Scholars Journal of Applied Medical Sciences

Abbreviated Key Title: Sch J App Med Sci ISSN 2347-954X (Print) | ISSN 2320-6691 (Online) Journal homepage: www.saspublishers.com **OPEN ACCESS**

Ophthalmology

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 ± 0.44 mm. The CHD was significantly greater in males (12.17 ± 0.45 mm) than in females (11.95 ± 0.41 mm) 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. **Copyright © 2019:** This is an open-access article distributed under the terms of the Creative Commons Attribution license which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use (NonCommercial, or CC-BY-NC) provided the original author and source are credited.

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 ± 0.44 mm (Table 1).

The mean AL, CR, ACD, height was 24.10 ± 1.50 mm, 7.70 ± 0.28 mm, 3.27 ± 0.47 mm, and 160.3 ± 9.4 cm, respectively (Table 1).



Corneal Horizontal Diameter (mm) Fig-1: Distribution of corneal horizontal diameter

	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 ± 0.41 mm in females with statistically significant gender difference (p<0.001) (Fig. 2).

	Table-2	: Corne	ai norizoittai (nameter	r by age	
	All Subjects		Male		Female	
Age	mean \pm SD	n	mean \pm SD	n	mean \pm 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

Table-2: Corneal horizontal diameter by age



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

CHD in males was 12.36 ± 0.41 mm in group 1 and 12.01 ± 0.42 mm in group 2, while the corneal diameter in females was 12.08 ± 0.42 mm in group 1 and 11.88 \pm 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)

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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) $y=8.986+0.127\times AL$; r = 0.431 (p<0.0001)



Corneal radius of curvature (mm)

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



Anterior chamber depth (mm)

Fig-7: Relationship between corneal horizontal diameter and anterior chamber depth (ACD) $y=10.584+0.45\times$ ACD; r = 0.473 (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 C	orrelation Co	pefficient	
	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 Co	orrelation Co	efficient	
	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= $5.640+0.670\times$ CR+ $0.383\times$ ACD. CHD calculated by this equation was strongly correlated with CHD by actual measurement (Fig. 9).



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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

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Salout R et al. 2013 [g]IranPentacam HR101(101) $20-46(28\pm5)$ $M/F 41/60$ 11.76 \pm 0.381193 \pm 0.40Martin R et al. 2013 [g]SpainOrbscan II $200-46(28\pm5)$ $M/F 41/60$ 11.66 \pm 0.371191 \pm 0.38Martin R et al. 2013 [g]SpainOrbscan II $201(101)$ $20-46(28\pm5)$ $M/F 41/60$ 11.66 \pm 0.371191 \pm 0.38Martin R et al. 2013 [g]SpainOrbscan II $238(164)$ $18-67(364\pm93)$ $M/F 62/102$ 12.99 ± 0.40 1181 \pm 0.38Huang J et al. 2014 [10]ChinaDLMaster $88(68)$ $41-84(67.72\pm9.05)$ $M/F 27/41$ 1127 ± 0.44 1160 ± 0.35 Gharemet H et al. 2015 [12]ChinaDLMaster $68(68)$ $41-84(67.72\pm9.05)$ $M/F 419/1224$ 11.60 ± 0.35 Fu T et al. 2015 [12]IranLENSTAR $473(772+8)$ $M/F 419/1224$ $11.87(mean)$ 11.60 ± 0.35 Ober Y et al. 2016 [14]ChinaDLMaster $100(100)$ $8-392.018\pm5.12$ $M/F 51/49$ $11.37(mean)$ Ober I et al. 2016 [15]KiterNo $100(100)$ $8-392.018\pm5.12$ $M/F 51/49$ $11.87(mean)$ Ober I et al. 2016 [15]KiterIndatter $100(100)$ $8-392.018\pm5.12$ $M/F 51/49$ $11.37(mean)$ Shajari M et al. 2016 [16]GermanyIOLMaster $100(100)$ $8-392.018\pm5.12$ $M/F 51/49$ $11.87(mean)$ Shajari M et al. 2016 [16]GermanyIOLMaster $100(100)$ $8-392.018\pm5.12$ $M/F 17/23$ $12.2-6.51$ Shajari M et al. 2016 [16]Germany <td>Salouti R et al. 2013 [8] Iran Pentacam HR 101(101) 20-46(28 \pm 5) M/F 41/60 1 Martin R et al. 2013 [9] Spain Orbssen IIz 101(101) 20-46(28 \pm 5) M/F 41/60 1 Martin R et al. 2013 [9] Spain Orbssen IIz 328(164) 18-67(38.4 \pm 9.3) M/F 62/102 1 Huang J et al. 2014 [10] China AL Scan 68(68) 41-84(67.72 \pm 9.05) M/F 27/41 1 Huang J et al. 2015 [12] China AL Scan 68(68) 41-84(67.72 \pm 9.05) M/F 27/41 1 Fu T et al. 2015 [12] Iran IOLMaster 68(68) 41-84(67.72 \pm 9.05) M/F 41/9%/58.1% 1 Fu T et al. 2015 [12] Iran IOMaster 100(100) 8-93(20.18 \pm 5.12) M/F 41/9%/58.1% 1 Fu T et al. 2016 [15] Iran LENSTAR 473(4787) 40-64(50.7 \pm 6.2) M/F 41/9%/58.1% 1 China IOLMaster 100(100) 8-39(20.18 \pm 5.12) M/F 51/49 1 China ITan LENSTAR 4737(4787) 40-6</td> <td>Reinstein DZ et al. 2013 [7]</td> <td>Italy</td> <td>Orbscan II</td> <td>50(25)</td> <td>$22-51(35.04\pm7.06)$</td> <td>NA</td> <td>11.83 ± 0.28</td> <td></td> <td></td>	Salouti R et al. 2013 [8] Iran Pentacam HR 101(101) 20-46(28 \pm 5) M/F 41/60 1 Martin R et al. 2013 [9] Spain Orbssen IIz 101(101) 20-46(28 \pm 5) M/F 41/60 1 Martin R et al. 2013 [9] Spain Orbssen IIz 328(164) 18-67(38.4 \pm 9.3) M/F 62/102 1 Huang J et al. 2014 [10] China AL Scan 68(68) 41-84(67.72 \pm 9.05) M/F 27/41 1 Huang J et al. 2015 [12] China AL Scan 68(68) 41-84(67.72 \pm 9.05) M/F 27/41 1 Fu T et al. 2015 [12] Iran IOLMaster 68(68) 41-84(67.72 \pm 9.05) M/F 41/9%/58.1% 1 Fu T et al. 2015 [12] Iran IOMaster 100(100) 8-93(20.18 \pm 5.12) M/F 41/9%/58.1% 1 Fu T et al. 2016 [15] Iran LENSTAR 473(4787) 40-64(50.7 \pm 6.2) M/F 41/9%/58.1% 1 China IOLMaster 100(100) 8-39(20.18 \pm 5.12) M/F 51/49 1 China ITan LENSTAR 4737(4787) 40-6	Reinstein DZ et al. 2013 [7]	Italy	Orbscan II	50(25)	$22-51(35.04\pm7.06)$	NA	11.83 ± 0.28		
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Martin R et al. 2013 [9]SpainOrbscan II $328(164)$ $18-67(36.4\pm9.3)$ $M/F 62/102$ 11.69 ± 0.37 11.69 ± 0.40 Huang J et al. 2014 [10]ChinaIOLMaster $328(164)$ $18-67(35.4\pm9.3)$ $M/F 62/102$ 11.69 ± 0.40 Huang J et al. 2014 [11]ChinaIOLMaster $328(164)$ $18-67(35.4\pm9.3)$ $M/F 62/102$ 11.69 ± 0.40 Gharaee H et al. 2014 [11]IranIoLMaster $68(68)$ $41-84(67.7\pm9.05)$ $M/F 27/41$ 112 Gharaee H et al. 2015 [12]ChinaIOLMaster $1721(121)$ $40-91(57.0\pm8.7)$ $M/F 23/616)$ 11.65 ± 0.36 11.60 ± 0.35 Hashemi H et al. 2015 [12]ChinaOrbscan II $2002(1001)$ $8-93(20.18\pm5.12)$ $M/F 51/49$ $11.87-0.34$ 11.66 ± 0.36 Hashemi H et al. 2016 [14]ChinaOrbscan II $100(100)$ $8-93(20.18\pm5.12)$ $M/F 51/49$ $11.87-0.34$ 11.66 ± 0.52 Guber I et al. 2016 [15]SwitzerlandPentacam $107(56)$ NANANA 11.86 ± 0.52 Guber I et al. 2016 [16]Germany $107(56)$ NANA 11.86 ± 0.62 11.65 ± 0.61 Shajari M et al. 2016 [16]Germany $107(56)$ NANA 11.86 ± 0.62 11.65 ± 0.61 Shajari M et al. 2016 [16]Germany $107(56)$ NANA 11.86 ± 0.52 11.65 ± 0.61 Shajari M et al. 2016 [16]Germany $107(56)$ NANA 11.86 ± 0.52 11.65 ± 0.61 Shajari M et al. 2016 [16]Germany $107(56)$ NANA 10.8	Martin R et al. 2013 [9] Spain Orbscan II 328(164) 18-67(38,4±9.3) M/F 62/102 1 Huang J et al. 2014 [10] China AL Scan 68(68) 41-84(67.72±90.5) M/F 62/102 1 Huang J et al. 2014 [11] Iran Orbscan I 328(164) 18-67(38,4±9.3) M/F 62/102 1 Fu T et al. 2014 [11] Iran Orbscan II 2002(1001) 18-45(29.07±5.80) M/F 62/102 1 Fu T et al. 2015 [12] Iran Orbscan II 2002(1001) 18-45(29.07±5.80) M/F 63/1244) 1 Hashemi H et al. 2015 [12] Iran Orbscan II 2002(1001) 18-45(29.07±5.80) M/F 63/1244) 1 Hashemi H et al. 2016 [14] Iran Orbscan II 100(100) 8-39(20.18±5.12) M/F 63/1244) 1 Guber I et al. 2016 [15] Switzerland Pentacam 107(56) NA NA NA 1 Guber I et al. 2016 [16] Switzerland Pentacam H 107(56) NA NA NA NA Suber I et al. 2016 [15] Swit			Orbscan Iiz	101(101)	$20-46(28\pm 5)$	M/F 41/60	11.66 ± 0.37	1181 ± 0.38	11.56 ± 0.32
$ \begin{array}{l lllllllllllllllllllllllllllllllllll$	Induction Interview 328(164) 18-67(36.4 \pm 9.3) M/F 62/102 1 Huang J et al. 2014 [10] China AL Scan 68(68) 41-84(67.72 \pm 90.5) M/F 27/41 1 Gharasee He al. 2015 [12] Lens Orbaster 68(68) 41-84(67.72 \pm 90.5) M/F 62/102 1 Fu T et al. 2015 [12] Iran Orbaster 1721(1721) 40-91(57.0 \pm 8.7) M/F 63/14) 1 Hashemi H et al. 2015 [13] Iran China IOLMaster 1721(1721) 40-91(57.0 \pm 8.7) M/F 63/1224) 1 Hashemi H et al. 2016 [14] China IOLMaster 1721(1721) 40-91(57.0 \pm 8.7) M/F 63/1224) 1 Guber I et al. 2016 [15] Switzerland Pentacam 100(100) 8-39(20.18 \pm 5.12) M/F 51/49 1 Guber I et al. 2016 [16] Switzerland Pentacam 107(56) NA NA NA 1 Shijari M et al. 2016 [16] Switzerland Pentacam 107(56) NA NA NA 1 Suber I et al. 2016 [16]	Martin R et al. 2013 [9]	Spain	Orbscan II	328(164)	$18-67(36.4\pm9.3)$	M/F 62/102	11.69 ± 0.37		
	Huang J et al. 2014 [10] China AL Scan 68(68) 41-84(67.72±9.05) M/F 27/41 1 Idharee H al. 2014 [11] Iran IOLMaster 68(68) 41-84(67.72±9.05) M/F 27/41 1 Fu T et al. 2015 [12] Iran Orbaster 68(68) 41-84(6.7.72±9.05) M/F (387/14) 1 Fu T et al. 2015 [12] Iran Orbaster 1721(1721) 40-91(57.02±9.05) M/F (387/14) 1 Hashemi H et al. 2015 [13] Iran LENSTAR 473(4.787) 40-64(50.7±6.2) M/F (497/1224) 1 Ohen Y et al. 2016 [14] Iran LENSTAR 473(4.787) 40-64(50.7±6.2) M/F 41.9%/58.1% 1 Ouber I et al. 2016 [15] China IOLMaster 100(100) 8-39(20.18±5.12) M/F 51/49 1 Guber I et al. 2016 [16] Switzerland Pentacam 107(56) NA NA NA NA Shidari M et al. 2016 [16] Germany IOLMaster 107(56) NA NA NA NA Shidari M et al. 2016 [16] Germany			IOLMaster	328(164)	$18-67(36.4\pm9.3)$	M/F 62/102	12.19 ± 0.40		
	IOLMaster 68(68) 41-84(67.72±9.05) M/F 27/41 Gharaee H et al. 2014 [11] Iran Orbscan II 2002(1001) 18-46(5.72±9.05) M/F 237/41 Fu T et al. 2015 [12] Iran Orbscan II 2002(1001) 18-46(5.72±9.05) M/F 439/Y1224) 1 Hashemi H et al. 2015 [13] Iran LENSTAR 4787(4787) 40-91(57.0±8.07) M/F 419/W581% 1 Orbscan II IOM 00100 8-39(20.18±5.12) M/F 41.9W581% 1 1 Orbscan I Orbscan I 100(100) 8-39(20.18±5.12) M/F 51/49 1 Ouber I et al. 2016 [16] China Orbscan I 100(100) 8-39(20.18±5.12) M/F 17/23 Shajari M et al. 2016 [16] Germany IOLMaster 107(56) NA NA NA Shajari M et al. 2016 [16] Germany IOLMaster 107(56) M/F 17/23 1 1 Shajari M et al. 2016 [16] Germany IOLMaster 107(56) M/F 17/23 1 1 1 1 1 1 1 1 <td>Huang J et al. 2014 [10]</td> <td>China</td> <td>AL Scan</td> <td>68(68)</td> <td>$41 - 84(67.72 \pm 9.05)$</td> <td>M/F 27/41</td> <td>1127 ± 0.44</td> <td></td> <td></td>	Huang J et al. 2014 [10]	China	AL Scan	68(68)	$41 - 84(67.72 \pm 9.05)$	M/F 27/41	1127 ± 0.44		
	Gharaee H et al. 2014 [11] Iran Orbscan II 2002(1001) 18-45(2907±5.86) M/F (385/616) 1 Fu T et al. 2015 [12] China IOLMaster 172(1(1721) 40-91(57).0±8.7) M/F (397/1224) 1 Hashemi H et al. 2015 [13] China ILENSTAR 172(1(1721) 40-91(57).0±8.7) M/F (397/1224) 1 Anahemi H et al. 2016 [14] China Drbscan II 100(100) 8-39(20.18±5.12) M/F 51/49 1 Chen Y et al. 2016 [15] Switzerland Pentacam 107(56) NA NA NA 1 Guber I et al. 2016 [16] Switzerland Pentacam 107(56) NA NA NA 1 Switzerland Pentacam HR 107(56) NA NA NA NA NA 1			IOLMaster	68(68)	$41 - 84(67.72 \pm 9.05)$	M/F 27/41	NA		
$ \begin{array}{l l l l l l l l l l l l l l l l l l l $	Fu T et al. 2015 [12] China IOLMaster 1721(1721) 40-91(57.0±8.7) M/F (497/1224) 1 Hashemi H et al. 2015 [13] Iran LENSTAR 478(4.487) 40-91(57.0±8.7) M/F (497/1224) 1 Chen Y et al. 2016 [14] China UCN5acn II 000(100) 8-39(20.18±5.12) M/F 51/49 1 Chen Y et al. 2016 [15] Switzerland Pentacam 100(100) 8-39(20.18±5.12) M/F 51/49 1 Guber I et al. 2016 [15] Switzerland Pentacam 107(56) NA NA 1 Shajari M et al. 2016 [16] Switzerland Pentacam 107(56) NA NA 1 Shajari M et al. 2016 [16] Germany 107(56) NA NA NA 1 Shajari M et al. 2016 [16] Germany 107(56) NA NF 17/23 1 Lenstar 40(40) 21-71(36.5±15.5) M/F 17/23 1 1 1 1 2 1 1 2 1 1 2 1 2 1	Gharaee H et al. 2014 [11]	Iran	Orbscan II	2002(1001)	$18-45(29.07\pm5.86)$	M/F (385/616)	11.65 ± 0.36	11.60 ± 0.35	11.71 ± 0.36
$ \begin{array}{l l l l l l l l l l l l l l l l l l l $	Hashemi H et al. 2015 [13] Iran LENSTAR 4787(4787) 40-64(50.7\pm6.2) M/F 41,9%/58.1% 1 Ohen Y et al. 2016 [14] China Orbscan II 1000(100) 8-39(20.18±5.12) M/F 51/49 1 Guber I et al. 2016 [15] Switzerland Orbscan II 100(100) 8-39(20.18±5.12) M/F 51/49 1 Guber I et al. 2016 [15] Switzerland Pentacam 107(56) NA NA 1 Shajari M et al. 2016 [16] Switzerland BioGraph 107(56) NA NA 1 Shajari M et al. 2016 [16] Germany IOLMaster 40(40) 21-71(36.5±15.5) M/F 17/23 Sung Y et al. 2016 [16] LenStar 40(40) 21-71(36.5±15.5) M/F 17/23 Sung Y et al. 2016 [17] Korea Pentacam HR 88(88) (59±13) M/F 23/54 Sung Y et al. 2016 [18] Iran Orbscan II 78(41) 21-71(36.5±15.5) M/F 17/23 Sung Y et al. 2016 [18] Korea Pentacam HR 80(40) 21-71(36.5±15.5) M/F 17/23 Sung Y	Fu T et al. 2015 [12]	China	IOLMaster	1721(1721)	$40 - 91(57.0 \pm 8.7)$	M/F (497/1224)	11.75 ± 0.40		
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 Guber I et al. 2016 [15] Switzerland Trace 100(100) 8-39(20.18±5.12) M/F 51/49 11.33±0.36 Shajari Me tal. 2016 [16] Switzerland Pentacam 107(56) NA NA 11.38±0.52 Shajari Me tal. 2016 [16] Germany IOMaster 40(40) 21-71(36.5±15.5) M/F 17/23 11.8±0.4 Shajari M et al. 2016 [16] Germany IOMaster 40(40) 21-71(36.5±15.5) M/F 17/23 11.8±0.4 Sung Y et al. 2016 [17] Kora Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 12.3±0.4 Sung Y et al. 2016 [17] Kora Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 12.3±0.4 Sung Y et al. 2016 [17] Kora Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 12.3±0.4 Sung Y et al. 2016 [18] Kora Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 12.3±0.4 Sung Y et al. 2016 [18	Chen Y et al. 2016 [14] China Orbscan II 100(100) 8-39(20.18±5.12) M/F 51/49 1 Guber I et al. 2016 [15] Switzerland Pentacam 107(56) NA NA 1 Shajari M et al. 2016 [16] Switzerland Pentacam 107(56) NA NA 1 Shajari M et al. 2016 [16] Switzerland Pentacam 107(56) NA NA 1 Shajari M et al. 2016 [16] Germany IOLMAster 40(40) 21-71(36.5±15.5) M/F 17/23 1 Shajari M et al. 2016 [16] Germany IOLMAster 40(40) 21-71(36.5±15.5) M/F 17/23 1 Sung Y et al. 2016 [17] Korea Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 1 Sung Y et al. 2016 [17] Korea Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 1 Sung Y et al. 2016 [17] Korea Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 1 Sung Y et al. 2016 [17] Ina Na 38(88) 0(40)	Hashemi H et al. 2015 [13]	Iran	LENSTAR	4787(4787)	$40-64(50.7\pm6.2)$	M/F 41.9%/58.1%	11.87(mean)		
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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 11,8±0.4 LenStar 40(40) 21-71(36,5±15,5) M/F 17/23 12,3±0.4 Sung Y et al. 2016 [17] Korea Pentacam HR 840(40) 21-71(36,5±15,5) M/F 17/23 12,3±0.4 Sung Y et al. 2016 [18] Korea Pentacam HR 840(15) 21-71(36,5±15,5) M/F 17/23 12,4±0.5 Salouti R et al. 2016 [18] Korea Pentacam HR 84(15) 21-45(3,1±13+48) M/F 22/19 11,4±0.5 Salouti R et al. 2017 [19] Iran 10LMaster 100(100) 33-86(6,5,9±3.3) M/F 58/42 11,712,40.45 Pentacam HR 100(100) 33-86(6,5,9±3.3) M/F 58/42 11,41±0.42	Pentacam HR 40(40) 21-71(36.5±15.5) M/F 17/23 LenStar 40(40) 21-71(36.5±15.5) M/F 17/23 LenStar 40(40) 21-71(36.5±15.5) M/F 17/23 Sung Y et al. 2016 [17] Korea Pentacam HR 88(88) (59±13) M/F 17/23 Sung Y et al. 2016 [18] Korea Pentacam HR 88(88) (59±13) M/F 34/54 Zhong QY et al. 2016 [18] China Orbscan II 78(41) 21-45(31.21±7.48) M/F 22/19 1 Salouit R et al. 2017 [19] Iran IO(Master 100(100) 33-86(65.9±3.3) M/F 58/42 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 58/42 1 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 58/42 1 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 58/42 1 1	Shajari M et al. 2016 [16]	Germany	IOLMaster	40(40)	$21 - 71(36.5 \pm 15.5)$	M/F 17/23	12.0 ± 0.3		
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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 11.72±0.45 11.41±0.42	Zheng QY et al. 2016 [18] China Orbscan II 78(41) 21-45(31.21±7.48) M/F 22/19 1 Salouti R et al. 2017 [19] Iran IOLMaster 100(100) 33-86(65.9±3.3) M/F 58/42 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 58/42 1 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 58/42 1 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 58/42 1 1 Pentacam HR 100(100) 33-86(65.9±3.3) M/F 181/172 1	Sung Y et al. 2016 [17]	Korea	Pentacam HR	88(88)	(59 ± 13)	M/F 34/54	11.4 ± 0.5		
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	present study Japan IOLMaster 333(333) 21-89(54±19) M/F 161/172 11			Pentacam HR	100(100)	$33 - 86(65.9 \pm 3.3)$	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		present study	Japan	IOLMaster	333(333)	21-89(54土19)	M/F 161/172	12.05±0.44	12.17土0.45	11.95±0.41

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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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