TÜBİTAK

Turkish Journal of Medical Sciences

http://journals.tubitak.gov.tr/medical/

Research Article

Turk J Med Sci
(2014) 44: 687-690
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doi:10.3906/sag-1303-98

Age-related changes in biomechanical parameters of the cornea and intraocular pressure in a healthy Turkish population

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Received: 22.03.2013 • **Accepted:** 19.08.2013 • **Published Online:** 27.05.2014 • **Printed:** 26.06.2014

Background/aim: To investigate age-related changes in intraocular pressure (IOP) and biomechanical parameters of the cornea in healthy subjects.

Materials and methods: There were 404 healthy subjects included prospectively in this study. The subjects were divided into 3 groups (Group 1: 93 subjects aged <18, Group 2: 189 subjects aged between 18 and 59, and Group 3: 122 subjects aged ≥60). Corneal compensated IOP (IOPcc), Goldmann correlated IOP (IOPg), corneal hysteresis (CH), and corneal resistance factor (CRF) were measured by the Ocular Response Analyzer.

Results: When all the study groups were evaluated, a moderately significant negative correlation was found between age and CH and between age and CRF (Spearman's rho = –0.372 and –0.353, respectively; P < 0.0001 for both correlations). There were significant age-related differences among the 3 groups in terms of IOPg, CH, CRF, and central corneal thickness (P = 0.002, P = 0.000, P = 0.000, P = 0.006). There was no confirmation of any difference of IOPcc among the groups (P = 0.427).

Conclusion: The mean values of IOPg, CH, and CRF were lower than the other parameters in Group 3 but no significant differences were determined in IOPcc values in the age groups.

Key words: Corneal biomechanics, corneal hysteresis, corneal resistance factor, intraocular pressure, ocular response analyzer

1. Introduction

The Goldmann applanation tonometer (GAT), the gold standard method used to measure intraocular pressure (IOP), is affected by central corneal thickness (CCT), corneal biomechanical parameters, and some clinical conditions such as astigmatism, corneal edema, and ocular surface diseases.

The Ocular Response Analyzer (ORA; Reichert Inc., Depew, NY, USA) is an instrument that measures IOP free from the influence of corneal biomechanical factors (1–3). It provides measurements of the corneal hysteresis (CH), corneal resistance factor (CRF), Goldmann-correlated IOP (IOPg), and corneal compensated IOP (IOPcc).

As some corneal anatomical, histological, and topographic changes occur with aging (4,5), there should also be some changes in corneal biomechanical parameters. In this study, our aim was to investigate age-related changes in IOP and corneal biomechanical parameters in healthy subjects using the ORA.

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2. Materials and methods

Our prospective study involved 189 eyes of 189 (46.8%) males and 215 eyes of 215 (53.2%) females who applied to the Ankara Ulucanlar Eye Research Hospital for routine ocular examination. The study was approved by the ethics committee of the Ankara University Faculty of Medicine. All of the study procedures were conducted in accordance with the Declaration of Helsinki and upon receipt of informed consent from all the participants.

Healthy subjects with no familial or personal history of systemic diseases, glaucoma, or ocular problems, except refractive errors, were included. The exclusion criteria were eyes with an IOP of >21 mmHg by GAT, glaucomatous optic nerve appearance (cup-to-disc ratio greater than 0.6, vertical cup asymmetry more than 0.2, neuroretinal rim loss or notching, with or without disc hemorrhages and nerve fiber layer defects), the presence of active ocular inflammation and pseudoexfoliation, and high spherical (above ±3.0 D) or cylindrical (above ±1.0

D) refractive errors. Individuals with a background of any systemic disease, corneal disease, aphakia, contact lens use, and ocular trauma or ocular surgery and pregnant subjects were excluded from the study.

The subjects were divided into 3 age groups (Group 1: 93 subjects aged <18, Group 2: 189 subjects aged between 18 and 59, and Group 3: 122 subjects aged ≥60). All the subjects underwent detailed ophthalmologic examinations, including best-corrected visual acuities with Snellen charts, slit-lamp anterior chamber examinations, dilated fundus examinations, CCT measurements by ultrasonic pachymeter, and IOP measurements with a GAT.

Corneal biomechanical parameters were measured by the same experienced physician (ES) according to normal clinical practice and the manufacturer's (Reichert) guidelines for the ORA between 0900 and 1100 hours. An air puff indents the cornea to a flat shape and then to a slight concavity. When the air puff is turned off, the cornea first becomes flat and then resumes its normal convex shape. The instrument records the pressure at the 2 points when the cornea is flat (P1 and P2). CH, the viscous dampening in the cornea to a deformation, is the difference between P1 and P2 and is related with viscoelastic properties of the cornea. IOPg is the mean of P1 and P2. IOPcc is the most accurate IOP, independent from corneal properties, and is derived from the equation P2 – (kP1). CRF is related to elastic behavior and the stiffness of the cornea.

Since a strong correlation was found between the values of the right and left eyes, the right eyes were included in the study. For the continuous variables, the data were tested for normality by using Kolmogorov–Smirnov test, histograms and P–P plots for all the groups. All the continuous data, except age, had a normal distribution for all 3 groups, and they were compared using an ANOVA test. Age was compared among the groups using the Kruskal–Wallis test. The correlations between age and CH, CRF, IOPcc, IOPg, and CCT values were evaluated using the Spearman correlation test for all the groups. Categorical variables were compared by chi-square test. Statistical significance was set as $P < 0.05$. All statistically analyses were performed using SPSS 16.

3. Results

The demographic characteristics of the subjects in all groups are summarized in Table 1. The mean age of all the subjects was 42.7 ± 22.2 (8–86) years. The mean values of IOPcc, IOPg, CH, and CRF were 15.7 ± 3.1 (8.0–22.5) mmHg, 14.9 ± 3.2 (6.0–22.0) mmHg, 9.9 ± 1.7 (5.0–14.6) mmHg, and CRF 9.9 ± 1.8 (5.0–15.4) mmHg, respectively (Table 2). There were significant age-related differences among the 3 age groups in terms of IOPg, CH, CRF, and CCT (ANOVA test, P = 0.002, P = 0.000, P = 0.000, P = 0.006, respectively), but no significant differences were found among the groups in terms of IOPcc (ANOVA test, P = 0.427).

When all the study groups were evaluated, a moderately significant negative correlation was found between age and CH and between age and CRF (Spearman's rho = –0.372 and –0.353, respectively; P < 0.0001 for both correlations). Significantly weak negative correlations were found between age and IOPg and between age and CCT (Spearman's rho = –0.121, P = 0.015, and Spearman's rho = –0.155, P = 0.004, respectively). Moreover, there was no correlation between age and IOPcc (Spearman's rho = 0.058, P = 0.247).

4. Discussion

The age-related increase in corneal stiffness by increased collagen cross-linking may cause changes in corneal biomechanical parameters (6–10). In this study, we investigated these changes in a healthy Turkish population. We determined a significant negative correlation between age and CH and CRF, which might be caused by age-related corneal stiffness and a decrease in corneal elastic behavior. While Kamiya et al. (11) and Kirwan et al. (12) found no age-related differences in CH in 86 adults and 42 children, respectively, some other reports support a decrease in CH due to aging (6,8–10). These different results might be caused by the number and demography of the subjects. Thus, to avoid any discrepancies in our study, the utmost care was taken in selecting the age and sex distribution of the groups.

Table 1. The demographic characteristics of the subjects.

	Group 1 Mean ± SD	Group 2 Mean ± SD	Group 3 Mean ± SD	All subjects Mean ± SD	*P-value
Number of subjects	93	189	122	404	
Age	13.1 ± 2.9	39.9 ± 10.7	69.6 ± 6.6	42.7 ± 22.2	0.0001*
Sex: Number (%)					
Male	37 (39.8)	89 (47.1)	63 (51.6)	189 (46.8)	0.224**
Female	56 (60.2)	100 (52.9)	59 (48.4)	215 (53.2)	

*: Kruskal–Wallis test, **: chi-square test.

Table 2. The corneal biomechanical parameters of the subjects.

	Group 1 Mean ± SD	Group 2 Mean ± SD	Group 3 Mean ± SD	All subjects Mean ± SD	*P-value
IOPcc (mmHg)	15.4 ± 3.3	15.9 ± 3.1	15.8 ± 3.0	15.7 ± 3.1	0.427*
IOPg (mmHg)	15.5 ± 3.2	15.1 ± 2.9	14.1 ± 3.3[x]	14.9 ± 3.2	0.002*
CH (mmHg)	10.8 ± 1.6	10.1 ± 1.6	9.1 ± 1.4[µ]	9.9 ± 1.7	0.000*
CRF (mmHg)	10.8 ± 1.6	10.1 ± 1.7	8.9 ± 1.7[µ]	9.9 ± 1.8	0.000*
CCT (µm)	549.4 ± 37.8	541.3 ± 28.9	533.8 ± 36.5[ŋ]	540.7 ± 34.2	0.006*

*: ANOVA test; [x]: Group 1 and Group 2 are similar, Group 3 is lower than the first 2 groups; [µ]: all the groups are significantly different; [ŋ]: Group 1 and Group 3 are significantly different, Group 2 is similar to Group 1 and Group 3 ([x, µ, ŋ]: post-hoc Tukey test).
IOPcc: Corneal compensated intraocular pressure, IOPg: Goldmann-correlated IOP, CH: corneal hysteresis, CRF: corneal resistance factor, CCT: central corneal thickness.

The age-related increase in corneal stiffness may cause a decrease in the corneal capacities of elastic resistance and energy absorption (10). CH was found to be correlated with optic nerve surface incompliance related to intermittent increases in IOP in glaucoma subjects (13). Decreased elasticity of the lamina cribrosa and low CH are thought to be related with increased optic nerve sensitivity to neurodegenerative factors, both in glaucoma and in older nonglaucomatous subjects (13). Low CH is related to the progression of glaucoma, but corneal biomechanical characteristics and the effects of aging on them are different in healthy subjects and subjects with keratoconus, glaucoma, or refractive surgery (9). Accordingly, studies focusing on corneal biomechanical characteristics in normal populations are needed to determine normal values. In our study, healthy subjects with no systemic or ocular diseases other than refractive errors were included. Individuals with a history of glaucoma, raised IOP, or ocular surgery were excluded. Considering that racial factors can affect corneal biomechanical parameters, in our study all of the subjects were Turkish Caucasians. We detected decreases in CCT, CH, and CRF related to aging. However, the literature presents some contradictory results. Shen et al. (14) found no correlation between CH and age in healthy subjects or subjects with high myopia (above –9.0 D). Kirwan et al. (12) found no significant differences in CH between adults and children, while Ortiz et al. (15) determined low values of CH in older subjects. As per the study by Ortiz et al. (15), we found the highest mean values of CCT, CH, and CRF in Group 1 with a mean age of 16, and this result supports the fact that CH and CRF decrease with aging.

Kamiya et al. (10,11) reported in their studies that CCT was the most important factor affecting corneal biomechanics. Nevertheless, they could not find any correlation between CCT and age, and they pointed out that age-related decreases in CH and CRF might have been associated with structural changes in collagen cross-linking (10).

There may be some diurnal changes in CCT. Kida et al. (6) determined that aging might cause decreases in CH and CRF without any diurnal variations, but CCT had diurnal variations without age-related changes. Kamiya et al. (10) reported that low CH and CRF values might have been associated with low CCT in a Japanese population, but they also suggested that there might be some changes in corneal biomechanics independent of CCT and IOP.

In some of the earlier studies, age had no significant effect on CCT (16–22). All these reports postulated that the number and race of the subjects, and differences in pachymeter instruments, might affect the results (10). Altinok et al. (22) also did not find any effects of age on CCT in their study. Unlike the findings presented in their study, a weak negative correlation was found between age and CCT in this study.

IOPg is the average of P1 and P2 and is correlated with IOP as measured by GAT. IOPcc is the most accurate IOP, independent of corneal properties. Kamiya et al. (10) reported no relationship between IOPcc and IOPg. In this study, a weak correlation was found between age and IOPg, but no effects of age on IOPcc were observed. Based on this finding, it can be said that the measurements of IOPcc provide the most accurate results in advanced age groups for IOP measurement.

Our study demonstrates that aging can cause significant decreases in CH and CRF. It also supports a weak negative correlation between aging and IOPg, but no age-related differences in IOPcc. Studies on corneal biomechanical characteristics in a normal population are needed to determine normal values; thus, further investigations involving the use of the ORA and larger populations with different demographic characteristics should be encouraged.

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