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The study of relationship between ocular biometry and exophthalmometry in adult Malay population of Kelantan, Malaysia

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Abstract:

PURPOSE: Exophthalmometry value has great clinical significance in the presence of many orbital diseases which can cause proptosis, including thyroid-associated orbitopathy, tumors, inflammation, head and orbital trauma, and craniofacial abnormalities. Measurements of exophthalmometry and ocular biometry vary between races and countries. This study aimed to present the normative values of exophthalmometry in adult Malays of Kelantan and the relationship between ocular biometry (axial length, corneal curvature, anterior chamber depth, and white-to-white) with the obtained exophthalmometry values.

MATERIALS AND METHODS: This was a hospital-based, cross-sectional study in the Ophthalmology Clinic of Universiti Sains Malaysia, Kubang Kerian, Kelantan, where 267 individuals above 20 years old participated between August 2018 and May 2020. Participants were examined with Hertel exophthalmometer and intraocular lens Master by the same investigator. Data were analyzed using the Statistical Package of the Social Science software (version 24.0). Multiple linear regression was used to assess any significant correlation between exophthalmometric value and each biometric variable.

RESULTS: In the data collected, the mean exophthalmometric value for the right eye was 13.93 ± 2.221 mm and the left eye was 13.93 ± 2.232 mm. Overall, male had a higher exophthalmometric value than the female with a statistically significant $P = 0.001$. Axial length was uniquely significant for the amount of variance in the exophthalmometric value with $P < 0.001$, while corneal curvature, anterior chamber depth, and white-to-white showed no statistical significance.

CONCLUSION: Our study had established the normal exophthalmometric value for Malay adults in Kelantan for future clinical reference. The axial length had shown to have a significant positive correlation with exophthalmometric values.

Keywords:

Adult, exophthalmos, Malay, ophthalmology, orbital diseases

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Introduction

Exophthalmometry is the measurement of the anterior position of the eye globe in relation to the orbital rim. Methods consist of clinical exophthalmometry, digital photography, and radiological exophthalmometry (via computed tomography measurement). The assessment of normal globe protrusion has great clinical significance in the presence of many orbital diseases which can cause proptosis, including thyroid-associated orbitopathy, inflammation, tumors, trauma of the head and orbital, and craniofacial abnormalities.[1-4] It is vital as a parameter to assist diagnosis, management, and further monitoring of progression. The measurement of exophthalmometry should be readily available, easy to use with reproducible results. Computed

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tomography measurement has great accuracy and correlates well with Hertel exophthalmometry. However, this method's high cost, exposure to radiation, and not easily available pose its limitations for routine exophthalmometry.[5,6] Photography measurement, although simple and noninvasive, has been found to have a weak correlation which compromises reproducibility.[7] Thus, the Hertel exophthalmometer is still one of the most widely used methods as clinical exophthalmometry is still the easiest, most convenient, and affordable method.[1-3] It allows measurements of the distance between the two lateral orbital rims (i.e., interorbital distance) and the vertical distance of corneal apex to the frontal plane.[1,3,4]

Literature reviews have shown that normal exophthalmometric values vary according to ethnicity, locality, gender, and age. According to Beden *et al*., the Turkish adult population with a sample size of 2477 showed a median exopthalmometric value of 13 mm and an upper limit of 17 mm in both eyes in 95% of the sample population. The obtained mean exophthalmometric value was documented as a significant decrease after the third decade.[8] Nath *et al*. noted in their sample size of 629 among the Indian race that the mean exophthalmometic value of the right eye for male was 15.2 mm and left eye was 14.8 mm, while the female was 14.4 mm for the right eye and left eye was 14.0 mm. The upper limit in adults for the population group study was 22.0 mm.[9] Kumari *et al*. also conducted a study on the Indian race in a different locality and noted a slightly lower upper limit. An adult male was 19.0 mm and a female was 21.0 mm.[10]

Predictors which have been shown to have a positive correlation to exophthalmometric value in literature review include axial length, age, gender, body mass index, weight, height, interpupillary distance, and refraction.[8,10,11-17] Various mean ocular biometry values including axial length, anterior chamber depth, and corneal curvature radius were reported by Chen *et al*. in population-based studies [Table 1].[13] Currently, there are no normative exophthalmometric data on the Malay population of Malaysia. Ocular biometric reading varies between races.[1,9,10,18-23] There are no conclusive data on the effects of ocular biometry on exophthalmometry value of the Malay population in Malaysia.[11,13] This study aims to provide normative exophthalmometric data and determine its relationship with ocular biometry (axial length, corneal curvature, anterior chamber depth, and white-to-white) in the adult Malay population of Kelantan.

Methods

Participation and selection criteria

This was a hospital-based, cross-sectional study conducted in the Ophthalmology Clinic of Universiti Sains Malaysia, Kubang Kerian, Kelantan, from August 2018 to May 2020. This study was approved by the Human Research Ethics Committee USM, Division of Research and Innovation (RandI), USM Health Campus, 16150, Kubang Kerian, Kelantan USM/JEPeM/18060268) and was conducted in accordance to the Good Clinical Practice guidelines and principles outlined by the Helsinki Declaration on human research.

Malay adults in Kelantan, hospital staff of Universiti Sains Malaysia, relatives, and friends who accompanied patients during appointments to the Ophthalmology Clinic of Universiti Sains Malaysia, Kubang Kerian, Kelantan, were recruited via poster announcements both in Malay and English language which were placed within the Ophthalmology Clinic compound of Universiti Sains Malaysia, Kubang Kerian, Kelantan.

Eligible participants must be Malay adult individuals, age above 20 years old, born in Kelantan and include all range of refractive errors. Exclusion criteria included a history of orbital disease: inflammatory causes such as orbital cellulitis, idiopathic orbital inflammatory disease, orbital apex syndrome, cavernous sinus thrombosis, neoplastic such as lymphoma, optic nerve sheath meningioma, optic glioma, rhabdomyosarcoma, vascular such as carotid-cavernous fistula, cavernous hemangioma, trauma such as retrobulbar hemorrhage, orbital emphysema, orbital wall fracture, and others such as dermoid cyst and lymphangioma. History of ocular diseases which contributes to change in axial length such as keratoconus, posterior staphyloma, buphthalmos, phthisis bulbi, and endocrine disease such as thyroid eye disease; a history

Table 1: Mean axial length, anterior chamber depth, and corneal curvature radius reported in population-based studies

Study	Ethnicity	Axial length (mm)		Anterior chamber depth (mm)		Corneal curvature (mm)	
		Male	Female	Male	Female	Male	Female
The Los Angeles Latino Eye Study	Latinos	23.65	23.18	3.48	3.36	43.35	43.95
The Mongolian Study	Mongolians	23.43	23.08	2.87	2.77	43.65	44.24
The Reykjavik Study	White	23.74	23.20	3.20	3.08	43.41	43.73
The Liwan Eye Study	Chinese	23.38	22.83	2.75	2.61	43.50	44.25
The Blue Mountain Eye Study	White	23.75	23.20	3.16	3.06	43.01	43.74

Data are from Chen *et al*. (2016)[13]

of ocular surgery including anterior segment surgery, for example, corneal graft surgery, pterygium surgery, corneal collagen cross-linking, cataract surgery and post ocular injury repair, posterior segment surgery, for example, pars plana vitrectomy, and post ocular injury repair and orbital wall fracture repair; and a history of ocular injury such as closed globe injuries such as lamellar laceration, iridodialysis, cyclodialysis, angle recession, traumatic hyphema, open-globe injuries including laceration such as penetrating, perforating and intraocular foreign bodies, globe rupture, and orbital fracture were all excluded.

Sampling size calculation

The sample size was calculated using formula estimated mean via sample size calculator for estimations (ver.1.0.03; Naing L, Winn T and Rusli BN) and obtained 267 participants compared to 85 participants using linear regression formula usingG*Power software (ver. 3.1.9.2; Heinrich-Heine-Universität Düsseldorf). Thus, in view that sample size calculation was larger by using formula estimated mean compared to linear regression formula, the sample size was according to the former calculation of 267 individuals.

Sampling method

The simple random sampling method was used to recruit individuals who fit into the inclusion criteria with written consent. Patient's age and gender are confounding factors as they have different normal exophthalmometry values in a normal healthy adult population.[8,24] Thus, individuals in this study were grouped according to gender and age: young adulthood (21–44 years old), middle adulthood (45–64 years old), and elderly (above 65 years old).[25]

Research tools

Inami Hertel exophthalmometer

Inami Hertel exophthalmometer was used for precise measurement of corneal projection through simple alignment of twin prism, linear vertical targets. The device allowed measurement of the forward distance of the corneal apex from the lateral orbital rim. The method for exophthalmometry examination was done as described by Kumari Sodhi *et al*.[10] At the primary position of gaze, the participants sat down with their faces at the same level as the examiner. The footplates of the instrument were positioned gently at the lateral bony margin of the orbits without exerting excessive pressure. The left footplate was fixed and was placed on the right lateral orbital rim, while the other footplate was adjusted until both footplates rested on lateral orbital rims symmetrically. The rest of the instrument was held parallel to the frontal plane of the patient in line with the pupils.[26] To avoid error, Hertel exophthalmometer was held horizontally with the parallax correcting device (red line) aligned with the vertical target to ensure prism alignment. When these targets overlapped, the degree of projection can be read directly off the superimposed millimeter scale (mm). The right eye of the investigator was used to read the participant's left exophthalmometry values, while the left eye was used for the participant's right eye. Measurement was taken to the nearest 1 mm of the measuring scale of Hertel's exophthalmometer coinciding with the apex of the cornea.[26]

Intraocular lens master

Intraocular lens (IOL) Master from ZEISS was used to measure axial length, cornea curvature, anterior chamber depth, and determination of white-to-white in the calculation for required IOL. The corneal curvature was determined by measuring the distance between reflected light images projected onto the cornea. The results were obtained in millimeters radius and were converted to diopters using the keratometric refractive index 1.3375.[27] This index accounted for the negative power introduced by the posterior corneal surface. The corneal power in diopters was given by $\Phi = 337.5/R$, for R in mm. The white-to-white was determined from the image of the iris, measuring the horizontal width from white sclera to opposite white sclera. Measurement of anterior chamber depth was the distance between the corneal endothelium and anterior surface of the natural crystalline lens.[27]

The IOL Master measured the axial length using light via the distance from the anterior surface of the cornea to the retinal pigmented epithelium. Thus, the axial length obtained was slightly longer than that of A-scan ultrasound which reflects off the surface of the internal limiting membrane at the macula.[27]

The measurement procedures were automated after the operator had adjusted the device to the patient's eye and initiated measurement. The signal-to-noise ratio (SNR) is a measure of accuracy and decreased with increasing cataract density. SNR >2.0 was valid and good if repeatable, SNR between 1.6 and 2.0 was borderline but usable if repeatable, and SNR <1.6 was not usable.

Data collection

All eligible participants who fulfilled the inclusion and exclusion criteria were given a thorough explanation about the study. Written consent was then obtained if agreeable. The study did not offer treatment or payment to participants. Each participant was given full information regarding their eye examination results.

All participants underwent a comprehensive ocular examination that included visual acuity, anterior and posterior segment examination under a slit lamp, intraocular pressure via air-puff tonometer, and autorefraction to exclude further individuals who did fit into the selection criteria. The eligible individual's ocular biometry measurement (axial length, corneal curvature, anterior chamber depth, and white-to-white) and exophthalmometry measurements were conducted. All ocular parameters of data collection required about half an hour per participant. Participants received information about their eye status from any eye examination done in the study. Data collected were categorized according to gender and age group.

Measures to minimize study error

Steps were taken to minimize the study error. The same instruments and equipment were used. Instruments were calibrated. Interobserver agreement between investigator and qualified senior ophthalmologist ensured correct measurement via Hertel exophthalmometer (this was done by achieving 100% agreement during the examination of the first five participants). The examination procedure was performed by the same investigator.

Statistical analysis

Data were analyzed using the Statistical Package of the Social Science (SPSS) software (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). Mean and standard deviation of exophthalmometric values were calculated for both eyes separately, different age groups, and gender. Multiple linear regression was used to assess any significant correlation between exophthalmometric value and each biometric variable with data of the whole sample population. The level of significance was set at $P < 0.05$.

Results

Mean exophthalmometric value

In the total sample size of 267, the mean measurement of exophthalmometric value of the adult Malay population in Kelantan obtained in this study for the right eye was 13.93 ± 2.221 mm and left eye was 13.93 ± 2.232 mm. The difference between both eyes was analyzed using independent samples *t*-test and obtained $P = 0.984$ which was statistically insignificant [Table 2].

The sample population was divided into three groups: 78 in young adulthood with a mean age of 31.00 ± 7.396 years old, 94 in middle adulthood with a mean age of 55.72 ± 5.575 years old, and 95 in elderly with a mean age of 71.91 ± 4.578 years old. The mean exophthalmometric value of males in all three different age groups was generally higher than females [Table 3]. The mean exophthalmometric values were obtained for overall male and female of all ages for each eye and were analyzed using independent samples *t*-test. $P = 0.001$ was obtained and showed a statistically significant difference between exophthalmometric values of male and female. Among the different age groups, the mean exophthalmometric values of the young adults were highest, followed by middle adults and the lowest in the elderly group. The data were analyzed using multiple comparisons and obtained $P < 0.001$ which was statistically significant [Table 4]. In the multiple linear regression analysis for the correlation between exophthalmometric values and age, we observed a significant negative correlation with $P = 0.002$ [Tables 5 and 6].

Table 2: Mean of exophthalmometric values of adult Malay in the Kelantan population

Eye	Mean of exophthalmometric values, mm	*P*	Minimum-Maximum, mm
Right (*n*=267)	13.93±2.221	0.984*	9-18
Left (*n*=267)	13.93±2.232		9-19

**P* value difference between both eyes was statistically nonsignificant at the level >0.05 with independent samples *t*-test

Correlation between exophthalmometric value and ocular biometry

The mean ocular biometry analysis had shown that there were no significant differences between the measurements of both eyes [Table 7]. *P* values obtained via independent samples *t*-test for difference between both eyes' axial length, corneal curvature, anterior chamber depth, and white-to-white were 0.703, 0.840, 0.462, and 0.930, respectively.

In the multiple linear regression analysis for the right eye, the R^2 value was 0.130; taken as a set, the right eye axial length, corneal curvature, anterior chamber depth, and white-to-white account for 13% of the variance of right eye exophthalmometric value. In ANOVA analysis (test using alpha = 0.05), the overall regression model was significant; $F(4, 262) = 9.799$, $P < 0.001$, $R^2 = 0.13$. However, when individual variants were analysed (test each predictor at alpha = 0.05), we observed that only the right eye axial length was statistically significant with $P < 0.001$. Based on the unstandardized coefficient, each 1 mm increase of axial length, there is an increase in 0.535 mm of exophthalmometric value [Table 8]. Thus, right eye axial length was uniquely significant for the amount of variance in right eye exophthalmometric value.

From an analysis of the left eye via multiple linear regressions, R^2 was 0.123; taken as a set, the left eye axial length, corneal curvature, anterior chamber depth, and white-to-white account for 12% of the variance of left eye exophthalmometric value. The ANOVA analysis (test using alpha = 0.05) showed that the overall regression model was significant; $F(4, 262) = 9.156$, $P < 0.001$, $R^2 = 0.12$. However, when individual variants were analyzed (test each predictor at alpha = 0.05), only left eye axial length was statistically significant with

Table 3: Mean of exophthalmometric values of adult Malay in the Kelantan population according to different age groups

Gender	Male, 45.3%				Female, 54.7%			
Age group (n=267)	Young adult (n=22)	Middle adult (n=45)	Elderly (n=54)	Overall (n=121)	Young adult (n=56)	Middle adult (n=49)	Elderly (n=41)	Overall (n=146)
Age (mean±SD, year)	33.59±6.850	56.56±5.983	71.70±4.529	59.14±14.953	29.98±7.411	54.96±5.115	72.17±4.685	50.21±18.373
OD								
Mean±SD, (mm)	15.86±1.781	14.49±2.546	13.80±1.975	14.43±2.283	14.09±2.117	13.00±1.904	13.34±2.105	13.51±2.085
Range (minimum-maximum)	6 (12-18)	8 (10-18)	8 (10-18)	8 (10-18)	8 (10-18)	8 (9-17)	8 (10-18)	9 (9-18)
OS								
Mean±SD, (mm)	15.86±1.807	14.51±2.599	13.78±1.930	14.43±2.294	14.11±2.129	12.96±1.848	13.39±2.178	13.52±2.098
Range (minimum-maximum)	7 (12-19)	9 (10-19)	8 (10-18)	9 (10-19)	8 (10-18)	7 (9-16)	8 (10-18)	9 (9-18)

Independent samples t-test had shown significant P=0.001 for difference between mean exophthalmometric values for overall male and female for each eye. EV=Exophthalmometric value, OS=Left eye, OD=Right eye, SD=Standard deviation

Table 4: Mean exophthalmometric values of adult Malay in Kelantan by different age groups

Age group (n=267)	EV (mean±SD, mm)	P
Young adulthood (n=78)		
OS	14.60±2.182	<0.001*
OD	14.59±2.171	
Middle adulthood (n=94)		
OS	13.70±2.359	<0.001*
OD	13.71±2.345	
Elderly (n=95)		
OS	13.61±2.038	<0.001*
OD	13.60±2.034	

*P value using multiple comparisons for mean exophthalmometric values of different age groups was statistically significant, <0.05. EV=Exophthalmometric value, OS=Left eye, OD=Right eye, SD=Standard deviation

$P < 0.001$. Based on the unstandardized coefficient, each 1 mm increase of axial length, there is an increase in 0.485 mm of exophthalmometric value [Table 9]. Thus, left eye axial length was also uniquely significant for the amount of variance in left eye exophthalmometric value.

Discussion

The steady increase of ocular protrusion from age 3 to 20 was noted by Lang *et al*.[14] Kashkouli *et al*. also described a positive correlation between age and ocular protrusion at 6–19 years' old.[15] Thus, to avoid the confounding factor of increasing exophthalmometric value attributed to the emmetropic growth of the globe, the minimum age of adults recruited into this study was 21 years' old.[28] The sample population was then further divided into different age groups according to the provisional guidelines on standard international age classifications by the United Nations: young adulthood (21–44 years' old), middle adulthood (45–64 years' old), and elderly (above 65 years' old).[25]

In this study with a sample size of 267, the difference between mean exophthalmometric values obtained for both eyes had no statistical significance. This similarity between both eyes was also noted by Wu *et al*. which documented 19.0 mm for the right eye and 18.8 mm for the left eye.[1]

Among the different age groups in this study, we observed a statistically significant decrease in mean exophthalmometric values with age. This was also observed by Wu *et al*. where adults were with a mean age of 39.1 ± 14 which showed a slightly higher mean exophthalmometric value of 15.7 ± 1.8 mm compared to the elderly with a mean age of 76.6 ± 4.1 which showed a slightly lower value of 15.3 ± 2.2 mm.[1] However, this pattern of a gradual decrease in exophthalmometric value in the elderly was not observed by Bilen *et al*. who reported no statistical significance difference between

Table 5: Multiple linear regression of right eye exophthalmometric values with age

Variables	Unstandardized, *B*	Coefficients, SE	Standardized coefficients, *B*	*t*	Significance	95.0% CI for B	
						Lower bound	Upper bound
Right eye (constant)	15.240	0.437		34.858	0.000	14.379	16.101
Age	−0.024	0.008	−0.190	−3.150	0.002*	−0.039	−0.009

*Statistical significance (*P*<0.05). *t*=*t* statistic, CI=Confidence interval, *B*=Beta, SE=Standard error

Table 6: Multiple linear regression of left eye exophthalmometric values with age

Variables	Unstandardized, *B*	Coefficients, SE	Standardized coefficients, *B*	*t*	Significance	95.0% CI for B	
						Lower bound	Upper bound
Left eye (constant)	15.254	0.439		34.718	0.000	14.388	16.119
Age	−0.024	0.008	−0.190	−3.158	0.002*	−0.040	−0.009

*Statistical significance (*P*<0.05). *t*=t statistic, CI=Confidence interval, *B*=Beta, SE=Standard error

age groups.[21] In our study, for each year increase of age, there is a decrease in exophthalmometric value by 0.024 mm for both right and left eyes.

Migliori and Gladstone conducted a study on the African-American and Caucasian race of the United States of America and documented a higher male mean exophthalmometric values in both African-American with 18.5 mm and Caucasian race with 16.5 mm compared to female with 17.8 mm for the former and 15.4 mm for the latter.[19] We also observed significantly higher mean exophthalmometric value in male compared to female in all three age groups.

The mean exophthamometric value obtained in this study showed variation from other races and countries as seen in other literature.[1, 8-10, 15, 18-23] [Table 10]. The mean results were close to that seen among Chinese in Taiwan by Tsai *et al*. with a male of 13.97 ± 2.26 mm and female 13.86 ± 2.39 mm.[20] However, they were lower than that compared to Chinese in Hong Kong by Quant and Woo who reported right eye 16.7 ± 1.9 mm and left eye 16.6 ± 1.8 mm and Chinese Han in northern China by Wu *et al*.[1,29] The upper limit for both eyes in all age groups in this study ranged from 18 mm to 19 mm.

The ocular biometry measurements were compared to the Singapore Malay Eye Study results which also used IOL Master in Malay race.[30] The mean axial length in this study according to different age groups was noted to be highest among the young adults with right eye 24.00 ± 1.173 mm and left eye 23.95 ± 1.146 mm and lowest in middle adults with right eye 23.48 ± 0.986 mm and left eye 23.46 ± 0.972 mm. The values obtained reflected that the average mean axial length among Malay adults in Kelantan (right eye 23.72 ± 1.188 mm and left eye 23.68 ± 1.176 mm) was higher than the mean in Singapore Malay Eye Study of 23.55 mm. The anterior chamber depth and corneal curvature mean data in this study were noted to be higher too. The respective measurements were anterior chamber depth (right eye 3.24 ± 0.431 mm and left eye 3.27 ± 0.425 mm) noted to be higher than 3.10 mm and corneal curvature (right eye 44.40 ± 1.577 D and left eye 44.42 ± 1.506 D) was steeper than 7.65 mm (44.12D).

The mean values obtained in this study for white-to-white were right eye 11.99 ± 0.464 mm and left eye 11.99 ± 0.415 mm which were both higher than 11.80 mm in adults of Northern Iran as documented by Hashemi *et al*.[31]

Chan *et al*. had documented a statistically significant positive correlation between axial length and ocular protrusion; every 4 mm increase in axial length was associated with a 1 mm increase in exophthalmometric measurement.[11] Karti *et al*. also demonstrated that every 4.7 mm increase in axial length was associated with a 1 mm increase in exophthalmometric value.[12] In our study, we found that only the axial length has significant positive correlation with exophthalmometric value [Tables 8 and 9]. When analyzed with the unstandardized coefficients of axial length in the tables, every increase of 1.87 mm in the right eye and 2.06 mm in the left eye was associated with a 1 mm increase in exophthalmometric value. There was no significant correlation between exophthalmometric value with corneal curvature, anterior chamber depth, and white-to-white in this study.

A positive correlation between axial length and anterior chamber depth had been documented.[32-37] This was also observed in our study when analyzed with linear regression, anterior chamber depth had $P < 0.001$ correlation with axial length. However, despite the statistically significant correlation, anterior chamber depth was not correlated with exophthalmometric value. We postulate this could be contributed by the higher number of older patients in our sample population: 78 in young adulthood with a mean age of 31.00 ± 7.396, 94 in middle adulthood with mean age 5of 5.72 ± 5.575, and 95 in elderly with a mean age of 71.91 ± 4.578. Studies have shown that anterior chamber depth decreased with age and may be due to the thickening of the lens in the progression of senile cataract.[38-41]

Table 7: Mean ocular biometry of adult Malay in Kelantan by different age groups

Ocular biometry	Young adulthood (*n*=78)		Middle adulthood (*n*=94)		Elderly (*n*=95)		Overall ages (*n*=267)		*P*
	OS	OD	OS	OD	OS	OD	OS	OD	
Axial length (mean±SD, mm)	23.95±1.146	24.00±1.173	23.46±0.972	23.48±0.986	23.68±1.339	23.73±1.335	23.68±1.176	23.72±1.188	0.703*
Corneal curvature (mean±SD, D)	43.98±1.547	43.97±1.597	44.72±1.520	44.71±1.601	44.42±1.507	44.40±1.577	44.42±1.506	44.40±1.577	0.840*
Anterior chamber depth (mean±SD, mm)	3.53±0.300	3.51±0.306	3.24±0.390	3.21±0.371	3.27±0.425	3.24±0.432	3.27±0.425	3.24±0.432	0.462*
White-to-white (mean±SD, mm)	12.12±0.379	12.16±0.510	11.94±0.415	11.95±0.424	11.99±0.415	11.99±0.464	11.99±0.415	11.99±0.464	0.930*

*The *P* values obtained via independent samples *t*-test for overall difference between both eyes' ocular biometry readings were statistically nonsignificant, >0.05. OS=Left eye, OD=Right eye, SD=Standard deviation

A strong correlation between white-to-white corneal diameter with axial length and corneal curvature was documented by Hashemi *et al*.[31] Using the multiple linear regression correlation with axial length, we documented a nonsignificant white-to-white $P = 0.505$ and a significant corneal curvature $P < 0.001$. Lee *et al*. reported corneal curvature increased while axial length, anterior chamber depth, and white-to-white decreased with age.[40] Hashemi *et al*. noted that white-to-white significantly decreased linearly from 11.91 mm in the 40–44-year-old age group to 11.67 mm in the 60– 64-year-old age group.[31] However, when study was conducted by Hashemi *et al*. in Tehran, this relationship was not observed. They noted corneal diameter had no significant correlation with age but showed an increase of 0.18 mm for each millimeter increase in the anterior chamber depth.[42] In our study, we found that the young adults had the highest values in axial length, corneal curvature, anterior chamber depth, and white-to-white.

There were a few limitations in this study. First, the sample population recruited participants with clear lens and various stages of cataract which might have been a confounding factor to anterior chamber depth measurements. Second, this was a cross-sectional study. Thus, the evaluation of changes in correlation between exophthalmometric value and ocular biometry cannot be followed up with age. Third, refraction, interpupillary distance, weight, height, and body mass index which have a strong correlation with exophthalmometry were not analyzed in this study.[16,17,41] To address the limitations of this study, larger population-based prospective studies with the analysis of the severity of cataract, refraction, interpupillary distance, weight, height, and body mass index should be conducted to reflect more accurate results on the correlation between exophthalmometric values and ocular biometry.

Conclusion

Our study had established the normal exophthalmometric value for Malay adults in Kelantan for future clinical reference. The axial length had shown to have a significant positive correlation with exophthalmometric values. There was no significant correlation between exophthalmometric value with corneal curvature, anterior chamber depth, and white-to-white in this study.

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Nil.

Conflicts of interest
The authors declare that there are no conflicts of interests of this paper.

Table 8: Multiple linear regression of right eye exophthalmometric values with ocular biometry of adult Kelantanese Malay

Variables	Unstandardized coefficients		Standardized coefficients, *B*	*t*	Significance	95.0% CI for B	
	B	SE				Lower bound	Upper bound
Right eye (constant)	−2.509	6.927		−0.362	0.717	−16.149	11.130
Axial length	0.535	0.129	0.286	4.154	0.000*	0.281	0.788
Corneal curvature	−0.059	0.090	−0.042	−0.652	0.515	−0.237	0.119
Anterior chamber depth	0.149	0.336	0.029	0.445	0.657	−0.511	0.810
White-to-white	0.491	0.296	0.103	1.662	0.098	−0.091	1.073

*Statistical significance (P<0.05). t=t statistic, CI=Confidence interval, *B*=Beta, SE=Standard error

Table 9: Multiple linear regression of left eye exophthalmometric values with ocular biometry of adult Kelantanese Malay

Variables	Unstandardized coefficients		Standardized coefficients, *B*	*t*	Significance	95.0% CI for B	
	B	SE				Lower bound	Upper bound
Left eye (constant)	3.593	7.866		0.457	0.648	−11.894	19.081
Axial length	0.485	0.132	0.255	3.672	0.000*	0.225	0.744
Corneal curvature	−0.155	0.099	−0.104	−1.569	0.118	−0.349	0.039
Anterior chamber depth	0.008	0.348	0.001	0.022	0.983	−0.677	0.692
White-to-white	0.476	0.344	0.089	1.384	0.168	−0.201	1.154

*Statistical significance (P<0.05). t=t statistic, CI=Confidence interval, *B*=Beta, SE=Standard error

Table 10: Comparison of Exophthalmometric Values of Adult Population According to Race with Other Literature

Authors, year	Race	Sample size (*n*)	Mean exophthalmometric value (mm)		Results of exophthalmometry upper limit in adults (mm)	
			Male	Female	Male	Female
This study	Malay (Kelantan)	267	OD 14.43 OS 14.43	OD 13.51 OS 13.52	OD 18 OS 18	OD 19 OS 18
Wu *et al.*, 2015 [1]	Han Chinese	2010	18.8 OS and 19.0 OD (no significant difference among genders)		19.7 OS and 19.9 OD (no significant difference among genders)	
Nath *et al.*, 1977 [9]	Indian	629	OD 15.2 OS 14.8	OD 14.4 OS 14.0	22.0 (for population study group)	
Kumari *et al.*, 2001 [10]	Indian	250	-	-	19.0	21.0
de Juan *et al.*, 1980 [18]	Black	402	-	-	24.0	23.0
	White	325	-	-	21.0	19.0
Migliori and Gladstone, 1984 [19]	Black	354	18.5	17.8	24.7	23.0
	White	327	16.5	15.4	21.7	20.1
Tsai *et al.*, 2006 [20]	Taiwanese Chinese	419	13.9 (both genders)		18.6 mm (no gender difference or asymmetry)	
Bilen *et al.*, 2007 [21]	Turkish	840	13.5	13.4	20.0	19.0
Erb *et al.*, 2003 [22]	Asia	89	15.5	13.5	19.7	18.3
Kook *et al.*, 2003 [23]	Korean	176	17.2	16.1	-	-

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