Distribution and Determinants of Ocular Biometric Parameters in an Asian Population: The Singapore Malay Eye Study

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Purpose. To examine the distribution and systemic determinants of ocular biometry as measured using partial laser interferometry in an adult Asian population.

Methods. A population-based, cross-sectional study of 3280 persons (78.7% participation rate) ages 40 to 80 years, of Malay ethnicity residing in Singapore, was conducted. Axial ocular dimensions, including axial length (AL), anterior chamber depth (ACD), and corneal curvature (CC), were determined with partial laser interferometry. Participants had a comprehensive interview and a standardized examination.

Results. After 492 persons were excluded who had undergone cataract surgery, data on 2788 subjects were available. The mean AL, ACD, and CC were 23.55, 3.10, and 7.65 mm, respectively. AL and ACD decreased with increasing age. In multivariate models that adjusted for age, sex, education, height, weight, number of reading hours, diabetes, and current smoking, longer AL was associated with being male, height, increasing weight, higher education levels, and total reading hours. Increasing CC was associated with greater age and greater height and weight after multivariable adjustment.

Conclusions. Age, sex, and stature were the most consistent predictors of the results of ocular biometry in the Singapore Malay adult population. (*Invest Ophthalmol Vis Sci.* 2010;51: 103–109) DOI:10.1167/iovs.09-3553

Myopia and other refractive errors are major causes of visual impairment worldwide,[1] and an in-depth knowledge of ocular biometric parameters, particularly axial length (AL), is critical, both in understanding the risk factors and determinants of ammetropia[2–5] and in formulating appropriate preventative and treatment strategies. Effective visual rehabilitation after cataract surgery also depends on accurate intraocular lens (IOL) power calculations, which are primarily derived from normative ocular biometric data.[6–9]

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Population-based data on ocular biometric parameters are therefore important, as these are less susceptible to the selection biases that may be present in smaller, hospital- or clinic-based populations.[10–13] To date, data on ocular biometric parameters in adults older than 40 years in the general population have been relatively limited.[2–4,14–16] Furthermore, most existing adult studies have performed ocular biometry with A-scan ultrasound, which is known to be limited by measurement errors and is not now routinely used to assess IOL power before cataract surgery. The distribution and determinants of AL, as measured with newer techniques, such as partial laser interferometry (IOLMaster; Carl Zeiss Meditec, Dublin, CA), have been less well described.[14] The IOLMaster offers several significant advantages over A-scan ultrasound biometry, including noncontact testing, greater reproducibility, higher precision, and applications in certain pathologic conditions like staphyloma.[17–21] The Beaver Dam Eye Study (BDES)[14] recently reported on the distribution of ocular biometric measures with the IOLMaster at their 15-year follow-up examination in older white persons and found associations between ocular dimensions and age, sex, stature, and education. However, data from the BDES are only applicable to white people 58 to 100 years of age, and may be influenced by selection biases (<50% of the original cohort were examined). These relationships are yet to be verified in other ethnic groups and populations.

The purpose of this study was to describe the distribution and systemic determinants of ocular biometric parameters measured with the IOLMaster in an adult Asian Malay population residing in Singapore.

Methods

Study Population

The Singapore Malay Eye Study (SiMES) is a population-based, cross-sectional study of urban Malay adults aged 40 to 80 years residing in Singapore. In Singapore, people of Malay ethnicity constitute approximately 14% of the population, with people of Chinese ethnicity constituting the majority (~75%) and Indians and other minority races accounting for the rest. Study design and population details have been described elsewhere.[22] In brief, an age-stratified random sampling process was used to select Malay subjects from a national database. Of those eligible, 3280 (78.7% response rate) were examined between 2004 and 2006.

All study procedures were performed in accordance with the tenets of the Declaration of Helsinki, as revised in 1989. Written informed consent was obtained from all subjects, and the study was approved by the Institutional Review Board of the Singapore Eye Research Institute.

Examination Procedures

The ocular biometric parameters AL, anterior chamber depth (ACD), and corneal curvature (CC) were measured with noncontact partial

TABLE 1. Characteristics of Participants Included and Excluded from Analysis

Characteristics	Included (n = 2788)	Excluded (n = 492)	P*
Age, y	57.3 (10.66)	66.6 (9.67)	<0.001
Sex, male	1333 (47.8)	243 (49.4)	0.52
Education			<0.001
No formal education	508 (18.3)	178 (36.6)	
Less than elementary	224 (8.0)	77 (15.8)	
Elementary	1291 (46.4)	183 (37.6)	
High school	559 (20.1)	39 (8.0)	
College/university	201 (7.2)	10 (2.1)	
Current smoker, yes vs. no	601 (21.6)	61 (12.5)	<0.001
Alcohol intake, yes vs. no	52 (1.9)	1 (0.2)	0.01
Hypertension, yes vs. no	1835 (65.8)	411 (83.7)	<0.001
Cataract, yes vs. no	582 (20.9)	182 (37.1)	<0.001
Diabetes, yes vs. no	1220 (44.3)	256 (82.1)	<0.001
Systolic BP, mm Hg	145.8 (23.30)	154.8 (24.92)	<0.001
Diastolic BP, mm Hg	79.8 (11.14)	79.1 (11.60)	0.17
Height, cm	158.7 (9.01)	156.1 (9.51)	<0.001
Weight, kg	66.2 (13.58)	65.1 (14.46)	0.08
BMI, kg/m^2	26.3 (5.07)	26.7 (5.34)	0.14
Serum glucose, mmol/L	6.7 (3.59)	7.4 (4.09)	<0.001
$HbA1_c$, %	6.4 (1.53)	6.8 (1.66)	<0.001
Total cholesterol, mmol/L	5.6 (1.14)	5.6 (1.29)	0.88
HDL-cholesterol, mmol/L	1.4 (0.33)	1.3 (0.35)	0.58
LDL-cholesterol, mmol/L	3.6 (1.00)	3.5 (1.05)	0.06
Serum creatinine, μmol/L	90.8 (45.24)	110.2 (96.77)	<0.001
Intraocular Pressure, mm Hg	15.4 (3.50)	15.4 (4.62)	0.86
Spherical equivalent, D	−0.08 (2.01)	−0.52 (2.90)	0.003

Data are presented as the mean (SD) or n (%), as appropriate for the variable.

* P for the difference in characteristics in included and excluded participants, based on χ^2 test or t-test, as appropriate.

coherence laser interferometry (IOLMaster ver. 3.01; Carl Zeiss Meditec AG, Jena, Germany). Refraction was determined with a methodology similar to that used in the Tanjong Pagar Survey.[4] Noncycloplegic refraction and the radii of corneal curvature (CC) in the horizontal and vertical meridians were first estimated with an autorefractor (CRK-5 Auto Ref-Keratometer, Canon Inc. Ltd., Tokyo, Japan). The refraction was further refined subjectively by trained optometrists until the best visual acuity was obtained. The final subjective refraction result was used in the analysis.

All participants had a standardized slit lamp (model BQ-900; Haag-Streit, Köniz, Switzerland) examination, as described previously.[22] Intraocular pressure (IOP) was measured before pupil dilation in a standardized protocol by Goldmann applanation tonometry.

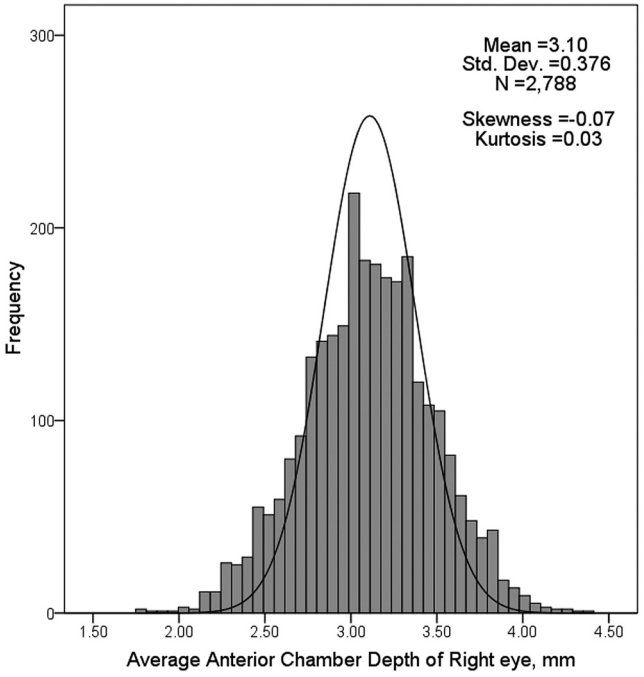

FIGURE 2. Distribution of ACD.

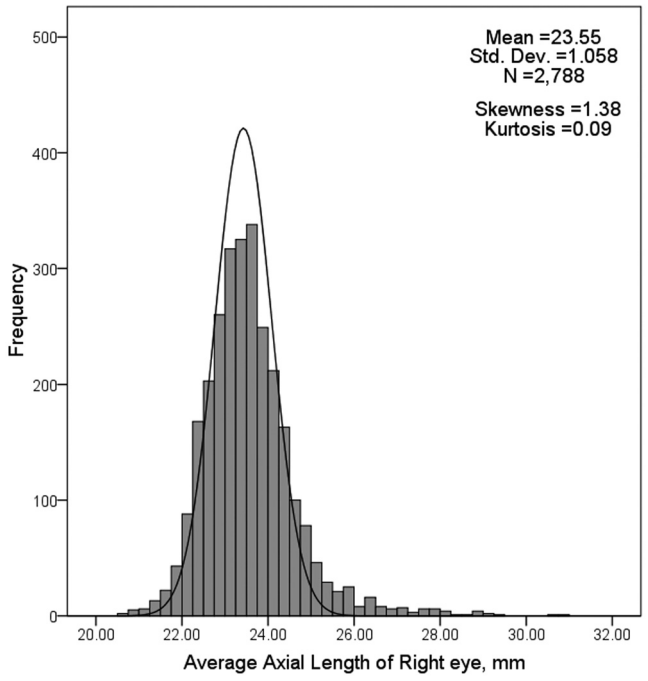

FIGURE 1. Distribution of AL.

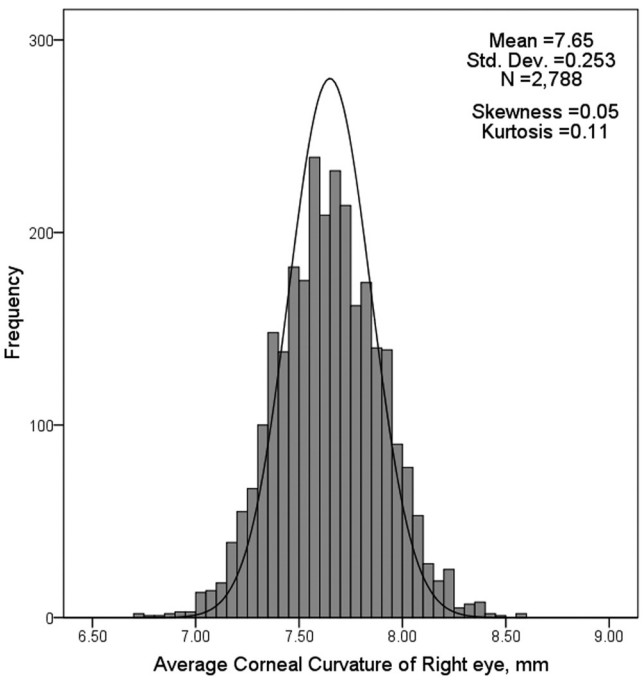

FIGURE 3. Distribution of CC.

TABLE 2. Means for AL, ACD, and CC, by Age, Sex, Spherical Equivalent, and Refractive Error Categories

Sex/Age Group (y)	*n*	AL	ACD	CC
All persons				
40–49	777	23.78 (0.04)	3.30 (0.01)	7.66 (0.01)
50–59	886	23.59 (0.04)	3.15 (0.01)	7.65 (0.01)
60–69	640	23.40 (0.04)	2.96 (0.01)	7.64 (0.01)
70–80	485	23.37 (0.05)	2.89 (0.02)	7.64 (0.01)
P		<0.001	<0.001	0.17
Men				
40–49	361	23.88 (0.05)	3.34 (0.02)	7.71 (0.01)
50–59	398	23.83 (0.05)	3.19 (0.02)	7.71 (0.01)
60–69	310	23.69 (0.06)	3.05 (0.02)	7.70 (0.01)
70–80	264	23.58 (0.05)	2.93 (0.02)	7.70 (0.02)
P		<0.001	<0.001	0.34
Women				
40–49	416	23.66 (0.06)	3.27 (0.02)	7.62 (0.01)
50–59	488	23.36 (0.05)	3.11 (0.02)	7.59 (0.01)
60–69	330	23.12 (0.05)	2.88 (0.02)	7.57 (0.01)
70–80	221	23.36 (0.03)	2.84 (0.02)	7.59 (0.02)
P		<0.001	<0.001	0.13

Data are presented as mean millimeters (SD).

Assessment of Covariates

Participants underwent a standardized interview, examination, and collection of nonfasting venous blood samples. Height was quantified in centimeters, with a wall-mounted measuring tape; weight was assessed in kilograms, on a digital scale. Both measurements were performed on participants without shoes and excess clothing. Systolic and diastolic blood pressures and pulse rate were evaluated with a digital automatic blood pressure monitor (Dinamapp model Pro Series DP110X-RW, 100V2; GE Medical Systems Information Technologies, Inc., Milwaukee, WI). Nonfasting venous blood samples were analyzed for serum glucose, HbA1C, total cholesterol, HDL, and LDL cholesterol, and serum creatinine on the same day.

A detailed, interviewer-administer questionnaire was used to gather a self-reported medical history of hypertension, diabetes, current cigarette smoking (never smoked, current smoker, or past smoker), alcohol consumption (yes or never), education level (no formal education, less than elementary, elementary, high school, college, and university), occupation (professional, service worker, production worker, homemaker, retired, unemployed, and others), and housing type (one- to two-room flat, three- to four-room flat, five-room flat, and private housing). Other data collected included whether the participant could read or write and the number of hours spent reading and using a computer each week.

Definitions

Spherical equivalent (SE) was defined as sphere plus half negative cylinder. We used right eyes with no history of cataract surgery for the primary analysis of refractive errors. Refractive errors were defined as low to moderate myopia (SE between −0.5 D and −5 D), high myopia (> −5 D) and hyperopia (SE > +1 D).

Hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or physician-diagnosed. Diabetes mellitus was identified from plasma glucose ≥200 mg/dL (11.1 mmol/L), self-reported use of diabetic medication, or physician-diagnosed diabetes. Current smokers were defined as those currently smoking every day or on some days.

Statistical Analysis

As biometric data for the right and left eyes correlated highly (Pearson correlation coefficient for AL = 0.93, $P < 0.001$), analyses were performed using only data for right eyes. Participants with a prior history of right-eye cataract surgery were excluded. Analysis of variance (ANOVA) was conducted to evaluate the variation in different biometric components. A linear test for trend was used to investigate significance. Univariate and multivariate analyses were performed to determine association of ocular biometric components with SE refraction and associations of various anthropomorphic, demographic, socioeconomic, and systemic factors with ocular biometric components. We performed these analyses separately for the three biometric components (AL, ACD, and CC) with initial adjustments for age and sex, followed by further analyses in three multivariable models. Significant variables in initial age- and sex-adjusted models were selected to be included in the multivariate models for the respective outcomes (AL/ACD/CC). Where the variables were closely related to one another (e.g., education with housing and occupation), only the most significant one was included. Further backward selection of the variables in the multivariate model was performed based on a criterion of $P < 0.05$, after adjustment for every other variable, to achieve a parsimonious model. Model 1 for AL was adjusted for age, sex, education, height, weight, number of reading hours per week, diabetes, and smoking status; model 2 for ACD was adjusted for age, sex, education, and height; and model 3 for CC was adjusted for age, sex, education, height, and weight (all analyses: SPSS version 15.0 SPSS, Inc., Chicago, IL).

RESULTS

Of the 3280 participants, 492 who had prior cataract extraction in the right eye, were excluded, leaving 2788 (85%) for further analysis. Table 1 shows the characteristics of the 2788 participants included in the analysis. Compared with those excluded from the analyses, the study population was younger (57.3 years vs. 66.6 years) and taller, had higher education, were more likely to smoke, and had lower serum creatinine, but were less likely to have hypertension, diabetes, or cataract (all comparisons, $P < 0.001$).

The mean age- and sex-adjusted AL, ACD, and CC were 23.55, 3.10, and 7.65 mm, respectively. AL, ACD and CC were

TABLE 3. Multivariate Linear Regression Models for SE Refraction, by AL, ACD, and CC, Stratified by Age and Sex

	40–59 y				60–80 y			
	Men		Women		Men		Women	
Characteristics	Standardized β	*P*	Standardized β	*P*	Standardized β	*P*	Standardized β	*P*
AL*	−0.727	<0.001	−0.744	<0.001	−0.477	<0.001	−0.457	<0.001
ACD†	−0.333	<0.001	−0.332	<0.001	−0.097	0.022	−0.148	0.001
CC‡	0.135	<0.001	0.024	0.478	0.042	0.329	0.111	0.010

* Adjusted for education, height, weight, number of reading hours per week, diabetes, and smoking status.
† Adjusted for education and height.
‡ Adjusted for education, height, and weight.

Table 4. Age and Sex-Adjusted Means for AL, ACD, and CC, by Ocular and Systemic Parameters

Characteristics	*n*	AL	ACD	CC
Occupation				
Professional/office	272	23.74 (0.07)	3.12 (0.02)	7.66 (0.02)
Service workers	644	23.60 (0.04)	3.11 (0.01)	7.67 (0.01)
Production workers	335	23.40 (0.06)	3.09 (0.02)	7.65 (0.01)
Homemakers	905	23.53 (0.04)	3.09 (0.01)	7.63 (0.01)
Retired/unemployed	576	23.59 (0.05)	3.11 (0.02)	7.66 (0.01)
Others	52	23.43 (0.14)	3.12 (0.05)	7.62 (0.04)
P		0.003	0.802	0.220
Housing type				
1–2 room flats	417	23.51 (0.05)	3.09 (0.02)	7.64 (0.01)
3–4 room flats	1900	23.53 (0.02)	3.10 (0.01)	7.65 (0.01)
5 room flats	426	23.70 (0.05)	3.12 (0.02)	7.66 (0.01)
Private housing	41	24.24 (0.16)	3.29 (0.05)	7.65 (0.04)
P		<0.001	0.004	0.502
Education				
No formal education	508	23.36 (0.05)	3.06 (0.02)	7.63 (0.01)
Less than elementary	224	23.43 (0.07)	3.08 (0.02)	7.64 (0.02)
Elementary	1291	23.50 (0.03)	3.10 (0.01)	7.65 (0.01)
High school	559	23.78 (0.05)	3.15 (0.02)	7.67 (0.01)
College/university	201	24.01 (0.07)	3.17 (0.03)	7.69 (0.02)
P		<0.001	<0.001	0.089
Pulse pressure, mm Hg				
1st quartile	712	23.59 (0.04)	3.12 (0.01)	7.66 (0.01)
2nd quartile	699	23.64 (0.04)	3.13 (0.01)	7.67 (0.01)
3rd quartile	688	23.47 (0.04)	3.09 (0.01)	7.63 (0.01)
4th quartile	687	23.54 (0.04)	3.08 (0.01)	7.64 (0.01)
P		0.034	0.081	0.041
Serum glucose, mmol/L				
1st quartile	755	23.64 (0.04)	3.14 (0.01)	7.66 (0.01)
2nd quartile	615	23.56 (0.04)	3.11 (0.01)	7.65 (0.01)
3rd quartile	643	23.52 (0.04)	3.08 (0.01)	7.65 (0.01)
4th quartile	660	23.52 (0.04)	3.08 (0.01)	7.65 (0.01)
P		0.107	0.001	0.494
Smoking status				
Never Smoked	1705	23.64 (0.03)	3.11 (0.01)	7.65 (0.01)
Current smokers	601	23.42 (0.05)	3.08 (0.02)	7.66 (0.01)
Past smokers	476	23.48 (0.05)	3.11 (0.02)	7.65 (0.01)
P		0.002	0.126	0.592
Alcohol intake				
Never	2725	23.57 (0.02)	3.11 (0.01)	7.65 (0.01)
Yes	52	23.24 (0.14)	3.03 (0.05)	7.59 (0.03)
P		0.021	0.102	0.083
Reading hours per week				
0	369	23.36 (0.06)	3.04 (0.02)	7.63 (0.01)
0.1–1	1341	23.54 (0.03)	3.11 (0.01)	7.65 (0.01)
1–2	623	23.58 (0.04)	3.11 (0.01)	7.67 (0.01)
3–4	195	23.76 (0.07)	3.16 (0.02)	7.64 (0.02)
4–5	67	23.51 (0.13)	3.10 (0.04)	7.64 (0.03)
More than 5 hours	178	23.91 (0.08)	3.15 (0.03)	7.68 (0.02)
P		<0.001	0.001	0.197
Computer hours per week				
0	1717	23.49 (0.03)	3.09 (0.01)	7.65 (0.01)
0.1–1	667	23.61 (0.04)	3.12 (0.01)	7.66 (0.01)
1–2	100	23.79 (0.10)	3.09 (0.03)	7.66 (0.03)
3–4	62	23.80 (0.13)	3.12 (0.04)	7.71 (0.03)
4–5	29	23.54 (0.19)	3.08 (0.06)	7.62 (0.05)
More than 5 hours	155	23.95 (0.08)	3.19 (0.03)	7.67 (0.02)
P		<0.001	0.014	0.354
Diabetes				
No	2206	23.58 (0.02)	3.11 (0.01)	7.65 (0.01)
Yes	582	23.49 (0.04)	3.09 (0.01)	7.64 (0.01)
P		0.064	0.162	0.233
Height, cm				
1st quartile	723	23.29 (0.05)	3.05 (0.02)	7.57 (0.01)
2 nd quartile	670	23.60 (0.04)	3.12 (0.01)	7.64 (0.01)
3rd quartile	702	23.60 (0.04)	3.12 (0.01)	7.66 (0.01)
4th quartile	680	23.76 (0.05)	3.12 (0.02)	7.73 (0.01)
P		<0.001	0.003	<0.001

(*continues*)

TABLE 4 (*continued*). Age and Sex-Adjusted Means for AL, ACD, and CC, by Ocular and Systemic Parameters

Characteristics	*n*	AL	ACD	CC
Weight, kg				
1st quartile	697	23.39 (0.04)	3.08 (0.01)	7.61 (0.01)
2nd quartile	698	23.51 (0.04)	3.09 (0.01)	7.65 (0.01)
3rd quartile	691	23.59 (0.04)	3.12 (0.01)	7.65 (0.01)
4th quartile	689	23.75 (0.04)	3.12 (0.01)	7.70 (0.01)
P		<0.001	0.094	<0.001
BMI, kg/m^2				
1st quartile	694	23.47 (0.04)	3.09 (0.01)	7.64 (0.01)
2nd quartile	694	23.50 (0.04)	3.10 (0.01)	7.64 (0.01)
3rd quartile	693	23.62 (0.04)	3.13 (0.01)	7.64 (0.01)
4th quartile	694	23.66 (0.04)	3.10 (0.01)	7.68 (0.01)
P		0.001	0.142	0.006
HDL cholesterol, mmol/L				
1st quartile	707	23.59 (0.04)	3.11 (0.01)	7.66 (0.01)
2nd quartile	667	23.61 (0.04)	3.13 (0.01)	7.66 (0.01)
3rd quartile	671	23.46 (0.04)	3.08 (0.01)	7.64 (0.01)
4th quartile	694	23.60 (0.04)	3.11 (0.01)	7.65 (0.01)
P		0.029	0.054	0.612

Data are presented as mean millimeters (SD). Other variables examined but not statistically significant include systolic and diastolic blood pressure, total and LDL cholesterol, and serum creatinine.

fairly normally distributed (Figs. 1, 2, 3). There was a significant trend of decreasing AL and ACD with increasing age for the population as a whole as well as for men and women. CC did not vary significantly with age (Table 2). Table 3 describes the results of multivariate linear regression analyses of the determinants of SE in the men and women 40 to 59 or 60 to 80 years of age. Longer AL and ACD were significant determinants of more myopic SE in all groups. Steeper CC was a significant determinant in men aged 40 to 59 years and women aged 60 to 80 years. The standardized β coefficients indicated that AL was the most important determinant of SE in all groups, but was less important in those 60 to 80 years of age than in those 40 to 59.

In age- and sex-adjusted models (Table 4), persons with higher education ($P < 0.001$), better housing ($P < 0.001$), professional occupations ($P = 0.003$), or longer hours spent reading or performing computer work ($P < 0.001$ for both) had longer AL ($P < 0.05$). Taller and heavier subjects with higher BMI had longer AL ($P < 0.001$ for both). Current or past smoking and any alcohol consumption were associated with shorter AL ($P = 0.002$ and 0.02, respectively). There were no significant associations between ocular biometry and blood glucose, lipid profile, or serum creatinine. Steeper CC was associated with higher pulse pressure, shorter height, and lower BMI ($P = 0.04$, <0.001 and <0.006, respectively).

The multivariate adjusted influences of different biometric parameters are shown in Table 5. After adjustment for age, sex, education, height, weight, number of reading hours, diabetes, and current smoking, increasing AL was associated with being male ($\beta = -0.079$, $P = 0.017$), height ($\beta = 0.162$, $P < 0.001$), increasing weight ($\beta = 0.078$, $P < 0.001$), higher education levels ($\beta = 0.118$, $P < 0.001$), greater reading hours ($\beta = 0.054$, $P = 0.009$), and a nonsmoking history (current versus never smoked $\beta = -0.072$, $P = 0.003$; ever versus never smoked $\beta = -0.053$, $P = 0.021$). Increasing CC was associated with older age ($\beta = 0.062$, $P = 0.006$) and greater height and weight ($\beta = 0.250$ and 0.063, $P < 0.001$ and $P = 0.002$, respectively) after multivariate adjustment (Table 4).

Figure 4 shows unadjusted and height-adjusted means of AL, ACD, and CC by age group and sex. In height-adjusted models,

TABLE 5. Multivariate Linear Regression Models for AL, ACD, and CC, by Systemic Parameters

	AL*		ACD†		CC‡	
Characteristics	Standardized β	*P*	Standardized β	*P*	Standardized β	*P*
Age, y	−0.014	0.552	−0.358	<0.001	0.062	0.006
Female vs. male	−0.079	0.017	−0.059	0.025	−0.016	0.576
Education	0.118	<0.001	0.088	<0.001	0.038	0.088
Height, cm	0.162	<0.001	0.075	0.005	0.250	<0.001
Weight, kg	0.078	<0.001	—	—	0.063	0.002
Reading hours per week	0.054	0.009	—	—	—	—
Smoking status			—	—	—	—
Current vs. never	−0.072	0.003				
Past vs. never	−0.053	0.021				
Diabetes, yes vs. no	−0.044	0.018	—	—	—	—
Adjusted R^2	0.105		0.199		0.087	

Data are presented as mean millimeters (SD).

* Model 1: adjusted for age, sex, education, height, weight, number of reading hours per week, diabetes, and smoking status.

† Model 2: adjusted for age, sex, education and height.

‡ Model 3, adjusted for age, sex, education, height and weight.

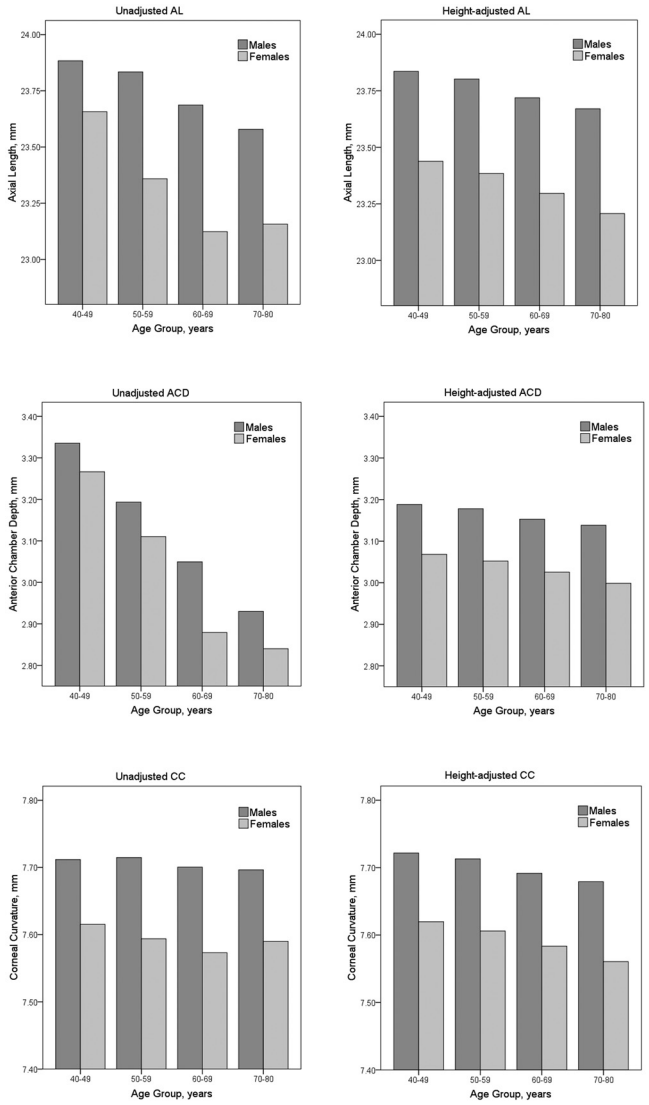

FIGURE 4. Age- and height-adjusted means of AL, ACD, and CC by age group and sex.

AL, ACD, and CC were still significantly higher in men than in women across all age groups.

DISCUSSION

Our study provides cross-sectional normative data on AL, ACD, and CC based on IOLMaster measurements in an adult population of Malays aged 40 to 80 years. In SiMES, older people had shallower ACD, but AL did not vary with age, and females had shorter AL and shallower ACD than males. These patterns are similar to those observed in the Tanjong Pagar Survey (TPS),[4] a population-based study of Singaporean Chinese that used similar protocols and study definitions but measured biometry with A-scan ultrasound, rather than the IOLMaster. The mean AL in our study (23.55 mm) is longer than that reported in other population based surveys in Chinese (mean, 23.23 mm)[4], Latinos (23.38 mm),[3] Mongolians (23.13 mm),[5] and Burmese[2] The mean CC of 7.65 mm in our population is similar to that in Chinese (7.65 mm) and less steep than in Burmese (7.62 mm).[2,4] AL was the main determinant of SE, whereas CC was of relatively minor importance, consistent with reported data.[5]

Ocular biometric parameters and their physiological determinants are known to vary considerably across racial groups and populations. For example, age and sex are reportedly associated with AL variations in Chinese,[4] but not Mongolians,[5] Burmese,[2] or Latinos[3], whereas cataract has been identified as a major cause of refractive error in the Burmese and Chinese[2,4] but not in Latinos.[3] There is also emerging evidence in some populations that biometric parameters are influenced by anthropometric measurements, social status, education, and occupation.[2,14,23–25]

Our study further highlights the usefulness of analyzing biometric data to understand the etiology of refractive error, as previously described in the BDES[26,27] and the TPS.[4] In the latter, myopia in younger persons aged 40 to 49 years was due mainly to differences in AL, whereas myopia in older persons aged 70 to 79 years was mainly due to nuclear sclerosis.[4] Similarly, we demonstrated that the importance of AL in determining SE was reduced in older subjects aged 60 to 80 years compared to younger subjects aged 40 to 59 years.

Age-related differences in AL have been attributed either to a cohort effect[28] or to an actual reduction of AL with age. In the BDES, adjustment for height and education negated the association between age and AL, implicating a cohort effect in which younger subjects with a more favorable socioeconomic background and correspondingly larger stature develop longer AL. In SiMES, we observed a similar relationship, as AL was significantly associated with age in univariate analyses but not in the multivariate analysis that was adjusted for height, weight, and education.[29]

Sex-related differences in biometry have been documented in several populations. In general, men have longer eyes, deeper anterior chambers, and flatter corneas than do women as measured by A-scan ultrasound[2–5] and IOLMaster[14] (Table 5). Much of the variation has been attributed to differences in stature between men and women, particularly height, as adjustment for height in multivariate analyses tended to attenuate the association.[3,5] For example, the BDES[14] reported that men had generally longer ALs and larger eyes, but adjustment for height rendered the association nonsignificant. In SiMES, however, sex differences in AL and ACD were still significant in multivariate analyses controlling for stature (Table 4, Fig. 4), suggesting that sex may be an independent determinant of AL. Genetic and other factors may account for the differences in biometry in men and women.[30]

Taller individuals were found to have longer ALs and ACDs and flatter corneas, suggesting an overall increase in globe size. Significant relationships between stature and AL have been reported in other adult populations including the Rejkjavik Eye Study[31], the TPS,[23] the BDES,[14] and the Meiktila[32] study. Two main hypotheses have been proposed to account for these associations. Proportionate changes in ocular size may occur concomitantly with normal growth and development.[23,33] Furthermore, individuals of higher socioeconomic status may be taller due to various factors, such as better nutrition and greater amounts of near work activity.[23,34,35] In both SiMES and the BDES,[14] both education, as a proxy for socioeconomic status, and height were independent determinants of AL.

A weak association between smoking and myopia has been suggested from epidemiologic studies.[36] In our study, however, smoking was associated with shorter AL after adjustment for socioeconomic factors. In animal models, nicotinic antagonists inhibit experimental myopia in chicks,[37] and these receptors may be activated by nicotine in cigarette smoke.[38] Further research in this area may be useful.

Strengths of our study design include high reproducibility of the biometric measurements using the IOLMaster, standardized assessments of refraction, anthropometric measures and blood pressure, and a large population-based sample. General

limitations of our study include the possibility of selection bias, as some participants were excluded because of missing data. IOLMaster measurements have been reported to either overestimate[18,19] or underestimate[17] ocular measurements relative to A-scan ultrasound, and so caution must be exercised in any direct comparisons with data using A-scan ultrasound. The IOLMaster also does not provide information on other important biometric determinants of refraction, such as lens thickness and vitreous chamber depth.

In conclusion, age, sex, and stature were the most consistent predictors of ocular biometry measured with the IOLMaster in the Singapore Malay adult population. In general, associations shown by IOLMaster measurements show good agreement with those shown in studies in which A-scan ultrasound was used.

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