Original Article

Corneal Biomechanical Parameters after 60-Year-Old

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Abstract

Purpose: To determine the distribution of corneal biomechanical parameters in an elderly population.

Methods: This cross-sectional study was conducted in subjects above 60 years living in Tehran. The participants were selected using multi-stage cluster sampling. Corneal biomechanical parameters were measured in a randomly selected subsample of this population using the Reichert Ocular Response Analyzer (Reichert Ophthalmic Instruments, Inc., Buffalo, NY, USA).

Results: Of 470 subjects, the data of 420 participants aged over 60 years were analyzed (mean age: 69.3 ± 6.5 years and range: 61–88 years), 363 (86.4%) of whom were male. The mean and standard deviation of corneal hysteresis (CH) and corneal resistance factor (CRF) were 8.37 ± 1.55 mmHg (95% confidence interval [CI]: 8.02–8.72) and 9.06 ± 1.70 mmHg (95% CI: 8.69–9.44), respectively. The mean CH was 8.27 ± 1.54 mmHg in men and 9.25 ± 1.28 mmHg in women, and the mean CRF was 9.00 ± 1.71 mmHg in men and 9.63 ± 1.37 mmHg in women. According to the results of multiple linear logistic regression analysis, CH had a significant association with younger age ($\beta = -0.05$, $P = 0.032$), female sex ($\beta = 1.83$, $P < 0.001$), reduced maximum keratometry ($\beta = -0.22$, $P = 0.06$), and increased anterior chamber volume ($\beta = 0.01$, $P = 0.007$). CRF had a significant correlation with a younger age ($\beta = -0.06$, $P = 0.02$), female sex ($\beta = 1.01$, $P = 0.05$), central corneal thickness ($\beta = 0.02$, $P < 0.001$), and reduced maximum keratometry ($\beta = -0.39$, $P = 0.010$).

Conclusion: The mean CH and CRF values were low in this sample of the Iranian population aged over 60 years indicating the weaker elasticity of the corneal connective tissue.

Keywords: Cornea, Corneal biomechanics, Corneal hysteresis, Corneal resistance factor

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Submitted: 23-Jun-2021; **Revised:** 08-Jan-2022; **Accepted:** 12-Jan-2022; **Published:** 30-Nov-2022

Introduction

The viscoelastic properties of the cornea are part of its biomechanical properties. Knowledge of the biomechanical properties provides useful biological information.[1] Corneal hysteresis (CH) and corneal resistance factor (CRF) represent corneal viscosity, elasticity, and resistance, and the lower values of these parameters indicate a weaker cornea.[2]

Knowledge of the CRF and CH values has practical applications in contact lens wear, corneal ulcer improvement, and intraocular pressure (IOP) related issues.[3] For example, corneal warpage is caused by the use of contact lenses wear, which is believed to affect the biomechanics of the cornea.[4] According to a study, differences in corneal biomechanics between individuals may have a greater effect on IOP measurement compared to corneal thickness or curvature.[5] Moreover, biomechanical values are of great importance in cases such as keratoconus and corneal topographic changes and assist in diagnosis and management of these conditions.[6] Several studies have reported a high prevalence of some ocular surgeries such as cataract surgery in people over 60 years.[7-11] Cataract surgery affects the biomechanical properties of the

Access this article online

Quick Response Code:

Website: www.jcurrophthalmol.org

DOI: 10.4103/joco.joco_201_21

How to cite this article: Shokrollahzadeh F, Hashemi H, Yekta A, Ostadimoghaddam H, Khabazkhoob M. Corneal biomechanical parameters after 60-year-old. J Curr Ophthalmol 2022;34:284-9.

cornea.[12-15] The viscoelastic properties of the cornea change in the elderly population due to connective tissue changes with age.[16]

Changes in the corneal biomechanical properties are expected in the elderly due to hormonal and tissue changes with age. Since corneal parameters are related to other ocular parameters, their changes may affect other ocular parameters too. A review study on corneal structural changes in different layers with age showed inconsistencies in the results of the studies.[17] Therefore, many unknown scientific principles need to be elucidated regarding structural changes, ocular components characteristics, and their alteration with age. Ocular changes in the elderly have a significant effect on the quality of life.[18] Ocular changes also affect vision, which may disrupt daily activities, such as social interactions. Knowledge of the corneal biomechanical properties of the elderly makes it possible to offer appropriate solutions for the follow-up of their visual health and predict the trend of ocular connective tissue changes over time. Early diagnosis of corneal tissue abnormalities using corneal biomechanical parameters reduces treatment costs and length of stay. No study has yet evaluated the relationship between ocular biomechanical parameters and demographic and biometric parameters exclusively in the elderly, and the majority of the available studies are done on either children or adolescents or in wide age ranges.[1,19-21] Population aging requires a special attention to the elderly population. The present study was conducted to determine the distribution of corneal biomechanical parameters and some of their determinants in an elderly population.

Methods

This study was part of the Tehran Geriatric Eye Study, a population-based cross-sectional study conducted in individuals over 60 years in Tehran, Iran in 2019.[22,23] In this study, sampling was done proportional to the population of 22 districts of Tehran using multi-stage stratified cluster sampling. One hundred and sixty clusters each containing 20 subjects were randomly selected from all 22 districts such that the number of clusters in each district was proportional to its population. After determining each cluster, a sampling team was dispatched to its address, and all individuals above 60 years were invited to participate in the study. This process continued until the required sample size was achieved in each cluster. If the number of eligible people in the last household of a cluster exceeded one person, the cluster could include more than 20 samples. If a household was not found, another visit was scheduled (preferably in the same afternoon). The subjects were transferred to the examination place on a predetermined day. The Ethics Committee of Mashhad University of Medical Sciences approved the study protocol, which was conducted in accordance with the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants (Ethics code: IR.MUMS.REC.1398.287).

The Reichert Ocular Response Analyzer (ORA, Reichert Ophthalmic Instruments, Inc., Buffalo, NY, USA software version: 2.04) was used to measure corneal biomechanical properties. The height of the instrument table was adjusted. Then, the examinee was instructed to lean forward to have their chin inward and fixate on the green light inside the device tube. The examinee was instructed to blink several times and then fixate again on the green light. The operator then started the measurement by pressing a button, which generated a puff of air. The ORA readings were performed first on the right eye followed by the left eye, and good quality readings were used. Three high-quality measurements were carried out in each eye. All examinations were performed between 10 am and 4 pm to minimize any potential confounding effect related to diurnal variation in pressure or hydration. One eye was included in our study.

The Pentacam AXL (Oculus Optikgeräte GmbH, Wetzlar, Germany) was used to measure the axial length using partial coherence interferometry. According to the Pentacam default, the data of the image with a signal-to-noise ratio of more than 6.3 was recorded.

Patients with a history of ocular trauma, contact lens wear, ocular diseases like glaucoma, ocular surgery such as refractive surgery and cataract, systemic diseases affecting corneal biomechanics like diabetes and connective tissue disorders, and systemic autoimmune diseases were excluded from the study. These systemic diseases alter and reduce the biomechanical parameters of the cornea. Moreover, subjects with a waveform score of <3.7[24] were also excluded.

Refractive error was defined according to manifest refraction and determined using spherical equivalent (SE). A SE of higher than −0.5 diopter (D) and +0.5 D was considered myopia and hyperopia, respectively.

Statistical analysis

The Stata 12.0 software (Stata Corp LP, College Station, TX, USA) and IBM SPSS Statistics Version 22 (IBM Corp., Armonk, NY, USA) were used for data analysis. For biomechanical comparisons, the thickness was also assessed using descriptive and analytic statistics. The mean CH and CRF along with their 95% confidence intervals (CIs) are reported for all subjects and according to age, sex, and refractive error. Moreover, the 25%, 50%, 75%, 95%, and 99% percentiles are also used to describe these parameters. The cluster effect was considered for accurate estimation of the standard error, and all measurements were standardized according to the 2016 Tehran population[25] using direct standardization method. A multiple linear regression model was used to investigate the relationship between the study variables and corneal biomechanical parameters.

Results

In this study, from 470 subjects who were screened, 451 met the inclusion criteria. Finally, considering a waveform score of above 3.7, the data of 420 subjects were analyzed. The mean age of the participants was 69.3 ± 6.5 years (range, 61–88 years), and 363 (86.4%) subjects were male.

The mean SE was 1.74 ± 0.18 D (−5.5 to –7.38 D). Table 1 presents the 25%, 50%, 75%, 95%, and 99% percentiles of CH and CRF according to sex, age, and refractive error. Figure 1 demonstrates the correlation between CRF and CH (Pearson's correlation coefficient = 0.635, $P < 0.001$).

Table 2 shows the mean, standard deviation, and 95% CI of study variables according to age, sex, and refractive error. The mean CH and CRF was 8.37 ± 1.55 mmHg (8.02–8.72) and 9.06 ± 1.70 mmHg (8.69–9.44), respectively. Simple linear regression showed that the mean CH was significantly lower in men than in women ($P < 0.001$) while there was no significant difference in CRF between men and women ($P = 0.129$). The mean CH was 8.45 ± 1.46 mmHg in the age group of 60–70 years, which reduced to 8.32 ± 0.84 mmHg in subjects over 80 years ($P < 0.001$). The mean CRF also decreased significantly from 9.37 ± 1.61 mmHg in the age group of 60–70 years to 8.10 ± 1.30 mmHg in patients over 80 years ($P < 0.001$). The mean central corneal thickness (CCT) was 530 ± 24.9 µm (489–595 µm). According to linear regression analysis, considering the emmetropic group as the reference group, there was no significant difference in CRF between myopic ($P = 0.588$) and hyperopic ($P = 0.799$) subjects compared to emmetropic individuals. This finding was also true for CH (myopia; $P = 0.470$ and hyperopia; $P = 0.567$).

The association of CH and CRF with study variables and some biometric and anterior corneal parameters was investigated. The variables that were entered into the simple linear regression model included age, sex, CCT, anterior chamber depth, axial length, keratometry in steep and flat meridian, anterior chamber angle and volume, and refractive error. Table 3 shows the results of the final multiple linear regression model. CH had a significant correlation with a younger age, female sex, reduced keratometry, and increased anterior chamber volume, and CRF had a significant correlation with a younger age, female sex, CCT, and reduced maximum keratometry.

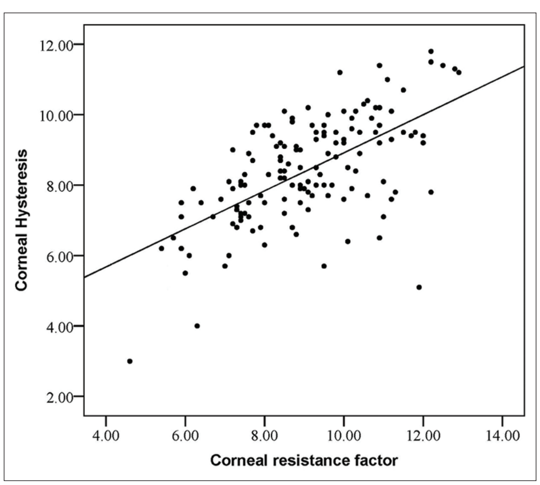

Figure 1: Correlation of corneal hysteresis and corneal resistance factor

Table 1: Values of 25%, 50%, 75%, 95%, 97.5%, and 99% percentiles of corneal hysteresis and corneal resistance factor according to age, sex, and refractive error

	n	Percentile				
		25%	50%	75%	95%	99%
Corneal hysteresis (mmHg)						
Total	420	7.70	8.70	9.60	11.10	11.50
Sex						
Male	363	7.60	8.50	9.50	11.20	11.70
Female	57	8.40	9.60	10.10	10.40	10.50
Age						
60-70	242	7.70	8.80	9.60	11.20	11.70
70-80	150	7.40	8.90	9.60	10.40	11.50
>80	28	7.90	8.40	8.80	9.80	9.80
Refractive errors						
Emmetropia	106	7.50	8.20	9.40	11.20	11.80
Myopia	58	7.50	8.80	9.70	11.40	11.40
Hyperopia	84	7.70	8.40	9.40	10.20	11.20
Corneal resistance factor (mmHg)						
Total	420	7.90	9.20	10.40	12.00	12.90
Sex						
Male	363	7.70	9.00	10.40	12.00	13.60
Female	57	9.10	10.20	10.90	11.40	12.70
Age						
60-70	242	8.40	9.50	10.90	12.20	12.90
70-80	150	7.60	8.90	10.40	11.80	13.60
>80	28	7.20	8.50	9.20	10.60	10.60
Refractive errors						
Emmetropia	106	8.20	9.30	10.30	12.00	12.20
Myopia	58	7.50	8.50	10.40	12.50	12.80
Hyperopia	84	8.40	9.15	9.80	11.30	12.90

Table 2: Mean, standard deviation 95% confidence interval of corneal hysteresis and corneal resistance factor according to age, sex, and refractive error

	n	Mean±SD (95% CI)	
		Corneal hysteresis (mmHg)	Corneal resistance factor (mmHg)
Total	420	8.37±1.55 (8.02-8.72)	9.06±1.70 (8.69-9.44)
Sex			
Male	363	8.27±1.54 (7.92-8.62)	9.00±1.71 (8.60-9.40)
Female	57	9.25±1.28 (8.56-9.93)	9.63±1.37 (8.87-10.39)
Age			
60-70	242	8.45±1.46 (7.97-8.93)	9.37±1.61 (8.76-9.98)
70-80	150	8.24±1.85 (7.61-8.86)	8.75±1.8 (8.16-9.35)
>80	28	8.32±0.84 (7.79-8.84)	8.10±1.30 (7.21-9.00)
Refractive errors			
Emmetropia	106	8.34±1.45 (7.94-8.73)	9.26±1.45 (8.79-9.74)
Myopia	58	8.64±1.96 (7.79-9.49)	8.98±2.20 (7.99-9.98)
Hyperopia	84	8.44±1.41 (8.02-8.85)	9.18±1.41 (8.60-9.76)

CI: Confidence interval, SD: Standard deviation

Table 3: Results of multiple regression analysis of corneal hysteresis and corneal resistance factor with some biometric parameters

	Coefficient (95% CI)	P
Corneal resistance factor		
Age (years)	−0.06 (−0.1 - −0.01)	0.022
Sex (male/female)	1.01 (−0.02-2.03)	0.053
Central corneal thickness (micron)	0.02 (0.01-0.03)	<0.001
Maximum keratometry (diopter)	−0.39 (−0.66 - −0.11)	0.010
Corneal hysteresis		
Age (years)	−0.05 (−0.09 - −0.01)	0.032
Sex (male/female)	1.83 (1.01-2.66)	<0.001
Maximum keratometry (diopter)	−0.22 (−0.45-0.01)	0.060
Anterior chamber volume	0.01 (0-0.02)	0.007

CI: Confidence interval

Discussion

This study is one of the few studies investigating the distribution of corneal biomechanical parameters in the elderly population. According to the results, the mean CH and CRF were 8.37 mmHg and 9.06 mmHg in subjects over 60 years, respectively. Few studies in this age range have been performed worldwide and, therefore, it is difficult to compare the results with similar studies.[1,21] In a study performed in the age range of 20–90 years, corneal biomechanical parameters were evaluated using the ORA. The mean CH and CRF were 11.49 mmHg and 11.40 mmHg in this study, respectively, which reduced to 11.00 mmHg and 10.50 mmHg in the age group of 60–80 years when the results were categorized according to age, indicating reduced biomechanical properties in the elderly compared to young subjects.[1] Some studies reported CH and CRF values of about 10.5 mmHg in older subjects.[1,21,26-29] For example, in a study on a population with a mean age of 43 years, these values were close to 11.5 mmHg. The reason for the difference between the results of this study and other studies was attributed to racial differences.[1] The mean age could also be another reason for the difference. The results were different in our study, and lower values were found. It should be noted that the sample size of the present study was relatively large, and only subjects over 60 years were included, while different studies used different definitions for old age.[27] Another important point is that this study was conducted in a limited age range. Attention should also be paid to ethnic differences. Two studies found that ethnicity affected the results of corneal biomechanical parameters.[30,31] Previous studies in the Iranian population showed a high prevalence of keratoconus.[32-34] On the other hand, these parameters decrease in keratoconus,[29,35,36] which may explain the lower values of these parameters in this study compared to other studies. Previous studies found a high prevalence of keratoconus in young and elderly populations.[32-34]

As mentioned earlier, the CRF and CH values decreased with age in participants aged over 60 years, which was consistent with previous studies.[1,3,26-28,37-40] The phenomenon of cross-linking and increased diameter and distance between corneal collagen fibers with age result in a decrease in corneal resistance and its viscoelastic properties. Studies have shown that corneal fragility reduces with age. Therefore, corneal structural resistance decreases with age.[18,41] CH is in fact related to the tissue and its characteristics.[42]

As mentioned earlier, the mean values of corneal biomechanical parameters were significantly higher in women in this study. Some studies investigated the relationship between sex and corneal biomechanical parameters. Although a number of studies found significantly higher values of corneal biomechanical parameters in women,[21,31,39,43] they did not report the results and attributed this finding to a larger proportion of women in their study populations.[43] However, a study found an indirect correlation and reported higher values of corneal biomechanical parameters in men, and attributed this finding to ethnic differences.[3] Some studies found no inter-gender difference.[38,44]

As mentioned earlier, the age range of the participants in the present study was limited to subjects above 60 years, and the hormonal profile in this age range is completely different from young people. Sex hormones decrease after menopause.[45] It should be noted that sex hormones reduce to their minimum values in the elderly, which decreases their effects. In addition, some studies found a higher prevalence of keratoconus in men.[46] A review study found that more outdoor activities in men made them more exposed to environmental factors such as sunlight. The age of onset of keratoconus also varies in men and women. Therefore, the differences in the age range of the subjects affect the results.[46]

Both CH and CRF had an indirect relationship with Kmax, suggesting that biomechanical properties reduce in subjects with higher Kmax. It should be noted that the corneal structure in fact becomes weaker with an increase in Kmax, and therefore it is not unexpected for corneal elastic properties to decrease. Keratoconus patients have higher Kmax values and weaker biomechanical properties.[35,47,48]

Corneal biomechanical parameters had no significant correlation with anterior depth and angle while they had a significant correlation with anterior chamber volume. In other words, corneal viscosity reduced with a decrease in the anterior chamber volume and vice versa. A study found no significant correlation between anterior chamber volume and corneal biomechanical parameters.[49] However, another study found a significant correlation between corneal biomechanical parameters and anterior chamber volume. This study used the CORVIS for measurement and found a decrease in corneal stiffness in glaucoma suspect patients, which could be considered an indicator for people with shallower anterior chambers and increased IOP values.[50]

Several studies investigated the relationship between CCT and corneal biomechanical parameters.[38,51,52] Only CRF, which is related to corneal stiffness, had a direct correlation with CCT in the present study. One study found a significant correlation between CRF and CCT and reported that CRF was an indicator for CCT, not CH. In fact, the behavior of these two parameters is quite different.[53]

The present study found no significant correlation between different refractive errors and corneal biomechanical parameters, which is consistent with a number of previous studies.[38,43,54] However, some studies found a significant correlation between these parameters. It should be noted that the final SE and age range (mostly pediatric patients) were different in these studies.[19,37,55]

One of the limitations of this study is the limited age range of the subjects. A wider age range would have provided more comprehensive information on corneal biomechanical changes with age. Another limitation was that the Corvis ST (OCULUS, Germany) was not used together with the ORA, which would have provided comprehensive information on corneal biomechanics.

The present study was an extensive study of the biomechanical properties in a large sample size of subjects over 60 years. This study provides valuable information considering a lack of similar studies exclusively conducted in this age range. The differences in the results were most likely due to racial differences. The evaluation of corneal biomechanical parameters can provide valuable information for examination and diagnosis purposes.

Financial support and sponsorship

This project was supported by Mashhad University of Medical Sciences, Mashhad, Iran.

Conflicts of interest

There are no conflicts of interest.

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