, ACD & PSL show strong prediction with high R squared value and coefficient in both cases (R^2 = 0.914) and control (R^2 = 0.996) eyes (supplementary tables 2, 3). The results of linear regression models are likely influenced by multicollinearity between the “assumed independent” variables, so the feature importance analysis was also performed as explained in the section on statistics.

Feature importance of ocular biometry in predicting AL

The corresponding feature importance of posterior segment length (**PSL)** in highly myopic eyes (**0.9001)** was 9.7% higher in case eyes compared to non-myopic fellow control eyes (**0.8232).** In contrast, the feature impact of ASL was 53% lesser in the highly myopic case eyes **(0.0509)** as compared to the control eyes **(0.1099).** The contribution of rest of the ocular biometry to AL was negligible (Fig. 4, Table 1).

Table 1
Feature importance scores for the biometric parameters. PSL is the primary factor influencing the AL in both affected and unaffected eyes but highest in the case eyes. ASL shows corresponding decrease in importance in the case eyes.

Feature	Importance (control group)	Importance (cases)
PSL	0.8232	**0.900151**
ASL	0.109967	0.050976
LT	0.016945	0.008417
K	0.008345	0.007253
ACD	0.008066	0.006993
PSL: AL	0.008407	0.006463
PSL:ASL	0.007173	0.005716
ASL: AL	0.006503	0.005515
CT	0.005573	0.00422
WTW	0.005819	0.004295
Supplementary table 1: The paired t-test and Mann-Whitney U test to assess the difference between groups		

Discussion

In this study, we compared ocular biometric parameters between highly myopic eyes and their fellow eyes in individuals using a hospital-based case-control design. The primary finding suggests that posterior segment, is the primary structural change associated with high myopia. However, using a random forest algorithm, we found the effect of ASL to be of wider difference (53%, 0.109 vs. 0.050) between the two groups, as compared to PSL (9.7%, 0.823 vs. 0.900); driven more by the differences in LT (50%, 0.016 vs. 0.008) than those by ACD (25%, 0.008 vs. 0.006) (Table 1, Fig. 4).

Larsen (1971) used ultrasound to explore the relationship between biometric parameters and myopia.[14] While valuable at the time, USG lacked the precision of newer techniques like partial coherence interferometry (PCI) employed by instruments used in the current study.[14] In his multiple studies of

sagittal ocular measurements, Larsen explored the balance between anterior and posterior biometry in children with less or no refractive error. This study measured axial length in 926 children (1852 eyes), including 80 new-borns and 846 children aged 6 months to 13 years. The mean AL increased from 16.78 mm to 23.15 mm in boys and 16.40 mm to 22.66 mm in girls, showing a sex-linked difference of 0.3–0.4 mm, with boys having longer ALs. The optical axis approximates adult emmetropic eye measurements around 13 years of age. This growth follows three phases: a rapid postnatal phase (3.7–3.8 mm increase in the first 1.5 years), a slower infantile phase (1.1–1.2 mm increase until age 5), and a slow juvenile phase (1.3–1.4 mm increase until age 13). These phases provide insight into normal eye development and its implications for refractive errors.[15–17]

There is limited literature evaluating anterior segment parameters in high myopia. It has been suggested that individuals with myopia tend to have a thinner crystalline lens and deeper anterior chamber compared to non-myopic individuals. Further increase in every mm of ACD has also been linked to axial elongation.[18] Understanding the contribution of these anterior segment factors can help in developing targeted approach for myopia control.

We found ASL and particularly the LT to be the differentiating feature between the myopic and the control eyes in our clinical model of high anisomyopia (Table 1). Myopic eyes consistently display morphological changes in the ciliary muscle attached at the ciliary spur that is involved in controlling accommodation and may also play a role in regulating axial elongation in myopia.[19] The tension exerted by the ciliary body and its interaction with the sclera could therefore influence eye growth. Ciliary muscle contractions may restructure the local arrangement of scleral collagen predisposing the eye to axial elongation and lead to subsequent myopia development.[11, 20, 21 19, 22, 23] Though it is beyond the scope of the current study, it is possible that the LT depends on ciliary muscle tone, and our findings on ASL and LT may have hypothetically been contributed by a similar mechanism.[26]

This study contributes to understanding of AL in high myopia and provides a foundation for future research due to the strength of the clinical model that reduces confounding factors. There are several limitations of our study, including a retrospective study design that prevents causal inferences, and multicollinearity between variables that affected the precision of the regression model. We overcame the latter by using a machine-learning based statistical algorithm. Most of the patient biometric records included were obtained from a refractive service, thus introducing a possible sampling bias. Further, we hypothesized unilateral high myopia to be a similar biological disease to high myopia in general, which is an assumption without any support from literature. While there are studies to support the global or equatorial expansion models emerging evidence suggests that anterior segment parameters may also be associated with ocular growth.[27] Although the underlying mechanisms remain unclear, our findings highlight the need for longitudinal studies to further investigate the contribution of anterior segment biometry to myopia development and progression.

Conclusion

In individuals with high anisomyopia, posterior segment length (PSL) appears to be a dominant factor associated with increased axial elongation in both eyes. Anterior segment parameters, particularly LT appear to contribute to overall asymmetric biometric changes. Our findings highlight potential role of anterior structure variation in regulating of ocular growth. Further prospective studies, especially in paediatric populations, are warranted to validate these results and explore the implications for targeted myopia control strategies.

Declarations

Informed Consent

Written informed consent has been obtained for all patients for all procedures.

Ethical statement:

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of LV Prasad Eye Institute, Hyderabad, on February 15, 2025.

The institutional review board (IRB) approved the study (LEC-BHR-R-08-2025-248).

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Figures

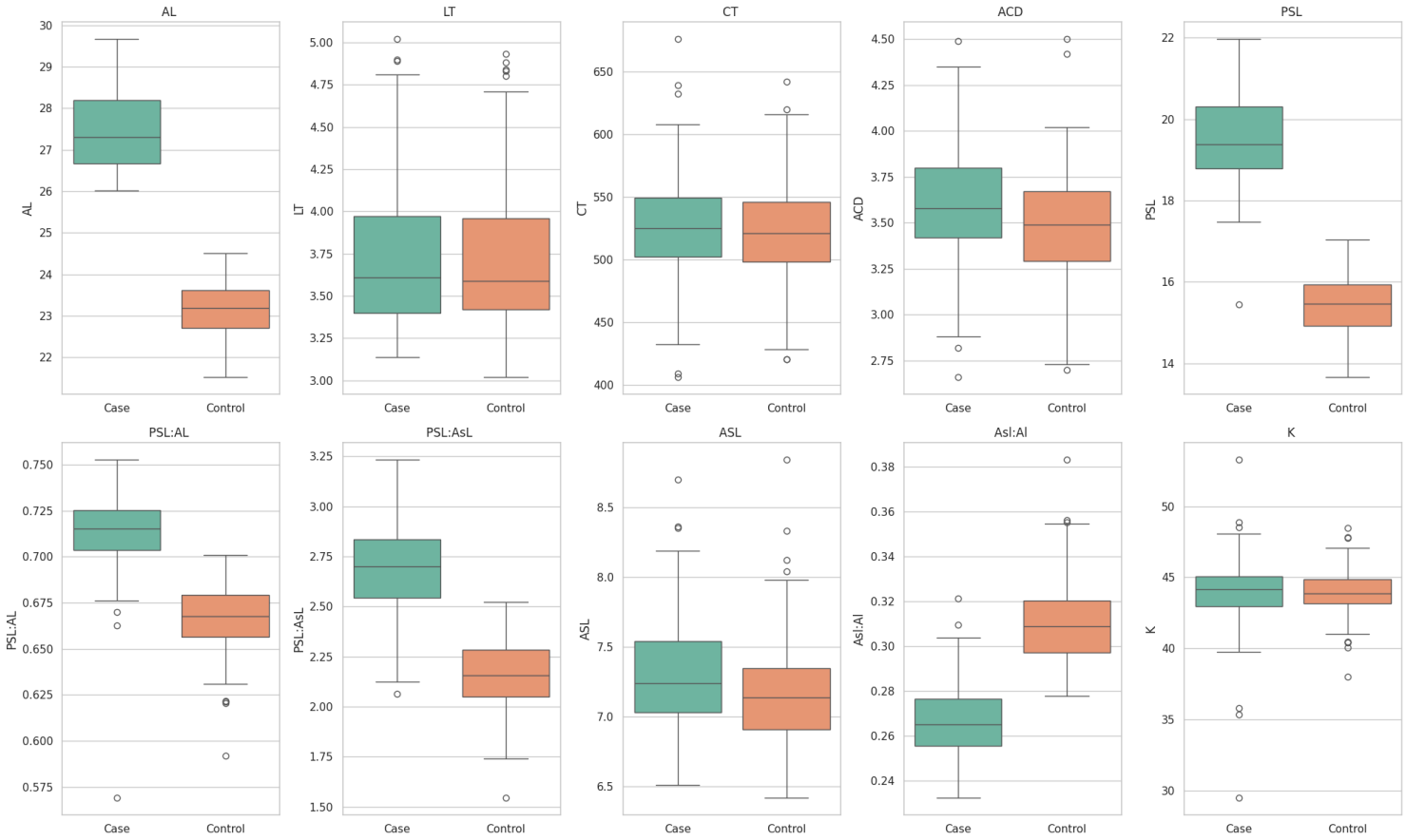


Figure 1

Box plots showing variations of biometric features between the 2 groups.

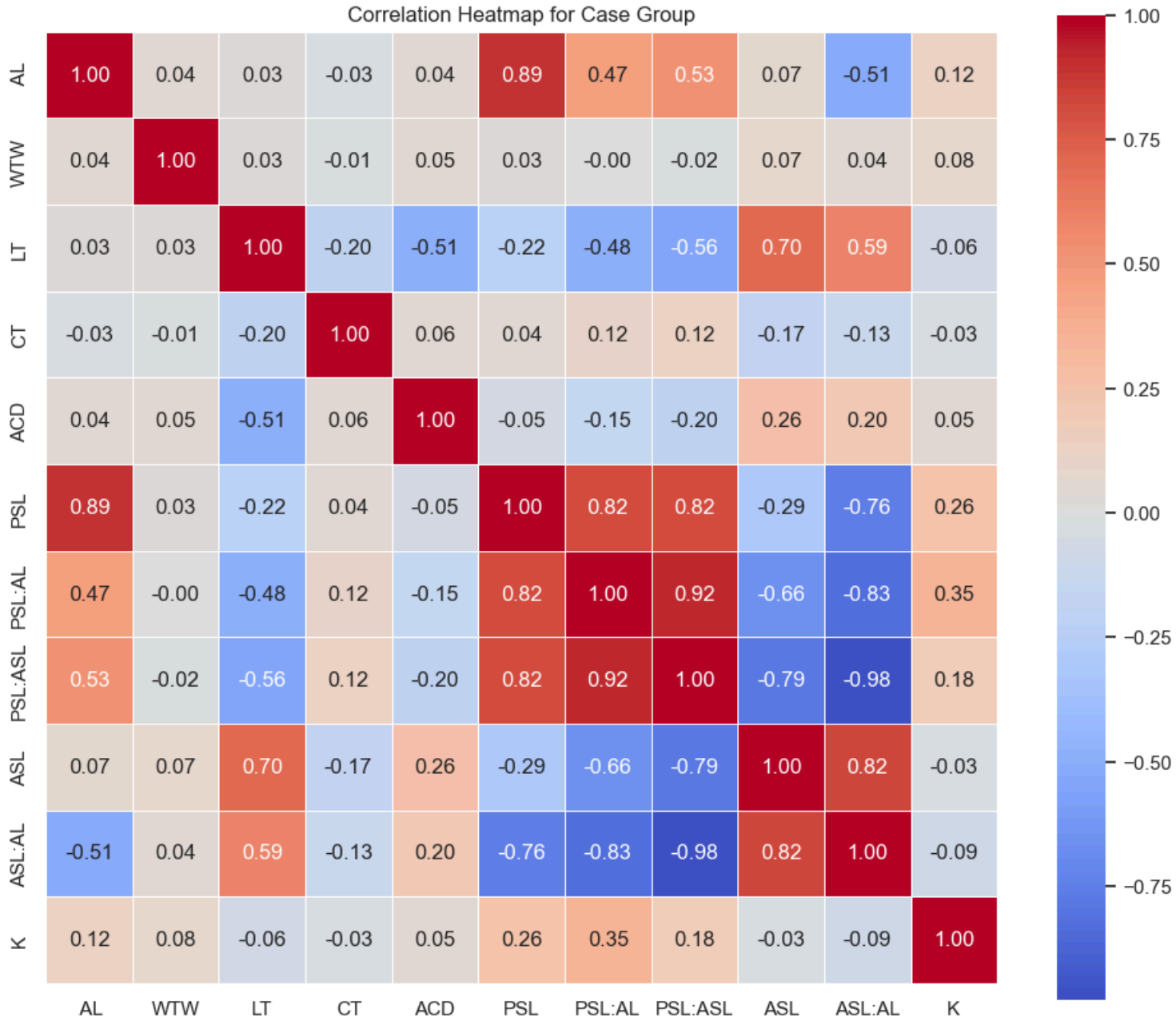


Figure 2

Correlation matrix heatmap showing correlation between various biometric variables in the case eyes

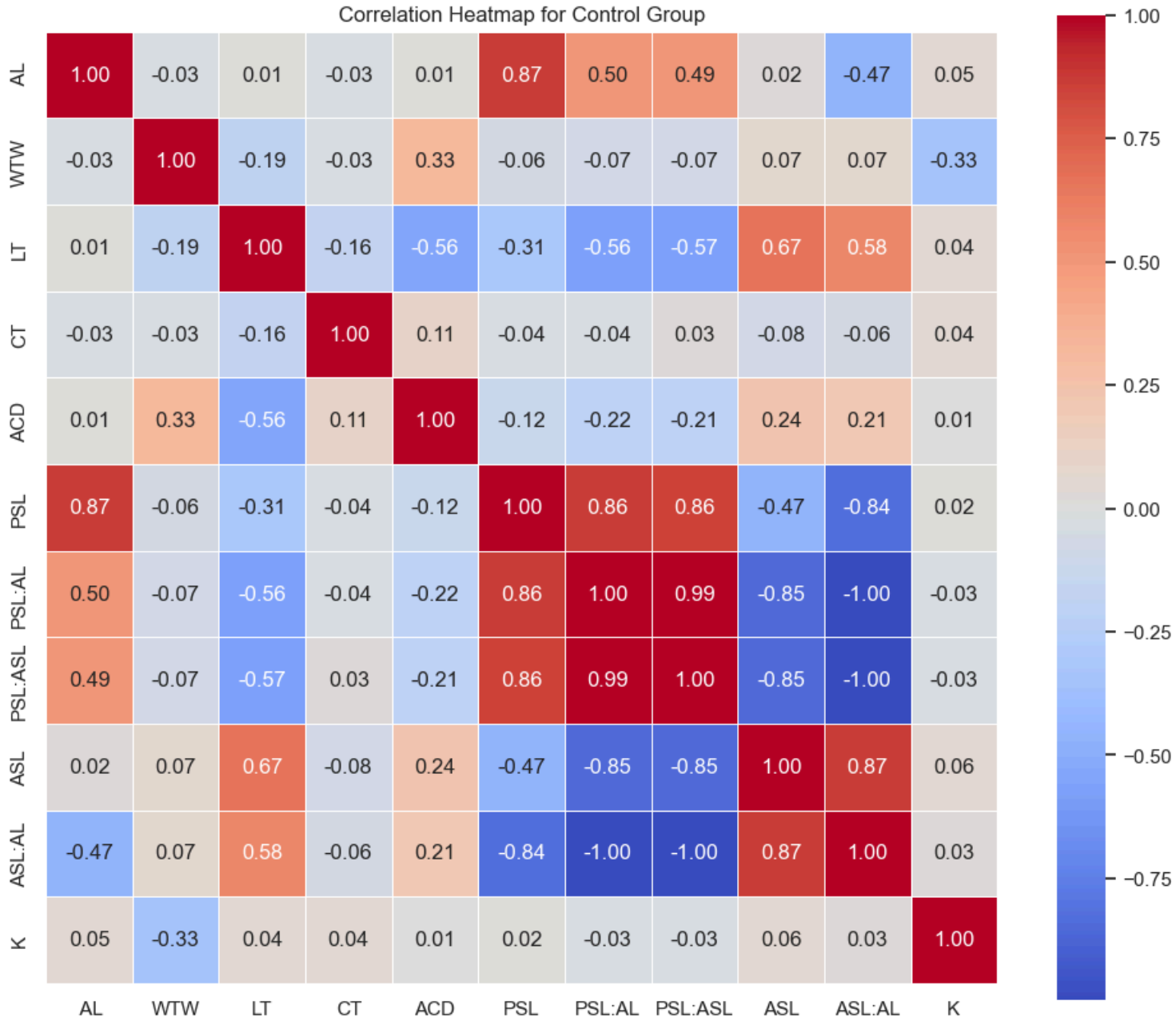


Figure 3

Correlation matrix heatmap showing correlation between various biometric variables in the control eyes

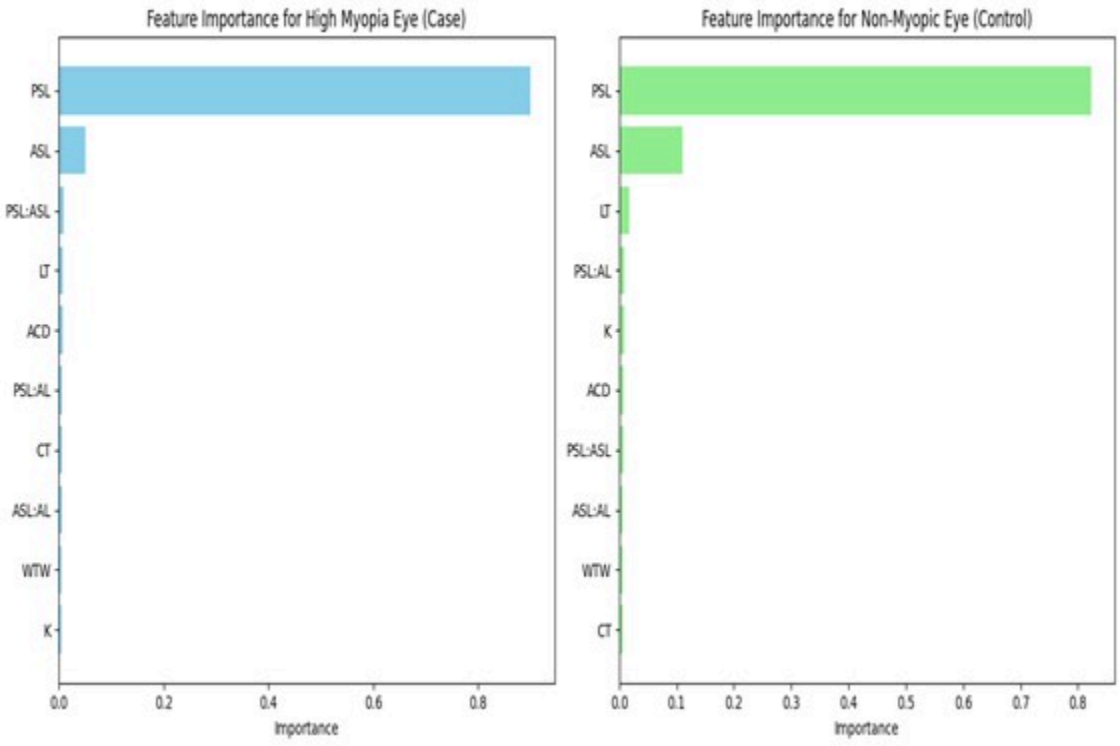


Figure 4

Feature importance plots showing importance of each biometric feature in predicting AL.

Supplementary Files

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- Supplementarytables.docx