

Axial length and anterior chamber indices in elderly population: Tehran Geriatric Eye Study

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Abstract

• **AIM:** To determine the normative distribution of axial length (AL), anterior chamber depth (ACD), anterior chamber volume (ACV), anterior chamber angle (ACA), and some of their associated factors in subjects aged 60 and over.

• **METHODS:** In this cross-sectional study, 160 clusters were sampled using multi-stage cluster sampling in Tehran, Iran. After a preliminary interview, the participants underwent optometric examinations including visual acuity and refraction measurement followed by slit lamp biomicroscopy. Finally, ocular imaging was done using the Pentacam AXL to measure AL, ACD, ACV, and ACA.

• **RESULTS:** A total of 4519 eyes of 2436 participants were evaluated, of whom 58.0% ($n=1412$) were female. The mean age of the subjects was 67.32 ± 6.05 y (range: 60-95y). The mean AL, ACD, ACV, and ACA was 23.22 mm (23.18-23.27 mm), 2.61 mm (2.59-2.62 mm), 126.56 mm^3 ($125.08-128.04 \text{ mm}^3$), and 30.61° ($30.3^\circ-30.92^\circ$), respectively. In the multivariable model, after adjusting for the effect of both eyes, the longest and shortest AL was seen in myopic and hyperopic subjects, respectively. AL, ACD, ACV and ACA were significantly larger in men compared to women ($P<0.001$). Except ACA, other evaluated parameters showed an inverse correlation with age ($P<0.001$), however, this correlation was insignificant for AL ($P=0.623$).

• **CONCLUSION:** Normative value of AL, and other biometric parameters are specific for each ethnicity, age and sex group. Any alteration in these parameters and their effect on refraction should be considered in this age group, especially in case of cataract surgery.

• **KEYWORDS:** biometry; elderly; axial length; anterior chamber depth

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INTRODUCTION

Considering the high prevalence of ocular problems in the elderly population, especially cataract and glaucoma, evaluation of ocular parameters is of special importance in this age group. One of the very important ocular parameters in older subjects is ocular axial length (AL), which has a great effect on the optical quality of the retinal image^[1]. AL is one of the most important factors influencing intraocular lens (IOL) power calculation^[2-4]. Choosing an IOL with an appropriate power results in lower refractive error and better uncorrected distance visual acuity, which improves the patient's satisfaction with the surgical results^[3,5]. AL has a key role in ocular diagnostic and therapeutic interventions like cataract and may be affected in several pathological conditions like glaucoma^[6], staphyloma^[7], and other retinal disease like retinal detachment^[8]. Moreover, AL of the eyeball is introduced as an important contributing factor leading to secondary dislocation of the IOL, capsular bag, and capsular tension ring (CTR) complex. Klysik *et al*^[9] reported that longer AL of the eyeball makes dislocation of the capsular tension ring/IOL complex more likely especially in the presence of pseudoexfoliation. Therefore, knowledge of its normative distribution and differences in both sexes and different age groups and its determinants assists ophthalmologists and other specialists in decision-making in different areas including surgery or other health policies. Moreover, considering the changes of ocular biometric components with age, accurate measurement of anterior chamber parameters in the elderly

population is of great importance. Measurement of anterior segment parameters not only affects IOL power calculation in new formulas, estimation of IOL vault, and prediction of possible damage to the corneal endothelium in cases requiring phakic intraocular lens (PIOL) implantation, but also is very important in diagnosis, monitoring, and treatment of glaucoma and peripheral refraction profile^[10-12]. Anterior chamber depth (ACD), volume (ACV), and angle (ACA) are some of the most important risk factors for glaucoma. Several population-based studies have measured the mean values of AL and other ocular biometric components in different age groups in different populations and have investigated their determinants; however, there are clear discrepancies between their results^[2,13-15].

Moreover, to our knowledge, this is the first comprehensive study which has examined these parameters exclusively among elderly population. In previous studies, the elderly population was considered only as a small part of the study. Therefore, owing to the small sample size the results could not be extrapolated to their peer group.

Since ocular parameters depend on factors like genetics, ethnicity, age, gender, *etc.* and previous studies evaluated wide age ranges, this study was conducted to measure AL, ACD, ACV, and ACA exclusively in subjects over 60y living in Tehran and to investigate some of their determinants like age, sex, height, education level, and refractive error.

SUBJECTS AND METHODS

Ethical Approval Informed consent was obtained from all participants. The principles of the Helsinki Declaration were followed in all stages of this study. The protocol of the study was approved by the Ethics Committee of the National Institute for Medical Research Development (NIMAD) under the auspices of the Iranian Ministry of Health (No.963660).

This study was part of Tehran Geriatric Eye Study (TGES), a population-based cross-sectional study that was conducted on individuals above 60y using multistage stratified cluster random sampling in Tehran, Iran in 2019.

One hundred and sixty-five clusters were randomly selected from 22 strata of Tehran on a proportional to size basis. After determining each cluster, a sampling team was dispatched to its address. All individuals above 60y were invited to participate in the study after providing a detailed explanation on the objectives of the study and data confidentiality. If the person was willing to participate, informed consent was obtained, an ID card was issued, and the person was transported to Noor Eye Hospital for examinations.

In the hospital, complete information including demographic, anthropometric, and socioeconomic (SES) data were collected from the participants by trained research assistants; then, the subjects underwent optometric and ophthalmic examinations.

Optometric examinations started with measuring refraction

using the Nidek ARK-510A auto refractometer (Nidek Co. LTD, Aichi, Japan). Next, uncorrected visual acuity (UCVA) was measured using the Smart LC 13 LED visual chart (Medizs Inc., Korea) at 6 m. Lensometry was done if the subject used spectacles, and best corrected visual acuity (BCVA) was also measured. All the above examinations were also done at the near distance. Then, complete slit-lamp examinations including the assessment of anterior and posterior segments were done using the Slit lamp B900 (Haag-Streit AG, Bern, Switzerland) and a +90 D lens.

Finally, all subjects underwent the Pentacam AXL imaging. The Pentacam AXL, in addition to HR characteristics, measures AL using partial coherence interferometry (PCI). Imaging was done by one operator and according to Pentacam default the data of the images with a signal to noise ratio of more than 6.3 were recorded. Ophthalmic examinations (both eyes) were performed between 9:00 *a.m.* and 14:00 *p.m.* To avoid diurnal variations, the examinations were done at least 2h after waking up.

In this report, subjects with a history of any ocular surgery, ocular trauma, lack of proper fixation, which their image-quality specification (QS) of Pentacam was not OK and their signal to noise ratio in measuring the AL of the eye was lower than 6.3, and dry eye subjects in case of non-OK QS or inappropriate map were exclude.

Definition In this study, spherical equivalent (SE) based on auto-refraction was used to define myopia and hyperopia^[16]. Myopia and hyperopia were defined as an SE worse than -0.5 diopters (D) and +0.50 D, respectively. An SE of -0.50 D to +0.50 D was considered as emmetropia. Lens opacity was graded according to the WHO Cataract Grading Group, in which the severity of lens opacities separated into three groups of nuclear, cortical, and posterior subcapsular (PSC) is graded according to photographic standards. Significant nuclear, cortical and PSC cataract was defined as the presence of a WHO grade of ≥ 2 for nuclear, cortical, and PSC cataract in at least one eye, respectively^[17].

Statistical Analysis The study variables are reported as mean and 95% confidence interval (CI). Standard error and cluster sampling method were considered in calculating the 95%CI, and all mean values were reported after direct standardization. Univariable and multivariable linear regression analysis were applied to find analytical relationships and their coefficients were reported. Independent variables evaluated in the multivariable model were age, sex, refractive errors, education, mean keratometry (mean-K), eccentricity (ECC), pupil diameter (PD), central corneal thickness (CCT), corneal diameter (CD), and height. The Pearson correlation coefficient of AL between right and left eye was 0.558. Due to the low correlation between fellow eyes, the results of both eyes were

Table 1 Mean and 95%CI of axial length, anterior chamber depth, anterior chamber volume and anterior chamber angle in geriatric

Parameters	No. of eyes	AL, mm		ACD, mm		ACV, mm ³		ACA, degree	
		Mean (95%CI)	P	Mean (95%CI)	P	Mean (95%CI)	P	Mean (95%CI)	P
Total	4519	23.22 (23.18 -23.27)		2.61 (2.59 -2.62)		126.56 (125.08 -128.04)		30.61 (30.30 -30.92)	
Sex			<0.001 ^a		<0.001 ^a		<0.001 ^a		<0.001 ^a
Male	1849	23.43 (23.37 -23.50)		2.65 (2.62 -2.67)		130.81 (128.52 -133.10)		31.08 (30.59 -31.57)	
Female	2670	23.01 (22.96 -23.07)		2.56 (2.55 -2.58)		122.32 (120.73 -123.91)		30.15 (29.75 -30.54)	
Age			0.135		0.004		<0.001		<0.001
60-64	1946	23.22 (23.15 -23.29)		2.63 (2.60 -2.65)		129.67 (127.45 -131.90)		30.29 (29.83 -30.76)	
65-69	1413	23.21 (23.14 -23.29)		2.60 (2.58 -2.63)		126.52 (124.41 -128.63)		30.42 (29.85 -31.00)	
70-74	745	23.28 (23.14 -23.41)		2.59 (2.55 -2.63)		123.36 (120.07 -126.65)		31.06 (30.17 -31.96)	
75-79	279	23.23 (23.05 -23.42)		2.58 (2.52 -2.64)		121.25 (115.92 -126.58)		31.86 (30.28 -33.43)	
≥80	136	23.10 (22.81 -23.38)		2.46 (2.39 -2.54)		109.90 (105.29 -114.52)		32.05 (29.39 -34.70)	
Education			0.090 ^b		0.146 ^c		0.020 ^d		0.882 ^e
Illiterate	508	22.96 (22.83 -23.10)		2.58 (2.54 -2.62)		120.44 (116.76 -124.11)		31.53 (30.38 -32.67)	
Primary school	1277	23.13 (23.04 -23.22)		2.58 (2.55 -2.62)		123.32 (119.93 -126.71)		30.73 (30.13 -31.33)	
Guidance School	831	23.18 (23.08 -23.27)		2.60 (2.57 -2.63)		127.28 (124.33 -130.23)		30.72 (30.02 -31.42)	
High school	1252	23.32 (23.24 -23.40)		2.62 (2.59 -2.65)		128.83 (126.58 -131.07)		30.38 (29.81 -30.96)	
College	625	23.42 (23.30 -23.54)		2.65 (2.61 -2.68)		131.17 (127.25 -135.10)		30.12 (29.32 -30.93)	
Refractive errors			<0.001 ^e		0.122 ^c		0.150 ^c		0.904 ^c
Emmetropia	1360	23.28 (23.22 -23.34)		2.62 (2.59 -2.64)		127.69 (125.50 -129.88)		30.99 (30.45 -31.54)	
Myopia	886	23.77 (23.64 -23.89)		2.68 (2.64 -2.71)		131.90 (128.76 -135.05)		31.61 (30.89 -32.32)	
Hyperopia	2227	22.97 (22.91 -23.02)		2.57 (2.55 -2.59)		123.92 (122.00 -125.85)		29.97 (29.53 -30.41)	

^aThe P-value was calculate independent sample t-test with controlled the effect of both eyes using the GEE method, and other P-value was calculated with ANOVA; ^bAfter adjusting for the effect of age and sex using Bonferroni correction, the post hoc results showed a significantly lower AL values in illiterate subjects compared to those with secondary school, high school, and university education; ^cThe P-value calculated with Bonferoni correction after controlling age and sex effect; ^dAfter adjusting for the effect of age and sex using Bonferroni correction, it was found that the anterior chamber volume was lower in subjects with high school and university education compared to illiterate participants; ^eAfter adjusting for the effect of age and sex using Bonferroni correction, the results showed a significantly higher and lower AL values in myopic and hyperopic participants compared to illiterate subjects, respectively. AL: Axial length; ACD: Anterior chamber depth; ACV: Anterior chamber volume; ACA: Anterior chamber angle.

used. Due to the fact that the results of both eyes were pooled, and due to the correlation between the two eyes, generalized estimating equation (GEE) was used to control the effect of this correlation.

RESULTS

A total of 4519 eyes of 2436 subjects were evaluated of whom 58% (n=1412) were women. The mean age of the participants was 67.32±6.05y (range: 60-95y). The mean SE was 0.35±1.88 D in the present study.

The refraction information of 46 eyes was not available. Of 4473 eyes whose refraction information was available, 19.8% were myopic and 49.8% were hyperopic. Totally 56.4% of the eyes had at least one type of cataract. The mean UCVA was 0.6±0.27 decimal and the mean BCVA was 0.86±0.2 decimal. Table 1 presents the mean and 95%CI of AL, ACD, ACV, and ACA in all subjects and according to age, sex, education level, and refractive error. The mean AL was 23.22 mm. In all subjects, and was significantly longer in men compared to women (P<0.001). There was no significant correlation between AL changes and age (P=0.623).

According to Table 1, AL increased with an increase in the education level. Univariable linear regression analysis showed that each one-year increase in the education level was associated with 0.03 mm increase in AL (P<0.001). Myopic subjects had the longest and hyperopic individuals had the shortest AL, and the difference between these two groups of participants and emmetropic individuals was significant. This relationship was still significant after adjustment for the effect of cataract. A multivariable linear regression model was used to investigate the relationship between AL and a number of study variable and anterior segment indices (Table 2). The results of the multivariable model showed that AL was the longest in myopic subjects and the shortest in hyperopic individuals. Moreover, AL had a significant indirect correlation with mean-K reading and ECC and a significant direct correlation with education level, PD, CD, and height. The mean ACD was 2.61 (2.59-2.62) in this study. The results of the univariable linear model showed that ACD was significantly longer in men (P<0.001) and decreased significantly with age (P<0.001). Moreover, ACD increased

Table 2 Association of axial length, anterior chamber depth, anterior chamber volume and anterior chamber angle with some variable in multiple regression model

Parameters	Coefficient (95%CI); P			
	AL	ACD	ACV	ACA
Sex (female/male)	NS	NS	-3.06 (-6.05 to 0.08); 0.045	-1.11 (-1.75 to 0.46); 0.001
Age (y)	NS	0 (-0.01 to 0); <0.001	-0.54 (-0.73 to -0.35); <0.001	0.08 (0 to 0.15); 0.046
Refractive errors				
Myopia	0.58 (0.46 to 0.69); <0.001	0.07 (0.03 to 0.1); <0.001	5.29 (2.23 to 8.35); 0.001	0.36 (-0.57 to 1.28); 0.447
Hyperopia	-0.4 (-0.45 to -0.34); <0.001	-0.05 (-0.08 to -0.03); <0.001	-5.73 (-8.05 to -3.41); <0.001	-1.09 (-1.76 to -0.41); 0.002
Education (year)	0.01 (0 to 0.02); 0.002	NS	0.29 (0.08 to 0.5); 0.008	NS
Mean keratometry (D)	-0.32 (-0.35 to -0.28); <0.001	0.03 (0.02 to 0.04); <0.001	NS	0.41 (0.16 to 0.67); 0.002
Eccentricity	-0.2 (-0.39 to 0); 0.05	-0.32 (-0.37 to -0.27); <0.001	-22.98 (-27.46 to -18.51); <0.001	-4.24 (-5.76 to -2.72); <0.001
Pupil diameter (mm)	NS	0.02 (0.01 to 0.03); <0.001	3.82 (3.03 to 4.61); <0.001	NS
CCT (μm)	NS	NS	-0.07 (-0.1 to -0.04); <0.001	NS
Corneal diameter (mm)	0.19 (0.09 to 0.28); <0.001	0.25 (0.22 to 0.29); <0.001	26.9 (23.85 to 29.94); <0.001	1.3 (0.33 to 2.27); 0.009
Height	0.01 (0.01 to 0.01); <0.001	0 (0 to 0.01); <0.001	0.21 (0.05 to 0.36); 0.009	NS

NS: Not significant; D: Diopter; CCT: Central corneal thickness; AL: Axial length; ACD: Anterior chamber depth; ACV: Anterior chamber volume; ACA: Anterior chamber angle.

with an increase in the education level, was the longest in myopic subjects, and the shortest in hyperopic participants.

The relationship between ACD and the above parameters as well as some anterior segment indices and height was evaluated using a multivariable linear regression model (Table 2). The results showed that ACD had an indirect correlation with age, ECC, and hyperopia and a direct correlation with myopia, PD, CD, height, and keratometry reading.

The mean ACV was 126.56 (125.08-128.04) mm³ in this study. It was significantly larger in men versus women. As for the refractive error, the largest ACV was seen in myopic subjects compared to emmetropic ones. A multivariable model was used to evaluate the relationship between ACV and the study variables (Table 2). The results showed that ACV had an indirect relationship with age, female sex, hyperopia, ECC, and CCT and a direct relationship with myopia, education level, PD, CD, and height.

The mean ACA was 30.61° (30.3°-30.92°). The mean ACA was significantly larger in men (P=0.013) and increased significantly with age. Hyperopic subjects had the smallest ACA value compared to emmetropic individuals. The results of a multivariable model (Table 2) showed that ACA had an indirect correlation with female sex, hyperopia, and ECC and a direct relationship with age, mean-K reading, and CD.

DISCUSSION

This study was conducted to evaluate the normative distribution of AL, ACD, ACV, and ACA and some of their determinants including age, sex, education level, refractive error, and height in the elderly population over 60y. Although several studies have investigated ocular biometric parameters in different populations, there is no comprehensive study of anterior

segment parameters and AL especially in the elderly population and this age group has been usually evaluated as a small part of the majority of the studies. Due to the large sample size and random cluster sampling from Tehran dwellers, the results can be well extrapolated to the entire elderly population.

The mean AL value was 23.22 mm in the present study, which was slightly smaller than the values in subjects above 60y in studies by Chen *et al*^[13], Cui *et al*^[18], Huang *et al*^[14], Fotedar *et al*^[19], and Wickremasinghe *et al*^[20] and slightly larger than the values reported by Warriar *et al*^[21] and Hashemi *et al*^[2]. Hashemi *et al*^[2] reported a mean AL value of 23.04 mm in the age group 60-64y (Table 3).

There was no marked difference in AL in this age range (23.22 vs 23.04) between these two studies conducted in different parts of Iran (Shahroud and Tehran). The slight difference between these studies can be ascribed to genetic differences and measurement tools^[22-23].

Several studies have evaluated the factors affecting AL, reporting age, sex, and education level as the most important determinants^[6,24-25]. Evaluation of the relationship between sex and AL in the present study showed that AL was longer in men versus women (23.43 vs 23.01), which is consistent with previous studies where the longer AL in men has been attributed to their taller stature as well as physical differences between men and women^[26-28].

Evaluation of the role of age in AL changes showed a decrease in AL with age in the study population, which was consistent with the majority of the previous studies^[14,18,24]. However, the trend of AL changes relative to age is not a regular trend in some studies^[7], and some studies even found an increase in AL with age^[24]. Therefore, there is no consistency between the

Table 3 summary of other studies about axial length measurement

Parameters	Total	Male	Female
Chen ^[13] , South China			
60-69	23.50	23.83	23.22
70-79	23.60	23.97	23.26
≥80	23.41	23.54	23.13
Cui ^[18] , South China			
60-69	24.11	24.31	23.97
70-79	23.84	24.10	23.64
≥80	23.75	23.99	23.48
Huang ^[14] , Western China			
60-69	24.46	25.13	23.92
70-79	24.05	24.49	23.62
≥80	23.81	24.12	23.36
Fotedar ^[19] , Australia			
59-64	23.60	23.88	23.37
65-74	23.44	23.68	23.25
75-84	23.39	23.81	23.08
≥85	23.23	23.63	23.03
Wickremasinghe ^[20] , Mongolia			
60-69	23.30	23.50	23.20
≥70	23.30	23.60	23.10
Warrier ^[21] , Myanmar			
60-69	22.75	23.60	22.54
≥70	22.73	23.00	22.52
Hashemi ^[2] , Iran			
60-64	23.04	-	-

results of different studies; however, since ageing is associated with some degrees of atrophy in ocular structures^[2], ageing is expected to be associated with a decrease in AL.

Hence, an increase in age after 60y is associated with some AL changes, possible refraction alterations due to AL changes should be considered in this age group especially in case of cataract surgery.

Regression analysis showed an inverse correlation between AL and the value of SE. Therefore, a reduction in AL in the elderly is expected to be associated with an increase in hyperopia and a decrease in myopia. This finding was consistent with a cohort study by Hashemi *et al*^[29] in which SE changed by +0.24 D after five years.

AL changes were associated with alterations in other ocular biometric parameters. As mentioned earlier, AL had a direct correlation with ACD and ACV. This finding was consistent with previous studies that found that eyes with longer ALs had deeper anterior chambers^[14,16]. The correlation between ACD and AL in the elderly population may indicate the role of AL in reducing ACD and increasing the odds of angle closure and glaucoma; therefore, it is very important to consider the risk of angle-closure glaucoma due to ACD reduction in this age group^[30].

Subjects with higher education levels had longer ALs in the present study, but no correlation was found between ACD and education level, indicating a deeper vitreous chamber and longer AL in people with higher education levels. A higher education level, as a crude marker, indicates the amount of near work activity. According to previous studies, the prevalence of myopia and a longer AL is higher in this population^[31-34].

The mean ACD and ACV was 2.61 mm and 126.56 mm³ in this study, which reduced significantly with age. A reduction in the ACD and volume due to an increase in the lens volume and a decrease in AL with age is not unexpected and is consistent with previous studies^[35-36]. He *et al*^[35] reported an ACD value of 2.49 mm in Chinese people over 50y. The reason for the slightly smaller ACD in the Chinese population is the higher prevalence of primary angle closure in East Asian populations. They also found that ACD reduced from 2.61 mm in the age group 50-59y to 2.33 mm in participants aged 80-93y^[35]. Similar to previous studies, the ACD and volume were larger in men and those with a taller stature versus women and those with a shorter stature^[2,35]. Previous studies showed that ACV had a marked association with anterior segment parameters so that 85% of its changes are resulted from ACD changes^[37]. Therefore, factors affecting ACD have similar effects on ACV. The mean ACV value was slightly larger in previous studies, which could be due to demographic, ethnic, age, or measurement tool differences. According to previous studies, the accuracy of the swept-source tools is higher than the Pentacam^[38-39]. On the other hand, all of the participants were phakic in the present study and subjects with a history of cataract surgery were excluded. According to previous studies, cataract surgery can cause widening of the anterior chamber^[40]; therefore, increase in the lens volume with age may be a reason for the lower ACV in the present study compared to previous studies. The mean ACA was 30.61° in the present study. The accuracy of the Pentacam for ACA measurement is relatively low because it cannot visualize the most extreme end of the angle. Since ACA is very much dependent upon the configuration of the peripheral part of the ACA, ACD and volume are better parameters for anterior chamber assessment. Similar to other anterior chamber parameters and in line with previous studies, ACA was larger in myopes compared to hyperopes and in men versus women in the present study; however, contrary to the literature and expectations, it increased markedly with age. More studies are required to evaluate the relationship between ACA and age.

One of the limitations of the present study was lack of using other biometry methods for comparison; however, since non-contact methods are faster and easier to apply, they are widely used in population-based studies. On the other hand, this tool is helpful for evaluation used in many clinics. Therefore,

the normative distribution of the study parameters in such a large sample of elderly patients can be used as a reference for evaluation and comparison purposes in future studies in this population.

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