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The Relation between Corneal Horizontal Diameter and Ocular Dimensions and Stature in Japanese Adults

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Abstract **Original Research Article**

To evaluate the relation between corneal horizontal diameter (white-to-white, CHD) and axial length (AL), corneal radius of curvature (CR), anterior chamber depth (ACD), and body height, we measured CHD, AL, CR, and ACD using IOLMaster in 333 eyes of 333 Japanese volunteers and preoperative adults aged 21-89 years. There were 161 male subjects and 172 female subjects. The CHD in Japanese adults was 12.05±0.44mm. The CHD was significantly greater in males (12.17±0.45mm) than in females (11.95±0.41mm) and significantly greater in subjects under 50 years of age than in subjects over 50 years of age. The CHD was strongly associated with CR and ACD.
Keywords: corneal horizontal diameter, axial length, corneal radius of curvature, anterior chamber depth, body height.

INTRODUCTION

Measurement of corneal diameter yields important clinical information for diagnostic purposes (i.e. microcornea, macrocornea, etc.) as well as for new surgical procedures (i.e. phakic intraocular lens implantation, etc.) [1]. Although normal corneal diameter is described in many textbooks, the references had been a few in MEDLINE until 2010. We often think that corneal diameter in elderly people and women are a little smaller than the one in young people and men during cataract surgery and contact lens prescription.

The purposes of this research are as follows; 1) to measure corneal horizontal diameter (white-to-white, CHD) in Japanese adults, 2) to evaluate the relation between CHD and age and gender, and 3) to evaluate the relation between CHD and axial length (AL), corneal radius of curvature (CR), anterior chamber depth (ACD), and body height.

Subjects and Methods

To evaluate above purposes, CHD, AL, CR, and ACD was measured with IOLMaster (Carl Zeiss, Germany) in 333 eyes of 333 Japanese volunteers and preoperative adults aged 21-89 years (mean, 54±19 years). There were 161 male subjects and 172 female subjects.

CHD measurement was repeated three times and the average was calculated. Five valid readings of AL and ACD and three keratometry readings were obtained with IOL Master. CR was defined as the average of the greatest corneal radius of curvature (R1) and the least corneal radius of curvature (R2). The heights were self-reported.

Basically, both eyes was measured, however, the eyes with a history of ocular surgery were excluded in this study. The eyes with refractive errors and cataracts were included in this study. In cases with the data obtained from both eyes, only the data from the right eyes were used because there was a high correlation between right and left eye CHD (r=0.894).

Correlation between CHD and age was statistically analyzed by Spearman's rank correlation test. Correlations between CHD and the other parameters were statistically analyzed by Pearson correlation coefficients and stepwise multiple regression analysis. To analyze the relation between CHD and age alternatively, the subjects were divided into two age groups: group 1, 21-49 years of age (n=135); group 2, 50-89 years of age (n=198) and the statistical analysis was performed by non-paired t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

CHD was normally distributed as shown in Fig. 1. The mean CHD was 12.05±0.44mm (Table 1). The mean AL, CR, ACD, height was 24.10±1.50mm, 7.70±0.28mm, 3.27±0.47mm, and 160.3±9.4cm, respectively (Table 1).

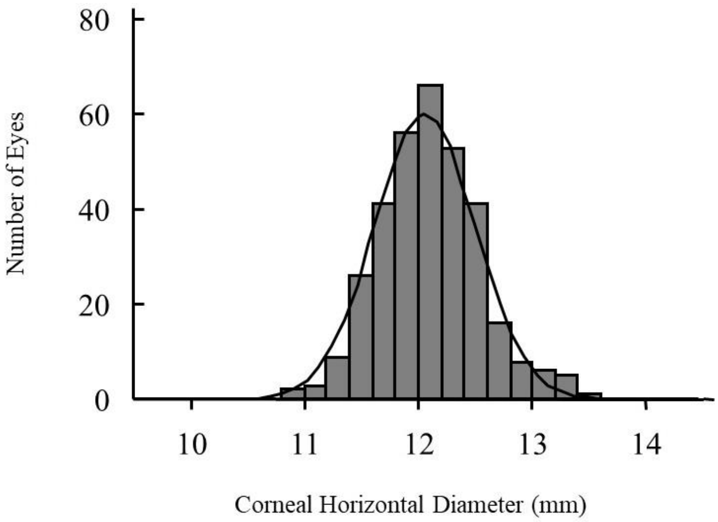

Fig-1: Distribution of corneal horizontal diameter

Table-1: Ocular dimensions and heights of all subjects

	Mean±SD	Range
Corneal horizontal diameter (mm)	12.05±0.44	10.80-13.50
Axial length (mm)	24.10±1.50	21.05-29.97
Corneal radius of curvature (mm)	7.70±0.28	6.79-8.52
Anterior chamber depth (mm)	3.27±0.47	1.89-4.33
Height (cm)	160.3±9.4	134-190

The mean CHD separated by age was shown in Table 2. The mean CHD was 12.17±0.45mm in males and 11.95±0.41mm in females with statistically significant gender difference ($p<0.001$) (Fig. 2).

Table-2: Corneal horizontal diameter by age

	All Subjects		Male		Female	
Age	mean ± SD	n	mean ± SD	n	mean ± SD	n
20-29	12.29±0.42	46	12.39±0.41	26	12.15±0.41	20
30-39	12.29±0.43	55	12.42±0.40	29	12.15±0.42	26
40-49	12.05±0.42	34	12.20±0.39	17	11.89±0.40	17
50-59	11.95±0.42	42	11.99±0.42	16	11.92±0.42	26
60-69	12.01±0.41	74	12.07±0.40	37	11.95±0.42	37
70-	11.86±0.39	82	11.95±0.45	36	11.79±0.33	46
Total	12.05±0.44	333	12.17±0.45	161	11.95±0.41	172

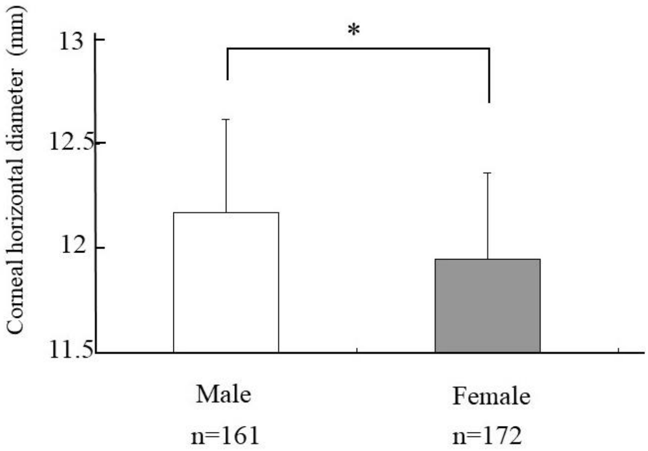

Fig-2: Relationship between corneal horizontal diameter and gender
*p<0.001, non-paired t-test

CHD in males was 12.36±0.41mm in group 1 and 12.01±0.42mm in group 2, while the corneal diameter in females was 12.08±0.42mm in group 1 and 11.88±0.39mm in group 2. CHD was significantly greater in young group of each gender (p<0.0001) (Fig. 3).

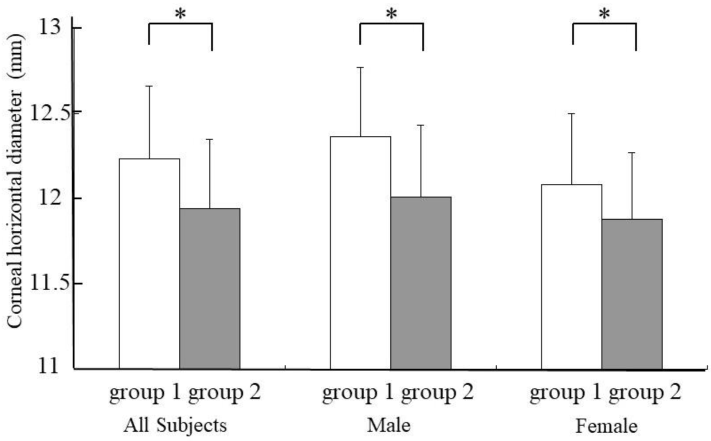

Fig-3: Relationship between corneal horizontal diameter and age
group 1=21-49 years of age, group 2=50-89 years of age, *p<0.0001, non-paired t-test

CHD decreased with age in all subjects (Fig. 4, Spearman's rank correlation test, ρ=−0.363, p<0.0001). CHD decreased with age in each gender group (p<0.0001).

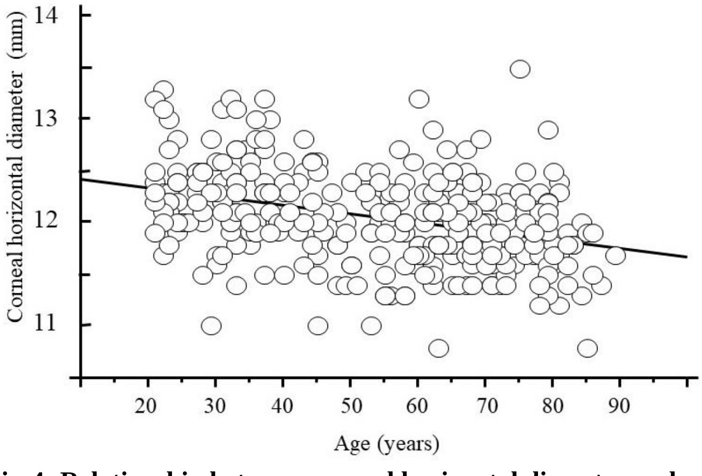

Fig-4: Relationship between corneal horizontal diameter and age
y=12.506−0.008×Age; ρ=−0.363 (p<0.0001)

CHD increased with AL (Fig. 5), CR (Fig. 6), ACD (Fig. 7), and body height (Fig. 8).

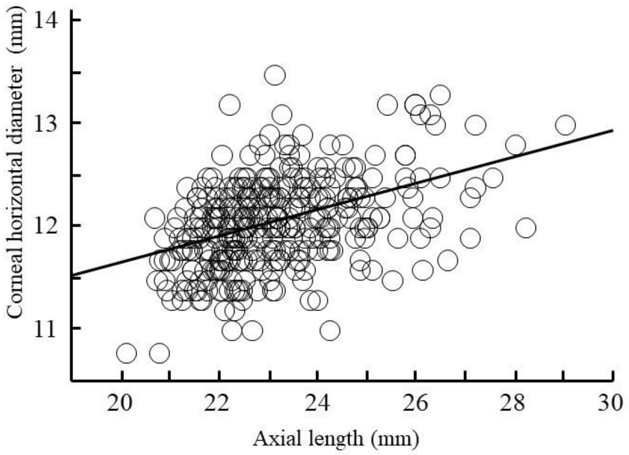

Fig-5: Relationship between corneal horizontal diameter and axial length (AL)
y＝8.986＋0.127×AL; r = 0.431 (p<0.0001)

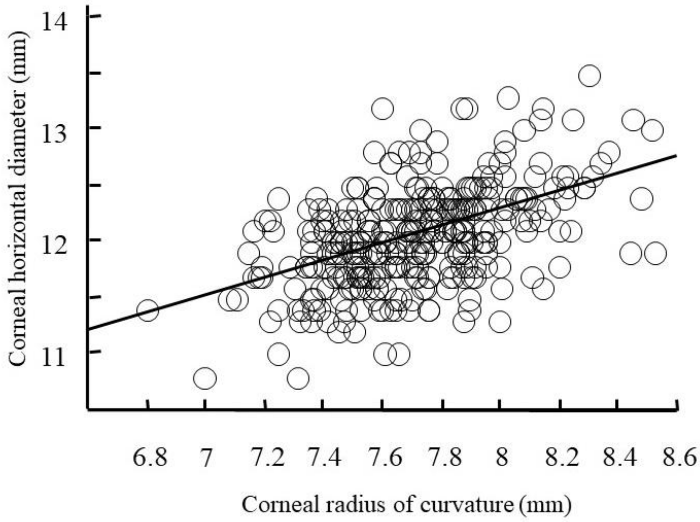

Fig-6: Relationship between corneal horizontal diameter and corneal radius of curvature (CR)
y＝6.092＋0.774×CR; r = 0.491 (p<0.0001)

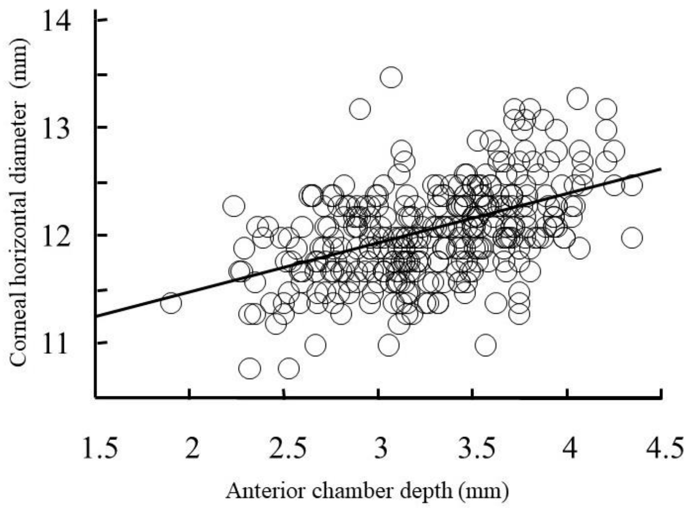

Fig-7: Relationship between corneal horizontal diameter and anterior chamber depth (ACD)
y＝10.584＋0.45×ACD; r = 0.473 (p<0.0001)

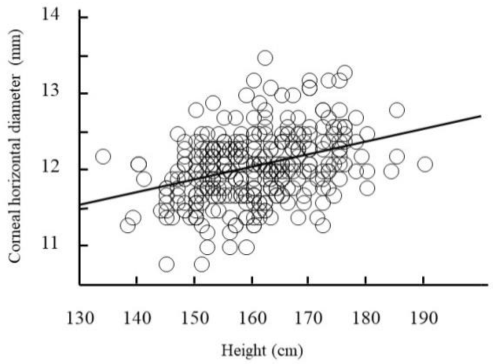

Fig-8: Relationship between corneal horizontal diameter and height
y=9.379+0.017×Height; r = 0.355 (p<0.0001)

The simple correlation coefficients between CHD and AL, CR, ACD, and height were 0.431, 0.491, 0.473, and 0.355, respectively (Pearson correlation coefficient, p<0.0001) (Table 3). The partial correlation coefficients between CHD and AL, CR, ACD, and height were -0.029, 0.407, 0.346, and 0.049, respectively, suggesting that CHD was closely related to CR and ACD.

Table-3: Correlation coefficient

	Simple Correlation Coefficient				
	CHD	AL	CR	ACD	Height
CHD	1.000				
AL	0.431*	1.000			
CR	0.491*	0.469*	1.000		
ACD	0.473*	0.607*	0.164**	1.000	
Height	0.355*	0.371*	0.426*	0.366*	1.000
	Partial Correlation Coefficient				
	CHD	AL	CR	ACD	Height
CHD	1.000				
AL	-0.029	1.000			
CR	0.407	0.413	1.000		
ACD	0.346	0.513	-0.407	1.000	
Height	0.049	0.031	0.254	0.100	1.000

CHD: corneal horizontal diameter, AL: axial length, CR: corneal radius of curvature,
ACD: anterior chamber depth, *p<0.0001, **p<0.005

Stepwise multiple regression analysis revealed that CHD was correlated with CR and ACD. The following equation was derived by the analysis: CHD=5.640+0.670×CR+0.383×ACD. CHD calculated by this equation was strongly correlated with CHD by actual measurement (Fig. 9).

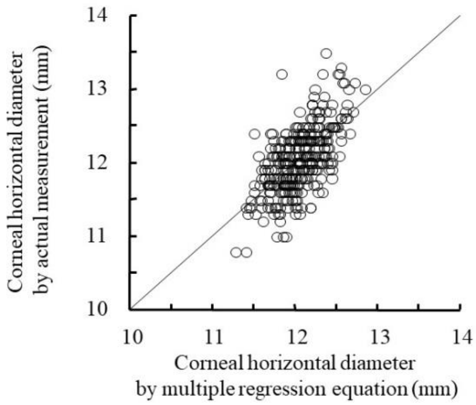

Fig-9: Stepwise multiple regression analysis
Corneal Horizontal Diameter=5.640+0.670×CR+0.383×ACD; r=0.635 (p<0.0001)
CR: corneal radius of curvature, ACD: anterior chamber depth

DISCUSSION

There are various reports on corneal diameter [1-19] (Table 1). In 2002, Wang and Auffarth [1] showed that very accurate white-to-white measurements are possible with the Orbscan. After that, there are several reports on corneal diameter for various purposes, such as the agreement of various devices [3, 8-10, 14, 19] and preoperative evaluation for phakic IOLs [7, 9, 14, 15, 18]. However, there were few population-based studies [2, 4]. The first published population-based study was done by Rüfer *et al*. [2] in 2005. Their study population included 390 healthy individuals between the ages of 10 and 80 years, and the mean corneal diameter was 11.71±0.42 mm as measured with the Orbscan. In 2010, Hashemi *et al*. [4] reported that the mean corneal diameter in the population of Tehran was 11.68±0.46 mm as measured with the Orbscan. In this present study, the mean corneal diameter was 12.05±0.44 mm as measured with the IOLMaster. According to previous study, values with IOLMaster are generally higher than those with the Orbscan [4, 9].

Table-4: Corneal horizontal diameter reported in different studies and their measurement device

References		Devices	No. of eyes (cases)	Age(mean± SD)	Sex eyes(cases)	Corneal horizontal diameter (mm) Total	Male	Female
Wang L et al. 2002 [1]	Germany	Orbscan	26(13)	NA	NA	12.01±035		
Rüfer F et al. 2005 [2]	Germany	Orbscan II	743(390)	10−80(40.7±16.4)	M/F (242/148)	11.71±0.42	11.77±0.37	11.64±0.47
Salouti R et al. 2009 [3]	Iran	Galilei	74(37)	27.4±7.2	M/F 18/56(9/28)	12.01±0.61		
		EyeSys	74(37)	27.4±7.2	M/F 18/56(9/28)	12.09±0.87		
		Orbscan II	74(37)	27.4±7.2	M/F 18/56(9/28)	11.67±0.29		
Hashemi H et al. 2010 [4]	Iran	Orbscan II	399(410)	14−81(40.7±16.8)	M/F 155/244	11.68±0.46	11.76±0.48	11.63±0.45
Venkataraman A et al. 2010 [5]	India	Orbscan	73(37)	NA	M/F (12/25)	1174±0.32		
		Eyemetrics	73(37)	NA	M/F (12/25)	11.92±0.33		
Sanchis-Gimeno JA et al. 2012 [6]	Spain	Orbscan II	379(379)	18−53(29±7)	M/F 198/181	11.9±0.2	11.9±0.2	11.8±0.2
Reinstein DZ et al. 2013 [7]	Italy	Orbscan II	50(25)	22−51(35.04±7.06)	NA	11.83±0.28		
Salouti R et al. 2013 [8]	Iran	Pentacam HR	101(101)	20−46(28±5)	M/F 41/60	11.76±0.38	1193±0.40	11.64±0.32
		Orbscan Iiz	101(101)	20−46(28±5)	M/F 41/60	11.66±0.37	1181±0.38	11.56±0.32
Martin R et al. 2013 [9]	Spain	Orbscan II	328(164)	18−67(36.4±9.3)	M/F 62/102	11.69±0.37		
		IOLMaster	328(164)	18−67(36.4±9.3)	M/F 62/102	12.19±0.40		
Huang J et al. 2014 [10]	China	AL Scan	68(68)	41−84(67.72±9.05)	M/F 27/41	1127±0.44		
		IOLMaster	68(68)	41−84(67.72±9.05)	M/F 27/41	NA		
Gharaee H et al. 2014 [11]	Iran	Orbscan II	2002(1001)	18−45(29.07±5.86)	M/F (385/616)	11.65±0.36	11.60±0.35	11.71±0.36
Fu T et al. 2015 [12]	China	IOLMaster	1721(1721)	40−91(57.0±8.7)	M/F (497/1224)	11.75±0.40		
Hashemi H et al. 2015 [13]	Iran	LENSTAR	4787(4787)	40−64(50.7±6.2)	M/F 41.9%/58.1%	11.87(mean)		
Chen Y et al. 2016 [14]	China	Orbscan II	100(100)	8−39(20.18±5.12)	M/F 51/49	11.57±0.34		
		iTrace	100(100)	8−39(20.18±5.12)	M/F 51/49	1133±0.36		
Guber I et al. 2016 [15]	Switzerland	Pentacam	107(56)	NA	NA	11.86±0.52		
		BioGraph	107(56)	NA	NA	12.12±0.51		
Shajari M et al. 2016 [16]	Germany	IOLMaster	40(40)	21−71(36.5±15.5)	M/F 17/23	12.0±0.3		
		Pentacam HR	40(40)	21−71(36.5±15.5)	M/F 17/23	11.8±0.4		
		LenStar	40(40)	21−71(36.5±15.5)	M/F 17/23	12.3±0.4		
		Visante OCT	40(40)	21−71(36.5±15.5)	M/F 17/23	12.0±0.5		
Sung Y et al. 2016 [17]	Korea	Pentacam HR	88(88)	(59±13)	M/F 34/54	11.4±0.5		
Zheng QY et al. 2016 [18]	China	Orbscan II	78(41)	21−45(31.21±7.48)	M/F 22/19	11.36±0.29		
Salouti R et al. 2017 [19]	Iran	IOLMaster	100(100)	33−86(65.9±3.3)	M/F 58/42	11.72±0.45		
		Pentacam HR	100(100)	33−86(65.9±3.3)	M/F 58/42	11.41±0.42		
present study	**Japan**	**IOLMaster**	**333(333)**	**21−89(54±19)**	**M/F 161/172**	**12.05±0.44**	**12.17±0.45**	**11.95±0.41**

Our results indicated significantly larger corneal diameters in men. Although Rüfer *et al*. [2] did not find statistically significant differences between male and female, values in male (11.68±0.37 mm) are larger than those in female (11.64±0.47 mm). In addition, corneal diameter in male was larger than that in female in many previous reports [4, 6, 8, 9].

In our study, CHD decreased with increasing age. Rüfer *et al*. [2] reported that age was significantly correlated with a decrease in the corneal diameter, whereas Hashemi et al. [4] found no significant correlation between age and the corneal diameter. However, these different findings may be attributable to ethnic, genetic, and environmental factors [4].

In our study, we evaluate the relation between CHD and AL, CR, ACD, and body height. However, there are few reports that describe the relationship between corneal diameter and other ocular biometrics. Hashemi *et al*. [13] described that corneal diameter significantly correlated with AL and CR. They indicated that corneas with a larger CR, i.e. flatter surface, are larger in diameter. Hashemi *et al.* [20] described decreases in AL of the eye with aging. Since AL is one of the important indices of eye size, when it is large, other ocular components would be large as well. There seems to be an optical explanation for this observation. We believe that as part of the emmetropization process in long eyes, which tend to be myopic, the cornea might elongate to increase CR and shift towards hyperopia to compensate for myopia [13]. On the other hand, as demonstrated, corneal diameter directly correlated with spherical equivalent. This relationship is due to the role of CR in different types of refractive error.

There are limitations to this study. First, we did not evaluate the refractive error data in this study. Second, it is necessary to examine the longitudinal changes for each individual. Furthermore, as only relatively normal corneas were measured in this study, the relevance of these results to post-operative corneas or corneas with pathological alterations remains unknown.

CONCLUSIONS

The CHD in Japanese adults was 12.05±0.44mm. The CHD was significantly greater in males than in females and significantly greater in subjects under 50 years of age than in subjects over 50 years of age. The CHD was strongly associated with CR and ACD.

Disclosure

No conflicts of interest were declared in relation to this paper.

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