

Association between Refractive Errors and Ocular Biometry in Iranian Adults

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Abstract

Purpose: To investigate the association between ocular biometrics such as axial length (AL), anterior chamber depth (ACD), lens thickness (LT), vitreous chamber depth (VCD) and corneal power (CP) with different refractive errors.

Methods: In a cross-sectional study on the 40 to 64-year-old population of Shahrood, random cluster sampling was performed. Ocular biometrics were measured using the Allegro Biograph (WaveLight AG, Erlangen, Germany) for all participants. Refractive errors were determined using cycloplegic refraction.

Results: In the first model, the strongest correlations were found between spherical equivalent with axial length and corneal power. Spherical equivalent was strongly correlated with axial length in high myopic and high hyperopic cases, and with corneal power in high hyperopic cases; 69.5% of variability in spherical equivalent was attributed to changes in these variables. In the second model, the correlations between vitreous chamber depth and corneal power with spherical equivalent were stronger in myopes than hyperopes, while the correlations between lens thickness and anterior chamber depth with spherical equivalent were stronger in hyperopic cases than myopic ones. In the third model, anterior chamber depth + lens thickness correlated with spherical equivalent only in moderate and severe cases of hyperopia, and this index was not correlated with spherical equivalent in moderate to severe myopia.

Conclusion: In individuals aged 40-64 years, corneal power and axial length make the greatest contribution to spherical equivalent in high hyperopia and high myopia. Anterior segment biometric components have a more important role in hyperopia than myopia.

Keywords: Adult; Middle East Region; Ocular Biometry; Refractive Errors

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INTRODUCTION

Refractive errors are one of the leading causes of vision impairment around the world and many studies

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have addressed their etiology.^[1-3] In some studies, part of refractive errors has been attributed to ocular biometrics.^[2-4] Most reports suggest axial length (AL) and vitreous chamber depth (VCD), as the most important components in relation to refractive errors.^[5,6]

Studies on the association between refractive errors and ocular biometrics such as corneal power (CP), central corneal thickness (CCT), anterior chamber depth (ACD), and lens thickness (LT) are inconclusive. For example, Shufelt et al^[7] and Mallen et al^[4] reported a correlation between refractive errors and CP while McBrien et al^[8] and Yekta et al^[9] found no significant correlation between these two variables. Some studies have reported higher ACD readings in myopes and lower readings in hyperopes,^[4,10] while Warriar et al^[2] and Wickremasinghe et al^[11] found no association between refractive errors and ACD in their population-based studies with large sample sizes. Despite numerous studies, only AL (especially VCD) was a common finding, and the association of refractive errors with other components is still a matter of question. Lower levels of refractive errors are attributed to an imbalance among the components of ocular biometrics, while at higher levels, one particular component, such as AL, plays a greater role; thus the etiology of lower levels of refractive errors is more complicated and multi-factorial. The present report concerns part of the first phase of the Shahroud Eye Cohort Study during which ocular biometric and refraction data were collected in a 40 to 64-year-old sample population of the city. Since the contribution of ocular biometrics to lower levels of refractive errors has been less elaborated, herein we intend to examine the association between ocular biometrics with different levels of refractive errors.

METHODS

The present report is part of the first phase of the Shahroud Eye Cohort Study, conducted in 2009. Details of the protocol have been published elsewhere, and we present a brief summary of its methodology.^[12]

During the Shahroud Eye Cohort Study, stratified cluster sampling was done to randomly choose 300 clusters of the city of Shahroud in 9 strata. Each stratum represented one health care center. In each cluster, 20 people between the ages of 40 and 64 years were selected to participate in the study. After sample selection and explaining the goals of the study to them, participants were then asked to sign informed consent forms and have an interview. During the interview, we inquired demographics, occupation, and medical and ophthalmic history.

For all participants a complete eye examination was performed. First an optometry examination including near and distance visual acuity measurement was done

with and without correction. Autorefractometry using the Topcon AR 8800 autorefractometer (Topcon Corporation, Tokyo, Japan) was performed, the results of which were used to conduct objective refraction and subjective refraction. At the next stage, slit lamp biomicroscopy was done, and for those who had no contraindication for the use of cyclopentolate eye drops 1%, cycloplegic refraction was performed after inducing dilation. Other examinations which were conducted after cycloplegia included clinical lens opacity grading, and assessment of vitreous opacities at the slit lamp and retinoscopy using direct and indirect ophthalmoscopy.

Measurement of Ocular Biometrics

Ocular biometrics were measured after determining visual acuity and before ophthalmic examinations and cycloplegic refraction. We used the Allegro Biograph (WaveLight AG, Erlangen, Germany) in all cases and extracted AL, ACD, LT, VCD, and CP readings.

Inclusion and Exclusion Criteria

We used data from study participants who were phakic and had no history of ocular surgery. Subjects with no cycloplegic refraction were also excluded. The presence of pterygium was another criterion for exclusion from the database.

Definitions

Refractive errors were classified according to spherical equivalent (SE). Myopia was defined as an SE of -0.5 diopter (D) or less, and hyperopia was an SE of 0.5 D or more. Further classifications included low, moderate, and high myopia as an SE of -0.5 to -3.0 D, -3.1 to -6.0 D, and less than -6.0 D, respectively. To classify hyperopia, we used SE ranges of 0.5 - 2.0 D, 2.1 - 4.0 D, and more than 4.0 D for mild, moderate, and high hyperopia, respectively. Astigmatism was defined as a cylinder error of 1.0 D or more.

Statistical Analysis

The mean and standard deviation of measured ocular biometrics was calculated in different levels of refractive errors, and we used the Pearson correlation coefficient to test the correlation between SE and different components of ocular biometrics. Associations were examined through linear regression, and to show the degree of association, we used multiple linear regression analysis. The correlation of each biometric component at different levels of refractive errors was tested in the presence of other variables using partial correlation coefficients, and the contribution of each component was determined in multiple models with beta-standardized coefficients.

RESULTS

Of the 6,311 invitees, 5,190 (82.2%) subjects participated in the study; of these, we excluded 151 people for having non-virgin eyes (115 for cataract surgery, 7 for glaucoma surgery, 8 for retinal surgery, and 21 for post-traumatic surgery) and 96 for extensive pterygia. Data of 308 people were eliminated because they did not have cycloplegic refraction testing or had missing biometric data, and 354 people had nuclear cataracts with grade >1.

Eventually, analyses were done on data from 4,281 right eyes. The number of female participants was 2,494 (58.3). Mean age of the participants was 50.0 ± 5.9 (range: 40-64) years; 20.8% were 40-44 years old, 29.5% were 45-49, 25.8% were 50-54, 16.3% were 55-59, and 7.6% were in the 60 to 64-year-old age group.

Table 1 summarizes mean ocular biometric measurements at different levels of refractive errors.

AL, VCD, ACD, and CP significantly increased at higher levels of myopia and significantly decreased at higher levels of hyperopia ($P < 0.001$). High hyperopic eyes had the highest LT readings ($P < 0.001$).

Figure 1 demonstrates the correlation between SE and AL, VCD, ACD, LT and CP. Pearson correlation coefficients were highest for SE with AL and VCD, and weakest for CP. The coefficients for correlations between SE and AL, VCD, ACD, LT, CP, and ACD + LT were -0.610 , -0.594 , -0.301 , 0.168 , -0.146 , and -0.173 , respectively.

The association between ocular biometric measurements with refractive errors was examined in three linear regression models. As demonstrated in Table 2, we studied the correlation of SE with AL and CP after adjusting for age and gender. Table 2 summarizes the results of this model in different types of refractive errors.

Table 1. Mean (\pm SD) of ocular biometric components at different levels of refractive error

| | <i>n</i> | AL (mm) | ACD (mm) | LT (mm) | VCD (mm) | CP (diopter) | ACD + LT (mm) |
|--------------------|----------|------------------|-----------------|-----------------|------------------|------------------|-----------------|
| High myopia | 50 | 26.89 \pm 1.81 | 2.91 \pm 0.30 | 4.15 \pm 0.27 | 19.32 \pm 1.75 | 44.07 \pm 2.91 | 7.06 \pm 0.29 |
| Moderate myopia | 111 | 24.62 \pm 0.94 | 2.94 \pm 0.32 | 4.11 \pm 0.28 | 17.05 \pm 0.86 | 44.1 \pm 1.88 | 7.05 \pm 0.29 |
| Mild myopia | 935 | 23.47 \pm 0.81 | 2.76 \pm 0.31 | 4.18 \pm 0.30 | 16 \pm 0.77 | 43.9 \pm 1.56 | 6.94 \pm 0.27 |
| Emmetropia | 1552 | 23.15 \pm 0.74 | 2.64 \pm 0.30 | 4.25 \pm 0.28 | 15.73 \pm 0.70 | 43.47 \pm 1.46 | 6.89 \pm 0.27 |
| Mild hyperopia | 1499 | 22.87 \pm 0.73 | 2.54 \pm 0.29 | 4.31 \pm 0.27 | 15.5 \pm 0.70 | 43.35 \pm 1.50 | 6.85 \pm 0.27 |
| Moderate hyperopia | 108 | 22.25 \pm 0.72 | 2.47 \pm 0.28 | 4.36 \pm 0.26 | 14.89 \pm 0.69 | 43.35 \pm 1.57 | 6.83 \pm 0.27 |
| High hyperopia | 26 | 21.42 \pm 0.84 | 2.48 \pm 0.28 | 4.33 \pm 0.22 | 14.07 \pm 0.88 | 42.49 \pm 1.89 | 6.81 \pm 0.27 |

AL, axial length; ACD, anterior chamber depth; LT, lens Thickness; VCD, vitreous chamber depth; CP, corneal power; ACD + LT, anterior chamber depth + lens thickness; SD, standard deviation

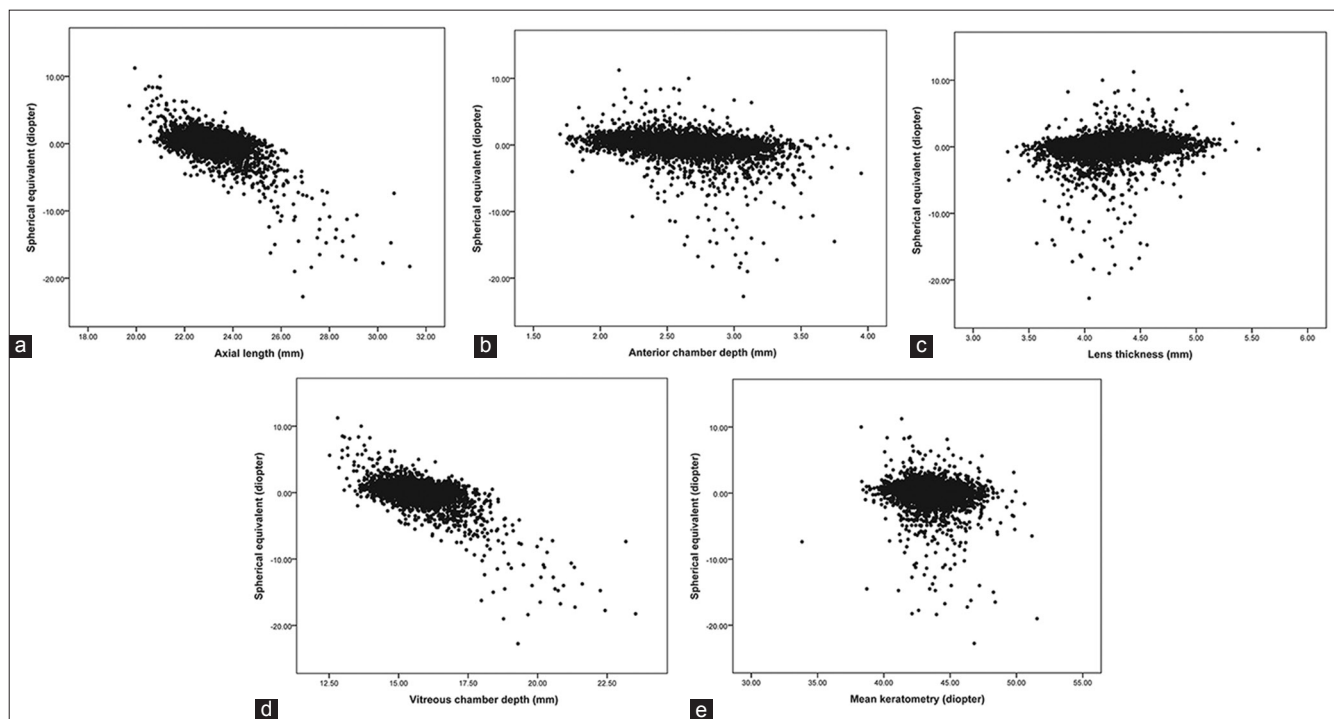


Figure 1. Correlation between spherical equivalent refractive error and axial length (a), anterior chamber depth (b), lens thickness (c), vitreous chamber depth (d) and mean keratometry (e).

Table 2. Associations between spherical equivalent error with AL and CP by age and gender in multiple linear regression models

| | Unstandardized coefficients (95% CI) | Standardized coefficients | Partial correlation | P |
|---|--------------------------------------|---------------------------|---------------------|--------|
| All subjects ($R^2=0.695$) | | | | |
| AL (mm) | -1.84 (-1.87--1.8) | -0.98 | -0.828 | <0.001 |
| CP (diopter) | -0.75 (-0.78--0.73) | -0.66 | -0.706 | <0.001 |
| Myopia ($R^2=0.737$) | | | | |
| AL (mm) | -2 (-2.07--1.93) | -0.98 | -0.858 | <0.001 |
| CP (diopter) | -0.78 (-0.83--0.73) | -0.55 | -0.675 | <0.001 |
| Hyperopia ($R^2=0.426$) | | | | |
| AL (mm) | -1.09 (-1.15--1.02) | -0.92 | -0.627 | <0.001 |
| CP (diopter) | -0.45 (-0.48--0.41) | -0.74 | -0.551 | <0.001 |
| Moderate and high myopia ($R^2=0.754$) | | | | |
| AL (mm) | -2.2 (-2.4--2) | -0.93 | -0.864 | <0.001 |
| CP (diopter) | -0.8 (-0.95--0.64) | -0.46 | -0.633 | <0.001 |
| Moderate and high hyperopia ($R^2=0.761$) | | | | |
| AL (mm) | -2.07 (-2.28--1.86) | -1.00 | -0.862 | <0.001 |
| CP (diopter) | -0.83 (-0.94--0.73) | -0.83 | -0.808 | <0.001 |

AL, axial length; CP, corneal power; CI, confidence interval

Axial length was correlated more strongly with spherical equivalent in eyes with moderate to severe myopia; nonetheless, as demonstrated in Table 2, corneal power was correlated more strongly with spherical equivalent in eyes with moderate and severe hyperopia as compared to myopia. As evidenced by partial correlation coefficients, spherical equivalent was strongly correlated with AL in cases of moderate and severe hyperopia and myopia.

In the second multiple regression model, as demonstrated in Table 3, the strongest correlations with SE were found for VCD and CP, and the weakest belonged to ACD.

VCD and CP correlated more strongly with spherical equivalent in eyes with myopia than hyperopia, while LT and ACD correlated more strongly with spherical equivalent in hyperopes than myopes. Nonetheless, stronger partial correlations were observed between SE and biometric components in cases of moderate to severe hyperopia than those with moderate to severe myopia.

In partial correlation testing, VCD, LT, and CP had the strongest correlations with SE in high and moderate hyperopia ($SE > 4.0D$). We observed a similar finding with beta standardized coefficients (the model $R^2 = 0.824$).

In the third model, ACD and LT were considered components of anterior segment axial length (ACD + LT) and SE correlations with VCD, ACD + LT, and CP were assessed.

As summarized in Table 4, after adjusting for age and sex, increases in all mentioned variables were associated with a myopic shift. Studying ACD + LT in high levels of refractive error revealed that ACD + LT correlated with SE only in eyes with moderate and severe hyperopia but not in moderate and severe myopia.; 77.7% of variations

in SE in high hyperopes could be explained by variations in VCD, CP and ACD + LT.

DISCUSSION

In this study, we describe the relationship between refractive errors and biometric components in different types of refractive errors. As shown in Table 1, AL, ACD, CP, and VCD significantly increased at higher levels of myopia and LT increased at higher levels of hyperopia. Among different components of AL, vitreous chamber depth made the most contribution to changes in refractive errors, while ACD and LT showed less variation with refractive errors. A longer AL and its components such as VCD and ACD in myopes, and the reverse in hyperopes has been discussed in previous reports as well.^[2,4,7,9,13] One of the findings of our study, which has been less stressed before, is higher LT values in hyperopic eyes. Hyperopes tend to accommodate more to keep the image in focus, and this causes the lens to thicken which can be associated with a decrease in VCD and less ACD, while in myopes, a thinner lens is associated with increased VCD and ACD.^[6]

According to our findings, corneal power is increased at higher levels of myopia and decreased at higher levels of hyperopia. Although few studies have shown changes in corneal power with the level of refractive errors, there is general agreement that corneal power is higher in myopes and lower in hyperopes.^[3] Descriptive results in this study have confirmed previous observations concerning the relationship between biometric components and refractive errors.^[2,4,7,9,13]

In the current study, the relationship between biometric components and spherical equivalent according to the type of refractive error and their severity

Table 3. Associations between spherical equivalent error and VCD, ACD, LT and CP adjusted by age and gender in multiple linear regression models

| | Unstandardized coefficients (95% CI) | Standardized coefficients | Partial correlation | P |
|---|--------------------------------------|---------------------------|---------------------|--------|
| All subjects ($R^2=0.747$) | | | | |
| ACD (mm) | -0.48 (-0.59--0.37) | -0.09 | -0.131 | <0.001 |
| LT (mm) | -2.14 (-2.26--2.01) | -0.34 | -0.444 | <0.001 |
| VCD (mm) | -2.2 (-2.25--2.16) | -1.11 | -0.846 | <0.001 |
| CP (diopter) | -0.88 (-0.9--0.86) | -0.76 | -0.763 | <0.001 |
| Myopia ($R^2=0.779$) | | | | |
| ACD (mm) | -0.29 (-0.56--0.02) | -0.04 | -0.063 | 0.039 |
| LT (mm) | -2.03 (-2.33--1.73) | -0.25 | -0.372 | <0.001 |
| VCD (mm) | -2.24 (-2.32--2.17) | -1.05 | -0.876 | <0.001 |
| CP (diopter) | -0.85 (-0.9--0.81) | -0.60 | -0.729 | <0.001 |
| Hyperopia ($R^2=0.533$) | | | | |
| ACD (mm) | -0.24 (-0.37--0.12) | -0.08 | -0.094 | <0.001 |
| LT (mm) | -1.63 (-1.79--1.47) | -0.47 | -0.444 | <0.001 |
| VCD (mm) | -1.5 (-1.57--1.42) | -1.21 | -0.708 | <0.001 |
| CP (diopter) | -0.59 (-0.62--0.55) | -0.97 | -0.655 | <0.001 |
| Moderate and high myopia ($R^2=0.776$) | | | | |
| ACD (mm) | 0.06 (-1.09-1.22) | 0.01 | 0.009 | 0.916 |
| LT (mm) | -1.42 (-2.73--0.1) | -0.10 | -0.169 | 0.035 |
| VCD (mm) | -2.32 (-2.52--2.12) | -0.96 | -0.875 | <0.001 |
| CP (diopter) | -0.82 (-0.97--0.68) | -0.48 | -0.661 | <0.001 |
| Moderate and high hyperopia ($R^2=0.824$) | | | | |
| ACD (mm) | -0.86 (-1.36--0.36) | -0.15 | -0.287 | <0.001 |
| LT (mm) | -2.57 (-3.19--1.95) | -0.39 | -0.588 | <0.001 |
| VCD (mm) | -2.3 (-2.5--2.1) | -1.10 | -0.899 | <0.001 |
| CP (diopter) | -0.88 (-0.97--0.78) | -0.87 | -0.857 | <0.001 |

CI, confidence interval; VCD, vitreous chamber depth; ACD, anterior chamber depth; LT, lens thickness; CP, corneal power

was examined using three separate linear regression models.

Since VCD, LT and ACD are components of AL, they were assessed with refractive errors in a separate model. In the first model, AL and CP showed a reverse correlation with spherical equivalent. A noteworthy observation was that correlations between SE and AL were similarly strong in high myopes (0.864) and high hyperopes (0.862); this confirms the role of AL in high levels of refractive errors.

The role of longer AL in myopia has been examined in many studies;^[4,11,14] nonetheless, few have shown a relationship between AL and spherical equivalent in cases of high hyperopia. Strang et al^[15] reported a strong correlation between AL and spherical equivalent in hyperopes similar to myopes. Since the AL range in mild to severe hyperopic cases is from 21.42 to 22.87 mm, which is a relatively narrower range than that in myopes (24.45-26.35 mm), part of this correlation appears to be statistical.

It is quite predictable to see more sensitivity to AL changes in subjects at the extremes of refraction. As demonstrated, mean AL was 20.96 in cases of high

hyperopia and 26.35mm in myopic cases; as AL decreases, every unit change in AL has a larger impact on refraction because it comprises a larger proportion of the focal length of the eye. In myopes, AL is longer, but corneal power is higher too. The higher the corneal power, the more change is seen in refractive error for every unit change in AL. Therefore, on one hand, one can expect to see more variation in refraction per unit change in AL in eyes at refraction extremes; on the other hand, as an optical system, every unit change can impact refraction even more as we move farther from the focal point of the eye.

The overall correlation between corneal power and refraction in the total sample was -0.146; others have reported values up to -0.3. Nonetheless, as demonstrated, corneal power was strongly correlated with refraction at all levels of refractive errors after adjusting for AL.^[3,16] Hirsch and Weymouth^[17] also observed that the correlation between corneal power and refraction can be as high as 0.70 when AL and ACD are constant. A noteworthy observation in our study was that the correlation between CP with spherical equivalent was stronger in cases of high hyperopia as compared to high myopia.

Table 4. Associations between spherical equivalent error and VCD, ACD + LT and CP adjusted by age and sex in multiple linear regression models

| | Unstandardized coefficients (95% CI) | Standardized coefficients | Partial correlation | P |
|---|--------------------------------------|---------------------------|---------------------|--------|
| All subjects ($R^2=0.708$) | | | | |
| ACD + LT | -1.06 (-1.17--0.95) | -0.16 | -0.284 | <0.001 |
| VCD (mm) | -1.93 (-1.97--1.89) | -0.98 | -0.830 | <0.001 |
| CP (diopter) | -0.78 (-0.8--0.76) | -0.68 | -0.719 | <0.001 |
| Myopia ($R^2=0.750$) | | | | |
| ACD + LT | -0.97 (-1.23--0.71) | -0.11 | -0.214 | <0.001 |
| VCD (mm) | -2.09 (-2.16--2.01) | -0.98 | -0.861 | <0.001 |
| CP (diopter) | -0.8 (-0.84--0.75) | -0.56 | -0.689 | <0.001 |
| Hyperopia ($R^2=0.441$) | | | | |
| ACD + LT | -0.65 (-0.77--0.52) | -0.19 | -0.237 | <0.001 |
| VCD (mm) | -1.16 (-1.23--1.1) | -0.94 | -0.637 | <0.001 |
| CP (diopter) | -0.47 (-0.5--0.44) | -0.78 | -0.567 | <0.001 |
| Moderate and high myopia ($R^2=0.768$) | | | | |
| ACD + LT | -0.47 (-1.56-0.62) | -0.03 | -0.069 | 0.393 |
| VCD (mm) | -2.28 (-2.49--2.08) | -0.94 | -0.870 | <0.001 |
| CP (diopter) | -0.81 (-0.97--0.66) | -0.47 | -0.650 | <0.001 |
| Moderate and high hyperopia ($R^2=0.777$) | | | | |
| ACD + LT | -1.38 (-1.91--0.85) | -0.23 | -0.417 | <0.001 |
| VCD (mm) | -2.13 (-2.34--1.92) | -1.02 | -0.871 | <0.001 |
| CP (diopter) | -0.85 (-0.95--0.75) | -0.84 | -0.821 | <0.001 |

VCD, vitreous chamber depth; ACD+LT, anterior chamber depth+lens thickness; CP, corneal power; CI, confidence interval

In the second model, AL components were assessed separately. ACD, VCD, and LT correlated with spherical equivalent. When assessed by the level of refractive error, LT correlated weakly with spherical equivalent in high myopia, while the correlation with VCD was strong. However, all of these components correlated with spherical equivalent in high hyperopia. In the third model, among AL components, only the posterior segment correlated with high myopia while in cases of high hyperopia both the anterior segment and the posterior segment were significantly correlated with spherical equivalent, which may reflect a smaller AL in these people. However, as descriptive results in Table 1 indicate, mean VCD varies from 17.0 to 19.3mm in myopes, while the variation in hyperopes is between 14.07 and 14.89 mm. Previous studies indicate that changes in VCD are the main reason for changes in refraction, especially in cases of high myopia.^[5,6,11]

This association shows that factors affecting the development of moderate and severe myopia impact the posterior segment. Zhu et al^[18] state that genetic changes responsible for myopia mostly cause changes in the posterior segment; it is possible that genes responsible for the growth of the anterior segment are different from those of the posterior segment, or the age-related impact of environmental factors affects the posterior segment to a greater extent. However, it should be noted that the participants in the study by Zhu et al^[18] were younger

than our participants. In our study, the factor of age could have dominated their genetic status.

In agreement with our results^[5,6,11,19] that increased vitreous depth contributes greatly to changes in spherical equivalent, especially in cases of myopia. However, standardized regression coefficients in Table 3 are challenging. According to Table 3, VCD unstandardized coefficient was higher in individuals with myopia than individuals with hyperopia. Nonetheless, according to VCD unstandardized coefficient in hyperopic individuals, VCD has a more prominent role in hyperopic individuals after adjustment for other biometric components. More studies are warranted in this regard.

Nonetheless, since the coefficient for the correlation between VCD and SE is also high in cases of moderate and severe hyperopia, the correlation appears to be rather a statistical one due to the limited range of VCD in moderate to severe hyperopia (14.07-14.89). The correlation of the anterior segment, especially lens thickness, with hyperopia can be due to more accommodation in these people.

According to Table 4, except for individuals with moderate and severe myopia, the anterior segment (LT and ACD) was correlated with refractive errors although the standardized coefficients of the anterior segment were less than VCD and CP standardized coefficients. It is worth noting that in all analyses, standardized coefficients of the anterior segment were

higher in patients with hyperopia, especially moderate and severe hyperopia. Few studies have investigated this relationship. It seems that changes of the anterior segment in hyperopic patients have more effects on the refractive error. For this reason, this finding should be kept in mind especially for calculating IOL power in cataract surgery.

In summary, in individuals aged 40-64 years corneal power and axial length make the greatest contribution to spherical equivalent in high hyperopia and high myopia. Anterior segment biometric components have a more important role in hyperopia than myopia. However, since this study was conducted in individuals aged 40-64 years, other factors may have confounded the results in addition to biometric components.

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Conflicts of Interest

There are no conflicts of interest.

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