African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

Normative values for retinal parameters in a Ghanaian clinical population at risk for glaucoma

Authors:
Doreen Nelson-Ayifah[1,2]
Khathutshelo P. Mashige[1]
Alvin J. Munsamy[1]

Affiliations:
[1]Discipline of Optometry, School of Health Sciences, University of KwaZulu-Natal, Durban, South Africa

[2]Kumasi Centre for Collaborative Research in Tropical Medicine, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Corresponding author:
Doreen Nelson-Ayifah,
nelsdayy@gmail.com

Dates:
Received: 24 May 2024
Accepted: 10 Oct. 2024
Published: 30 Nov. 2024

How to cite this article:
Nelson-Ayifah D, Mashige KP, Munsamy AJ. Normative values for retinal parameters in a Ghanaian clinical population at risk for glaucoma. Afr Vision Eye Health. 2024;83(1), a951. https://doi.org/10.4102/aveh.v83i1.951

Background: There is rarity of normative data on retinal parameters associated with glaucoma in Ghanaians.

Aim: This study aimed to provide normative data on retinal parameters associated with glaucoma in an at-risk Ghanaian clinical population.

Setting: The study was conducted at the Eye Clinic of the Komfo Anokye Teaching Hospital, Ghana.

Methods: Ophthalmic data were obtained from 338 eyes of 116 males and 222 females (mean age: 61.86 ± 9.54 years, range: 45–89 years). The participants underwent eye examinations including visual acuity measurement using the Snellen chart at 6 m, auto-refraction using the Retinomax K+ Screen Hand-Held Autorefractor Keratometer, Goldmann applanation tonometry, slit-lamp biomicroscopy, fundus examination using a 90D Volks lens, and optical coherence tomography (OCT) using the Zeiss Cirrus HD OCT (Carl Zeiss Meditec, Dublin, CA, United States). Height and weight of participants were measured using a measuring tape and a weighing scale, respectively.

Results: Mean ± standard deviation values for retinal parameters were: global peripapillary retinal nerve fibre layer (ppRNFL) = 96.11 ± 9.87 µm, global macula ganglion cell complex (mGCC) = 80.91 ± 5.61 µm, optic disc area = 2.05 ± 0.39 mm^2, rim area = 1.52 ± 0.27 mm^2, cup volume = 0.13 ± 0.12 mm^3, average cup to disc ratio (ACDR) = 0.47 ± 0.15 and vertical cup to disc ratio (VCDR) = 0.44 ± 0.14.

Conclusion: Thicker ppRNFL and mGCC may delay diagnosis of pre-perimetric glaucoma in Ghanaians, while larger ACDR and VCDR measurements may lead to glaucoma misdiagnosis.

Contribution: This study established normative values for retinal parameters associated with glaucoma in Ghanaians.

Keywords: glaucoma; Africans; normative database; Ghana; retina; optic nerve.

Introduction

Glaucoma, the leading cause of irrevocable blindness globally, is an optic neuropathy characterised by progressive degeneration of the optic nerve with associated visual field loss.[1] Several types of glaucoma exist with primary open-angle glaucoma (POAG) being the most common type among Africans and Caucasians, while primary angle closure glaucoma (PACG) is more common among Asians.[2] Although the exact cause of POAG remains unclear, elevated intraocular pressure (IOP), increased age, ethnicity, family history, refractive error, and low diastolic perfusion pressure are known risk factors for the disease.[3,4,5]

Previous reports show that Ghana has a high prevalence of glaucoma as well as a severe form of the disease and a high risk of glaucoma-related blindness.[6,7] Early detection and management reduce the rate of disease progression and the risk of blindness.[8] The diagnosis of glaucoma involves a clinical assessment of structural and functional loss by measuring glaucoma-related ocular parameters.[9,10] Therefore, measurements of ocular parameters form a substantial part of glaucoma assessment, and a deviation from the normal could indicate glaucoma. In view of this, there is the need to establish normative data for comparison in order for an early diagnosis of glaucoma. However, there is a paucity of normative data on most ocular parameters associated with glaucoma in Ghana, despite the reported high prevalence of the disease in the country.

Retinal parameters such as peripapillary retinal nerve fibre layer (ppRNFL), macula ganglion cell complex (mGCC) and optic nerve head (ONH) and its associated parameters play a vital role in the detection and management of glaucoma. Studies report that retinal parameter measurements are vastly influenced by ethnicity.[11,12,13,14] A review study[15] reported the mean ppRNFL thickness among certain ethnicities including Africans (108–110 µm), Caucasians (94–101 µm) and Asians (102–115 µm). In Ghana, a report from Ocansey et al.[16] appears to be the only published data on ppRNFL measurements and found a mean ppRNFL thickness of 102.37 µm however, the authors stated small size as a major limitation of their study.[16]

In addition, the ethnic variation in mGCC thickness was confirmed by Tham et al.[14] who reported an average mGCC thickness of 82.6 µm in Chinese, 81.5 µm in Malays and 78.0 µm in Indians. Rolle et al.[17] found an average mGCC thickness of 97.4 µm in Caucasians. There appears to be no published data on normative values of mGCC thickness among Ghanaians. Also, the ethnic variations in ONH parameters such as disc size, rim area, cup volume, average and vertical cup to disc ratios are well documented.[18,19,20,21]

The optical coherence tomography (OCT) machine has, in recent times, become the instrument of choice in clinical and research settings because of its ability to provide objective, precise, quantifiable and reproducible measurements of retinal parameters. Despite these existing ethnic variations in retinal parameter measurements, there is an under-representation of some ethnic groups particularly, African populations in normative databases used in OCT machines. This may pose a challenge in the accurate interpretation of OCT reports in individuals from such ethnic groups.[16,22] The normal reference ranges of the Cirrus Spectral Domain Optical Coherence Tomography (SD-OCT) were generated in a study, which included 284 subjects, with a sample of 51 African-Americans comprising 35% of the study population.[21] However, Zouache et al.[23] have reported that the macula thickness of Ghanaians differs significantly from that of African-Americans using the Cirrus High Definition Optical Coherence Tomography (HD-OCT). To buttress this, Ismail et al.[24] demonstrated that South African eyes had thicker RNFL than the normative database used by the Spectralis SD-OCT machine. Similarly, Sani et al.[25] and Mahmud-Ajeigbe et al.[26] found RNFL measurements in Northern Nigerian eyes to be similar to Japanese RNFL measurements, but thicker than RNFL measurements from Italian eyes using the Stratus SD-OCT machine.

In view of the ethnic variations in normative reference values for retinal parameters and the under-representation of some ethnic groups in the normative databases employed by OCT machines, it implies that the decision on the integrity of retinal parameters in Ghanaians is interpreted against a backdrop of normative reference values derived from different ethnic groups, which may lead to a misdiagnosis as a result of an overestimation or underestimation. Hence, there is the need for the documentation of normative reference values for retinal parameters specific to the Ghanaian population.

Despite the reported high prevalence of glaucoma in Ghana, there is a paucity of published normative data on retinal parameters associated with glaucoma in this population. Therefore, the aim of this study is to provide normative data on retinal parameters associated with glaucoma in a Ghanaian clinical population of older age, which places them at increased risk. Normative reference values for retinal parameters specific to the Ghanaian population will serve as a reference point for future development of OCT machines and allow for early detection of retinal tissue loss, which will make room for early diagnosis and management of pre-perimetric glaucoma. It will also enable clinicians to easily identify individuals at risk for some retinal pathologies such as glaucoma and monitor them closely as well as contribute to the future modelling of glaucoma care offered to Ghanaians and other vulnerable African populations.

Research methods and design

The study was part of a larger Genetics In Glaucoma Patients of African descent (GIGA) Study. The GIGA study was a multinational collaborative case-control study comprising open-angle glaucoma patients and healthy subjects from Ghana, Tanzania and South Africa. However, data for this study were collected from Ghanaian participants only. The Ghanaian version of the GIGA study was conducted in a clinical setting with participants recruited from the Eye Clinic of the Komfo Anokye Teaching Hospital (KATH), the second largest hospital in Ghana and a major referral centre – receiving referrals from 13 out of the 16 regions of Ghana because of its geographical location.

During the data collection phase, the study was incorporated into the daily clinical routine, and participants were recruited consecutively from the outpatient department. Participants were examined by a glaucoma specialist affiliated with KATH for eligibility. In total, 338 persons met the inclusion criteria of the study.

Ghanaians aged 45 years and older, without any corneal abnormalities, ocular infection and pterygium involving the cornea were included in the study. Persons with a history of ocular hypertension, ocular trauma and glaucoma were excluded. Only those without any history of retinal diseases such as diabetic retinopathy, epiretinal membranes, vitreomacular traction, age-related macular degeneration, hereditary macular disease, macular holes, retinal vascular diseases or glaucoma were included.

The study participants underwent the following examinations: visual acuity (VA) measurement using the Snellen or Tumbling E chart at 6 m, auto-refraction, IOP measurement with Goldmann applanation tonometry, slit-lamp biomicroscopy and fundus examination using a 90D Volks lens. Height (m) was measured with a measuring tape while the participants were bare-footed, and weight (kg) was measured using a weighing scale.

The Zeiss Cirrus HD-OCT 5000 software version 7.0.1.290 (Carl Zeiss Meditec, Dublin, California, United States) was used to examine the eyes of all study participants to determine normal values for ppRNFL thickness (µm), mGCC thickness (µm), optic disc area (mm^2), rim area (mm^2), cup volume (mm^3), average cup to disc ratio (ACDR) and vertical cup to disc ratio (VCDR). Reliable OCT test results were defined as those with a signal strength of 6 or above.[27]

Statistical analysis

Data were anonymised before analysis and then exported into an online digitised database (Castor EDC) and were analysed using the Statistical Software for Data Science (STATA) version 17. Descriptive statistics including means, standard deviations and ranges were calculated using STATA version 17. Multivariate regression model was used to determine the relationships between retinal parameters, demographic and other non-ocular factors, while scatter plots were used to provide a graphical view of these relationships. Multiple imputation was used to complete 8% of missing data for mGCC thickness. Statistical significance was set at $P < 0.05$.

Ethical considerations

Ethical clearance to conduct this study was obtained from the Committee for Human Research Publication and Ethics under the School of Medical Sciences of the Kwame Nkrumah University of Science and Technology, Kumasi – Ghana (reference number: CHRPE/AP/540/17) and the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (BREC/00005722/2023) before commencement of the study. Written consent was obtained from all study participants. This study was conducted according to the tenets of the Declaration of Helsinki.

Results

A total of 338 participants with a mean IOP of 14.88 ± 2.72 mmHg (range: 10–21 mmHg) and mean age of 61.86 ± 9.54 years (range: 45–89 years) satisfied the inclusion criteria of the study; of which 116 (34.3%) were males and 222 (65.7%) were females. Multivariate regression revealed no significant difference between right and left eye measurements for all measured ocular parameters ($P > 0.05$). Therefore, all analyses were conducted on right eyes only. The refractive status of the study participants based on spherical equivalent error was plano (124), low myopia (98), moderate myopia (30), high myopia (7), low hyperopia (71) and moderate hyperopia (8).

Gender and retinal parameters

Table 1 shows the mean measurements and standard deviation of all measured retinal parameters based on gender. As shown in Table 1, there were no significant difference between gender and all measured retinal parameters ($P > 0.05$). Therefore, Table 1 may serve as proposed normative sectoral measurements for ppRNFL; sectoral mGCC and optic disc area, rim area; cup volume and CD ratios in at risk Ghanaians for POAG.

TABLE 1: Retinal parameters of Ghanaians (≥ 45 years) by gender.

Retinal Parameter	Statistic	Total $N = 338$	Males $n = 116$	Females $n = 222$	P (Gender)
Peripapillary Retinal Nerve Fibre Layer Thickness (µm)					0.77
Global ppRNFL	Mean ± s.d.	96.11 ± 9.87	96.28 ± 10.50	96.04 ± 9.61	-
	Range	70.75–136.75	75.00–136.75	70.75–123.75	-
	95% CI	94.96–97.27	93.92–98.45	95.87–98.62	-
Superior ppRNFL	Mean ± s.d.	121.70 ± 15.76	122.48 ± 16.20	121.37 ± 15.59	-
	Range	83.00–187.00	93.00–187.00	83.00–168.00	-
	95% CI	119.98–123.75	118.92–126.18	119.36–123.79	-
Nasal ppRNFL	Mean ± s.d.	75.33 ± 13.04	76.28 ± 13.82	74.92 ± 12.70	-
	Range	45.00–127.00	45.00–127.00	47.00–125.00	-
	95% CI	73.71–76.84	73.02–79.18	73.09–76.75	-
Inferior ppRNFL	Mean ± s.d.	126.62 ± 17.53	124.13 ± 16.63	127.70 ± 17.85	-
	Range	85.00–184.00	91.00–184.00	85.00–175.00	-
	95% CI	124.76–128.94	120.59–128.01	125.40–130.47	-
Temporal ppRNFL	Mean ± s.d.	60.45 ± 10.20	60.63 ± 10.06	60.37 ± 10.29	-
	Range	33.00–90.00	33.00–85.00	35.00–90.00	-
	95% CI	59.25–61.67	58.77–63.08	58.79–61.73	-
Macula Ganglion Cell Complex (µm)					0.26
Global mGCC	Mean ± s.d.	80.91 ± 5.61	81.92 ± 5.97	80.44 ± 5.39	-
	Range	70.00–97.00	70.00–96.00	70.00–97.00	-
	95% CI	80.45–81.90	80.64–83.33	79.63–81.26	-
Superior mGCC	Mean ± s.d.	82.24 ± 6.84	83.13 ± 7.19	81.83 ± 6.66	-
	Range	69.00–103.00	69.00–98.00	70.00–103.00	-
	95% CI	81.64–83.41	82.04–85.33	81.00 –83.09	-
Superior nasal mGCC	Mean ± s.d.	82.22 ± 6.73	83.12 ± 6.81	81.80 ± 6.67	-
	Range	68.00–102.00	68.00–99.00	68.00–102.00	-
	95% CI	81.50–83.24	82.03–85.12	80.82–82.91	-
Superior temporal mGCC	Mean ± s.d.	80.01 ± 6.06	81.92 ± 6.41	79.12 ± 5.70	-
	Range	67.00–99.00	68.00–99.00	67.00–94.00	-
	95% CI	79.43–80.98	80.72–83.69	78.47–80.21	-
Inferior mGCC	Mean ± s.d.	79.62 ± 6.51	79.91 ± 6.85	79.48 ± 6.36	-
	Range	67.00–98.00	68.00–96.00	67.00–98.00	-
	95% CI	79.01–80.68	78.87–82.03	78.62–80.59	-
Inferior Nasal mGCC	Mean ± s.d.	81.48 ± 7.09	82.14 ± 7.05	81.18 ± 7.11	-
	Range	68.00–123.00	68.00–99.00	68.00–123.00	-
	95% CI	80.69–82.53	80.88–84.17	80.12–82.35	-
Inferior temporal mGCC	Mean ± s.d.	80.36 ± 5.93	81.84 ± 6.16	79.66 ± 5.70	-
	Range	69.00–99.00	69.00–97.00	69.00–99.00	-
	95% CI	79.73–81.25	80.66–83.55	78.92–80.66	-
Optic Nerve Head					
Optic disc area (mm^2)	Mean ± s.d.	2.05 ± 0.39	2.10 ± 0.41	2.03 ± 0.38	0.91
	Range	1.00–3.33	1.34–3.10	1.00–3.33	
	95% CI	2.00–2.10	2.01–2.19	1.98–2.09	
Rim area (mm^2)	Mean ± s.d.	1.52 ± 0.27	1.50 ± 0.25	1.53 ± 0.28	0.22
	Range	0.95–2.60	1.06–2.14	0.95–2.60	
	95% CI	1.49–1.55	1.44–1.55	1.49–1.57	
Cup volume (mm^3)	Mean ± s.d.	0.13 ± 0.12	0.15 ± 0.13	0.11 ± 0.11	0.44
	Range	0.00–0.57	0.00–0.57	0.00–0.50	
	95% CI	0.11–0.14	0.12–0.18	0.10–0.13	
ACDR	Mean ± s.d.	0.47 ± 0.15	0.50 ± 0.13	0.46 ± 0.16	0.22
	Range	0.07–0.69	0.12–0.69	0.07–0.69	
	95% CI	0.45–0.49	0.47–0.53	0.43–0.48	
VCDR	Mean ± s.d.	0.44 ± 0.14	0.47 ± 0.12	0.43 ± 0.15	0.35
	Range	0.05–0.68	0.16–0.67	0.05–0.68	
	95% CI	0.43–0.46	0.44–0.50	0.41–0.45	

ACDR, average cup-to-disc ratio; CI, confidence interval; mGCC, macula ganglion cell complex; ppRNFL, peripapillary retinal nerve fibre layer; s.d., standard deviation; VCDR, vertical cup-to-disc ratio.

Retinal parameter correlations with ethnicity in at-risk Ghanaians

The study participants were categorised into four major ethnic groups. Multivariate regression revealed no significant correlation between ethnicity and all measured ocular parameters – Global RNFL ($P = 0.65$), Global mGCC ($P = 0.51$), Disc area ($P = 0.74$), Rim area ($P = 0.27$), Cup volume ($P = 0.31$), ACDR ($P = 0.49$) and VCDR ($P = 0.49$).

Retinal parameter correlations with age in at-risk Ghanaians

Multivariate regression showed a negative correlation between age and global ppRNFL ($r = –0.255$, $P = 0.002$) as well as global mGCC ($r = –0.206$, $P < 0.001$) as depicted in Figure 1. As shown in Figure 1, the regression equations were: ppRNFL = 108–0.196*AGE; suggesting an approximate 0.20 µm decline in ppRNFL per year and global mGCC = 93.2–0.23*AGE; suggesting an approximate 0.23 µm decrease in global mGCC per year in Ghanaians.

However, a positive correlation was observed between age and ACDR ($r = +0.003$, $P = 0.016$) and VCDR ($r = +0.003$, $P = 0.003$) as shown in Figure 1. There were no significant correlations between age, disc area ($P = 0.10$) and rim area ($P = 0.45$) and cup volume ($P = 0.28$).

Retinal parameter correlations with anthropometric measurements in at-risk Ghanaians

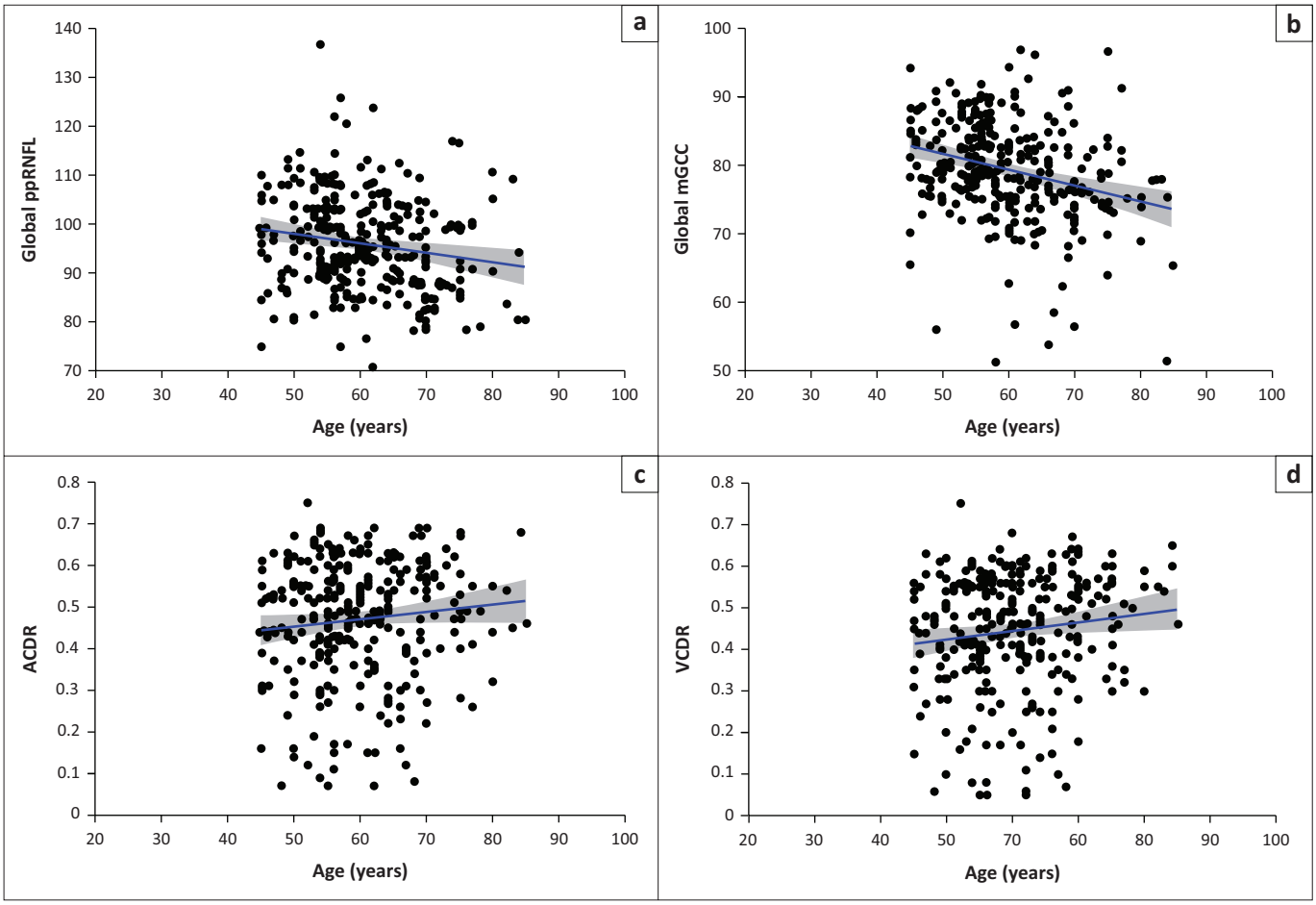
Height

A negative correlation was observed between height and rim area ($r = –3.172$, $P = 0.014$) as depicted in Figure 2. However, there were no significant correlations between height and global RNFL ($P = 0.42$), global mGCC ($P = 0.74$), disc area ($P = 0.19$), cup volume ($P = 0.26$), ACDR ($P = 0.42$) and VCDR ($P = 0.28$).

Weight

A positive correlation was observed between weight and rim area ($r = +0.04$, $P = 0.006$) as shown in Figure 3. However, there were no significant correlations between height and global RNFL ($P = 0.44$), global mGCC ($P = 0.88$), disc area ($P = 0.07$), cup volume ($P = 0.44$), ACDR ($P = 0.54$) and VCDR ($P = 0.44$).

A negative correlation was observed between BMI and rim area ($r = –0.106$, $P = 0.0006$) as shown in Figure 4. There were no significant correlations between BMI and the remaining retinal parameters measured in this study – global RNFL ($P = 0.34$), global mGCC ($P = 0.93$), disc area ($P = 0.07$), cup volume ($P = 0.48$), ACDR ($P = 0.56$) and VCDR ($P = 0.45$).



ACDR, average cup to disc ratio; mGCC, macula ganglion cell complex; ppRNFL, peripapillary retinal nerve fibre layer; VCDR, vertical cup to disc ratio.

FIGURE 1: Correlation between age and retinal parameters. (a) Correlation between age and global ppRNFL ($y = 108 – 0.196\ x$), (b) Correlation between age and global mGCC ($y = 93.2 – 0.23\ x$), (c) Correlation between age and average cup to disc ratio ($y = 0.366 + 0.00173\ x$), (d) Correlation between age and vertical cup to disc ratio ($y = 0.32 + 0.00207\ x$).

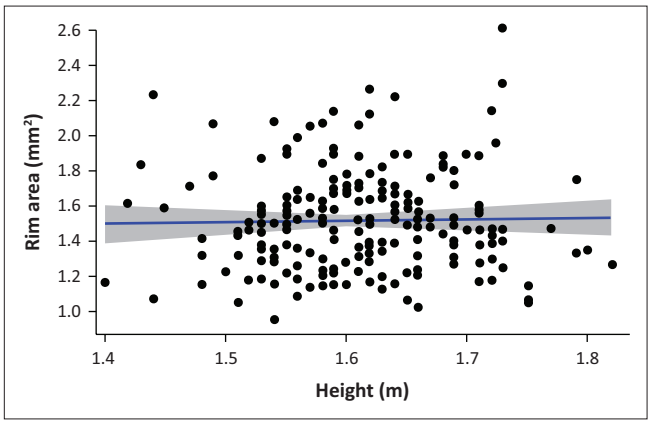


FIGURE 2: Correlation between height and rim area ($y = 1.39 + 0.0795\ x$).

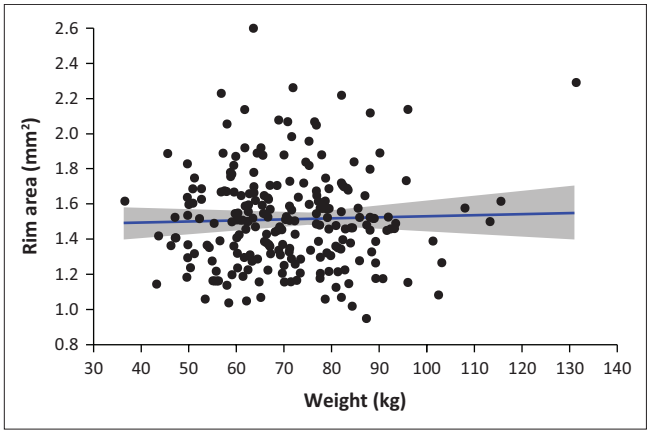
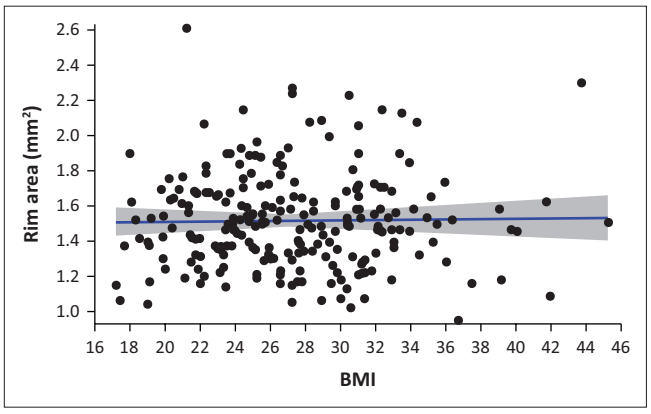


FIGURE 3: Correlation between weight and rim area ($y = 1.47 + 0.000645\ x$).



BMI, body mass index.

FIGURE 4: Correlation between body mass index and rim area ($y = 1.5 + 0.000558\ x$).

Discussion

Normative data of retinal parameters associated with glaucoma are important in identifying individuals at risk of the disease. This study reports on normative values for peripapillary retinal nerve fibre thickness, macula ganglion cell complex and optic nerve head measurements in at-risk Ghanaians for POAG.

The mean global ppRNFL measurement of 96.11 ± 9.87 µm measured in this study is slightly lower than the 102.37 ± 7.45 µm reported in a previous Ghanaian study using the Cirrus SD HD-OCT.[16] The difference could be attributed to variations in age cohorts in the two studies. The participants of this study were relatively older compared to the participants of the previous Ghanaian study.[16] The fact that ppRNFL decreases with age[13,15,21] may justify the lower mean ppRNFL measurement recorded in this study compared to the study by Ocansey et al.[16] Studies have reported ethnic variations in ppRNFL thickness with Caucasians having thinner measurements when compared to other ethnicities.[21,28] In a multiracial study, Alasil et al.[12] reported a mean global ppRNFL of 96.0 ± 9.2 µm in Caucasians (mean age: 55.2 ± 16 years), 102.9 ± 11 µm in Hispanics (mean age: 51.0 ± 19 years), 100.7 ± 8.5 µm in Asians (mean age: 51.0 ± 17) and 99.20 ± 10.2 µm in African-Americans (mean age: 52.0 ± 16) using spectral domain optical coherence tomography.

The mean ppRNFL measurements and ranges in all quadrants of the participants in this study were also relatively reduced compared to that of Ocansey et al.[16] Ocansey et al.[16] reported a mean superior RNFL measurement of 131.54 ± 14.79 µm (range: 104–168 µm), while this study found a mean superior RNFL measurement of 121.70 ± 15.76 µm (range: 83–187 µm); they found a mean inferior RNFL measurement of 133.60 ± 13.84 µm (range: 87–161 µm), while this study found a mean inferior RNFL measurement of 126.62 ± 17.53 µm (range: 85–184 µm). Ocansey et al.[16] also reported a mean nasal RNFL measurement of 76.73 ± 12.60 µm (range: 50–116 µm), while the mean nasal RNFL measurement for this study was 75.33 ± 13.04 µm (range: 45–127 µm). Lastly, Ocansey et al.[16] found a mean temporal RNFL measurement of 66.83 ± 9.48 µm (range: 50–104 µm), while this study found a mean temporal RNFL measurement of 60.45 ± 10.20 µm (range: 33–90 µm). The reduced ppRNFL thickness in this study may be attributed to the decline in ppRNFL thickness with increasing age[15] as earlier stated. Also, Sani et al.[25] reported ppRNFL thickness of 135.34 ± 20.40 µm (superior), 129.15 ± 16.87 µm (inferior), 85.10 ± 23.60 µm (nasal) and 67.19 ± 13.27 µm (temporal) among healthy Northern Nigerians with a mean age of 30.47 ± 7.80 years using Stratus OCT, while Mashige and Oduntan[15] found 131.72 ± 10.46 µm (superior), 135.06 ± 9.66 µm (inferior), 87.24 ± 13.22 µm (nasal) and 73.63 ± 15.66 µm (temporal) among healthy young South Africans with a mean age of 28.15 ± 13.09 years using iVue SD-OCT. O'rese et al.[21] reported ppRNFL thickness of 113.00 ± 1.20 µm (superior), 70.10 ± 1.00 µm (nasal), 115.90 ± 1.30 µm (inferior) and 61.20 ±0.90 µm (temporal) among persons of European descent with a mean age of 49.10 ± 18.30 years. Although a direct comparison among these studies may be inappropriate because of differences in ethnicity, age and methodology, the findings of this study together with those of the aforementioned studies confirm the fact that Africans have thicker ppRNFL measurements compared to other ethnicities especially Caucasians.[12,21,28] This is a significant finding in relation to OCT databases because most OCT databases have a higher representation of Caucasians than

other ethnicities.[22] This implies that pre-perimetric glaucoma diagnosis may be delayed in Africans because early ppRNFL loss may go undetected as thicker ppRNFL measurements from Africans are compared to thinner ppRNFL from Caucasians to make glaucoma diagnosis.

Peripapillary RNFL measurements were found to reduce with increasing age in this study, and this is in line with previous reports.[12,15,21] The correlation between ppRNFL and age in this study was represented by the equation: ppRNFL = 108–0.196*AGE, suggesting an approximate 0.20 µm decline in ppRNFL per year. This is similar to the 0.25 µm decline in ppRNFL per year previously reported among Ghanaians and black Americans[16,29] as well as the 0.19 µm reported in a multiracial study.[21] However, it is higher than the 0.11 µm ppRNFL decline per year recorded among South Africans.[15] The rate of ppRNFL decline recorded in this study may serve as a guide in distinguishing glaucoma-related global ppRNFL loss from age-related global ppRNFL thinning in Ghanaians.

There was no correlation between gender and global ppRNFL in this study. This is in accordance with previous reports.[12,30,31] However, some studies have reported thicker mean ppRNFL values in females.[16,28,32]

The lack of a correlation between ppRNFL and all the anthropometric measurements in this study was in concordance with the findings of Rougier et al.[33] for a French sample population and Zhao et al.[34] among a Chinese sample population. However, Mashige and Oduntan[15] reported shorter individuals to have thicker ppRNFL measurements but no correlation between ppRNFL and body weight in South Africans. Wu et al.[35] also reported a positive correlation between ppRNFL and BMI among Chinese and attributed it to the fact that higher BMI measurements could result in elevated intracranial pressure, which in turn can cause optic disc oedema, thereby, making ppRNFL measurements thicker in such individuals.

The mean global mGCC measurement of 80.91 ± 5.6 µm recorded in this study was comparatively lower than the 104.02 ± 6.71 µm reported among Southern Nigerians with a mean age of 39.92 ±13.40 years,[22] the 97.4 ± 5.4µm reported in Caucasians with a mean age of 57.8 ± 6.71 years,[17] the 82.6 ± 6.1µm reported in Chinese with a mean age of 55.2 ± 7.5 years and the 81.5 ± 6.8 µm in Malays with a mean age of 60.4 ± 8.8 years. However, higher than the 78.0 ± 6.9 µm reported in Indians with a mean age of 60.5± 7.8 years.[14] Although variations in methodology and ethnicity may partly account for the lower mean mGCC recorded in this study, differences in the age cohorts of the study participants may also account for this finding in Ghanaians because mGCC thickness declines with age[36] and the study participants in this study were somewhat older compared to the above-mentioned studies. However, it appears Ghanaians have thicker global mGCC than Asians. Besides, the mean sectoral mGCC thickness recorded in this study was similar to the findings of Mwanza et al.[19] in a multiethnic study comprising Africans, Asians, Europeans and Hispanics. Again, the mean sectoral mGCC thickness in this study compared well with the results observed in Chinese and Malays but were higher than the findings in Indians.[14]

According to literature, mGCC decreases with increasing age.[19,22,36] This was confirmed in this study as there was a negative correlation between age and global mGCC represented by the equation: global mGCC = 93.2–0.23*AGE. This equation suggests a 0.23 µm decrease in global mGCC per year in Ghanaians. This finding is in close agreement with the 0.25 µm global mGCC decline per year reported by Zhang et al.[36] among a multiethnic population and Tham et al.[14] in Asians, but lower than the 0.10 µm reported by Mwanza et al.[19] among a multiethnic population. This difference may be as a result of variations in patient characteristics and methodology. The rate of global mGCC decline recorded in this study may aid clinicians to differentiate age-related global mGCC thinning from glaucoma-related mGCC loss in Ghanaians.

In relation to gender, this study found no correlation between global mGCC and gender and this finding conforms to existing literature.[37,38,39] Nevertheless, Tham et al.[14] reported females to have thinner global mGCC than males and attributed their finding to the fact that women have a higher ratio of parvocellular retinal ganglion cells (the 'midget' type of retinal ganglion cells) than men.

Also, there were no correlations between height, weight, BMI and global mGCC in this study and this is in concordance with the findings of Demir et al.,[40] Baran et al.[41] and Paulsen et al.[42] However, von Hanno et al.[43] and Bloch et al.[37] found a higher BMI to be associated with thinner mGCC measurements. Von Hanno et al.[43] stated that the reason for their finding seemed to be complicated by the height component of BMI because height is associated with eye size and possibly retinal thickness. However, no justification for their finding was proposed.

The mean disc area of 2.05 ± 0.39 mm^2 recorded in this study is very similar to the 2.08 ± 0.40 mm^2 by Ocansey et al.[16] in Ghanaians using the Cirrus HD-OCT, the 2.01 ± 0.36 mm^2 reported among Ethiopians using Cirrus HD-OCT[44] as well as the 2.06 ± 0.47 mm^2 reported by Girkin et al.[45] among persons of African descent using the Heidelberg retina tomography. However, lower than the 2.38 ± 0.40 mm^2 reported by Lee et al.[11] among Africans using fundus photography and the 2.54 ± 0.48 mm^2 reported among Nigerians using SD-OCT.[46] However, the mean optic disc area recorded in this study is higher than the 1.77 ± 0.39 mm^2 reported among Europeans using the Heidelberg retina tomography,[45] the 1.78 ± 0.04 mm^2 reported among Chinese and the 1.86 ± 0.05 mm^2 reported among Hispanics using the Cirrus HD-OCT.[21] Although

variations in instrumentation and patient characteristics exist among the aforementioned studies, it appears Ghanaians have larger optic disc sizes than some ethnicities. This may partly explain the high prevalence of glaucoma among Ghanaians because larger optic disc sizes have been associated with increased vulnerability to intraocular pressure-induced deformation.[1]

Optic disc area did not correlate with age in this study and this is in agreement with previous studies.[16,18,21] Also, there was no gender predilection in relation to optic disc area in this study and this is in line with previous studies.[16,21] However, Awe et al.[46] and Zhang et al.[47] found males to have larger optic disc area in a Nigerian and Chinese population, respectively. Zhang et al.[47] observed that despite the fact that their study found males to have larger optic disc area than females, the difference was not large. No correlations between body height, body weight and BMI and optic disc area were observed and this was in agreement with the findings of Zhang et al.[47] and Zheng et al.[48]

The mean rim area measurement of 1.52 ± 0.27 mm^2 recorded in this study compares well with the 1.48 ± 0.21 mm^2 by Ocansey et al.[16] and the 1.45 ± 0.26 mm^2 reported among Ethiopians[44]. Zhang et al.[47] reported a higher mean rim area measurement of 1.8 ± 0.29 mm^2 among Chinese with a mean age of 48.02 ± 9.59 years, while Jonas et al.[49] reported a marginally higher mean rim area measurement of 1.6 ± 0.3 mm^2 among Indians with a mean age of 48 ± 13 years. Although this study found no correlation between age and rim area, some studies have reported a decline in rim area with increasing age.[16,49] Therefore, the higher mean rim area measurements recorded in the previously mentioned studies could be because of the fact that their study participants were relatively younger than the study participants in this study.

This study found no correlation between rim area and gender. Previous studies[16,47,49] reported similar findings in relation to gender. There was a negative correlation between body height and rim area in this study and this is consistent with the findings of Zheng et al.[48] among Malays. However, the Rotterdam Eye Study[50] reported a positive correlation between rim area and body height, while Xu et al.[51] and Jonas et al.[52] reported no correlation between body height and rim area. Body weight, on the other hand, positively correlated with rim area in this study and this is also consistent with the findings of Zheng et al.[48] among Malays. This may imply higher body weight to be protective against neuro-retinal tissue loss in Ghanaians. However, Xu et al.[51] and Jonas et al.[52] found no association between body weight and rim area. The reason for these discrepancies could be as a result of differences in methodology and patient characteristics. This study found a weak negative correlation between BMI and rim area. However, previous studies have reported a positive correlation between rim area and BMI.[48,49,51] Jonas et al.[49] stated that a high BMI may also imply a high cerebrospinal fluid pressure, which probably compensates for intraocular pressure changes in obese persons, thereby protecting against neuro-retinal tissue loss.

The mean cup volume measurement of 0.13 ± 0.12 mm^3 recorded in this study is slightly lower than the 0.19 ± 0.1 mm^3 recorded in a previous Ghanaian study using the Cirrus HD-OCT[16] but it is very similar to the 0.13 ± 0.14 mm^3 recorded among Australians[20] and the 0.14 ± 0.14 mm^3 reported among Ethiopians[44] using the Cirrus HD-OCT. Zhang et al.[47] also recorded a similar finding of 0.11 ± 0.12 mm^3 among Chinese using the Heidelberg Retina Tomograph II, while Pilat et al.[53] reported mean cup volume measurements of 0.12 ± 0.09 mm^3 and 0.11 ± 0.12 mm^3 among Asians and Caucasians, respectively. There were no correlations between cup volume measurements and age, gender and all anthropometric measurement in this study as reported by previous studies.[16,53] However, previous studies[20,47] found males to have higher cup volume measurements than females.

The mean ACDR (0.47 ± 0.15) and VCDR (0.44 ± 0.14) recorded in this study are consistent with the 0.50 ± 0.12 (ACDR) and 0.47 ± 0.13 (VCDR) reported in a previous Ghanaian study[16] as well as the 0.48 ± 0.15 (ACDR) and 0.46 ± 0.19 (VCDR) reported on Ethiopians[44] and the 0.44 ± 0.18 (ACDR) and 0.42 ± 0.17 (VCDR) reported among Australians[20] using the Cirrus HD-OCT. Comparatively lower VCDR measurements (0.27 ± 0.19) have been reported among Chinese using the Heidelberg Retina Tomograph II.[47] Also, Pilat et al.[53] found relatively lower ACDR measurements of 0.37 ± 0.16 and 0.31 ± 0.16 among Asians and Caucasians, respectively, using the Spectral Domain OCT. Despite differences in methodology and OCT software employed by some of the above-mentioned studies, it appears Ghanaians have larger ACDR and VCDR measurements than Asians and Caucasians. This finding should be considered in future OCT databases in order to avoid physiologically large ACDR and VCDR measurements in Ghanaians being diagnosed as glaucomatous.

A relatively weak positive correlation was observed between age and ACDR and VCDR in this study. The regression equation indicates an approximate 0.2 increase in ACDR and VCDR per 100 years, which is evidently negligible. Ocansey et al.[16] and Kuang et al.[54] also reported no association between age and ACDR and VCDR in Ghanaians and Chinese, respectively. In contrast, O'rese et al.[21] found an association between age and ACDR and VCDR in a multiethnic study. Gender was not associated with ACDR and VCDR in this study and this is consistent with the findings of Ocansey et al.[16] in a Ghanaian population. O'rese et al.[21] also reported no correlation between gender and ACDR and VCDR in a multiethnic study. Amerasinghe et al.,[55] on the other hand, found male Malays to have larger VCDR measurements. There were no correlations between ACDR and VCDR and all the anthropometric measurements in this study, and this is in line with the previous studies.[54,56,57,58] Although Zheng et al.[48] reported correlations between ACDR and body height,

body weight and BMI, they concluded that the magnitude of the associations was low; hence, the clinical significance of their finding required further confirmation.

Although the risk of developing glaucoma is largely influenced by age, the disease is also prevalent among relatively younger persons. This study is limited by the fact that it only included persons 45 years and older.

Although this study found no ethnic variations among all measured ocular parameters in Ghanaians, the study was underpowered to present a firm conclusion on this because of the fact that there was not an equal representation of the various Ghanaian ethnic groups in this study. Hence, future studies should have an equal representation of the various Ghanaian ethnic groups in order to confirm the findings of this study.

Conclusion

The findings of this study present normative reference values for retinal parameters associated with glaucoma in a Ghanaian population. Ghanaians, like other Africans, have thicker global and sectoral ppRNFL and mGCC measurements as well as larger optic disc areas, ACDR and VCDR than other ethnicities. We recommend the inclusion of these retinal variable into the normative database of the Zeiss Cirrus OCT, in order to allow for early detection of pre-perimetric glaucoma in Ghanaians and Africans to minimise the misdiagnosis. The physiologically large optic disc cups as glaucoma may also inform this concern.

Acknowledgements

The authors are grateful to the management and staff of the Eye Clinic of the Komfo Anokye Teaching Hospital (KATH). The GIGA Consortium includes Caroline Klaver (C.K.), Alberta Thiadens (A.T.), Pieter Bonnemaijer (P.B.), Sjoerd Jan Driessen (S.J.D.) from the Ophthalmology and Epidemiology, Erasmus MC, the Netherlands and Angelina Ampong (A.A.) from the Ophthalmology, Komfo Anokye Teaching Hospital, Kumasi, Ghana. The GIGA Study (of which this study is a subset) was conceptualised and designed by C.K., A.T., and P.B. Funding was secured by C.K. and A.T. A.A. and S.J.D. assisted in data collection.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article. The author, A.J.M., serves as an editorial board member of this journal. The peer review process for this submission was handled independently, and the author had no involvement in the editorial decision-making process for this manuscript. The authors have no other competing interests to declare.

Authors' contributions

D.N.-A., K.P.M. and A.J.M. were involved in conceptualising, designing and preparing the draft article. D.N.-A. collected the data. D.N.-A., K.P.M. and A.J.M. made equal contributions in writing this article.

Funding information

The GIGA Study, of which this study is a subset, received grants from Brightfocus Foundation, Combined Ophthalmic Research Rotterdam, Rotterdamse Oogheelkundige Onderzoeks Stichting and Landelijke Stichting voor Blinden en Slechtzienden through the Uitzicht Foundation.

Data availability

The data that support the findings of this study are available on request from the corresponding author, D.N.-A.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. It does not necessarily reflect the official policy or position of any affiliated institution, funder, agency, or that of the publisher. The authors are responsible for this article's results, findings, and content.

References

1. Bonnemaijer PW, Lo Faro V, Sanyiwa AJ, et al. Differences in clinical presentation of primary open-angle glaucoma between African and European populations. Act ophthalmol. 2021;99(7):e1118– e1126. https://doi.org/10.1111/aos.14772
2. Jacobs DS, Trobe J, Park L. Open-angle glaucoma: Epidemiology, clinical presentation, and diagnosis [homepage on the Internet]. UpToDate. 2015 [cited]. Available from: https://www.uptodate.com/contents/open-angle-glaucoma-epidemiology-clinical-presentation-and-diagnosis.
3. Alward WL. Open angle glaucomas. In: Alward WLM, editor. Glaucoma: The requisites in ophthalmology. St. Louis: Mosby, 2000; p. 128–140.
4. Khurana AK. Comprehensive ophthalmology. 4th ed. New Delhi: New Age International (P) Limited; p. 210–211.
5. Ekstrom C. Risk factors for incident open-angle glaucoma: A population-based 20-year follow-up study. Act Ophthalmol. 2012;90(4):316–321. https://doi.org/10.1111/j.1755-3768.2010.01943.x
6. Ntim-Amponsah CT, Amoaku WM, Ofosu-Amaah S, et al. Prevalence of glaucoma in an African population. Eye (Lond). 2004;18(5):491–497. https://doi.org/10.1038/sj.eye.6700674
7. Budenz DL, Barton K, Whiteside-de Vos J, et al. Prevalence of glaucoma in an urban West African population: The Tema Eye Survey. Ophthalmol. 2013;131(5):651–658. https://doi.org/10.1001/jamaophthalmol.2013.1686
8. Tatham AJ, Medeiros FA, Zangwill LM, et al. Strategies to improve early diagnosis in glaucoma. Prog brain res. 2015;221:103–133. https://doi.org/10.1016/bs.pbr.2015.03.001
9. Devereux JG, Foster PJ, Baasanhu J, et al. Anterior chamber depth measurement as a screening tool for primary angle-closure glaucoma in an East Asian population. Ophthalmology. 2000;118(2):257–263. https://doi.org/10.1001/archopht.118.2.257
10. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: A review and meta-analysis approach. Surv Ophthalmol. 2000;44(5):367–408. https://doi.org/10.1016/S0039-6257(00)00110-7
11. Lee RY, Kao AA, Kasuga T, et al. Ethnic variation in optic disc size by fundus photography. Curr Eye Res 2013;38(11):1142–1147. https://doi.org/10.3109/02713683.2013.809123
12. Alasil T, Wang K, Keane PA, et al. Analysis of normal retinal nerve fiber layer thickness by age, sex, and race using spectral domain optical coherence tomography. J Glaucoma. 2013;22(7):532–541. https://doi.org/10.1097/IJG.0b013e318255bb4a
13. AlSaad MM, Shatarat AT, AlRyalat SA. Normative values of the retinal macular thickness in a middle eastern population. BMC Ophthalmol. 2020;20(1):1–6. https://doi.org/10.1186/s12886-020-01391-3

14. Tham YC, Chee ML, Dai W, et al. Profiles of ganglion cell-inner plexiform layer thickness in a multi-ethnic Asian population: The Singapore epidemiology of eye diseases study. Ophthalmology. 2020;127(8):1064–1076. https://doi.org/10.1016/j.ophtha.2020.01.055
15. Mashige KP, Oduntan OA. A review of the human retina with emphasis on nerve fibre layer and macula thiscknesses. Afr Vis Eye Health. 2016;75(1):a330. https://doi.org/10.4102/aveh.v75i1.330
16. Ocansey S, Abu EK, Owusu-Ansah A, et al. Normative values of retinal nerve fibre layer thickness and optic nerve head parameters and their association with visual function in an African population. J Ophthalmol. 2020;2020:7150673. https://doi.org/10.1155/2020/7150673
17. Rolle T, Briamonte C, Curto D, et al. Ganglion cell complex and retinal nerve fiber layer measured by fourier-domain optical coherence tomography for early detection of structural damage in patients with preperimetric glaucoma. Clin Ophthalmol. 2011;5:961–969. https://doi.org/10.2147/OPTH.S20249
18. Marsh BC, Cantor LB, WuDunn D, et al. Optic nerve head (ONH) topographic analysis by stratus OCT in normal subjects: Correlation to disc size, age, and ethnicity. J Glaucoma. 2010;19(5):310–318. https://doi.org/10.1097/IJG.0b013e3181b6e5cd
19. Mwanza JC, Durbin MK, Budenz DL, et al. Profile and predictors of normal ganglion cell–inner plexiform layer thickness measured with frequency-domain optical coherence tomography. Invest Ophthalmol Vis Sci. 2011;52(11), 7872–7879. https://doi.org/10.1167/iovs.11-7896
20. Tariq YM, Li H, Burlutsky G, et al. Retinal nerve fiber layer and optic disc measurements by spectral domain OCT: Normative values and associations in young adults. Eye. 2012;26(12):1563–1570. https://doi.org/10.1038/eye.2012.216
21. O'Rese JK, Girkin CA, Budenz DL. Effect of race, age, and axial length on optic nerve head parameters and retinal nerve fiber layer thickness measured by cirrus HD-OCT. Arch Ophthalmol 2012;130(3):312–318. https://doi.org/10.1001/archopthalmol.2011.1576
22. Obasuyi OC, Osuji UE, Ifijen CO, et al. Optical coherence tomography retinal nerve fibre layer and ganglion cell complex measurements in normal Southern Nigerian Eyes. Cureus. 2022;14(12):e33101. https://doi.org/10.7759/cureus.33101
23. Zouache MA, Faust CD, Silvestri V, et al. Retinal and choroidal thickness in an indigenous population from Ghana: Comparison with individuals with European or African ancestry. Ophthalmol Sci. 2024;4(2):100386. https://doi.org/10.1016/j.xops.2023.100386
24. Ismail S, Ally N, Alli HD. Retinal nerve fibre layer thickness in a normal black South African population. Eye. 2020;34(8):1426–1431.
25. Sani RY, Abdu L, Pam V. Retinal nerve fiber layer thickness measurements of normal Northern Nigerian adults using optical coherence tomography. Ann Afr Med. 2016;15(2):52. https://doi.org/10.4103/1596-3519.172557
26. Mahmud-Ajeigbe FA, AbdulRahman HA, Rafindadi AL, et al. Retinal nerve fibre layer measurements in normal eyes in Zaria using optical coherence tomography. Sub Saharan Afr J Med. 2015;2(2):85. https://doi.org/10.4103/2384-5147.157430
27. Budenz DL. Signal strength, important factor when analyzing OCT scans. Ophthalmology Times, 2016.
28. Budenz DL, Anderson DR, Varma R, et al. Determinants of normal retinal nerve fiber layer thickness measured by stratus OCT. Ophthalmology. 2007;114(6):1046–1052. https://doi.org/10.1016/j.ophtha.2006.08.046
29. Nousome D, Mckean-Cowdin R, Richter GM, et al. Retinal nerve fiber layer thickness in healthy eyes of black, Chinese, and Latino Americans: A population-based multiethnic study. Ophthalmology. 2021;128(7):1005–1015. https://doi.org/10.1016/j.ophtha.2020.11.015
30. Malik A, Singh M, Arya SK, et al. Retinal nerve fiber layer thickness in Indian eyes with optical coherence tomography. Nepal J Ophthalmol. 2012;4(1):59–63. https://doi.org/10.3126/nepjoph.v4i1.5852
31. Cubuk M, Sahinoglu-Keskek N, Keskek SO. Retinal nerve fiber layer thickness in a healthy Turkish population measured by optical coherence tomography. Ann Saudi Med. 2016;36(6):409–413. https://doi.org/10.5144/0256-4947.2016.409
32. Leung CK, Mohamed S, Leung KS, et al. Retinal nerve fiber layer measurements in myopia: An optical coherence tomography study. Invest Ophthalmol Vis Sci. 2006;47(12):5171. https://doi.org/10.1167/iovs.06-0545
33. Rougier MB, Korobelnik JF, Malet F, et al. Retinal nerve fibre layer thickness measured with SD-OCT in a population-based study of French elderly subjects: The A lienor study. Acta Ophthalmol. 2015;93(6):539–545. https://doi.org/10.1111/aos.12658
34. Zhao L, Wang Y, Chen CX, et al. Retinal nerve fibre layer thickness measured by S pectralis spectral-domain optical coherence tomography: The Beijing Eye Study. Act ophthalmol. 2014;92(1):e35–e41. https://doi.org/10.1111/aos.12240
35. Wu J, Du Y, Lin C, et al. Retinal nerve fibre layer thickness measured with SD-OCT in a population-based study: The Handan Eye Study. Br J Ophthalmol. 2023;107(8):1156–1164. https://doi.org/10.1136/bjophthalmol-2021-320618
36. Zhang X, Francis BA, Dastiridou A, et al. Longitudinal and cross-sectional analyses of age effects on retinal nerve fiber layer and ganglion cell complex thickness by Fourier-domain OCT. Transl Vis Sci & Technol. 2016;5(2):1.
37. Bloch E, Yonova-Doing E, Jones-Odeh E, et al. Genetic and environmental factors associated with the ganglion cell complex in a healthy aging British cohort. JAMA Ophthalmol. 2017;135(1):31–38. https://doi.org/10.1001/jamaophthalmol.2016.4486
38. Huo YJ, Guo Y, Li L, et al. Age-related changes in and determinants of macular ganglion cell-inner plexiform layer thickness in normal Chinese adults. Clin Exp Ophthalmol. 2018;46(4):400–406. https://doi.org/10.1111/ceo.13067
39. Xu X, Xiao H, Lai K, et al. Determinants of macular ganglion cell–inner plexiform layer thickness in normal Chinese adults. BMC Ophthalmol. 2021;21(1):267. https://doi.org/10.1186/s12886-021-02023-0
40. Demir S, Özer S, Alim S, et al. Retinal nerve fiber layer and ganglion cell-inner plexiform layer thickness in children with obesity. Int J Ophthalmol. 2016;9(3):434.
41. Baran RT, Baran SO, Toraman NF, et al. Evaluation of intraocular pressure and retinal nerve fiber layer, retinal ganglion cell, central macular thickness, and choroidal thickness using optical coherence tomography in obese children and healthy controls. Niger J Clin Pract. 2019;22(4):539–545. https://doi.org/10.4103/njcp.njcp_471_18
42. Paulsen AJ, Pinto A, Merten N, et al. Factors associated with the macular ganglion cell-inner plexiform layer thickness in a cohort of middle-aged U.S. Adults. Optom Vis Sci. 2021;98(3):295–305. https://doi.org/10.1097/OPX.0000000000001650
43. Von Hanno T, Hareide LL, Småbrekke L, et al. Macular layer thickness and effect of BMI, body fat, and traditional cardiovascular risk factors: The Tromsø study. Invest Ophthalmol Vis Sci. 2022;63(9):16. https://doi.org/10.1167/iovs.63.9.16
44. Gessesse GW, Debela AS, Anbesse DH. Retinal nerve fiber layer thickness and optic disc parameters measured by Cirrus HD OCT among adults attending St. Paul's Hospital Medical College. Millenn J Health. 2022;2(1):2790–1378.
45. Girkin CA, Sample PA, Liebmann JM, et al. African Descent and Glaucoma Evaluation Study (ADAGES): II. Ancestry differences in optic disc, retinal nerve fiber layer, and macular structure in healthy subjects. Arch Ophthalmol. 2010;128(5):541–550. https://doi.org/10.1001/archophthalmol.2010.49
46. Awe OO, Onakpoya OH, Adeoye AO. Optic disc morphometry using spectral domain optical coherence tomography in a Nigerian population. Eur J Ophthalmol. 2022;32(2):1194–1200. https://doi.org/10.1177/11206721211008781
47. Zhang Q, Li S, Liang Y, et al. Characteristics of optic disc parameters and its association in normal Chinese population: The Handan Eye Study. Chin Med J. 2014;127(9):1702–1709. https://doi.org/10.3760/cma.j.issn.0366-6999.20133312
48. Zheng Y, Cheung CY, Wong TY, et al. Influence of height, weight, and body mass index on optic disc parameters. Invest Ophthalmol Vis Sci. 2010;51(6):2998–3002. https://doi.org/10.1167/iovs.09-4470
49. Jonas JB, Nangia V, Gupta R, et al. Retinal nerve fibre layer cross-sectional area, neuroretinal rim area and body mass index. Act Ophthalmol. 2014;92(3):e194–e199. https://doi.org/10.1111/aos.12297
50. Ramrattan RS, Wolfs RC, Jonas JB, et al. Determinants of optic disc characteristics in a general population: The Rotterdam study. Ophthalmology. 1999;106(8):1588–1596. https://doi.org/10.1016/S0161-6420(99)90457-8
51. Xu L, Wang YX, Wang S, et al. Neuroretinal rim area and body mass index. PLoS One. 2012;7(1):e30104. https://doi.org/10.1371/journal.pone.0030104
52. Jonas JB, Gründler AE, Papastathopoulos KI. Optic disc dimensions, body length, and body weight. Br J Ophthalmol. 1998;82(2):196. https://doi.org/10.1136/bjo.82.2.196a
53. Pilat AV, Gottlob I, Sheth V, et al. Gender-and ethnicity-related differences in optic nerve head topography in healthy Indian and Caucasian participants. Neuro-Ophthalmol. 2014;38(4):205–212. https://doi.org/10.3109/01658107.2014.894535
54. Kuang TM, Liu CJ, Ko YC, et al. Distribution and associated factors of optic disc diameter and cup-to-disc ratio in an elderly Chinese population. Chin Med J. 2014;77(4):203–208. https://doi.org/10.1016/j.jcma.2014.01.006
55. Amerasinghe N, Wong TY, Wong WL, et al. Determinants of the optic cup to disc ratio in an Asian population: The Singapore Malay Eye Study (SiMES). Arch Ophthalmol. 2008;126(8):1101–1108. https://doi.org/10.1001/archopht.126.8.1101
56. Pedro-Egbe CN, Awoyesuku EA. The relationship between vertical cup-disc ratio and body mass index in Port Harcourt, Nigeria. Niger J Clin Pract. 2013;16(4):517–520. https://doi.org/10.4103/1119-3077.116904
57. Fukuoka H, Tange C, Otsuka R, et al. The impact of anthropometric and ocular parameters on optic cup-to-disc ratio. BMJ Open Ophthalmol. 2017;1(1):e000012. https://doi.org/10.1136/bmjophth-2016-000012
58. Al Wadani F, Feroze KB, Al Yahya R. The relationship between vertical cup–disc ratio and body mass index in a population of adult Saudi females. Niger J Ophthalmol. 2018;26(2):121–127. https://doi.org/10.4103/njo.njo_6_18