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Relationship between biometry, fovea, and choroidal thickness in Nigerian children with myopia

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Background: Understanding the relationship between biometric and structural changes in childhood myopia is necessary to effectively manage myopia progression.

Aim: To determine the relationship between ocular biometry, fovea and sub-fovea choroidal thickness in school-aged children with myopia of Nigerian descent.

Setting: Abuja, Nigeria.

Methods: This study involved 189 children (117 girls and 72 boys), and myopia was defined as cycloplegic spherical equivalent refraction (SER) of ≤ −0.50 D. Keratometry values, biometry data, fovea and sub-foveal choroidal thickness (SFChT) values were obtained from medical records retrospectively and analysed.

Results: The median age was 13 years (interquartile range [IQR]: 5). The median SER, fovea and SFChTs were −2.63 D (IQR: 3.38), 249 μm (IQR: 118) and 225 μm (IQR: 341), respectively. Male children had flatter corneas, thicker fovea and thinner SFChT compared to female children. The vitreous chamber and axial length were longer and sub-fovea choroid was thinner in children with high myopia. There was a weak but significant positive correlation between myopia and sub-fovea choroidal thickness (r = 0.270 respectively, P < 0.01). A moderate negative correlation was found between myopia and vitreous chamber depth (r = −0.536, P < 0.001), and a strong negative correlation was found between myopia and axial length (r = −0.706, P < 0.001).

Conclusion: Myopia in school-aged Nigerian children is associated with sub-fovea choroidal thinning, increased vitreous chamber depth and axial elongation.

Contribution: This study provides data on the relationship between ocular biometry, fovea and sub-foveal choroidal thickness in school-aged Nigerian children with myopia.

Keywords: myopia; biometry; retina; choroid; axial length.

Introduction

Quantitatively, the International Myopia Institute (IMI) defines myopia as a condition in which the cycloplegic spherical equivalent refraction (SER) of an eye is ≤−0.50 D.[1] The global prevalence of myopia was reported to be 28.3% in 2010; however, there has been a significant rise in the prevalence of the condition worldwide. More recently, it has been predicted that half of the world's population will be myopic by 2050, and 10% of that population will have high myopia.[2] To mitigate these conditions, there is an urgent need to understand myopia, the structural changes which occur in myopia, and the efficacy and impact of myopia control strategies.

Axial length (AL) is a major determinant of refractive error and is one factor which has been studied extensively.[3] The AL of the human eye is about 16.8 mm in infancy which increases to 23.6 mm in adulthood.[4] It correlates negatively with myopia,[5,6] hence as AL increases, the magnitude of myopia increases. High myopia is associated with changes in the choroid and retinal thickness which results in pathological changes in the posterior pole of the eye, a condition termed pathological myopia.[7] Individuals with pathological myopia have a greater prevalence of retinal detachment, chorioretinal atrophy, maculopathy, and glaucoma.[8] On one hand, there is a negative correlation between high myopia and sub-foveal choroidal thickness (SFChT).[9,10] On the other hand, it has been reported that foveal thickness does not change significantly until an AL of

25.5 mm where there is a significant increase in foveal thickness with increasing AL.[11]

Studies exploring structural changes which occur in myopia are relevant in understanding structural pathological changes associated with the condition. They also help guide the development of clinical examination protocols on what structures need examination and targeted anatomical interventions to address any associated pathology. Myopia progression typically begins in childhood and progresses until the late teenage years, sometimes extending to early adulthood.[12,13] The prevalence of myopia in school-aged children, even in Africa, has been increasing over the years.[14]

There is a paucity of much-needed data on African school-aged children with myopia and the relationship and impact of structural changes which occur in myopia in this age group. Studies have shown that racial differences exist in the relationship between AL and SER,[15] AL itself,[16] choroid, fovea, and inner retina thickness.[17] Other studies have also shown a strong racial difference in AL growth rates.[18] Therefore, it is important to have data on African school-aged children in order to understand the structural changes in this age group with myopia. However, there are no studies in school-aged children with myopia of Nigerian or African descent that explore fovea or SFChT, and how these parameters relate to AL. This study therefore aimed to determine the relationship between AL, foveal, and SFChT in Nigerian school-aged children with myopia.

Methods

This was a retrospective cross-sectional study involving children between the ages of 4 and 18 years diagnosed with myopia between March 2018 and March 2022. Records were obtained from a myopia control centre in a multi-speciality optometric clinic, De Lens Ophthalmics Family Eye and Vision Care Centre, located in Abuja, Nigeria.

Subjects included in this study met the following criteria: age between 4 and 18 years, no missing data, cycloplegic automated SER of ≤−0.50 D, no ocular disease or systemic illness. Subjects excluded were those with other forms of refractive error or pseudo-myopia, previous history of myopia management and history of surgical intervention.

All subjects had undergone comprehensive ophthalmic evaluation which included complete history, visual acuity, intraocular pressures, ocular motility, pupil assessment, colour vision, slit lamp examination of the ocular adnexa and anterior segment, dilated posterior segment evaluation using a Volk 90 D and/or 20 D lens.

The data obtained from the patient's medical records included: demographic data, keratometry and cycloplegic automated refraction, foveal thickness data from the retina map display of a spectral domain optical coherence tomography (SD-OCT) device, I-Vue-100 (Optovue Inc, USA) (Figure 1). The measured foveal thickness generated by this device considers the retinal pigment epithelium (RPE) as its base and the internal limiting membrane (ILM) as the upper limit of the retina surface.

The SFChT was measured from the retina B-Scan image generated by the I-Vue 100 Optovue SD-OCT device (Figure 2) by measuring the minimum distance from the RPE boundary line to the choroid-sclera interface and/or boundary at the fovea centre means of a caliper tool. The minimum distance method measures the minimum distance between two opposing layers and has been previously used in other studies in measuring ocular tissue thickness.[19,20] Only retina scans with scan quality index (SQI) >40, which is the manufacturer recommended SQI for good scans were used and the images were enhanced in brightness and contrast to make the choroid/sclera interface more visible for measurement.

Biometry data (anterior chamber depth [ACD], lens thickness [LT], vitreous chamber depth [VCD] and AL) were obtained based on the averages five readings (less than 0.2 mm between each) measured using an ultrasound biometer (Suowei, SW-1000A/P, China).

Myopia was categorised into low myopia (cycloplegic SER of ≤−0.50 D to > −6.00 D) and high myopia (cycloplegic SER of <−6.00 D) based on the recommendation of the IMI.[1]

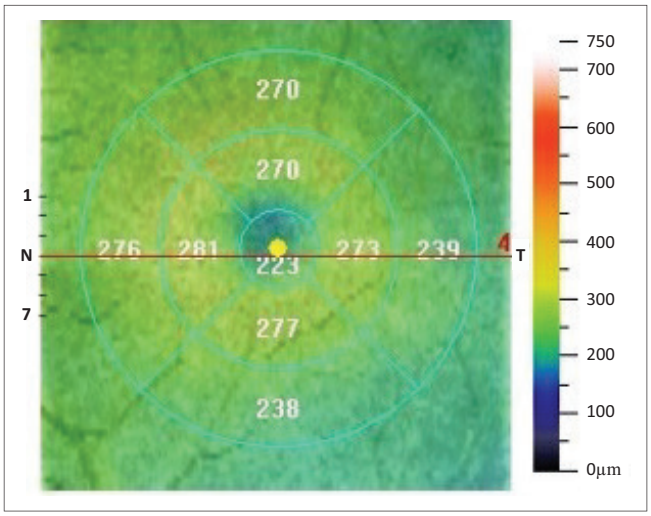

FIGURE 1: Image of the retina map display from the spectral domain optical coherence tomography device.

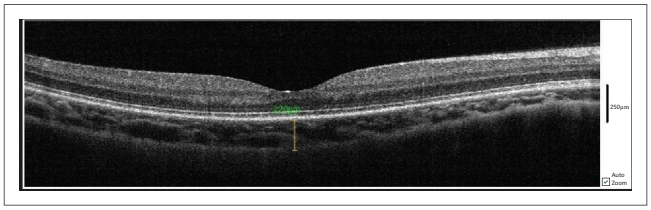

FIGURE 2: Image of the measurement of the sub-foveal choroidal thickness using the caliper tool function in the spectral domain optical coherence tomography device; the minimum distance between the retinal pigment epithelium boundary and the choroid-scleral junction is measured here.

Sample size calculation

Based on the last official census done in Nigeria in 2006, the population of Abuja was 1406239 persons with children making up about 46.7% of the population (0–19 years).[21] The projected population of Abuja as of the year 2016 was 3564100 persons; hence the population of school-aged children aged 0–19 years will be 1665860 persons. The prevalence of myopia in school-aged children varies from 2.7% to about 4.8% in Nigeria.[14] Assuming the upper prevalence of 4.8% of 1665860 children, the estimated population of children with myopia in Abuja was 79961.

Assuming a confidence level of 95%, with 5% margin of error and a population proportion of 4.8%, using the formula:

$$n = \frac{z^2 \times P(1-P)}{\varepsilon^2} \quad \text{[Eqn 1]}$$

where z is the z score, which at a confidence level of 95% is 1.96, ε is the margin of error (5%), and n is the sample size.

$$\text{Hence, } n = \frac{1.96^2 \times 0.048\left(1-0.048\right)}{0.05^2} = 70.2 \quad \text{[Eqn 2]}$$

Consequently, a sample size of at least 71 persons was required to achieve a confidence level of 95% in this study. The estimated sample size obtained was 120 subjects which exceeded the calculated sample size.

Ethical considerations

Ethical approval to conduct the study was obtained from the Health Research Ethics Committee of the Federal Capital Territory Administration Abuja, Nigeria with reference number FHREC/2022/01/82/04-05-22. The study was conducted following the tenets of the Declaration of Helsinki.

Statistical analysis

Data from only the right eye in cases of bilateral myopia, and the myopic eye in those with unilateral myopia were analysed. Tests for normality were done using the Shapiro-Wilk tests. Differences between the magnitude of myopia and gender-based differences in ACD, LT, vitreous chamber depth, AL, cycloplegic SER, fovea, and sub-fovea choroidal thickness were determined using the student's T-test or Mann Whitney-U test. The relationship between ocular biometry parameters, cycloplegic SER, AL, foveal retinal thickness (FT), SFChT, and age was determined using Pearson or Spearman's correlation test. Data were analysed using Statistical Package for Social Sciences (SPSS) version 22.0 (IBM Corps, Armonk, NY), and a P-value of less than 0.05 was considered statistically significant.

Results

A total of 189 eyes of 189 children (117 girls [61.9%] and 72 boys [38.1%]) with a median age of 13 years (8–18) were analysed. The median cycloplegic SER was −2.63 D (3.38). The mean average keratometry (Ave K), steep keratometry (Steep K) and flat keratometry (Flat K) values were 7.76 mm ± 0.26 mm, 7.64 mm ± 0.27 mm, 7.87 mm ± 0.28 mm, respectively. The biometry data are summarised in Table 1. The median FT and SFChT were 249 μm (118) and 225 μm (341), respectively.

There was no difference between boys and girls in terms of age, cycloplegic SER, steep keratometry value, ACD, LT, VCD, and AL ($P > 0.05$) (Table 2). However, there were significant differences in flat keratometry, fovea thickness, and SFChT between boys and girls. Boys had flatter corneas (7.92 mm ± 0.25 mm in boys and 7.81 mm ± 0.28 mm in girls, $P = 0.019$), thicker fovea (258.5 μm ± 20.66 μm in boys and 242.9 μm ± 16.0 μm in girls, $P < 0.01$), and thinner SFChT (219.44 μm ± 59.84 μm in boys and 252.25 μm ± 54.58 μm in girls, $P = 0.017$). The differences in the parameters between male children and female children are summarised in Table 2.

In the comparison of children with low myopia (≤−0.50 D to >−6.00 D) ($n = 155$) versus high myopia (<−6.00 D) ($n = 34$), there was no difference in ACD (3.51 mm ± 0.57 mm and 3.63 mm ± 0.52 mm for low and high myopia groups respectively, $P = 0.715$), or LT (4.22 mm ± 1.68 mm and 4.26 mm ± 1.63 mm for the low and high myopia groups respectively, $P = 0.130$) between both the groups. The mean cycloplegic SER was −9.87 D ± 4.35 D in children with high myopia, and it was significantly higher

TABLE 1: Summary of the ocular biometry data in the study population.

Parameter	Mean ± SD median (IQR)
ACD (mm)	3.72 ± 1.63
LT (mm)	4.18 ± 1.60
VCD (mm)	16.88 ± 2.21
AL (mm)	24.72 ± 1.56
FT (μm)	249 (118)
SFChT (μm)	225 (341)
Flat K (mm)	7.87 ± 0.28
Steep K (mm)	7.64 ± 0.27

SD, standard deviation; ACD, anterior chamber depth; LT, lens thickness; VCD, vitreous chamber depth; AL, axial length; FT, fovea thickness; SFChT, sub-foveal choroidal thickness; mm, millimetres; μm, micrometres; IQR, interquartile range; K, keratometry value.

TABLE 2: Gender-based differences in demographic, refraction, biometry and retina parameters.

Parameter	Male (n = 72)	Female (n = 117)	P
Age (yrs)	12.8 ± 3.8	12.2 ± 3.6	0.207
Myopic SER (D)	-4.21 ± 4.65	-3.25 ± 2.72	0.974
Flat K (mm)	7.92 ± 0.245	7.81 ± 0.278	0.019*
Steep K (mm)	7.69 ± 0.25	7.61 ± 0.27	0.062
ACD (mm)	3.92 ± 2.54	3.57 ± 0.59	0.470
LT (mm)	4.27 ± 1.78	4.07 ± 1.53	0.287
VCD (mm)	17.12 ± 2.62	16.62 ± 1.75	0.245
AL (mm)	25.08 ± 1.86	24.34 ± 1.24	0.059
FT (mm)	258.53 ± 20.66	242.89 ± 16.0	< 0.001*
SFChT (mm)	219.44 ± 59.84	252.25 ± 54.58	0.017*

*, indicates p value < 0.05

yrs, years; D, Diopter; mm, millimetres; SER, spherical equivalent refraction; K, keratometry value; ACD, anterior chamber depth; LT, lens thickness; VCD, vitreous chamber depth; AL, axial length; FT, fovea thickness; SFChT, sub-foveal choroidal thickness.

TABLE 3: Differences in ocular biometry, refraction, retinal parameters.

Parameter	High myopia	Low myopia	*P*
Cyclo SER (D)	-9.87 ± 4.35	-4.56 ± 0.58	< 0.001*
ACD (mm)	3.63 ± 0.52	3.51 ± 0.57	0.715
LT (mm)	4.26 ± 1.63	4.22 ± 1.68	0.130
VCD (mm)	18.81 ± 2.53	17.24 ± 1.82	< 0.001*
AL (mm)	26.82 ± 1.92	25.12 ± 0.92	< 0.001*
FT (μm)	249.0 (31)	243 (70)	0.809
SFChT (μm)	185 (55)	228.0 (277)	< 0.001*

*, indicates p value < 0.05.

D, Diopter; mm, millimetres; SER, spherical equivalent refraction; ACD, anterior chamber depth; LT, lens thickness; VCD, vitreous chamber depth; AL, axial length; FT, fovea thickness; SFChT, sub-foveal choroidal thickness.

compared to children with low myopia group (−4.56 D ± 0.58 D, $P < 0.001$). Similarly, the VCD (17.24 ± 1.82 mm and 18.81 mm ± 2.53 mm for the low and high myopia groups respectively, $P < 0.001$) and AL (25.12 mm ± 0.92 mm and 26.82 mm ± 1.92 mm for the low [≤−0.50 D to >−6.00 D] and high myopia groups respectively, $P < 0.001$) were significantly longer in the children with high myopia. There was also a statistically significant difference in the SFChT between the high myopia group (190.14 μm ± 55.6 μm) and low myopia group (237.0 μm ± 59.58 μm), with the high myopia group having thinner sub-foveal choroids compared to the low myopia group ($P < 0.001$). However, the difference in foveal thickness between both the groups (252.54 μm ± 23.19 μm for the high myopia group and 245.46 μm ± 17.03 μm for the low myopia group [≤−0.50 D to >−6.00 D]) was not statistically significant ($P = 0.809$). The differences between the biometry, fovea and sub fovea choroidal thickness values are summarized in Table 3.

There was a weak correlation between myopic SER and age and between myopic SER and SFChT; this correlation was negative for age and positive for SFChT ($r = −0.209$ and 0.270 respectively, $P = 0.04$ and <0.01 respectively). There was a negative moderate correlation between myopic SER and VCD ($r = −0.536$, $P < 0.001$). A strong negative correlation was found between myopic SER and AL ($r = −0.706$, $P < 0.001$). Other parameters such as ACD, LT and foveal thickness did not correlate with myopic SER.

Axial length showed a significant negative correlation with the SFChT ($r = −0.321$, $P < 0.001$) and did not correlate with foveal thickness. In a linear regression analysis, AL significantly predicted myopic SER, F (1.187) = 350.196, $P < 0.001$, and the $R^2 = 0.652$. The scatter plot of the linear regression for AL and myopic SER, and AL and SFChT is shown in Figure 3.

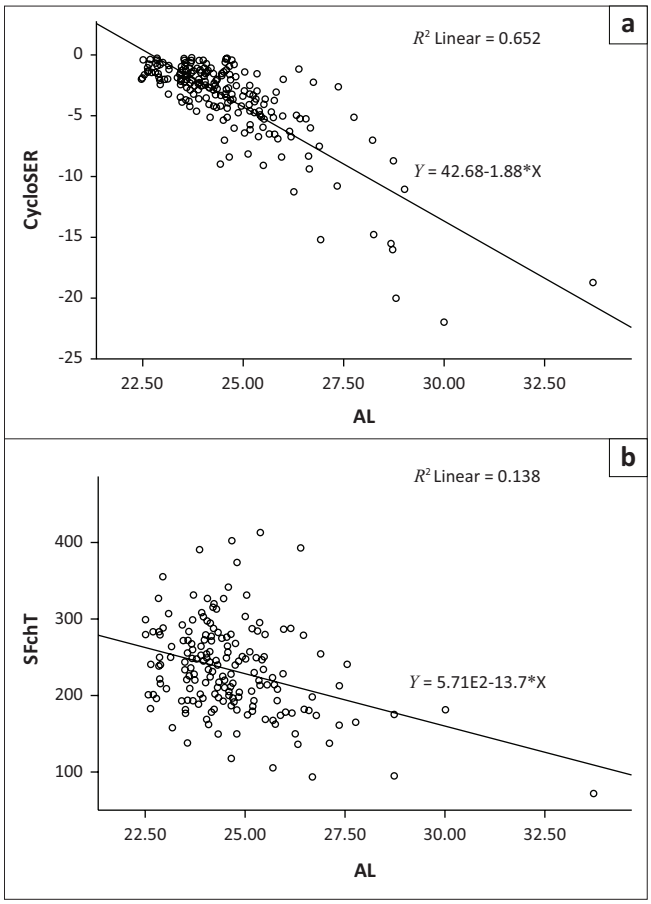

FIGURE 3: Scatter plot and regression line for the regression between axial length (AL) and myopic refractive error (a) and AL and sub-foveal choroidal thickness (b).

Discussion

This study sought to determine the relationship between ocular biometric parameters, fovea and SFChT in Nigerian school-aged children with myopia. Following the review of several databases, the authors believe the area of ocular and retina biometry in school-aged children with myopia of African origin may be a novel area worth exploring.

An increase in the magnitude of myopia with increasing age was noted in the study population. There was also significant increase in the VCD and AL, and thinning of the sub-foveal choroid with an increase in the magnitude of myopia. The reason for such relationship between myopia and age is likely because of increased incidence of myopia observed in school-aged children with increasing age.[22,23] Another possible reason is the increased near work with increasing age, and academic levels causing the environmental contribution to myopia progression.[24,25,26] The choroidal changes observed may be on account of continuous axial elongation from higher amounts of myopia leading to scleral stretching and thinning of the choroid.[27,28] Therefore, it might be appropriate to target myopia management in school-aged children to prevent or control progression as early as possible.

Refractive error is determined by the complex relationship between optical components (cornea and lens power) and biometry components (ACD, VCD and AL) of the eye.[29] There was a strong negative and moderate negative correlation between AL and VCD with myopic refractive error respectively. Anterior chamber depth and LT did not correlate with myopic refractive error in the present study. Such finding underscores the significance of monitoring posterior segment parameters in school-aged children with myopia. The AL changes aside from correlating with myopic

refractive error, actually predicts the refractive error changes, hence serving as a measure for myopia management interventions. For example, in the present study population, a change in AL of 1 mm was observed with 1.88 D increase in the magnitude of myopic refractive error. Other studies exploring biometric parameters in school-aged (6–15 years) children in South India reported VCD and AL as the most significant contributors to refraction in myopic children while ACD and corneal curvature did not contribute significantly.[30] It is, however, difficult to make comparisons with studies conducted on children in Africa because of inadequate literature on the subject matter. In the present study, the overall mean AL was 24.72 mm ± 1.56 mm; this is an expected finding considering the main characteristic of the subjects of this study is myopic refractive error, and an increased AL compared to normal would be expected. A similar result to that of our study was reported in 344 Turkish children aged 3–14 years which reported AL of 24.15 mm ± 0.88 mm.[31] In individuals of south western Nigerian origin, Betiku et al.[32] reported an AL of 24.4 mm ± 1.1 mm in a group of individuals with myopia. However, Betiku et al.'s study included adults and elderly subjects alongside children making proper comparison difficult.[32]

Longer AL is associated with several posterior segment pathologies.[33] An AL ≥26.5 mm is associated with glaucoma progression in myopic patients with glaucoma.[34] Furthermore, an AL of >25 mm was associated with retinal detachments following cataract surgery.[35] Hashimoto et al.[36] reported that an AL >25.3 mm in females and >25.9 mm in males was associated with myopic maculopathy. In sub-group analysis in the present study, children with higher myopia had significantly longer AL compared to those with low myopia (≤−0.50 D to >−6.00 D) (26.82 mm ± 1.92 mm and 25.12 mm ± 0.92 mm) indicating significant risk for posterior segment pathology in this population. A combination of long axial length and older age have been established as risj factors for development of more severe myopic maculopathy; early onset of myopia also carries a greater risk for myopic maculopathy.[37]

There was a weak but significant negative correlation between AL and SFChT in the present study. A change in SFChT of 13.7 μm per mm change in AL was noted on regression analysis (Figure 3b). This finding explains the thinner SFChT observed in the group with high myopia because of axial elongation and globe stretching. Similar results were reported in Chinese children with a mean age of 9.9 ± 0.3 years, where a 16.2 μm change per mm of AL difference was reported.[38] Considering that myopia typically begins in childhood and goes on to progress until the late teens to early 20s,[13] understanding the impact of progressive myopia on the choroid is important in the determination of associated pathological changes. It is recommended to consider SFChT measurements alongside AL data in children with myopia, not just as a parameter to explain the development and progression of myopic refractive error but also as a marker to determine the risk of pathological changes such as chorioretinal atrophy in the myopic eye.

In this study population, AL was longer in males compared to females; but this difference was not statistically significant ($P = 0.059$). The reason for such findings may be difficult to ascertain but it is possibly because of the fact that puberty and myopia onset occurs earlier in females compared to males,[39] hence myopia stabilisation may occur earlier in females leaving males with continuous axial elongation as they get older. He et al.[40] reported similar results in a group of Chinese children between the ages of 4–18 years, with females notably having shorter AL compared to males. Although the magnitude of myopia in the present study was higher in male children compared to female children, there was a greater number of female children ($n = 117$) with myopia compared to male children ($n = 72$). This result is similar to that reported in a systematic review of the prevalence of myopia in school-aged children where the prevalence of myopia was notably higher in females than in males.[14] Ovenseri-Ogbomo et al.[14] explained that such differences may be because of the limited time outdoors in female children compared to males. Females had significantly thicker SFChT compared to males, with a difference of approximately 33 μm. This finding is most likely because of males having higher myopia magnitude and significantly longer AL compared to their female counterparts. As seen in this study population, increased AL was associated with thinner SFChT. A similar finding was noted in Chinese children with females having a thicker SFChT, and a difference of 17 μm was reported.[38]

One limitation of this study is its retrospective design. However, despite this limitation, only patients' medical records with complete data set, and measurements taken by a single trained clinician was included and the findings of this study are similar to that reported in other ethnicities. This study provides information on posterior segment structural changes as it relates to ocular biometry in African school-aged children. Another potential limitation was the use of SER as a tool to classify myopia magnitude. While this is a known limitation of using the SER, the IMI in its definition and classification of myopia notes that this is adequate for most studies relating to myopia and should not affect the validity of results significantly except in studies where retinal defocus is the primary study outcome. This was not the case in the present study.

Conclusion

The findings of the present study show that myopia in school-aged children in Nigeria is associated with longer VCD and AL with associated thinning of the sub-foveal choroid. Females with myopia have thicker SFChT and thinner fovea retina thickness compared to their male counterparts. A recent survey[41] of African eye care practitioners revealed a low level of myopia management knowledge and practice in the continent. In light of the findings of this study, there is a need to adopt myopia management including measurement of AL and SFChT in African school-aged children to prevent

further axial elongation and choroidal thinning associated with increasing myopia.

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Competing interests

The authors have declared that no competing interest exists.

Authors' contributions

C.J.O. – Concept, methodology, investigation, study design, funding, writing original draft, review, data acquisition, analysis, final writing and submission.

K.S.N. – Concept, methodology, study design, original draft, supervision, correction, final draft approval.

K.P.M. – Concept, methodology, study design, original draft, supervision, correction, final draft approval.

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Data availability

There are no restrictions to data availability for this study.

Disclaimer

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