

# Ocular Axial Length Measurement Among Normal Adults Using Magnetic Resonance Imaging

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## Abstract

**Background/Introduction:** Macrophthalmia and microphthalmia are cardinal signs of many orbito-ocular and systemic diseases which are seen in northern Nigeria. Some cases of refractive error may also be directly related to the ocular axial length (AL). The need for an imaging parameter that will aid their early diagnosis is necessary, as visual compromise is a major consequence if they are not diagnosed and managed appropriately. **Aim and Objectives:** To use magnetic resonance imaging, to determine the normal AL of the eyeball and to establish the association, if any, between AL and inter-zygomatic line (IZL), age and sex. **Materials and Methods:** The study was conducted over a 6-month period (29<sup>th</sup> November 2011 to 28<sup>th</sup> May 2012) at the Department of Radiology, Ahmadu Bello University Teaching Hospital, Zaria. The antero-posterior dimension of the globes (AL) and the length of IZL were measured at the level of the lens for 340 normal ocular globes of 170 patients on T<sub>1</sub>-weighted MR images. **Results:** The normal ranges for ocular measurements were as follows (mean  $\pm$  SD): AL of the right globe, 23.32  $\pm$  1.34 mm (range 22.0–24.7) and AL of the left globe, 23.29  $\pm$  1.22 mm (range 22.10–24.51). The length of the IZL was 103  $\pm$  4.78 mm (range 98.2–107.78). All measurements in male patients were significantly higher than those in female patients ( $P < 0.001$ ). **Conclusion:** The results obtained from this study may help ophthalmologists, radiologists and other clinicians to quantitatively evaluate patients with macrophthalmia, microphthalmia and/or refractive errors.

**Keywords:** Inter-zygomatic line, magnetic resonance imaging, normal adults, ocular axial length

## INTRODUCTION

The axial length (AL) of the eyeball is objectively assessed at the level of the inter-zygomatic line (IZL), which is a line joining the anterior margins of the zygomas.<sup>[1,2]</sup> The eye is an important paired sense organ that permits visualization of objects around our environment. It consists of an eyeball (usually referred to as the globe) located in the orbital sockets of the skull which is connected to the brain by the optic nerve. It also has attached extra-ocular muscles, which help to move it, and adnexal structures, which support it both within the orbit and external to the orbit.

The distance between the anterior and posterior poles of the eye is the AL and report from previous studies suggest that in an adult, the average length is 23.30 mm<sup>[3]</sup> with a range of 23–25 mm.<sup>[4]</sup> There is also a suggestion that there may be racial variation.<sup>[5]</sup> More precisely, AL is the distance from the corneal apex to an interference peak corresponding to the retinal pigment epithelium/Bruch's membrane.<sup>[6,7]</sup> The average AL in a newborn is about 16 mm. While in infancy,

the eye grows to a length of approximately 19.5 mm, in adults, the AL remains practically unchanged.<sup>[4]</sup>

The AL is one of the important indicators of the refractive state of the eye. Eyes with AL <22 mm are classed as hyperopic and those >26 mm as myopic.<sup>[8]</sup> Variations in refractive error in older adults aged 50 years or older are mostly influenced by variations in AL and crystalline lens refractive power, followed by variations in corneal refractive power, and to a minor degree, variations in lens thickness and anterior chamber depth.<sup>[9]</sup> Some refractive errors, and thus indirectly, the AL are associated with some retinal diseases, such as age-related macular degeneration, and glaucoma.<sup>[10]</sup> Detailed knowledge of ocular dimensions and how they change with age are of considerable value in understanding ocular growth and the development of pathologies such

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as myopia. Surgical procedures for improving vision, such as intraocular lens implantation and refilling of lens capsular bags would also benefit from such information.<sup>[11-13]</sup>

Magnetic resonance imaging (MRI) measurement of the AL is also invaluable in the early detection of intrinsic ocular tumours as well as metastasis to the globe.<sup>[14]</sup> In our environment, knowledge of AL data measurements using MRI will provide useful comparatives when faced with refractive and pathological changes to the globe.

## MATERIALS AND METHODS

This study was performed over a 6-month period (29<sup>th</sup> November 2011 to 28<sup>th</sup> May 2012) at the Department of Radiology, Ahmadu Bello University Teaching Hospital, Zaria. The study was conducted with 0.2 T permanent magnet MRI (Siemens) systems with a general-purpose head coil for the acquisition of the images.

The study population involved adult individuals 18–80 years who did not have clinical or radiological evidence of orbito-ocular disease, referred for MRI of the brain and/or paranasal sinuses. The referring clinician examined the participants clinically and ensured that none of them had macrophthalmia or microphthalmia.

Individuals with endocrine diseases which affect the orbit, particularly thyroid ophthalmopathy, those with orbital disorders and individuals with asymmetric scans, or scans with artefacts for any reason (e.g., eye implants, eye motion, etc.), that may cause errors in ocular axial measurements and those with ferromagnetic prosthesis were all excluded from the study.

Having ascertained eligibility of the subjects, the procedure was explained to them, and informed consent was obtained. The weight of each participant was also documented. The examination was done in supine position with head-first and arms beside the trunk. Radiofrequency coil (head coil) was then applied and the field of view centred on the nasion in the midline.

T<sub>1</sub>- and T<sub>2</sub>-weighted spin echo sequences in the axial, coronal and sagittal 3 mm thick sections with 0.3 mm intersection gap were obtained with the MR system by the use of a 21-cm diameter head coil. The scan range in the axial plane spanned from the foramen magnum to the vertex, and the matrix size was 256 × 256. The participants were asked to maintain their gaze at primary position with gentle eye closure during the scans to prevent asymmetrical extra-ocular muscle contraction. Imaging of the orbit was performed sequentially with that of the brain. The axial plane corresponded to the line joining the genu and splenium of the corpus callosum while coronal plane was perpendicular to the same line, and sagittal plane was parallel to the corpus callosum.<sup>[15]</sup> T<sub>1</sub>-weighted axial images at the level of the lens (mid-globe section) were used for all ocular measurements. The IZL was drawn with electronic calliper and used as a reference line. The length of the IZL and the AL of the

globes were obtained with the aid of electronic callipers at this level. This is illustrated in Figure 1.

## Data analysis

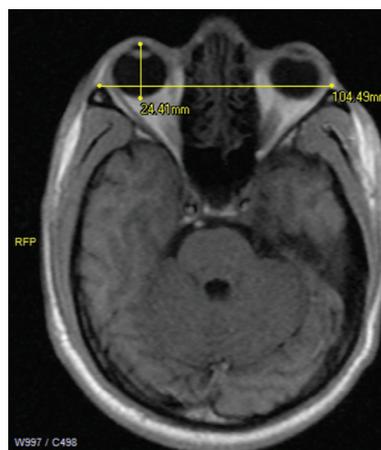
The data were analysed using the Statistical Package for the Social Sciences version 16 software. Analyses tests used in this study were independent samples *t*-test, paired samples *t*-test, analysis of variance and Pearson correlation. All tests of significance were two-tailed and *P* values ≤0.05 was considered statistically significant.

## RESULTS

A total of 340 globes of 170 patients were evaluated. The age range of these participants was 18–80 years, with a mean of 40.4 ± 14.84 years. One hundred and thirteen (66.5%) of the participants were males while 57 (33.5%) were females, giving a male:female ratio of 2:1. Paired samples correlation and paired samples test showed statistically significant differences between data obtained for the right and left globes. The AL of the globes showed statistically significant different measurements for the right and left globes (*P* < 0.001). In view of this, the mean values and normal ranges of the AL were individualized for each globe.

The mean values of the right and left orbital measurements by age group are shown in Table 1. The values obtained among various age groups show marginal differences in the entire parameters but the differences observed were not significant. In addition, the difference observed in the length of the IZL among the various age groups was not significant (*P* = 0.199).

The mean AL of the right globe was 23.32 ± 1.34 mm, while that of the left was 23.29 ± 1.22 mm (*P* < 0.001). There were also significant sex differences in the values of the ocular measurements. Higher values were observed right among male participants [Table 2]. The AL of the right globe was



**Figure 1:** Axial T<sub>1</sub>-Weighted MR image at the level of the lens, demonstrating the axial length of the right globe and length of the interzygomatic line (IZL). (Original image). Axial length of the right ocular globe (vertical line) = 24.41 mm. Length of IZL (transverse line) = 104.49 mm

**Table 1: The means and standard deviations of the right and left globe axial lengths by age groups**

Age group (years)	N	IZL <sub>mm</sub> ± SD	LAD <sub>mm</sub> ± SD	RAD <sub>mm</sub> ± SD
≤19	9	102.12 ± 3.90	23.48 ± 1.42	23.42 ± 1.46
20–29	42	102.60 ± 5.13	23.24 ± 1.28	23.39 ± 1.16
30–39	35	104.63 ± 4.40	23.40 ± 0.85	23.13 ± 1.42
40–49	47	102.10 ± 4.53	23.15 ± 1.45	23.16 ± 1.50
50–59	17	104.62 ± 4.64	23.32 ± 1.17	23.14 ± 1.23
60–69	11	103.37 ± 6.70	23.19 ± 1.11	23.55 ± 0.91
≥70	9	103.99 ± 3.06	23.72 ± 1.00	24.48 ± 1.10
Mean of total	170	103.18 ± 4.78	23.29 ± 1.22	23.32 ± 1.34

SD = standard deviation, RAD = axial length (anterio-posterior dimension) of the right globe, LAD = axial length (anterio-posterior dimension) of the left globe, IZL = length of the inter-zygomatic line.

**Table 2: The means and standard deviations of the globes' axial lengths by gender**

Parameters	Male	Female	Mean difference	P value
	Mean ± SD	Mean ± SD		
	N = 113	N = 57		
Age (years)	42.37 ± 14.77	36.49 ± 14.32	5.88	0.014
IZL (mm)	104.19 ± 4.82	101.17 ± 4.05	3.02	<0.001
RAD (mm)	23.51 ± 1.35	22.93 ± 1.35	0.58	0.008
LAD (mm)	23.54 ± 1.23	22.79 ± 1.04	0.75	<0.001

23.51 ± 1.35 mm in males as against 22.93 ± 1.35 mm ( $P = 0.008$ ) in females. In addition, the mean AL of the left globe in males was 23.54 ± 1.23 mm compared to 22.79 ± 1.04 mm in females ( $P < 0.001$ ).

The correlations of age with ocular measurements are shown in Table 3. There was no correlation between participants' age and the AL of both eyeballs ( $P = 0.335$  for the right globe and  $P = 0.766$  for the left globe). IZL length (facial size) also did not show any correlation with participants' age. A significant and positive correlation was, however, established between the ALs of the globes and IZL as shown in Table 4 ( $P = 0.009$  for right eyeball and  $P = 0.002$  for the left eyeball).

## DISCUSSION

The AL of the globe (AL) is the distance from the corneal apex to an interference peak corresponding to the retinal pigment epithelium/Bruch's membrane.<sup>[6,7]</sup> The mean length of the IZL, which is a reflection of the size of the face, was 103.18 ± 4.78 mm for the entire study subjects. It was, however, found to be significantly higher in males than females ( $P < 0.001$ ). The mean value in males was 104.19 ± 4.82 mm while that of the females was 101.17 ± 4.05 mm. This observation is in consonant with the larger head size found in males and also agrees with the findings of other authors.<sup>[16–19]</sup> Ozgen and Aydingöz<sup>[17]</sup> used 0.5 T MRI systems to determine the normal measurements of

**Table 3: Correlation of age with the right and left globes' axial length**

Parameters	Coefficient of correlations (r)	P value
RAD	0.074	0.335
LAD	0.023	0.766

\*\*Correlation is significant at 0.01 levels (two-tailed). \*Correlation is significant at 0.05 levels (one-tailed).

**Table 4: Correlations of IZL with right and left ocular measurements**

Parameters	Coefficient of correlation (r)	P value
RAD	0.20**	0.009
LAD	0.236**	0.002

\*\*Correlation is significant at 0.01 levels (two-tailed). \*Correlation is significant at 0.05 levels (one-tailed).

ocular structures in Turkey. They also found that the IZL length was significantly larger among male participants. Again, Ozgen and Ariyurek<sup>[18]</sup> and Jong *et al.*<sup>[19]</sup> used computerized tomography (CT) for normative measurements of ocular structures in Turkey and Korea, respectively. The length of IZL was also found to be higher among male participants in both studies.

Among adult populations in Zaria Nigeria, the mean ocular AL was found to be 23.31 ± 1.28 mm. This is larger than the value obtained in a study by Nangia *et al.*<sup>[20]</sup> in rural Central India where the mean AL was 22.6 ± 0.91 mm. They used ultrasonic biometry method, and the age range of their population was 49.4 ± 13.4 years. A South Indian population study using ultrasonic biometry by George *et al.*<sup>[21]</sup> also showed lower value than the mean value obtained in our study. The mean AL from that study was 22.28 ± 0.8 mm. On the other hand, the South China study by He *et al.*<sup>[22]</sup>, rural Mongolian study by Wickremasinghe *et al.*<sup>[23]</sup> and Tanjong-Pagar, a Singaporean study, by Wong *et al.*<sup>[24]</sup> obtained the AL values similar to the mean values obtained in our study. The values obtained in these studies were 23.11, 23.1 and 23.2 mm, respectively. The Los Angeles Latino Study by Shufelt *et al.*<sup>[25]</sup> also obtained a mean value of 23.4 mm, which is similar to ours. These four studies used ultrasonic biometry method.

Higher values of the AL of the globe were noted in the studies of other authors. In the Beaver Dam Eye Study<sup>[26]</sup> which used Partial Coherence Laser Interferometry, a mean value of 23.69 mm was obtained while that of Epic-Norfolk,<sup>[27]</sup> an England Study, was 23.80 mm. The differences that existed between the findings regarding the AL of the globe in the present study among Nigerians and findings among Indians, Chinese and Britons as stated above might be due to racial variation and environmental influence.<sup>[18]</sup> Benjamin and Borish<sup>[28]</sup> published an epidemiological study concerning ethnic differences, which suggested a general pattern of higher prevalence of myopia in Asians, intermediate in Caucasians and lowest in African-Americans. There is,

however, a paucity of data regarding this in Africa, thus making the comparison difficult.

The index study revealed a significant difference in the AL of the right and left globes ( $P < 0.001$ ). This observation is not consistent with the outcome of similar studies in other parts of the world.<sup>[17-19]</sup> Ozgen and Aydingöz<sup>[17]</sup> did not find any statistically significant difference between data for the right and left globes. There was also no significant difference in parameters for the right and left globes in the studies of Jong *et al.*<sup>[19]</sup> and Detorakis *et al.*<sup>[29]</sup> The discordance observed in the outcome of our study and earlier research works enumerated above may be due to differences in technique and possibility of asymmetrical extra-ocular muscles contraction that could occur during the scan as the 0.2 T MRI system used in the index study normally results in prolonged scan time as against 0.5 and 1.5 T MRI systems used by earlier authors.<sup>[17,29]</sup> In addition, some of the authors<sup>[18,19]</sup> used CT for their studies. Image acquisition is faster with CT and asymmetrical extra-ocular muscles contraction may not occur with this modality. Ultrasound was also used by some authors and their outcome shows statistically insignificant difference between the mean values of the AL of the globes.<sup>[30]</sup>

The AL of the globes shows sexual dimorphism with males having higher values than females. The AL of the right globe in males was  $23.51 \pm 1.35$  mm while that of the females was  $22.93 \pm 1.35$  mm ( $P = 0.008$ ), and the mean AL of the left globe among males was  $23.54 \pm 1.23$  mm compared to  $22.79 \pm 1.04$  mm for females ( $P < 0.001$ ). This agrees with Tanjong-Pagar and Angeles Latino Eye studies,<sup>[24,25]</sup> where it was reported that women had shorter globes compared to men. In the index study, there was no positive correlation between participants' age and the ocular AL. This differs from the observations of some authors.<sup>[20,23,24,26,31]</sup> The studies conducted by Lee *et al.*<sup>[26]</sup> (Beaver Dam Eye Study) and Wong *et al.*<sup>[24]</sup> (Tanjong-Pagar study) showed that the AL decreased with increasing age while a central Indian Eye and Medical Study by Nangia *et al.*<sup>[20]</sup> showed that the AL increased with increasing age. Similar observation was also noted by Guo *et al.*<sup>[31]</sup> and Wickremasinghe *et al.*<sup>[23]</sup> The contrast observed between our findings and that of these authors may be due to racial variations, environmental influences and/or technique employed in the studies.

The facial size, which is represented by the length of the IZL, showed statistically significant correlation with the AL of the globe. This finding is similar to that of Ozgen and Ariyurek.<sup>[18]</sup> They correlated length of the IZL with some of the measurements of ocular structures and found that majority of the variables showed statistically significant relationship with the IZL.

### Limitations of the study

The use of 0.2 T permanent magnet MRI systems was a major limitation of this study. Image acquisition was slow and possibility of asymmetrical extra-ocular muscles contraction

cannot be ruled out. A higher strength magnetic field MRI system with faster image acquisition time is advised for further studies.

### CONCLUSION

The AL of the globes has sexual dimorphism with males having higher values. In addition, the mean AL obtained in this study differs from the values obtained in China, India and Britain. This further affirms previous research findings that showed that racial variation and environmental influences affect the AL of the globe. The results obtained from this study may help ophthalmologists, radiologists and other clinicians to quantitatively evaluate patients with macrophthalmia, microphthalmia and/or refractive errors.

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### Conflicts of interest

There are no conflicts of interest.

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