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Morphometric evaluation of the ocular globe: A Nigerian retrospective study

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Abstract

Background: The ocular globe morphometry is essential in the screening, diagnosis and management of numerous ophthalmologic pathologies. *Aims and Objectives:* This study was designed to determine the globe diameters, position and protrusion among adults seen at a radiological unit in Delta State, Nigeria. *Material and Methods:* Digital brain Computed Tomography (CT) (150) and Magnetic Resonance (MRI) Images (150) archived in a Nigerian Teaching Hospital in Delta State were used to assess the ocular morphometry after seeking institutional approval. Inferential statistical analysis was done and regarded significant at $p < 0.05$. *Results:* Both MRI and CT groups, had symmetrical globe diameters while asymmetry was observed in the globe protrusion and the eyeball volume calculated from MRI measurements. The ocular parameters showed significant gender differences and the CT globe diameters had a negative correlation with age. Significant positive associations between the globe diameters, position, protrusion and interzygomatic line were observed. *Conclusion:* The values of the globe parameters obtained are useful to ophthalmologists and radiologists in the diagnosis, management and follow-up of different ocular conditions in the study region.

Keywords: Globe, axial length, protrusion, position, eyeball

Introduction

The organ responsible for vision is the eye, comprising the globe or eyeball encased within the eye sockets or orbits, situated within the skull. The globe is connected to the brain through the optic nerve [1]. An optimal orbital organization facilitates vision and any changes in the typical morphology and dimensions may cause visual abnormalities [2].

The Axial Length (AL) of the ocular globe is the distance between the corneal apex anteriorly (anterior pole) and an interference peak by the retinal pigment epithelium (Bruch's membrane) posteriorly (posterior pole) [1, 3]. The AL comprises the depth of the anterior chamber, the lens thickness and the vitreous length [2]. It shows population, geographical and racial variations. Additionally, it changes with age, growing from 16 mm in new-borns to 19.5 mm in infants. It reaches the adult emmetropic length by 13 years and thereafter, remaining practically unchanged in adulthood [1, 3-7].

The AL influences the refractive state of the eye and its alterations can cause refractive errors. For instance, a short AL (< 22 mm) reflects hyperopic or hypermetropia which predisposes to angle closure glaucoma while a long AL (> 26 mm) in myopia increases the risk of retinal detachment, open angle glaucoma and globe perforation during peribulbar anaesthetic block [3, 8]. The eyeball volume is vital in the diagnosis and management of macrophthalmus, buphthalmus, and microphthalmus. The globe may be enlarged in raised intracranial pressure caused by obstruction of the drainage channel of the intraocular fluid in congenital glaucoma [9].

The Interzygomatic Line (IZL) is used as landmark in globe morphometry conducted on axial scans [10]. The distance from the IZL to the posterior globe surface determines the globe position while the distance between the anterior ocular surface and the IZL defines the globe protrusion [5, 11]. The former distance is shorter hence, yields a lower margin of error during measurements. Moreover, abnormalities like staphyloma also reduce the precision of the morphometry [5]. The globe position is affected by various factors including race, ethnicity, environment, genetics, axial length of the globe and the prevalence of myopia [5, 10-14].

Alterations in the eyeball size may occur due to cancer, trauma, retinoblastoma, and congenital glaucoma [3]. Bulbar measurements are crucial in the screening and evaluation of patients with refractive errors, macrophthalmia, and microphthalmia, hence significant to radiologists, ophthalmologists, and other clinical specialists [1]. Awareness of the eyeball position relative to the surrounding bony landmarks aids in diagnosing exophthalmos and proptosis caused by either vascular, neoplastic, endocrine, inflammatory, infective, extraorbital or traumatic factors [10-13]. Proptosis is diagnosed when the anterior eyeball margin is > 21-23 mm anterior to the IZL [5]. Detecting changes in the globe size can be challenging, particularly in borderline cases where alterations aren't clearly visible. This emphasizes the significance of knowing the eye biometry, necessary for diagnosis, and monitoring the effectiveness of treatment and further visual compromise [3, 13].

The axial length can be measured using sonography, Computed Tomography (CT), laser Doppler interferometry and Magnetic Resonance Imaging (MRI). Ultrasonography is operator dependent and the probe usually contacts the eye, hence may introduce infection. CT facilitates faster image acquisition and is widely available currently. However, it exposes the patients to ionizing radiation [2, 13]. The MRI is safer in evaluating orbital soft tissues and provides accurate and objective ocular morphometry [2, 3]. We therefore designed this study to determine the globe diameters, position and protrusion in adult Nigerians seen at a tertiary health facility in Delta State.

Material and Methods

This cross-sectional study at a Nigerian hospital retrospectively assessed ocular bulbs using brain MRI and CT images from the Radiology database (Picture Archiving and Communications Software). The study was approved by the Institutional Health Research Ethics Committee (Ref no. DELSUTH/HRECC/2023/038/0567, dated 24th July, 2023). Being a retrospective study, the need for obtaining the patients' consent was waived by the committee. Images were conveniently sampled from the years 2016-2020, meeting inclusion criteria of symmetrical, adequately viewed brain MRI and CT images of patients aged ≥20 years acquired with patients in primary gaze. Exclusion criteria comprised oblique/lateral gaze, visible orbital pathology, prior orbital surgery, intracranial lesions, raised intracranial tension, eye implants, and artefacts. The study analyzed 150 MRI and 150 CT cranial images.

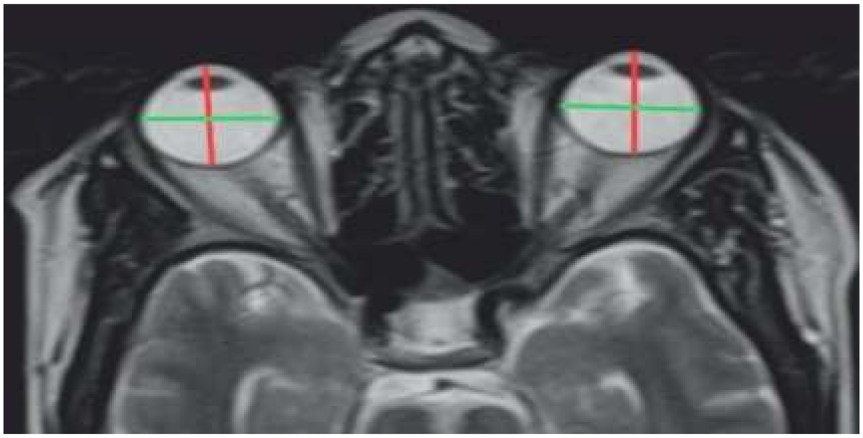
The images belonged to patients with complaints such as headaches, and altered consciousness, or had suspicious stroke, emboli, or intracranial tumors. A 64-slice CT scanner manufactured in Japan (Toshiba Aquillon) captured axial slices (5 mm thick), reformatted into coronal and sagittal images, with settings at 300 mAs and 120 kVP. A 1.5-Tesla MRI scanner (Toshiba Excelart Vantage, Japanese Model) acquired 3 mm thick axial brain sections using T1 and T2-weighted spin echo sequences, with heads immobilized by the head coil. The axial scan range extended from the skull base, precisely at the foramen magnum to the vertex, utilizing a 256×256 matrix size. Sagittal and coronal sections were generated through axial section reformatting.

Following sample image selection, the globes were identified in axial CT images using a constant window width and level (300 and 330H) on the soft tissue window. Similarly, on T2-weighted axial MRI scans, the eyeballs were located. One researcher, utilizing digital calipers in the PACS software, measured all the eyeball parameters at mid-globe axial sections. Each ocular measurement was determined thrice, and averages were recorded.

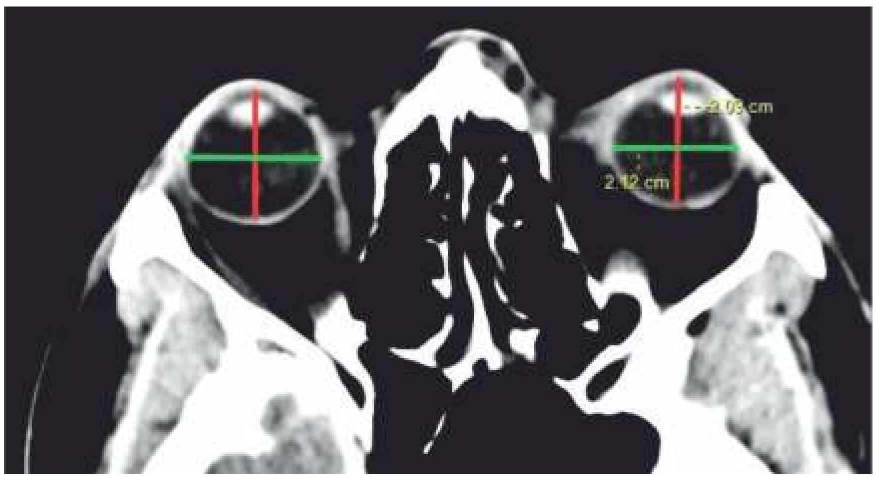
The axial length (anteroposterior diameter) was determined as the maximum distance from the anterior corneal surface to the posterior scleral surface, at right angles to the IZL and dividing the globe equally into left and right halves [1, 8]. This measurement encompassed the depth of the anterior chamber, the antero-posterior lens diameter, and the length of the vitreous. The transverse/mediolateral diameter of the globe represented the maximum horizontal distance from the nasal to temporal ends on axial slices (Figures 1A and 1B) [2].

Both axial length and transverse diameter were determined at midocular slices for maximum bulb and lens size display [2, 9]. Bulbar oculi volume was arithmetically calculated assuming a spherical shape, using the formula $V = 4/3\pi r^3$ (cm^3), where r = (axial length + transverse diameter)/4 [9]. The IZL was defined at the plane of the lens, represented as a line connecting the anterior limits of bilateral zygomas [1]. Globe protrusion was defined as the orthogonal dimension from the IZL to the corneal apex at the anterior bulbar margin [12]. Similarly, globe position was determined by the perpendicular distance from the IZL to the posterior ocular surface (Figures 2 and 3) [13].

The Statistical Package for Social Sciences (SPSS) IBM version 23, from Armonk, New York, USA, was used to group the data based on age and sex, and later analyse the data. We used descriptive statistics such as means and standard deviations to summarize the data in tables. Inferential statistics were applied to evaluate for sex, side and age related variations in the globe parameters. These were conducted using independent *t*-test, paired *t*-test and the Analysis of Variance (ANOVA) respectively. The relationship between the continuous variables was assessed employing the Pearson's correlation test. Significance level of $p < 0.05$ with a confidence interval of 95% was considered.



(1A)



(1B)

Figure 1: Measurement of the axial length (red) and the transverse diameter of the globe (green) on Axial section of a T2 weighted MRI sequence (A) and Axial CT section (B).

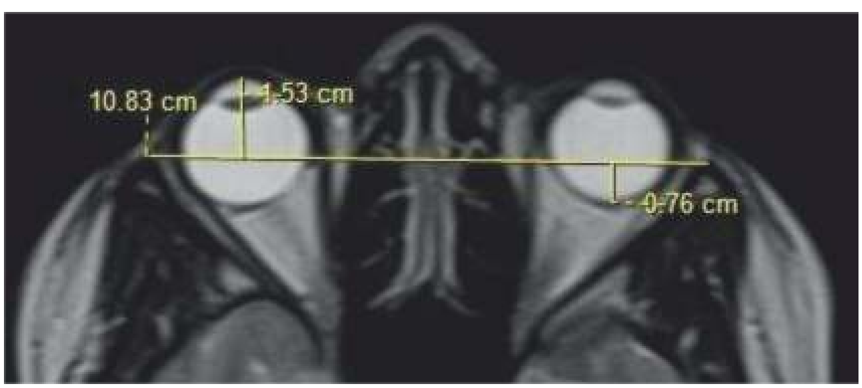


Figure 2: Axial section of a T2 weighted MRI sequence showing the measurement of the globe protrusion (1.53 cm), globe position (0.76 cm) and interzygomatic line (10.83 cm)

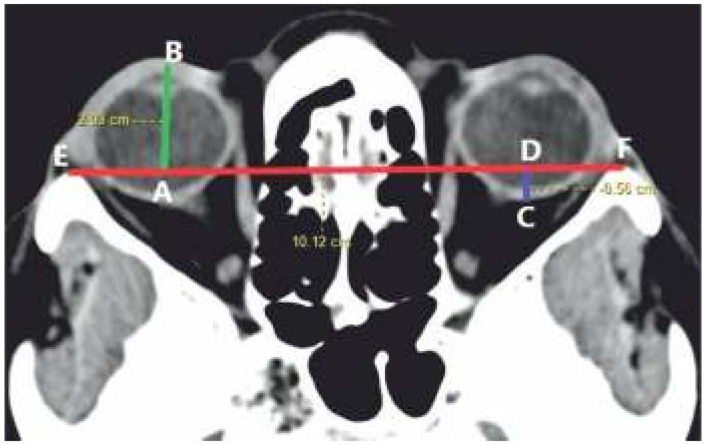


Figure 3: Axial CT scan showing the measurement of the globe protrusion (AB), globe position (CD) and interzygomatic line (EF)

Results

This study used brain CT (150) and MRI (150) images to assess the eyeball morphometry. The CT images belonged to 70 females (46.7%) and 80 males (53.3%) whose average age was 54.16 ± 16.89 years and 54.51 ± 16.14 years respectively. These 150 patients had an age range of 22-86 years. The T2 weighted sequences of axial MRI scans had an equal gender distribution; 75 males (50%) and 75 females (50%). This group had an average age of 52.54 ± 17.20 years (Range 20-89 years); 54.07 ± 16.23 years in males and 51.01 ± 18.09 years in females. The frequency of patients in each of the 10 years' age-groups is shown in Table 1.

The descriptive statistics of the MRI and CT eyeball parameters are shown in Table 2. Both imaging groups showed no significant asymmetry in axial length, transverse diameter and eyeball position. However, the globe protrusion showed significant laterality with more bulge on the right than the left (p=0.028, 0.012) (Table 3). The ocular globe's volume calculated from MRI was significantly larger on the right than the left globe (P = 0.038) (Table 3).The eyeball length, transverse diameter, volume, position and the IZL on both imaging methods measured significantly larger in males ($p < 0.05$) (Table 4). Conversely, globe protrusion lacked association with gender (p = 0.941, 0.051) (Table 4).

The ocular diameters, IZL and globe volume lacked significant disparities in the 10 years age group evaluated ($p > 0.05$) (Table 5). Age showed a significant negative association with the axial length and transverse globe diameter on CT (P 0.018, 0.004) (Tables 6).

Both imaging groups revealed the axial length's positive relationship with the mediolateral globe diameter r = 0.742, 0.691, p = 0.001). The IZL had a positive association with axial length, transverse ocular diameter and globe protrusion ($0 < r < 0.5$, $p < 0.05$). The globe position showed a positive association with transverse globe diameter and a negative relationship with globe protrusion in both imaging groups ($p < 0.05$). The globe protrusion had a positive association with the axial length and transverse diameter on CT and with axial length on MRI ($p < 0.05$) (Tables 6 and 7). Table 8 compares the eyeball morphometry in diverse population groups.

Table 1: Age-wise distribution of study participants

Age (Years)		21-30	31-40	41-50	51-60	61-70	71-80	81-90	Total
CT	N	10	27	32	32	26	16	7	150
	%	6.7	18.0	21.3	21.3	17.3	10.7	4.7	100
MRI	N	17	24	28	33	28	14	6	150
	%	11.3	16.0	18.7	22.0	18.7	9.3	4.0	100

CT- computed tomography, MRI- magnetic resonance imaging

Table 2: Distribution of the eyeball parameters

	CT (N=150)			MRI (N=150)		
Variables	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Axial length (cm)	1.45	2.49	2.16 ± 0.15	2.00	2.54	2.28 ± 0.10
Transverse diameter of globe (cm)	1.32	2.56	2.24 ± 0.17	2.06	2.67	2.32 ± 0.11
Globe protrusion (cm)	1.04	2.47	1.97 ± 0.26	1.20	2.02	1.70 ± 0.19
Globe position (cm)	0.25	1.09	0.55 ± 0.19	0.23	0.97	0.60 ± 0.17
IZL (cm)	10.04	11.25	10.16 ± 0.95	9.68	11.62	10.52 ± 0.42
Globe volume (cm^3)	4.79	8.41	5.68 ± 1.05	4.51	8.48	6.39 ± 0.81

CT- computed tomography, MRI- magnetic resonance imaging, IZL- interzygomatic line, Min-minimum, Max-maximum, SD-standard deviation

Table 3: Association between age and metric parameters

Parameters (cm)		CT				MRI			
		Min	Max	Mean ± SD	*p*	Min	Max	Mean ± SD	*p*
Axial length	R	1.42	2.49	2.17 ± 0.16	0.295	1.93	2.56	2.28 ± 0.11	0.374
	L	1.47	2.52	2.16 ± 0.16		1.88	2.52	2.28 ± 0.11	
Transverse diameter of globe	R	1.35	2.59	2.24 ± 0.22	0.501	2.00	2.66	2.31 ± 0.12	0.056
	L	1.58	2.59	2.25 ± 0.15		2.01	2.67	2.32 ± 0.12	
Globe protrusion	R	1.00	2.58	1.98 ± 0.26	0.028*	1.24	2.06	1.71 ± 0.19	0.012*
	L	1.07	2.48	1.96 ± 0.28		1.16	2.11	1.69 ± 0.21	
Globe position	R	0.25	1.11	0.55 ± 0.19	0.352	0.24	0.98	0.60 ± 0.17	0.642
	L	0.24	1.06	0.55 ± 0.19		0.22	0.99	0.60 ± 0.19	
Globe volume	R	0.91	8.38	5.70 ± 1.13	0.741	4.13	8.53	6.42 ± 0.83	0.038*
	L	1.91	8.53	5.68 ± 1.05		4.27	8.51	6.37 ± 0.86	

CT- computed tomography, MRI- magnetic resonance imaging, R- right, L- left, Min- minimum, Max- maximum, SD- standard deviation

Table 4: Gender-wise distribution of metric parameters

Metric parameters	CT (Mean ± SD)			MRI (Mean ± SD)		
	Males	Females	*P*	Males	Females	*P*
Axial length (cm)	2.21 ± 0.12	2.11 ± 0.17	0.001*	2.31 ± 0.09	2.25 ± 0.11	0.001*
Transverse diameter of globe (cm)	2.28 ± 0.15	2.20 ± 0.18	0.006*	2.32 ± 0.09	2.28 ± 0.13	0.014*
Globe protrusion (cm)	1.97 ± 0.27	1.97 ± 0.25	0.941	1.73 ± 0.19	1.67 ± 0.19	0.051
Globe position (cm)	0.58 ± 0.19	0.52 ± 0.17	0.029*	0.60 ± 0.17	0.56 ± 0.18	0.032*
IZL (cm)	10.41 ± 0.42	9.87 ± 1.26	0.001*	10.70 ± 0.37	10.35 ± 0.39	0.001*
Globe volume (cm^3)	5.97 ± 0.90	5.34 ± 1.10	0.001*	6.52 ± 0.67	6.25 ± 0.92	0.037*

CT- computed tomography, MRI- magnetic resonance imaging, IZL- interzygomatic line, SD- standard deviation

Table 5: Association between age and metric parameters

Variables (cm)	Age (Years)							*p*
	21-30	31-40	41-50	51-60	61-70	71-80	81-90	
CT measurements (Mean ± SD)								
Axial length	2.19 ± 0.21	2.23 ± 0.10	2.17 ± 0.16	2.12 ± 0.15	2.19 ± 0.12	2.10 ± 0.20	2.12 ± 0.14	0.056
Transverse diameter of globe	2.33 ± 0.14	2.29 ± 0.12	2.27 ± 0.18	2.21 ± 0.12	2.24 ± 0.21	2.18 ± 0.20	2.19 ± 0.14	0.126
Globe protrusion	1.97 ± 0.19	2.03 ± 0.27	1.97 ± 0.26	1.98 ± 0.22	1.94 ± 0.32	1.87 ± 0.29	2.03 ± 0.12	0.581
Globe position	0.64 ± 0.16	0.57 ± 0.21	0.55 ± 0.21	0.51 ± 0.15	0.56 ± 0.20	0.56 ± 0.17	0.48 ± 0.12	0.494
IZL	10.28 ± 0.69	10.24 ± 0.42	9.86 ± 1.73	10.25 ± 0.64	10.31 ± 0.42	9.94 ± 0.82	10.51 ± 0.19	0.398
Globe volume (cm^3)	6.10 ± 1.33	6.09 ± 0.79	5.79 ± 1.09	5.35 ± 0.91	5.73 ± 1.03	5.23 ± 1.17	5.29 ± 1.03	0.135
MRI measurements (Mean ± SD)								
Axial length	2.26 ± 0.08	2.29 ± 0.11	2.30 ± 0.08	2.30 ± 0.11	2.27 ± 0.12	2.24 ± 0.09	2.30 ± 0.09	0.546
Transverse diameter of globe	2.31 ± 0.08	2.33 ± 0.11	2.35 ± 0.10	2.31 ± 0.09	2.29 ± 0.16	2.28 ± 0.09	2.32 ± 0.10	0.477
Globe protrusion	1.64 ± 0.16	1.72 ± 0.21	1.73 ± 0.16	1.69 ± 0.21	1.70 ± 0.18	1.74 ± 0.20	1.69 ± 0.19	0.658
Globe position	0.67 ± 0.15	0.59 ± 0.18	0.58 ± 0.16	0.63 ± 0.17	0.58 ± 0.18	0.52 ± 0.17	0.61 ± 0.14	0.268
IZL	10.45 ± 0.48	10.36 ± 0.43	10.58 ± 0.35	10.49 ± 0.51	10.67 ± 0.32	10.45 ± 0.37	10.61 ± 0.44	0.182
Globe volume (cm^3)	6.30 ± 0.85	6.48 ± 0.84	6.58 ± 0.66	6.42 ± 0.75	6.24 ± 1.09	6.05 ± 0.70	6.49 ± 0.78	0.635

CT- computed tomography, MRI- magnetic resonance imaging, IZL- interzygomatic line, SD- standard deviation

Table 6: Correlation between age and the CT measurements of the eyeball

Variables		Age	Axial length	Transverse diameter of globe	Globe protrusion	Globe position	IZL
Age	r	1	-0.913	-0.232	-0.095	-0.106	0.026
	p	-	0.018*	0.004*	0.249	0.198	0.751
Axial length	r	-0.193	1	0.742	0.397	0.080	0.383
	p	0.018*	-	0.001*	0.001*	0.331	0.001*
Transverse diameter of globe	r	-0.232	0.742	1	0.241	0.167	0.298
	p	0.004*	0.001*	-	0.003*	0.041*	0.001*
Globe protrusion	r	-0.095	0.397	0.241	1	-0.727	0.260
	p	0.249	0.001*	0.003*	-	0.001*	0.001*
Globe position	r	-0.106	0.080	0.167	-0.727	1	-0.005
	p	0.198	0.331	0.041*	0.001*	-	0.952
IZL	r	0.026	0.383	0.298	0.260	-0.005	1
	p	0.751	0.001*	0.001*	0.001*	0.952	-

IZL-interzygomatic line, r- Pearson's coefficient, p-probability value

Table 7: Correlation between age and the MRI measurements of the eyeball

		Age	Axial length	Transverse diameter of globe	IZL	Globe protrusion	Globe position
Age	r	1	-0.041	-0.142	0.102	0.083	-0.146
	p	-	0.619	0.084	0.213	0.311	0.075
Axial length	r	-0.041	1	0.691**	0.246**	0.360**	0.109
	p	0.619	-	0.001	0.002	0.001	0.184
Transverse diameter of globe	r	-0.142	0.691**	1	0.226**	0.155	0.222**
	p	0.084	0.001	-	0.005	0.059	0.006
IZL	r	0.102	0.246**	0.226**	1	0.176*	-0.012
	p	0.213	0.002	0.005	-	0.031	0.880
Globe protrusion	r	0.083	0.360**	0.155	0.176*	1	-0.845**
	p	0.311	0.001	0.059	0.031	-	0.001
Globe position	r	-0.146	0.109	0.222**	-0.012	-0.845**	1
	p	0.075	0.184	0.006	0.880	0.001	-

*IZL-interzygomatic line, r- Pearson's coefficient, p-probability value, *significant correlation*

Table 8: Comparison of ocular globe morphometry in different studies

Authors	Population	Modality	N	IZL (mm)	Axial Width (mm)	Axial Length (mm)	Globe position (mm)	Globe Protrusion (mm)
Aiyekomogbon and Rafindadi [1]	Nigeria (Zaria)	MRI	170	103.18	-	13.31	-	-
Rokka *et al.* [2]	India (Kathmandu)	CT	172	94.3	-	-	12.3	-
Mohapatra *et al.* [3]	India (Odisha)	MRI	200	-	-	R 22.91 L22.73	-	-
Mashige and Oduntan [4]	South Africa	Echoscan	600	-	-	23.05	-	-
Ko *et al.* [5]	Chinese in Hong Kong	CT	256	97.7	-	25.8	9.1	16.7
Bukhatwa and Suliman [6]	Libya	Slit lamp	106	-	-	23.75	-	-
Clarke *et al.* [7]	-	CT	200	-	29.79	-	-	-
Gupta *et al.* [10]	India	CT	100	96.54	-	-	R-7.77 L 7.88	-
Borua *et al.* [11]	North East India	MRI	151	84	R 22.39 L 22.43	-	R 7.19 L 7.2	R 14.23 L 14.21
Kini and Davra [12]	India	CT	100	97.1	-	-	R-6.9 L-7.1	-
Raj and Prajjwal [13]	Nepal	MRI	150	97.74	-	-	R 5.68 L5.78	R 16.95 L 18.86
Lee *et al.* [14]	Korea	CT	214	105	-	-	11.1	-
Aprioku and Ejimadu [15]	Nigeria (Port Harcourt)	U/S	-	-	-	23.2	-	-
Ozgen and Aruyurek [16]	Turkey	CT	-	99	-	-	9.4	-
Current study	Nigeria (Delta)	CT	-	101.6	22.4	21.6	5.5	19.7
		MRI	-	105.2	23.2	22.8	6.0	17.0

R-right,L-left, CT-computed tomography, MRI- magnetic resonance imaging, U/S-ultrasound

Discussion

The axial length averagely measured 2.16 cm on CT and 2.28 cm on MRI scans, contrasting with prior Nigerian studies [1, 15]. Additionally, axial lengths among South Africans and Libyans exceeded our findings [4, 6]. Conversely, the Odisha population in India and Chinese residing in Hong Kong reported higher mean axial lengths (Table 8) [3, 5]. These variations in axial lengths across studies are influenced by myopia prevalence, known to be highest in Asians, intermediate in Caucasians, and lowest in African-Americans [1, 3, 7, 14].

The globe's transverse diameter measured 2.24 cm on CT and 2.32 cm on MRI, differing from findings in 151 Indian patients aged ≤16 years, who reported higher values bilaterally in the study by Boruah *et al*. [11]. The calculated eyeball volumes herein, were 5.68 cm^3 on CT and 6.39 cm^3 on MRI, utilizing the formula in the study by Ibinaiye *et al*. [9], who, using T1-weighted images of 100 Nigerians in Zaria, reported larger volumes of 6.75 cm^3 (right) and 6.74 cm^3 (left). In contrast, the study by Boruah *et al.* [11], employing a segmentation technique on a younger population (<16 years), reported smaller volumes of 4.56 cm^3 (right) and 4.57 cm^3 (left).

On MRI, the IZL measured higher than reported values in Nigeria (Zaria) and Nepal [1, 13]. Conversely, the CT measurement of IZL was lower compared to the mean in Koreans and higher than IZL reported in India, Turkey, and Hong Kong (Table 8) [2, 5, 10, 12, 14, 16]. Discrepancies may result from population differences in skull size and orbital width [17]. Globe position and protrusion differed from previous reports in various populations [2, 5, 10-14, 16]. This is possibly caused by differences in axial lengths and the diverse prevalence of myopia in various ethnic groups [13]. Ethnic disparities in globe position are further influenced by the varying depth of orbital sockets, with Caucasians typically having deeper eye sockets compared to Western populations. Understanding the normal ocular dimensions in Nigeria can help tailor screening programs and prevention strategies for ocular diseases prevalent in the region [5, 10].

Our study found symmetric axial length and transverse globe diameter, aligning with the study by Mohapatra *et al*. [3] and Clarke *et al*. [7]. In contrast, the study by Aiyekomogbon and Rafindadi [1] documented axial length asymmetry, potentially linked to asymmetrical contraction of Extraocular Muscles (EOM) during MRI, a phenomenon less likely with CT due to faster rate of image acquisition. Discrepancies in MRI scanners used across studies may explain variations, with a 0.2T system having longer scan times than 1.5 and 0.5T systems [1]. Our study reports a significantly larger right eyeball volume on MRI compared to the left, aligning with the larger right orbital size documented in a previous Nigerian study in Delta State. This was associated with the differential brain growth, with dominant cerebral hemispheres contributing to the observed asymmetry [17]. Conversely, the study by Ibinaiye *et al*. [9] recorded symmetrical eyeball volume.

Correspondingly, the study by Lee *et al*. [14] and Rokka *et al*. [2] found no asymmetry in globe position, contrasting with the study by Raj and Prajjwal [13]. However, our study identified significant asymmetry in globe protrusion, with greater protrusion on the right side, aligning with the study by Raj and Prajjwal [13]. Understanding such asymmetry in ocular parameters holds clinical significance for radiologists and ophthalmologists in diagnosing, managing, and monitoring ocular diseases.

Both imaging groups revealed significantly larger axial length, transverse diameter, globe position, volume and IZL in males compared to females. This corresponds with sexual dimorphism of the axial length and IZL seen in some populations [1, 5, 13]. Conversely, several studies observed no sex-related differences in axial length, volume, globe protrusion, and globe position [2, 3, 5, 9, 11, 13, 14, 16]. Although among the Chinese, males exhibited significantly higher globe protrusion than females [5]. The larger ocular variables in males are often attributed to their bigger body habitus and larger organs compared to females. Sexual dimorphism in eyeball volume could be from the differences in orbital size influenced by genetic composition and hormonal variations in the two sex groups within the Nigerian population of Delta State. Awareness of the sex differences enables more personalized surgical interventions, follow-up plans and assessments [9, 17].

The ocular measurements lacked significant disparities across 10-year age groups, a finding consistent with the study by Lee *et al*. of no significant variation in globe position. Conversely, the study by Raj and Prajjwal [13] observed significant differences in both globe position and protrusion within 10-year age groups. Age demonstrated a negative relationship with the globe's transverse diameter and axial length on CT, contrary to the study by Aiyekomogbon and Rafindadi [1] and Mohapatra *et al*. [3]. Ibinaiye *et al*. [9] noted a significant relationship between globe volume and age, indicating ongoing growth from childhood until around 40-50 years, with subsequent decline associated with aging [1, 3, 9, 18]. Congruent with some authors, age lacked significant correlation with globe position and protrusion [5, 16]. The study by Raj and Prajjwal [13] observed significant weak positive and weak negative correlations, respectively, in their MRI study. This discrepancy may perhaps be caused by age-related alterations in eyeball volume, with potential variations in vitreous content or replacement by a larger anterior segment. Having age-specific normative data allows more accurate detection and monitoring of ocular disorders such as myopia which is mainly affected by the age-related changes of the eyeball biometry [19].

There was a positive association between the globe's transverse diameter and axial length and between the IZL and globe diameters. Parallel with the study by Rokka *et al*. [2], the IZL lacked significant relationship with the globe position. Globe protrusion and position demonstrated significant positive correlations with axial length and transverse diameter respectively. This suggests that bulb diameters can be indicative of globe protrusion and position. Additionally, the negative relationship observed between the globe protrusion and position suggests that with the forward protrusion of the globe's anterior pole, the distance of its posterior pole from the IZL decreases, indicating an anterior shift in orbital contents.

Our findings deviate from numerous documented literature reports across different populations, attributable to variations in genetic, racial, ethnic, geographical, and environmental factors influencing globe growth and development [1, 3, 9, 11, 13, 20, 21]. Other contributions to the discrepancies include differences in sample sizes, imaging modalities (MRI, CT, or ultrasound), variations in head and eyeball angulation during image acquisition, the choice of landmarks, and the definition of parameters [1, 3, 8]. The study by Wiseman *et al*. [8] noted that MRI resolution may not adequately visualize globe margins, potentially introducing errors during ruler placement on the cornea or scleral border. Prolonged MRI scanning times may contribute to ocular movement, and asymmetric contraction of extraocular muscles can affect globe position, a phenomenon less common in CT due to faster image acquisition [13].

Utilization of modern imaging technology such as MRI and CT to establish the normative ocular values is the greatest strength of this research. The study's limitation included a sample size restricted from a single radiological centre. Being a retrospective study, patients with refractive errors could not be excluded. Moreover, including elderly (> 60 years) population, susceptible to age-related changes, may have influenced the findings.

Recommendations

A multi-centered study using prospective design may be conducted, enabling prior patient evaluation to exclude those with refractive errors and endocrine diseases affecting the globe, e.g. Grave's disease. To improve signal-to-noise ratio and spatial resolution, ultrahigh field strength MRI, such as a 7 Tesla MRI, coupled with a dedicated receiver coil positioned close to the eye can be adopted.

Conclusion

The study establishes the normal globe position and protrusion that will guide the radiologists and ophthalmologists in the study centre. This will enhance accurate diagnosis, effective management and follow-up of different ocular conditions.

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References

1. Aiyekomogbon JO, Rafindadi AL. Ocular axial length measurement among normal adults using magnetic resonance imaging. *Niger J Ophthalmol* 2017;25:6-10.
2. Rokka D, Poudel S, Kayastha P, Suwal S, Poudyal S, Chhetry S, *et al*. Normative measurement of orbital structures in computed tomography. *J Inst Med Nepal* 2020;42(3):42-6.
3. Mohapatra M, Swain B, Sahoo RK, Manoj K. Axial length evaluation of eye ball by magnetic resonance imaging in Odisha population. *Trop J Ophthalmol Otolaryngol* 2019;4(3):233-238.
4. Mashige KP, Oduntan OA. Axial length, anterior chamber depth and lens thickness: Their intercorrelations in black South Africans. *Afr Vis Eye Health* 2017;76(1):a362.
5. Ko TY, Cheng JH, Luk YS, Khoo JL. Normative measurements of orbital structures in the Hong Kong Population. *Hong Kong J Radiol* 2021;24(1):31.
6. Bukhatwa SA, Suliman M. Axial length, anterior chamber depth, and lens thickness in normal Libyan eyes; measured by the Aladdin ocular biometer. *Libyan Int Med Univ J* 2022;7(1):17–21.
7. Clarke J, Seah HM, Foo A, Agzarian M, Lake S. Computed tomography scan measurements of the globe and orbit to assess the risks of traumatic complications from medial peribulbar anaesthesia. *BMC Anesthesiol* 2022;22(1):133.
8. Wiseman SJ, Tatham AJ, Meijboom R, Terrera GM, Hamid C, Doubal FN, *et al*. Measuring axial length of the eye from magnetic resonance brain imaging. *BMC Ophthalmol* 2022;22(1):1-9.
9. Ibinaiye PO, Maduforo CO, Chinda D. Estimation of the eyeball volume on magnetic resonance images in Zaria, Nigeria. *Sub-Saharan Afr J Med* 2014;1(2):82.

10. Gupta V, Prabhakar A, Yadav M, Khandelwal N. Computed tomography imaging-based normative orbital measurement in Indian population. *Indian J Ophthalmol* 2019;67(5):659.
11. Boruah DK, Dutta HK, Sarma K, Hazarika K, Sharma BK, Goswami A. Normative magnetic resonance imaging measurements of orbital structures in pediatric population of North-Eastern India: A retrospective cross-sectional study. *Indian J Ophthalmol* 2021; 69(8):2099.
12. Kini A, Davra SV. Normative Orbital Measurement Based on Computed Tomography Imaging in Tertiary Care Hospital, Bangalore, Karnataka. *Int J Anat Radiol Surg* 2021;10(3):RO34-RO37.
13. Raj JB, Prajjwal U. MRI-Based Normative measurement of the ocular globe position in relation to inter-zygomatic line among Nepalese subjects*. Austin J Radiol* 2021;8(8):1155.
14. Lee JS, Lim DW, Lee SH, Oum BS, Kim HJ, Lee HJ. Normative measurements of Korean orbital structures revealed by computerized tomography. *Acta Ophthalmol Scand* 2001;79(2):197-200.
15. Aprioku IN, Ejimadu CS. Analysis of ocular axial length and anterior chamber depth in Port Harcourt, Nigeria. *W J Ophthalmol Vis Res* 2019;2(2):1-7.
16. Ozgen A, Ariyurek M. Normative measurements of orbital structures using CT. *AJR Am J Roentgenol.* 1998;170(4):1093-6.
17. Ominde BS, Iju W, Igbigbi PS. Retrospective CT study on orbital dimensions and their role in sex determination. *Acta Sci Anat* 2022;1(4):02-12.
18. Wong TY, Foster PJ, Ng TP, Tielsch JM, Johnson GJ, Seah SK. Variations in ocular biometry in an adult Chinese population in Singapore: The Tanjong Pagar survey. *Invest Ophthalmol Vis Sci* 2001;42(9):73-80.
19. Atchison DA, Markwell EL, Kasthurirangan S, Pope JM, Smith G, Swann PG. Age-related changes in optical and biometric characteristics of emmetropic eyes. *J Vision* 2008;8(4):29.
20. Yegburu OS, Ominde BS, Igbigbi PS. A retrospective radiological study on the morphometry of hand digits and phalanges: Role in sex determination. *J Krishna Inst MedSci Univ* 2022;11(2):46-61.
21. Ominde BS, Abadom GE, Imene GM, Ikubor JE, Omoro OF, Igbigbi PS. Optic canal dimensions in a Nigerian cohort: Implications for neurosurgery and radiology. *J Krishna Inst Med Sci Univ* 2024;13(1): 123-132.

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