Original Article

Factors Affecting Corneal Hysteresis in Taiwanese Adults

Jia-Kang Wang[1,2,3,4,], Tzu-Lun Huang[1,5], Pei-Yuan Su[1,4,6], Pei-Yao Chang[1,4]*

1 Department of Ophthalmology, Far Eastern Memorial Hospital, New Taipei City, Taiwan, China

2 Department of Medicine, National Yang Ming University, Taipei City, Taiwan, China

3 Department of Healthcare Administration and Department of Nursing, Oriental Institute of Technology, New Taipei City, Taiwan, China

4 Department of Medicine, National Taiwan University, Taipei City, Taiwan, China

5 Institute of Medical Sciences, Tzu Chi University, Hualien City, Taiwan, China

6 Department of Medicine, Fu Jen Catholic University, New Taipei City, Taiwan, China

Abstract

Purpose: To investigate the correlation of various corneal hysteresis (CH) factors in Chinese adults.

Methods: From January 2009 to November 2011, the healthy right eyes of a total of 292 adults were recruited into the study. Goldmann-correlated intraocular pressure (IOPG) and CH were measured using an ocular response analyzer (ORA). Central corneal thickness was measured using the ORA's integrated handheld ultrasonic pachymeter. The IOLMaster was used to obtain the ocular biometric measurements including axial length, anterior chamber depth, and keratometric values. The Pearson correlation coefficient was used to test correlations between CH and quantitative factors. The chi-square test was used to detect differences in categorical values.

Results: Longer axial length (P=0.0001), lower IOPG (P=0.03), older age (P=0.003), and thinner central corneal thickness (P=0.0001) were significantly associated with lower CH. The anterior chamber depth (P=0.34), gender (P=0.23), and corneal curvature (P=0.18) had no relationship to CH.

Conclusion: Various factors including axial length, intraocular pressure, age, and central corneal thickness can affect measurement of corneal biomechanical properties in Chinese adults. But the anterior chamber depth, gender, and corneal curvature were irrelevant to CH. (***Eye Science 2015;30:89–93***)

Keywords: corneal hysteresis; biometry; ocular response analyzer; axial length; central corneal thickness

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* **Corresponding author**: Dr. Jia-Kang Wang, Department of Ophthalmology, Far Eastern Memorial Hospital, 21 Sec 2, Nan Ya South Road, Pan-chiao District, New Taipei City, 220, Taiwan, China. E-mail: jiakangw2158@gmail.com

Introduction

Corneal hysteresis (CH) is described as viscous damping due to the viscoelastic resistance of the cornea to deformation caused by an air jet or puff of air from a tonometer[1]. CH can be measured by an Ocular Response Analyzer (ORA, Reichert Ophthalmic Instruments, Buffalo, NY, USA) in vivo[1-3].

CH can be affected by various ocular disorders and surgery. In previous studies, CH values were found to be significantly lower in cases of keratoconus, Fuchs' dystrophy, and glaucoma[1,4-6], and after laser in situ keratomileusis (LASIK)[6]. Systemic diseases such as diabetes also affected CH[7].

In normal adults, CH values vary between individuals, and CH is associated with several factors: age, gender, intraocular pressure (IOP), and central corneal thickness (CCT)[6-11]. CH was found to be lower in eyes with high myopia and long axial length (AL) compared to normal eyes, and to be affected by race[11-14].

However, the relevance of some factors to CH in normal adults is controversial. Our aim was to identify the biometric and demographic factors, including axial length, intraocular pressure, central corneal thickness, anterior chamber depth, corneal curvature, age, and gender, affecting CH in normal eyes of Chinese adults.

Subjects and methods

From January 2009 to November 2011, the healthy

right eye of a total of 292 adults (145 men, 147 women) from regular patients were recruited from the Department of Ophthalmology, Far Eastern Memorial Hospital, Taipei, Taiwan, China into our study. Subjects with previous ocular surgery, acute or chronic ocular trauma, glaucoma, diabetes mellitus, corneal or retinal disease, or history of wearing contact lenses were excluded. The IOLMaster (Carl Zeiss, Jena, Germany) was used to measure AL, anterior chamber depth (ACD), and mean keratometric value (K). An ORA was used to measure the Goldmann-correlated intraocular pressure(IOPG) and CH, and the integrated handheld ultrasonic pachymeter of the ORA was used to measure CCT under topical anesthesia. Each subject was assigned to the IOLMaster measurement first and then the ORA measurement, because the former examination was noncontact and not requiring anesthesia. All these examinations were performed by a technician who was experienced in performing the study protocol. All measurements were performed at the same time of day to decrease diurnal effects. Demographics of the patients were also recorded. All patients signed informed consent forms agreeing to the examinations.

This research was carried out in accordance with the Declaration of Helsinki and after obtaining approval from the Institutional Review Board of Far Eastern Memorial Hospital (Clinical Trials.gov Identifier: NCT01235780). The Pearson correlation coefficient was used to test correlations between CH and quantitative factors, including age, AL, ACD, K, CCT, and IOPG. The chi-square test was used to assess the significance of the correlation between CH and gender. The results are expressed as mean ± standard deviation, and p value less than 0.05 was

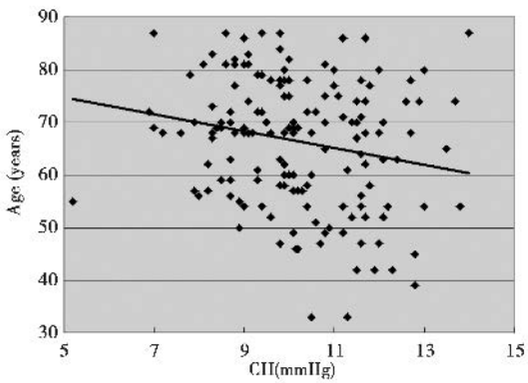

Figure 1 Graph showing a significantly negative correlation between the age and the value of corneal hysteresis (P = 0.003).

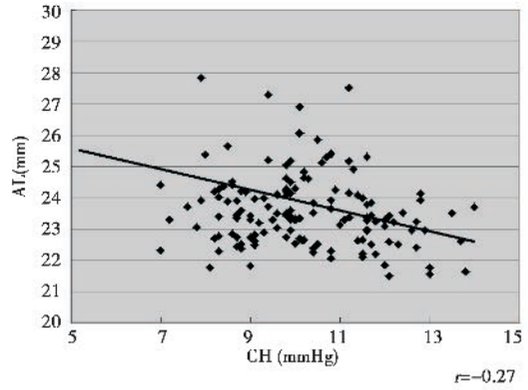

Figure 2 Graph showing a significantly negative correlation between the axial length and the value of corneal hysteresis (P = 0.0001).

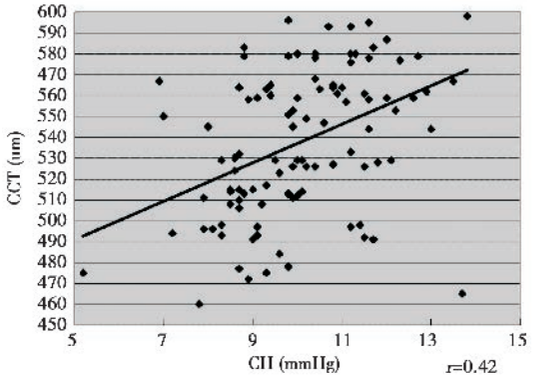

Figure 3 Graph showing a significantly positive correlation between the central corneal thickness and the value of corneal hysteresis (P = 0.0001).

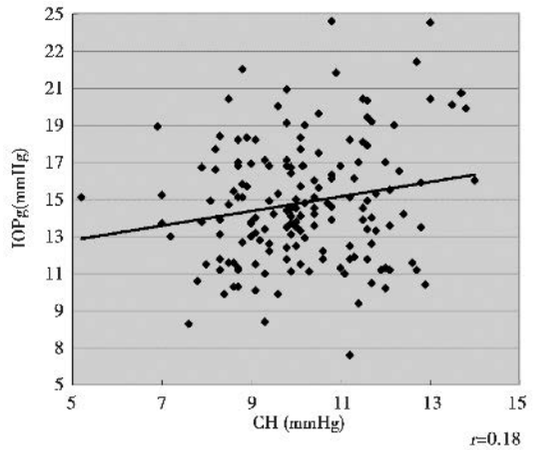

Figure 4 Graph showing a significantly positive correlation between the Goldmann-correlated intraocular pressure and the value of corneal hysteresis (P = 0.03).

considered statistically significant.

Results

The mean CH was 10.16±1.55 mmHg (range: 8–14). The age (mean 66.51±12.12 years; range, 33–87) and AL (mean 23.86±1.95 mm; range, 21.5–33.5) were significantly and negatively correlated with CH (the Pearson correlation coefficient[r]=–0.21, P=0.003 [Figure 1] and r=–0.27, P=0.0001 [Figure 2], respectively).

The CCT (mean 537.77 ± 35.24 μm; range, 460–598) and IOPG (mean 14.82 ± 3.28 mmHg; range, 6.6–24.6) were significantly and positively correlated with CH (r=0.42, P=0.0001 [Figure 3] and r= 0.18, P=0.03 [Figure 4], respectively).

The ACD (mean 2.94 ±0.43 mm; range, 1.83 – 4.13) and K (mean 44.23±1.48 diopters; range, 41–48.12) were not correlated with CH (r =–0.03, P = 0.34 and r = 0.12, p = 0.18, respectively). The CH was comparable in male and female eyes(P=0.23).

Discussion

CH is determined during rapid motion of the cornea in response to a short-duration (20-ms) pulse of air pressure applied to the cornea[1]. An electro-optical system detects the corresponding deformation of the cornea. The air pulse causes the cornea to move beyond the point of applanation to form a slight indentation. When the pressure of the air pulse decreases, the cornea returns to its normal configuration, passing for a second time the point of applanation. The difference in the two pressure values at the point of applanation, which is called the CH, depends on the viscoelastic properties of the corneoscleral shell. The average of the two applanation pressures is the IOPG.

Ortiz and associates reported lower CH values in older eyes; the difference in CH value between the youngest (9–14 years) and oldest (60–80 years) age groups was statistically significant[6]. Fontes and associates reported that CH in healthy adults was negatively associated with age[9]. It has also been demonstrated that the cornea stiffens with age as a result of glycation-induced cross-linking of collagen molecules[15]. Kamiya and coauthors demonstrated that aging significantly decreases CH without significantly changing CCT or IOP, suggesting that age-related structural changes due to collagen cross-linking may lead to a degeneration of corneal biomechanical properties independent of CCT or IOP[8]. These findings are in accordance with our present finding that older age is correlated with lower CH value.

Prior studies demonstrated that CH was positively associated with CCT measured by optical coherence tomography in normal Chinese[12,13]. Among healthy Japanese and Caucasian eyes, higher CH was associated with thicker CCT measured by ultrasonic pachymetry[10,16]. In normal eyes in Brazil, CH was significantly correlated with CCT measured using a Pentacam analyzer[9]. In the current study of normal Chinese eyes, CH was significantly and positively correlated with CCT measured using ultrasound. Thus, our findings are in agreement with those of previous studies, and CCT regardless of method of measurement is strongly associated with CH. It is hypothesized that CCT is an important determinant of corneal viscoelasticity in various races.

A significant and positive correlation between IOPG and CH was also found in cases of anisometropia[13]. In this article, eyes with increased CH were found to have higher IOPG, which was positively correlated with CCT (r=0.17, P=0.02). We postulated that reduction in IOPG may be caused by decrease in CCT. On the other hand, decreased IOPG may distort the cornea, change the physiological properties of the cornea, and alter CH value. For example, IOP readings are falsely low after LASIK surgery compared to normal IOP readings[3]. The reason may be corneal thinning due to ablation, or change in the biomechanical properties of the cornea as a result of flap creation, or both[6,17].

Xu and coauthors revealed, in patients with high anisometropia, that CH was lower in the myopic eye than in the contralateral control eye[13]. Shen and coauthors reported that CH was significantly lower in patients with high myopia (defined as spherical equivalent greater than-9 diopters), than in normal subjects[12]. In the current study, CH was also lower in eyes with longer AL. Previous studies found that change in CCT does not depend on degree of myopia or AL[13,18-20]. Lower CH in long eyes cannot be explained by changes of CCT, and may indicate

that the biomechanical properties of the cornea have become altered. Scleral biomechanical properties such as stiffness decrease during the progression of myopia because of pathologic changes in the scleral collagen[21,22]. The corneal stroma is composed of a collagenous extracellular matrix that is continuous with the sclera[21]. Elongation of AL can change the biomechanical properties of the sclera and possibly the cornea[12,13].

Kamiya and coauthors found no significant correlation between CH and gender in normal Japanese[10]. The present study also found no correlation. However, Fontes and coauthors reported that CH was higher in the normal healthy eyes of Brazilian women than in the normal healthy eyes of Brazilian men[9]. In Italian population, men demonstrated a higher CH than women did[23]. East Asians (Chinese and Japanese) were very different from South Americans and Italians in this respect. Therefore, racial difference may explain the gender difference.

Prior studies showed no significant correlation between CH and mean keratometric values measured by an autorefractometer and by a Pentacam[9,10]. In the present study, CH was not associated with K measured by the IOLMaster. Therefore, K measured by different approaches was not associated with CH.

The association was not significant between CH and ACD, either measured by Pentacam[9], anterior segment tomographer[24], or IOLMaster in our study.

CH values in healthy Taiwan-Chinese adults determined by the present study were comparable to those in children in our prior study[5]. Previous studies consisted of Hong Kong-Chinese[20] and Singapore-Chinese[26] adults also having similar CH data in Taiwan-Chinese in this study. CH values in East Asians (Japanese[10], Koreans[24], and Chinese[20,26]) were slightly lower than those in healthy Caucasians[1,16]. Therefore, it is hypothesized that biomechanical properties of the cornea may be influenced by ethnicity[1,10,13,16]. Actually, differences in CH values have been noted between healthy black and white subjects[14].

The ORA provides reproducible corneal biomechanical and intraocular pressure measurements[27]. The inter-observer and intra-observer short-term repeatability of ORA measurements was almost perfect for CH[28]. Diurnal variation in CH was not detectable in healthy eyes of Asian subjects[29]. Therefore, we believe that the repeatability of measurement by this device is reasonable.

Evaluation of CH is used as a screening tool for forme fruste keratoconus, to prevent postoperative unexpected corneal ectasia after LASIK[30]. The parameters of a newly developed Corvis ST tonometer (Oculus, Wetzlar, Germany), and CH and CRF values of ORA, can all evaluate biomechanical changes after LASIK[31,32]. Besides, corneal-compensated IOP (IOPCC), which excluding confounding corneal biomechanical properties in measurement of IOP, can be calculated by incorporating CH value and IOPG in ORA[1,2]. However, the results of this study demonstrated that the CH value should be adjusted according to axial length, intraocular pressure, age, and central corneal thickness.

In summary, longer axial length, lower Goldmann-correlated intraocular pressure, older age, and thinner central corneal thickness were significantly associated with lower CH in healthy Chinese adults, but anterior chamber depth, corneal curvature, and gender had no relevance to CH.

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Conflicts of interest

The authors have no proprietary or commercial interest in any materials discussed in this article. The authors declare no financial support or conflicts of interest.

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