

Effect of Race, Age, and Axial Length on Optic Nerve Head Parameters and Retinal Nerve Fiber Layer Thickness Measured by Cirrus HD-OCT

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Objective: To determine the effect of race, demographic, and ocular variables on optic nerve head and retinal nerve fiber layer (RNFL) thickness measurements using spectral-domain optical coherence tomography.

Methods: In a cross-sectional observational study, 284 normal subjects aged 18 to 84 years were evaluated at 7 sites using Cirrus HD-OCT. Disc area, rim area, average cup-disc ratio, vertical cup-disc ratio, cup volume, and average, temporal, superior, nasal, and inferior RNFL thicknesses were calculated. The main outcome measures were associations between Cirrus HD-OCT optic nerve head and RNFL measurements and age, sex, and race.

Results: The 284 subjects self-identified as being of European (122), Chinese (63), African (51), or Hispanic (35) descent. After adjusting for the effect of age, there was a statistically significant difference among racial groups for

all optic nerve head and RNFL parameters (all $P \leq .005$) except rim area ($P = .22$). Rim area, average cup-disc ratio, vertical cup-disc ratio, and cup volume were moderately associated with disc area ($r^2 = 0.15, 0.33, 0.33,$ and 0.37 , respectively). After a linear adjustment for disc area, there was no statistically significant difference among racial groups for any optic nerve head parameter. Individuals of European descent had thinner RNFL measurements except in the temporal quadrant.

Conclusions: There are racial differences in optic disc area, average cup-disc ratio, vertical cup-disc ratio, cup volume, and RNFL thickness as measured by Cirrus HD-OCT. These differences should be considered when using Cirrus HD-OCT to assess for glaucomatous damage in differing population groups.

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Group Information: The Cirrus OCT Normative Database Study Group participating centers and investigators are listed at the end of this article.

P RIMARY OPEN-ANGLE GLAUCOMA is the leading cause of irreversible blindness worldwide.¹ In particular, individuals of African descent have been shown to have an increased prevalence of primary open-angle glaucoma and have poorer visual outcomes.²⁻⁶ Racial and ethnic differences in optic nerve head (ONH) parameters and retinal nerve fiber layer (RNFL) thickness have been described⁷⁻¹⁶ using scanning laser polarimetry,^{7,8} confocal scanning laser ophthalmoscopy,⁹⁻¹⁶ and time-domain optical coherence tomography (OCT).^{15,16} Disc area (DA) is larger in individuals of African descent than in any other racial or ethnic group.¹⁷⁻¹⁹ There are fewer data available regarding these differences in RNFL thickness measurements.^{15,16} Differences in anatomic measures of the ONH and RNFL are important to quantify as they may affect the ability of quantitative imaging modalities to detect glaucoma and determine the normative ranges for these devices in clinical practice in specific racial groups.

Similar to time-domain OCT, spectral-domain (SD) OCT uses interferometry to interpret reflectance data of backscattered light from the retina. Spectral-domain OCT uses a spectrometer to detect the relative amplitudes of many optical frequencies within the backscattered light simultaneously. This allows for higher-resolution images to be acquired at faster speeds. Two reports have demonstrated the ability of SD-OCT to reproducibly measure ONH parameters.^{17,18} To our knowledge, there have been no reports that examine the effect that racial differences in ONH and RNFL morphology have on Cirrus HD-OCT (Carl Zeiss Meditec) measurements. The purpose of this study was to determine the effect that race, sex, age, and axial length (AL) have on ONH and RNFL measurements acquired by Cirrus HD-OCT.

METHODS

SUBJECTS

Data were obtained from a multicenter cross-sectional study conducted to define the range

of normal values for Cirrus HD-OCT. The study received approval by the human subjects research office and institutional review board at each testing site. The study protocol adhered to the Declaration of Helsinki. Individuals 18 years or older were recruited from the friends and family members of patients and the trainees, faculty, and staff at each of 7 testing sites. Subject enrollment was standardized to ensure adequate age and sex distribution. Each testing center could enroll no more than 10 subjects younger than 30 years, older than 70 years, or in each of the intervening decades; at least 4 subjects from each age group had to be male. Two hundred eighty-seven subjects were enrolled between June 2007 and November 2007. Written informed consent and consent for compliance with the Health Insurance Portability and Accountability Act were obtained from all subjects. Each subject completed a detailed medical history and a screening eye examination to determine eligibility. During the medical history interview, each subject self-identified with 1 of 9 predetermined racial groups. Hispanic was considered a separate racial group than those of European descent, although the investigators recognize that this is technically an ethnic division. The examination included assessment of best-corrected visual acuity, slitlamp biomicroscopy, Goldmann applanation tonometry, ultrasound pachymetry, gonioscopy, visual field quantification with the Humphrey Visual Field Analyzer (Carl Zeiss Meditec, Inc) using the Swedish interactive threshold algorithm standard 24-2 program, dilated fundus examination, AL measurements (IOL Master; Carl Zeiss Meditec, Inc), and stereo disc photographs of the macula and ONH.

Subjects were included if they had normal Humphrey Visual Field examination findings in both eyes defined by a mean deviation and pattern standard deviation within 95% confidence limits, a glaucoma hemifield test result within normal limits, and eyes judged as normal by both the enrolling physician and visual field evaluation center. A reliable test result was defined as false-negative responses, false-positive responses, and fixation loss rates of 15% or less and no visual field loss consistent with ocular or systemic disease.

Subjects were excluded if the best-corrected visual acuity in either eye was less than 20/40 on a Snellen or Snellen equivalent acuity chart or the refractive error (spherical equivalent) fell outside the -12.00 diopter to +8.00 diopter range. Subjects with a history of amblyopia, glaucoma, ocular hypertension, angle closure, disc hemorrhage, or glaucoma suspect diagnosis in either eye were excluded. Additionally, subjects with previous complicated cataract and/or refractive surgery, laser trabeculoplasty, laser iridoplasty, laser iridotomy, vitreoretinal surgery in either eye, previous uncomplicated cataract and/or refractive surgery in either eye within 12 months of study enrollment, a history of diabetes mellitus, leukemia, AIDS, uncontrolled systemic hypertension, dementia, multiple sclerosis, or a life-threatening or debilitating disease were excluded. Subjects found to have disc hemorrhage, RNFL defects on examination, vitreoretinal traction, epiretinal membrane, active infection or inflammation of the anterior or posterior segments, diabetic retinopathy, diabetic macular edema, or other vitreoretinal disease in either eye during the screening examination were also excluded.

OCT TECHNIQUE

All subjects underwent imaging with Cirrus HD-OCT. One eye from each enrolled subject was randomly chosen for inclusion in the normative database. After pharmacologic dilatation, both eyes were scanned 3 times each using the optic disc cube 200 × 200 protocol. All scans were acquired in the same session within 5 to 10 seconds of each other. In this protocol, the laser scans over a 6 mm × 6 mm area, capturing a cube of data con-

sisting of 200 A-scans from 200 linear B-scans (40 000 points) in about 1.5 seconds (27 000 A-scans/s). In total, 7 Cirrus HD-OCT instruments, 1 at each testing site, were used to acquire images of the ONH.

The ONH algorithm defines the disc and cup margins within the 3-dimensional data cube. The disc margin is defined as the termination of Bruch's membrane. The rim width around the entire circumference of the optic disc is then determined by measuring the thickness of the neuroretinal tissue in the optic nerve as it turns to exit through the opening in Bruch's membrane. The following ONH parameters were analyzed: DA, rim area (RA), average cup-disc ratio (ACDR), vertical cup-disc ratio (VCDR), and cup volume (CV). The ACDR is calculated by taking the square root of the ratio of the cup area to the DA. The VCDR is the ratio of the cup diameter to the disc diameter in a vertical meridian through the cup center. The CV is a 3-dimensional measurement defined as the volume between a plane created at 200 μm offset to the plane of the disc and the vitreoretinal interface. The ONH parameters were automatically generated by a Carl Zeiss Meditec analysis algorithm developed for Cirrus HD-OCT (version 6.0), which does not involve user interaction.

The RNFL algorithm provides standardized measurements of the RNFL within the same 3-dimensional data cube. The ONH center is defined by mapping the central dark spot in the break in the retinal pigment epithelium. A circle of data with a radius of 1.73 mm from the central dark spot is processed via bilinear interpolation and smoothing to create 512 A-scans of 2-dimensional data. Averaging of these A-scan measurements is performed to produce RNFL thickness maps.

The HD-OCT scans were included if the signal strength was greater than 6 and there were no saccades in the enface image. Scans in which the line-scanning laser ophthalmoscope image did not have sharp uniform focus or had poor centration, non-uniform illumination, or vitreous or media artifacts were also excluded.

STATISTICAL METHODS

Subject demographic and ocular characteristics including age, sex, visual field mean deviation, intraocular pressure, AL, and mean refractive spherical equivalent were compared between racial groups using 1-way analysis of variance. Correlations between ONH and RNFL parameters with each other as well as age and AL were assessed with Pearson and Spearman correlation coefficients. Associations of race and ONH and RNFL parameters accounting for the effects of age and sex were evaluated using general linear models (GLMs).

RESULTS

DEMOGRAPHIC VARIABLES

The Cirrus HD-OCT normative database comprised 284 subjects of 527 subjects screened for inclusion. Two hundred forty were disqualified for the following reasons: abnormal or unreliable visual field examination findings (138), posterior pole pathology (40), study-related medical issues (30), inability to continue (13), disqualifying ocular diagnoses (8), inability to obtain Cirrus HD-OCT scans (4), poor visual acuity (3), intraocular incisional surgery (2), use of photosensitizing medication (1), and diabetes (1). Of the remaining 287 enrolled subjects, 3 (1%) were excluded for poor-quality scans (2) or scans that could not be matched to the subject (1).

Table 1. Demographic and Ocular Characteristics

	African Descent	Chinese	European Descent	Hispanic	Total	P Value ^a
Sample size	51	63	122	35	271	
Sex, No.						.38
M	19	30	63	16	128	
F	32	33	59	19	143	
Age, y	45.8 (15.6)	44.8 (16.4)	49.1 (18.3)	39.1 (12.3)	46.2 (16.9)	.02 ^b
MRSE, mean (SD)	-0.25 (1.44)	-1.77 (2.59)	-0.73 (1.78)	-0.31 (1.17)	-0.82 (1.96)	<.001 ^b
MD, mean (SD)	-0.02 (1.09)	-0.16 (1.07)	0.22 (0.99)	-0.05 (1.07)	0.05 (1.05)	.11
IOP, mm Hg, mean (SD)	13.7 (2.2)	15.1 (2.4)	14.0 (2.5)	13.7 (2.2)	14.1 (2.4)	.002 ^b
AL, mm, mean (SD)	23.7 (0.8)	24.2 (1.3)	23.9 (1.0)	23.6 (0.8)	23.9 (1.0)	.005 ^b
CCT, μ m, mean (SD)	528 (28)	538 (33)	561 (35)	563 (39)	550 (37)	<.001 ^b

Abbreviations: AL, axial length; CCT, central corneal thickness; IOP, intraocular pressure; MD, mean deviation; MRSE, mean refractive spherical equivalent.

^aOne-way analysis of variance for all variables except sex, which was by χ^2 test.

^bSignificant.

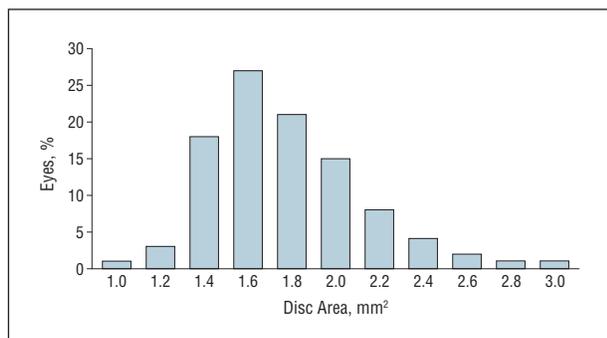


Figure 1. Histogram of the distribution of optic disc areas for the Cirrus Normative Database (N=271). The distribution of optic disc areas was fairly normal but right skewed.

The present analysis considers the 271 subjects that self-identified as white (122); Chinese (63); African American, African Caribbean, or black (51); and Hispanic (35). Thirteen subjects (4.6%) selected 1 of the remaining 5 choices (American Indian or Alaska Native, Native Hawaiian or other Pacific Islander, Indian, Japanese, and Korean) or did not indicate their race and were excluded from the current analysis because together they did not comprise a single identifiable race or ethnic group and analysis of these groups with a small sample size would not have produced interpretable results. Central corneal thickness was significantly thinner in the African descent and Chinese groups compared with the European descent and Hispanic groups.

The demographic and ocular characteristics of the 271 included subjects are shown in **Table 1**. The Hispanic group was younger than those of European descent while individuals of African descent and Chinese descent were intermediate between the the Hispanic and European descent groups (1-way analysis of variance, followed by post hoc least significant difference test). There were highly significant effects of race on all ocular parameters except mean deviation (Table 1). There were no significant differences in sex or mean deviation between racial groups. Intraocular pressure and AL were significantly greater and mean refractive spherical error was significantly more myopic in the Chinese group. Sixty-one of the 63 subjects included in the Chinese group were enrolled at the testing site in Hong Kong, China.

Because we included individuals with a history of remote uncomplicated cataract surgery, we could not fully examine the effect of refractive error. However, because AL and spherical equivalent were both measured, we used AL since it is independent of lens status. Additionally, only 5 eyes in the study population had had prior cataract surgery and none of the structural parameters differed when these subjects were excluded from analysis.

ONH PARAMETER MEASUREMENTS AND DEMOGRAPHIC VARIABLES

Figure 1 shows the distribution of optic DA as measured by Cirrus HD-OCT in the 271 normative database subjects. The mean (SD) optic DA, unadjusted for age, was 1.77 (0.34) mm² (range, 1.0-3.0 mm²). The distribution was fairly normal but right skewed, suggesting more outliers in the upper range of optic DA. **Figure 2** demonstrates the significant relationship between DA and VCDR, as well as defining the values for DA that are 1 SD less than (<1.426 mm²) and more than (>2.109 mm²) the mean value.

The means (SD) (range) of unadjusted ONH parameters in the 271 eyes were ACDR, 0.46 (0.17) (0.07-0.75); DA, 1.77 (0.34) mm² (1.01-2.93 mm²); RA, 1.31 (0.22) mm² (0.72-2.27 mm²); CV, 0.14 (0.13) mm³ (0-0.76 mm³); and VCDR, 0.44 (0.16) (0.06-0.74). All ONH parameters were highly significantly intercorrelated ($P < .001$ by either Pearson or Spearman nonparametric correlation); r^2 ranged from 15% (DA vs RA) to 95% (VCDR vs ACDR) (**Table 2**). Of the ONH parameters, only RA had correlations of substantial size ($r^2 \geq 10\%$) with RNFL parameters (Table 2).

Table 3 presents the ONH parameter means adjusted for age by race. Sex was not associated with any of the ONH parameters (GLM, all $P \geq .13$). The ACDR and VCDR were both affected by age and race (GLM, all $P \leq .005$), while DA and CV were affected by race (both $P \leq .001$) but not age (both $P \geq .13$) and RA was affected by age ($P = .008$) and not race ($P = .22$). There was no evidence of differing effects of age by race (GLM, all race \times age interaction, $P > .65$). After adjusting for DA and age, none of the other 4 ONH parameters was associated with race (GLM, all $P > .12$). Weak ($r^2 < 10\%$) but statistically sig-

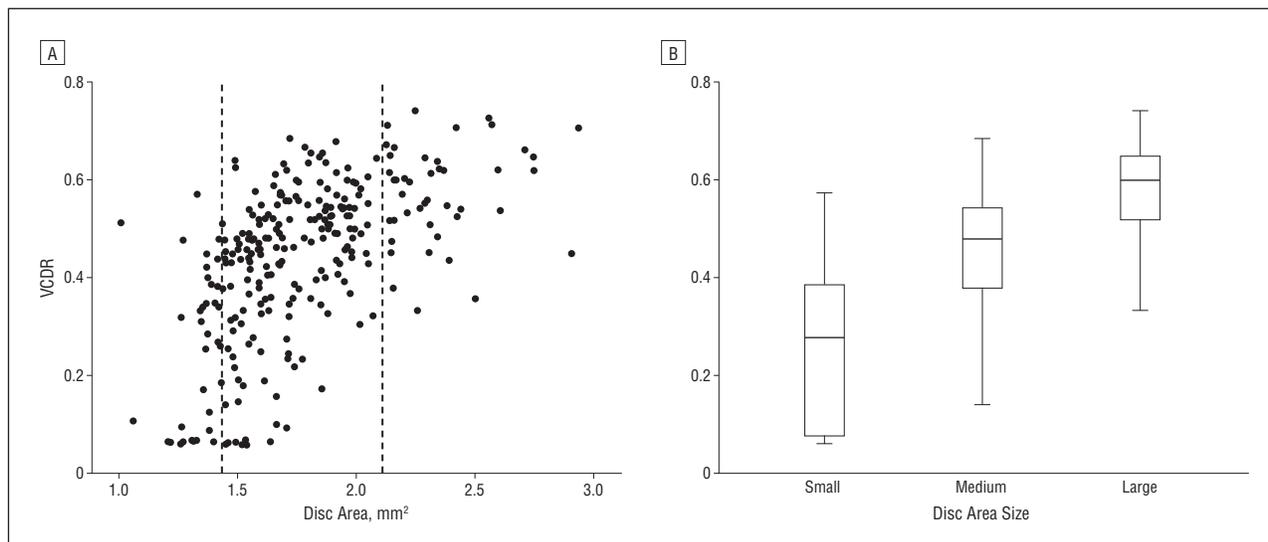


Figure 2. The relationship between disc area and vertical cup-disc ratio (VCDR). A, Scatterplot of disc area vs VCDR. The dotted lines represent mean disc area - 1 SD (1.436 mm²) and mean disc area + 1 SD (2.109 mm²). These values were used to define disc area size. The disc area mean is unadjusted for age for this figure. B, Box plot of disc area size vs VCDR demonstrating that there is a significant difference between small optic discs and large optic discs.

Table 2. Correlations Between Optic Nerve Head and RNFL Parameters^a

	DA	RA	CV	VCDR	aRNFL	tRNFL	sRNFL	nRNFL	iRNFL
CDR	0.572 ^b <.001 ^b	-0.442 ^b <.001 ^b	0.797 ^b <.001 ^b	0.973 ^b <.001 ^b	-0.079 .20	-0.112 .07	-0.046 .45	0.005 .93	-0.064 .30
DA		0.389 ^b <.001 ^b	0.608 ^b <.001 ^b	0.572 ^b <.001 ^b	0.283 ^b <.001 ^b	-0.044 .47	0.270 <.001 ^b	0.261 <.001 ^b	0.262 <.001 ^b
RA			-0.396 ^b <.001 ^b	-0.403 ^b <.001 ^b	0.446 ^b <.001 ^b	0.068 .27	0.406 ^b <.001 ^b	0.343 ^b <.001 ^b	0.377 ^b <.001 ^b
CV				0.763 ^b <.001 ^b	-0.025 .68	-0.096 .12	-0.029 .63	0.036 .56	0.015 .80
VCDR					-0.111 .07	-0.165 .007	-0.070 .25	0.016 .80	-0.086 .16
aRNFL						0.479 ^b <.001 ^b	0.805 ^b <.001 ^b	0.568 ^b <.001 ^b	0.846 ^b <.001 ^b
tRNFL							0.244 <.001 ^b	-0.114 <.001 ^b	0.239 <.001 ^b
sRNFL								0.315 ^b <.001 ^b	0.557 ^b <.001 ^b
nRNFL									0.420 ^b <.001 ^b

Abbreviations: a, average; CDR, cup-disc ratio; CV, cup volume; DA, disc area; i, inferior; n, nasal; RA, rim area; RNFL, retinal nerve fiber layer; s, superior; t, temporal; VCDR, vertical cup-disc ratio.

^aPearson correlations (*r* is the top value and *P* is the bottom value).

^bCorrelations where *r*² ≥ 0.1 (10%).

nificant correlations of AL with ONH parameters were found with DA (*r* = -0.29; *P* < .001) and RA (*r* = -0.24; *P* < .001) but not for ACDR, VCDR, or CV.

RNFL THICKNESS PARAMETERS AND DEMOGRAPHIC VARIABLES

Global and quadrant RNFL thicknesses differed significantly across racial strata. While DA was significantly associated with RNFL parameters (all *P* < .001), the correlations were all weak (*r*² < 10%) in contrast to the correlations between DA and other ONH parameters (*r*² from 15% to 37%) (Table 2). Superior, nasal, and inferior RNFL were all weakly but significantly negatively

correlated with AL (Pearson *r* from -0.15 to -0.21; all *P* < .02), while temporal RNFL was weakly and positively correlated with AL (*r* = 0.26; *P* < .001). The age- and DA-adjusted RNFL measurements are shown in **Table 4**.

COMMENT

This study describes the associations between race, age, and AL on ONH parameter and RNFL thickness measurements acquired by Cirrus HD-OCT. Race affected all ONH and RNFL measurements except RA. However, when the ONH measurements were corrected for DA, ACDR, VCDR, and CV no longer demonstrated any significant variation

Table 3. Adjusted Optic Nerve Head Parameters by Race^a

	Mean (SE)					P Value
	African Descent	Chinese	European Descent	Hispanic	Total	
DA, mm ²	1.93 (0.05)	1.78 (0.04)	1.68 (0.03)	1.86 (0.06)	1.81 (0.02)	<.001 ^b
RA, mm ²	1.32 (0.03)	1.30 (0.03)	1.29 (0.02)	1.38 (0.04)	1.32 (0.02)	.22
ACDR	0.53 (0.02)	0.47 (0.02)	0.43 (0.02)	0.46 (0.03)	0.47 (0.01)	.002 ^b
VCDR	0.51 (0.02)	0.44 (0.02)	0.41 (0.01)	0.44 (0.03)	0.45 (0.01)	.005 ^b
CV, mm ³	0.20 (0.02)	0.13 (0.02)	0.12 (0.01)	0.14 (0.02)	0.15 (0.01)	.001 ^b

Abbreviations: ACDR, average cup-disc ratio; CV, cup volume; DA, disc area; RA, rim area; VCDR, vertical cup-disc ratio.

^aMeans and standard errors for optic nerve head parameters by race using a general linear model to adjust for age.

^bSignificant.

Table 4. Adjusted RNFL Thickness Measurements by Race^a

	Mean (SE)					P Value
	African Descent	Chinese	European Descent	Hispanic	Total	
aRNFL	93.9 (1.2)	96.4 (1.1)	90.1 (0.8)	95.6 (1.4)	94.0 (0.6)	<.001 ^b
tRNFL	57.8 (1.3)	75.7 (1.2)	61.2 (0.9)	61.5 (1.6)	64.0 (0.6)	<.001 ^b
sRNFL	119.6 (1.9)	122.0 (1.7)	113.0 (1.2)	121.2 (2.3)	119.0 (0.9)	<.001 ^b
nRNFL	73.0 (1.5)	64.4 (1.4)	70.1 (1.0)	71.6 (1.8)	69.8 (0.7)	<.001 ^b
iRNFL	125.2 (2.0)	123.6 (1.8)	115.9 (1.3)	127.9 (2.4)	123.2 (1.0)	<.001 ^b

Abbreviations: a, average; i, inferior; n, nasal; RNFL, retinal nerve fiber layer; s, superior; t, temporal.

^aMeans and standard errors for RNFL thickness by race using general linear model to adjust for age and disc area.

^bSignificant.

due to race. Racial variations in RNFL measurements remained significant after correction for DA. Age had a negative correlation with both RA and RNFL thickness measurements. In the present study, RA declined by 0.003 mm²/y and RNFL thickness declined by 0.19 μm/y for all subjects. Two previous studies have documented the rate of RNFL decline in scanning laser polarimetry⁸ (0.38 μm/y) and OCT¹⁹ (2 μm/decade). There was no measured effect of AL on the acquired ONH measurements; however, AL had a negative correlation with mean and all nontemporal quadrant RNFL measurements. With regard to the temporal quadrant, AL had a positive correlation with RNFL thickness in the Chinese participants only.

The present study demonstrates that ONH parameter measurements are dependent on DA, RA is not dependent on race, and RNFL measurements vary by race. These findings are fairly consistent with similar studies in other imaging modalities. Using Stratus OCT, Marsh and associates²⁰ found that individuals of European descent had a smaller DA (2.17 mm²) compared with individuals of African descent (2.49 mm²) and Hispanic individuals (2.33 mm²), but they did not find any significant racial variation in RA or other ONH parameter measurements. In the multicenter African Descent and Glaucoma Evaluation Study, Girkin and colleagues¹⁶ observed a DA of 2.47 mm² and 2.26 mm² in individuals of African descent and European descent, respectively, and found no racial variation in any measured ONH parameters after correcting for DA. The same study examined ONH parameter measurements using Heidelberg retinal tomography (HRT). The DA was 1.77 mm² and 2.06 mm² in individuals of European descent and African descent, respectively. The observed racial variation in ACDR,

VCDR, CV, and RA lost significance after correction for DA, age, and reference height. Two other studies evaluated the variability of ONH parameter measurements in HRT. Seider and colleagues¹⁴ compared the racial variation of DA and RA. The DA was significantly smaller in individuals of European descent (2.15 mm²) than in individuals of African descent and Asian, Filipino, and Hispanic individuals (2.55 mm², 2.38 mm², 2.48 mm², and 2.57 mm², respectively). Further, the variation of RA measurements due to race was strong but insignificant (*P* = .07, likelihood ratio test). In a prior study, Girkin and associates¹³ again found significant differences in DA (2.2051 mm² and 1.8036 mm²), ACDR (0.2486 and 0.1897), and CV (0.1470 mm³ and 0.0727 mm³) in a study of 63 subjects of African descent and 42 subjects of European descent, yet there was no significant difference in VCDR (0.3337 and 0.2785) or RA (1.62 mm² and 1.543 mm²).

The RNFL differences across racial groups varied by quadrant. Individuals of European descent had the thinnest RNFL measures except in the temporal quadrant, corresponding to the papillomacular bundle, which was the thinnest in the African descent group. This relative regional difference between the African descent and European descent groups was also demonstrated with time-domain OCT in the African Descent and Glaucoma Evaluation Study.¹⁶ There is a great degree of variation due to race in DA, RA, and RNFL parameter measurements across imaging modalities in normal subjects, much of which may be due to racial variation in DA. However, RA is not dependent on race in OCT or HRT technologies.

The racial variation in ONH and RNFL parameters across imaging modalities has created some interest in race-specific normative databases. The HRT3 Normative Data-

base was developed to improve the diagnostic capabilities of HRT in individuals of African descent and Asian Indian individuals. The database included 215 individuals of African descent and was found to improve sensitivity and worsen specificity in glaucoma diagnosis for individuals of African descent in 2 studies.^{10,11} The HRT3 Normative Database also included 104 Asian Indian individuals but did not improve the diagnostic sensitivity or specificity for glaucoma in this group.²¹ Limited sample size and intraracial variation of ocular topography were identified as potential reasons for the limited impact of the expanded database on the diagnostic capability of HRT.^{11,21}

In agreement with the prior literature, the current study suggests that RA may be useful to assess the degree of glaucomatous damage independent of patient race. In studies comparing the diagnostic capability of ONH and RNFL parameters across imaging modalities, RA has consistently been identified as one of the better-performing ONH parameters for discriminating normal subjects from subjects with glaucoma. In prior studies using RA with Stratus OCT, HRT, and the HRT3 Normative Database, the areas under the receiver operating characteristic curves ranged from 0.691 to 0.905.²²⁻²⁵ The areas under the receiver operating characteristic curves observed for RA in studies using Stratus OCT range from 0.691 to 0.97.^{22,26-31} Most recently, ONH and RNFL parameters were evaluated for diagnostic capabilities in Cirrus HD-OCT. Rim area had an area under the receiver operating characteristic curve of 0.962.³² Vertical cup-disc ratio had an area under the receiver operating characteristic curve of 0.951 in the same study.³² Vertical cup-disc ratio also has excellent reproducibility in Cirrus HD-OCT.¹⁸ Previous studies have demonstrated that quantitative imaging devices can measure ONH parameters with less variability than subjective methods.³³⁻³⁵ However, these devices have not demonstrated superior diagnostic capability when compared with subjective ONH assessment. Defining VCDR with respect to DA may further improve the diagnostic value of VCDR measurements. To our knowledge, no previous study has examined a normal population and sought to define small or large optic discs. Figure 2 demonstrates the median VDCR for small, medium, and large discs as defined by mean DA - 1 SD and mean DA + 1 SD.

The current study corroborates the finding that as AL increases the mean RNFL thickness decreases.¹⁹ However, the Chinese cohort demonstrates a strong positive correlation between AL and temporal RNFL thickness. Two studies^{36,37} found a similar relationship between AL and temporal RNFL in Chinese subjects. While the relationship between AL and RNFL thickness has been extensively studied, only 3 studies examined the relationship between AL and sectoral RNFL thickness measurements. Rauscher and colleagues³⁸ examined 27 normal subjects with myopia with a racial distribution similar to the present study and found a nonsignificant positive correlation between AL and temporal RNFL thickness using Stratus OCT. Similarly, Kim and associates³⁹ used Stratus to examine this relationship in Korean subjects and found a significant positive correlation between AL and temporal RNFL thickness measurements. Most recently, Kang and colleagues⁴⁰ used a different cohort of Korean subjects and found a positive correlation between AL and temporal RNFL

thickness using Cirrus HD-OCT. Our study did not find this relationship in the non-Asian racial groups and, to our knowledge, there are no other studies currently available to determine whether this represents a phenomenon specifically of Asian ocular topography or of high myopia in all racial groups.

There are several limitations of the sample population that may reduce generalizability within specific ethnic groups. While the overall normative database is large and represents a diverse population, some of the individual ethnic and racial subgroups were somewhat small. Thus, while the sample size was sufficient to address the hypothesis of this study, they may not be large enough to be fully representative when using these normative ranges within specific populations. Furthermore, the data for each racial/ethnic group were obtained from specific sites that may not be reflective of an entire racial or ethnic group. For example, the majority of individuals of Chinese ancestry were obtained from Hong Kong and this certainly may not be representative of the entire Chinese population.

Additionally, while the population as a whole was not recruited directly from a clinic population, some selection bias may be present because subjects included in the study may be more likely to be those seeking eye care. This may affect some parameters such as the prevalence of myopia within the study groups. This may also limit generalizability to the overall populations, but it is likely reflective of those individuals seeking eye care services.

In conclusion, this study demonstrates differences in optic nerve and retinal topography across racial strata using Cirrus HD-OCT. Global and regional RNFL measurements are affected by race, age and AL. Most ONH measurements, once corrected for DA, are only affected by age, except RA, which did not vary with race or DA. Rim area may be of particular utility in assessing glaucoma across racial groups because this parameter did not vary by race. Additionally, methods of glaucoma detection using optic disc topography that account for the effect of DA may perform more robustly across the various population groups.

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