

Assessment of ocular axial length as a factor in refractive errors (myopia and hyperopia)

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Abstract

Background: Refractive errors account for a large proportion of patients presenting with visual impairment. In the developed nations, ocular axial length has been found to be the strongest determinant of refractive errors, however, there is paucity of knowledge on this issue in the West African sub-region. This study was undertaken at the University of Benin Teaching Hospital to determine the relationship between axial length and the form of refractive errors seen.

Study Design: A prospective study of the ultrasonic measurement of the axial length of the eye in 100 myopic and 100 hyperopic adult patients was carried out over a 6-month period. All the patients had refraction and were confirmed to have either of refractive errors by the ophthalmologist.

Result: Ocular axial lengths were consistently higher in the myopic patients than in the control group ($P < 0.001$) while axial lengths were consistently lower in the hyperopic patients in comparison to the control group ($P < 0.001$). There was no significant difference between the axial length of the right and left eye in any one individual whether myopic or hyperopic. Myopia was found to be common in the younger age group in contrast with hyperopia, which was mainly seen in the middle aged and elderly. In addition, individuals with higher body mass indices were found to have shorter axial lengths than those with lower body mass indices, therefore the heavier patients were mainly hyperopic while the lighter ones were myopic.

Conclusion: This study showed a strong association between myopia and longer axial length and this is synonymous with large eyeballs. On the contrary, a shorter axial length was found in the hyperopic group indicating a smaller eyeball size.

Keywords: Axial length, refractive errors, myopia, hyperopia.

Introduction

Refractive error is one of the commonest causes of visual impairment and it cuts across all age groups and races.¹⁻

³The pathophysiology and pathogenesis of ocular refractive errors are still a matter of controversy; however, the following have been implicated.⁴⁻¹³

i. Heredity

ii. Reading at an early age/amount of near work

iii. The size of the eyeball, which has a direct relationship to the axial length of the eye, among other factors.

The axial length of the eye, however, is a more constant factor^{14,15,16}. Factors which influence the eyeball size of an individual include height, weight or body mass index (BMI) and heredity^{10,16}.

Some researchers feel that reading at an early age may contribute to increasing nearsightedness; some even find a link between increasing nearsightedness and

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intelligence^{12,17}. However, this does not suggest that farsighted individuals are less intelligent¹⁷.

In myopic images from distant objects are formed in front of the retina due to excessive focusing power of the lens and the large eyeballs with longer axial length. Myopia typically begins in late child hood (age 8 or 9) and usually stabilizes by the mid twenties^{13,18}.

In hyperopia, near objects are focused behind the retina due to poor focusing power of the lens and the smaller eyeball. Hyperopia frequently does not cause symptoms until the fourth or fifth decade and then progressively gets worse as the lens of the eye becomes stiffer and unable to focus^{13,18}.

The aim of this study is to determine any variation in axial length as a factor in these two forms of refractive errors.

Materials and Methods

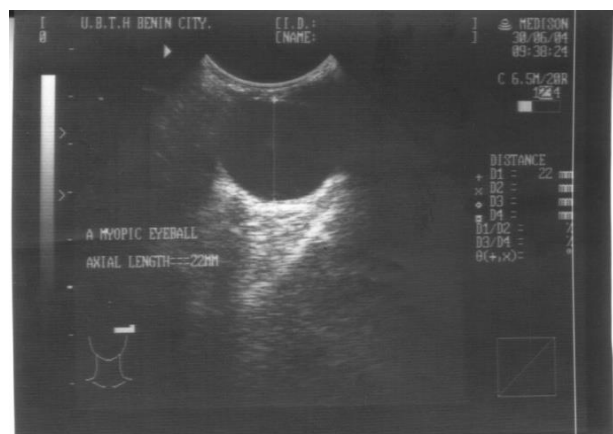
The study was composed of assessment of ocular axial lengths of two hundred (200) adult Nigerians; 100 cases of myopia and 100 cases of hyperopia. This included consecutive prospective cases of these groups of patients seen at the University of Benin Teaching Hospital from June 2008 to November 2008. All the patients are those attending the ophthalmology clinic and confirmed to have refractive errors. Vital data obtained from the request cards and case notes of the patients included the age, sex, presenting complaint, duration of symptom and power of corrective lenses used in Diopters.

All ultrasonic assessment was carried out in this centre and referrals were mainly from the optometry section of the Ophthalmology clinic. Informed consent was obtained from the patient before commencement of the procedure and before the use of their optometry records. Questionnaires were filled out by or for each patient. Written approval was also obtained from the ethics committee.

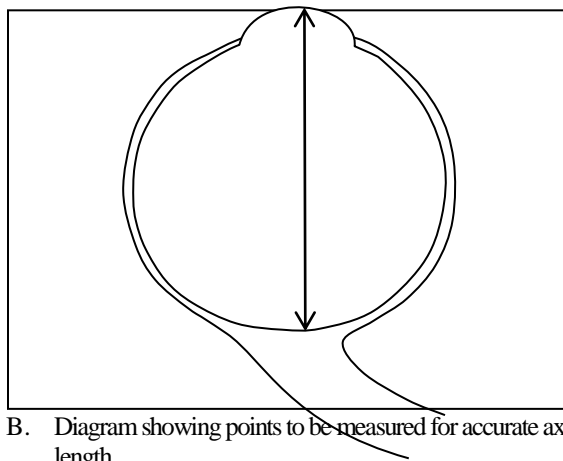
Ultrasonic technique and image analysis

The ocular scan was done in supine position with the head properly immobilized and the eyelids closed naturally (not tightly). The patient was instructed to keep a fixed gaze on the ceiling with the eyelids shut. A B – mode ultrasound scanner (Sonoace 1,500 Medison) with high frequency curvilinear probe of 6.5 MHz was used. The scan was done through the closed eyelid after

applying a coupling gel. Measurements were taken with the electronic cursor demonstrating the optical axis on the frozen image (Fig. 1). Care was taken not to apply pressure on the globe while scanning to avoid subjective shortening of the axial length as well as patient discomfort.



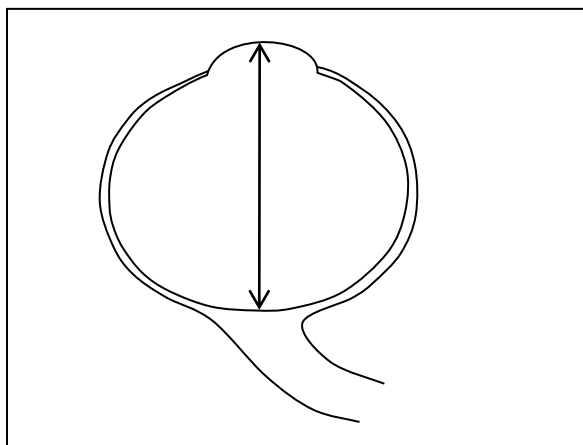
A. Ultrasound picture of a myopic eye



B. Diagram showing points to be measured for accurate axial length



C. Ultrasound picture of a hyperopic eye



D. Diagram showing points to be measured for accurate axial length

Results

One hundred myopic patients (60 females, 40males) aged 18- 49 years (mean 29.42 years) and 100 hyperopic patients (60 females, 40 males) aged 20-69 years (mean 50.30years) were studied. The anthropometrical measurements in the myopic and hyperopic patients are shown in table 1. In the group with myopia, the mean height, weight and body mass index was 161.30cm, 64.08kg, 24.70 respectively while the group with hyperopia had mean height, weight and body mass index of 161.73cm, 72.98kg, 27.98 respectively.

The myopic male patients had a lower mean height (160.30cm) than the females (161.80cm), however, the mean height and body mass index in males was higher (64.90kg, 25.27) than the females (63.68kg, 24.41).

Also in the study of group with hyperopia the mean height for the males was lower (161.58cm) than the females (161.80cm). Similar the mean weight and body mass index for the males was higher (73.40kg, 28.17) than the females (72.78kg, 27.88) (Table 1).

Axial length of the eyeball in myopes

The mean axial length of the right and left eye for males is 2.305cm ±0.143cm and 2.300cm ±0.121 with a median of 2.300cm for both eyes. The mean axial length of the right and left eye for the females is 2.313cm and 2.323cm with a median of 2.300cm for both eyes (Table 2).

A comparison of the mean axial length of the right and left eye for males and females was statistically insignificant at a P value of 0.838 and 0.519 respectively.

The mean power of the lens for right and left eye in males is -2.250 dioptres and -2.313 dioptres with a median of -2.25 dioptres and -2.50 diopters respectively. The mean power of lens for the right and left eye in females is -2.366 dioptres and -2.344 dioptres with a median of -2.500 dioptres for both eyes (Table 2). A comparison of the mean power of lens in the right and left eye of both males and females was statistically insignificant at a P value of 0.632 and 0.867 respectively.

Axial length of eyeball in Hyperopes

The mean axial length of the right and left eye for males is 1.940cm and 1.930cm with a median of 1.950cm and 1.900cm respectively. The mean axial length of the right and left eye for females is 1.920cm and 1.923cm with a median of 1.900cm for both eyes (Table 2).

A comparison of the mean axial length of the right and left eye for males and females was statistically insignificant at a P value of 0.390 and 0.719 respectively.

The mean power of lens for the right and left eye of males is 2.800 dioptres and 2.788 dioptres with a mean of 2.000 dioptres and 2.625 dioptres respectively. The mean power of lens for the right and left eye of females is 2.656 dioptres and 2.675 dioptres with a median of 2.500 dioptres for both eyes (Table 2).

A comparison of the mean power of lens for the right and left eye of both males and females was statistically insignificant with a P value of 0.642 and 0.692 respectively.

Table 1: Anthropometric measurements in myopia and hyperopia

| | Males | Myopia | Hyperopia |
|-----------------------|-------|----------------------|----------------------|
| Age (years) | | 27.90 ± 6.63 | 48.55 ± 9.52 |
| Height (cm) | | 160.30 ± 5.79 | 161.58 ± 3.58 |
| Weight (kg) | | 64.90 ± 6.41 | 73.49 ± 13.17 |
| Body mass index (BMI) | | 25.27 ± 2.23 | 28.17 ± 5.22 |
| Females | | | |
| Age (years) | | 30.18 ± 8.57 | 51.18 ± 6.99 |
| Height (cm) | | 161.80 ± 5.61 | 161.80 ± 4.24 |
| Weight (kg) | | 63.68 ± 6.11 | 72.78 ± 13.57 |
| Body mass index (BMI) | | 24.41 ± 2.89 | 27.88 ± 5.38 |

Table 2: Axial length measurement in centimeters with power of lens in dioptres

| | Myopia | | Hyperopia | | P-value |
|----------------|----------------|-------------|---------------|-------------|---------|
| | Mean (cm) | Median (cm) | Mean (cm) | Median (cm) | |
| Males | | | | | |
| Right eye | 2.305 ± 0.143 | 2.30 | 1.940 ± 0.094 | 1.950 | <0.001 |
| Power of lens | -2.250 ± 0.585 | -2.250 | 2.800 ± 1.317 | 2.00 | |
| Left eye | 2.300 ± 0.121 | 2.300 | 1.930 ± 0.080 | 1.900 | |
| Power of lens | -2.313 ± 0.595 | -2.500 | 2.788 ± 0.168 | 2.625 | <0.001 |
| Females | | | | | |
| Right eye | 2.313 ± 0.128 | 2.300 | 1.920 ± 0.079 | 1.900 | <0.001 |
| Power of lens | -2.366 ± 0.684 | -2.500 | 2.656 ± 0.017 | 2.500 | |
| Left eye | 2.32 ± 0.129 | 2.300 | 1.923 ± 0.079 | 1.900 | |
| Power of lens | -2.344 ± 0.713 | -2.500 | 2.675 ± 0.959 | 2.500 | |

Discussion

The mean age of patients with myopia in this current study is 29.42 years. This is lower than the mean age of 35 years found in a similar study of Alaskan Eskimos by Van Rens *et al*¹. This lower mean age may be a true reflection of the pattern of myopia in our local population or a reflection of the pattern of hospital visit but there are no previous works to support this. However, it has generally been reported that myopia is commoner in the younger age group especially below the age of 40 years^{1-5, 7,8,10,11,14-16}.

The sex prevalence in myopia was 66.7% for females and 33.3% for males. A similar study of Alaskan Eskimos also showed a higher frequency offemales (48.3%) than males (41.3%)¹. The higher preponderance of females in this current study may be attributable to the fact that females visit hospitals more than males or it may just be a true reflection of the prevalence of myopia in our population.

The mean age of patients with hyperopia was 50.30 years, though this is lower than the mean age of 65 years

in the study as reported by Van Rens *et al*¹. The same study, however, reported that there was very little hyperopia seen in Eskimos before the age of 50 years, after which there was a rapid increase till about the age of 80 years. This current study did not show this pattern of increase. The following reasons may be responsible; with increasing age especially after 60 years, patients with refractive errors may develop other systemic diseases which are primarily unrelated to refraction but which result in deterioration of vision. These illnesses include diabetes, hypertension and cataract and therefore such patients were excluded from our study. Secondly the life expectancy in Nigeria is lower than what obtains in developed countries such as North America under which Alaska falls. Nevertheless, hyperopia is commoner in the older age group than myopia and this is the pattern in this current study.

More females (62.5%) were found to have hyperopia than their male counterparts (37.5%). A different observation was made in the study of Alaskan Eskimos with hyperopia by Van Rens *et al*¹ in which more males (94%) were found than females (11.4%). The researchers did not provide the reason for the sex variation. The same factors responsible for female preponderance in myopia may also be at play in hyperopia. Though these claims cannot be substantiated for now, future research will prove this right or wrong. In this current study, females outnumbered the males in the myopic and hyperopic sub groups.

A comparative evaluation of the mean age incidence of myopia and hyperopia shows that while myopia was more prevalent before the age of 40 years, hyperopia was commoner above this age, a finding that is supported by other works^{1,8,10}. Why this is so has been attributed to a lot of factors including axial length of the eyeball, heredity, the effect of reading at an early age and amount of near work as well as anthropometric measurements of the individuals^{2,7,8,10,11,14-17}. Axial length has however been reported to be the strongest determinant of refractive errors^{7,8,10-12,14,15}.

In this present study, myopics had a significantly longer mean axial length (2.310cm) than hyperopics (1.926cm) $P < 0.001$. Though this is the pattern of variation in axial length measurements by other studies^{1-8,14-18}, the exact values obtained by some of them were significantly higher than those obtained in our study. Koraszewska - Matuszewska *et al*⁴ obtained a mean axial length of

2.605cm in myopia and a mean axial length of 2.000cm in hyperopia. This variation may be due to racial differences in eyeball sizes, the method of axial length measurement (contact or non-contact A mode ultrasonography) or a combination of both factors. This invariably means that eyes with longer axial lengths are commoner in younger individuals while eyes with shorter axial lengths are commoner in older individuals as confirmed by the aforementioned studies^{1-8,14-18}.

It may be correct then to infer from this study and previous works that younger individuals have larger eyeballs than the older ones. The reason for this could be explained by the generalized reduction in organ sizes, as people grow older. This is further supported by a study of ocular dimensions with aging in normal eyes done by Lim *et al*¹⁹ using contact ultrasonography. They found a gradual decrease in ocular dimensions (axial length and anterior chamber depth) with increasing age in both sexes but this change was more prominent in females than males. The potential influence of systemic endocrine or metabolic factors may also be responsible for these changes.

In all groups of patients studied (myopes and hyperopes), the difference in axial lengths in the right and left eyes were statistically insignificant.

In myopes, the mean axial lengths for the right and left eyes were 2.310cm and 2.315cm respectively ($P = 0.626$) while in hyperopes, the mean axial lengths were 1.926cm and 1.925cm respectively ($P = 0.854$). These findings are not surprising as most paired organs within the human body are not symmetrical in size, for example, the kidneys, thyroid, ovaries amongst others.

Axial length measurements in both sexes were compared in the myopes and hyperopes. In each group of patients, the difference in axial lengths was statistically insignificant for both sexes. In myopes, the mean axial length was 2.305cm in males and 2.313cm in females ($P = 0.838$) while in hyperopia; the mean axial length was 1.940cm in males and 1.920cm in females ($P = 0.390$). These findings are at variance with the study by Osuobeni *et al*⁶ and Koraszewska – Matuszewska *et al*⁴ who found that males had longer axial lengths than females. The reason for these differences in both sexes is not known, however, hormonal and racial factors may have a part to play. This present study also showed that the mean axial length differed little between age groups

in myopes and hyperopes, a finding also reported by Wickremasinghe *et al*⁷.

Refractive errors are corrected with lenses and this study showed that the longer the axial length in myopics, the lower in the negative value the power of lens worn by these patients, thus giving a negative correlation ($r = 0.789$). On the other hand, the shorter the axial length in hyperopes, the higher the power of lens worn by these patients also giving a negative correlation ($r = 0.812$). These findings were also reported by Lo *et al*⁸. The myopics use concave lenses (Negative Dioptre) while the hyperopics use convex lenses (Positive Dioptre). These lenses help to focus incoming light rays from objects onto the retina to form an image which otherwise would have been focused in front of the retina in myopics and behind the retina in hyperopic patients.

Saw *et al*¹⁶ carried out a study to examine the association between the anthropometric measurements of height, weight and body mass index (BMI) and refraction with ocular parameters in Singapore school children. They discovered that those individuals who were taller had eyeballs with longer axial lengths while those who were heavier (having larger weights and body mass index) had smaller/shorter eyeballs. They therefore concluded that controlling for age, gender, parental myopia, reading, school and weight showed that taller individuals had eye with longer axial lengths and refractions that tended towards myopia. Those who had higher weights and body mass index had shorter eyeballs with a refraction that tended towards hyperopia. Coincidentally, this study has displayed a similar pattern.

Overall, the patient with hyperopia had a significantly higher mean body mass index (BMI) of 28.17 for males and 27.88 for females than patients with myopia whose mean body mass index was 25.27 for males and 24.41 for females ($P < 0.001$). The differences in mean body mass index in males and females in the same group is however statistically insignificant ($P = 0.834$) and this further explains why the difference in axial length in both sexes in the same group was statistically insignificant.

The role of the radiologist in the management of refractive errors has been limited to identifying the complications of these visual disorders, a major and common complication being retinal detachment in high myopia. Routine ocular ultrasound scan is rarely

requested in patients who have been diagnosed by the ophthalmologist to have only refractive errors as the cause of visual impairment. Instead they are immediately referred to the optometrist to have refraction for which refractive lenses are quickly prescribed. Even though there is no permanent cure for refractive errors, a screening program can be designed for those at risk to have routine ocular biometry early. Leung *et al*³ conducted a 2-year study on high risk primary and secondary school children in a Chinese society with myopia and discovered that the early use of progressive lenses reduced the progression of myopia. These children had in the past been subjected to perform large amounts of reading and homework and thus spend long periods performing near work during their growth years. Therefore, if such children were followed up with routine ocular scans for the purpose of biometry before the onset of myopia, it may have been possible to pick up early and subtle changes in ocular sizes that may suggest the beginning of a refractive error.

Axial length measurements obtained by using the newer non-contact methods (IOL master, partial coherent interferometry and laser interferometry) and results obtained from this present study showed the same pattern of variation in eyeball sizes in patients with refractive errors. Myopics were found to have significantly larger eyeball sizes than hyperopics. Though the values obtained using this newer non-contact methods were higher than what was obtained here in our local population, the difference cannot necessarily be said to be due to the different techniques used as the populations studied are of different races. The population that was studied by the newer non-contact methods are Caucasians and no Nigerian studies have been done using either the newer non-contact methods or the contact A or B –mode ultrasonographic method.

In view of the above findings, it is therefore safe to conclude that the “through the eyelid” techniques of ocular biometry are reliable and justifiable.

Conclusion

From this study, myopics have been found to have longer axial lengths than hyperopics. Myopics were also found to be younger than hyperopic individuals. Those individuals with higher body mass indices were found to have shorter axial lengths than those with lower body mass indices, therefore the heavier patients were mainly

hyperopic while the lighter ones were myopics. These findings were found to be similar to those of previous works done in other parts of the world.

Recommendations

- (1) Ocular ultrasonography for axial length assessment should be part of the routine work up for patients with refractive errors or patients who are at risk of developing refractive errors.
- (2) All patients who are incidentally found to have abnormal axial length measurements should be referred to the ophthalmologist for refraction.

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