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Variations in Ocular Biometrics Related to Refractive Errors Among Adult Patients Attending the University Teaching Hospitals-Eye Hospital in Lusaka, Zambia

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ABSTRACT

Coordination among anatomical components (Ocular biometrics) of the eye [corneal and lens power (CP/LP), anterior chamber depth (ACD), lens thickness (LT), and axial length (AL)] determine the refractive state of the eye. Ocular biometric measurements are crucial for the selection of the correct IOL and prescription of power to achieve the desired refractive outcome after cataract surgery and refractive errors respectively. This was a cross-sectional study conducted at University Teaching Hospitals Eye Hospital in Lusaka– Zambia; from April to June 2021, to assess the relationship between ocular biometrics and refractive errors. The study involved the measurement of refractive errors and ocular biometrics (Axial length, Lens power, Lens thickness, anterior chamber depth, corneal dioptric power, corneal radius, and Pupil size) in 205 study participants aged between 16 and 60 years of which 64 (31.2%) were males and 141 (68.8%) were females. Refractive errors were measured with a KR-9600 autokeratorefractometer whilst Ocular biometric parameters were done using an Optilex 780 marvels 11 A/B Scan Dell ultrasonography machine and autokeratometry. Out of 205 recruited study participants, 135 (65.9%) had refractive errors. The proportion of types of refractive errors were 66 (48.9%), 39 (28.9%), 19 (14.1%), and 11 (8.1%) for myopia, presbyopia, astigmatism, and hyperopia respectively. Variations of ocular biometrics among participants showed that mean values of anterior chamber depth, axial length and pupil size were greater in myopic study participants (2.7 mm, 23. 9 mm, and 4.39 mm respectively). Mean Lens thickness was much thicker in Presbyopia (3.95+/-0.65) while Lens power varied across all types of REs. Ocular biometrics related to refractive errors were axial length, anterior chamber depth, and lens thickness. Axial length and anterior chamber depth associated strongly with Myopia while lens thickness was more linked to Presbyopia. Age (16 and 47) years, inheritance, and childhood-onset associated strongly with Myopia while Presbyopia increased with increase in age.

Key words: *Variations, Refractive Errors, Ocular biometrics, and SER*
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INTRODUCTION

Variant anatomy, which is an integral part of anatomical science, is related to abnormalities in the human body structure. These abnormalities generally do not interfere with the function of the human body and do not typically manifest as pathological-nosological units (Kachlik *et al.*, 2020). However, under certain conditions, these abnormalities can worsen existing pathological states or even evoke new ones. Refractive errors linked to ocular biometric variants have also potential to increase the risk of ocular diseases, such as retinal detachment in myopic eyes and acute glaucoma in hyperopic eyes (Mallen *et al.*, 2005).

Refractive Errors are problems with focusing light accurately on the retina due to the shape of the eye, the shape of the cornea, and aging of the lens, with significant genetic and environmental involvement (Goldschmidt and Jacobsen, 2014). They are the most common type of eye disorder, and the leading cause of visual impairment as well as one of the major causes of loss of vision worldwide (Hashemi *et al.*, 2018). This has a direct negative economic and psychosocial effect on different societies (Hashemi *et al.*, 2018). Coordination among refractive components of the eye [corneal and lens power (LP), anterior chamber depth (ACD), lens thickness (LT), and axial length (AL)] determine the refractive state of the eye. Different studies have often indicated AL as a major determinant of the refractive state with each study yielding at least different results in one or more other ocular parameters (Momeni-Moghaddam *et al.*, 2019); Gaurisankar *et al.*, 2019). This reason adds to the fact that, though there are many studies conducted on Europe and Caucasian populations (Hashemi *et al.*, 2013; Kuo et al, 2011; Ferreira *et al.*, 2017) , there has been little done regionally and no study done particularly in Zambia as far as the literature was searched. This study was aimed at assessing the association between refractive errors and ocular biometric variations in adults who presented at the UTH`s-EH in Lusaka- Zambia.

A study conducted in Taiwan to understand the ocular biometric and corneal anatomical variation in high-anisometropic patients showed deeper ACD, longer AL and corneal thickness was thicker in Myopic eyes (Kuo, et al 2011). This finding was different from other studies which found CCT to be insignificant and could be attributed to the difference in methodologies (Chen *et al.*, 2009). In a population-based study conducted in Jordan (Mallen et al., 2005b), results showed that AL correlated most with SER, longer in males as compared to females. Similar findings were found in a Mongolian study (Wickremasinghe *et al.*, 2004; Mallen et al., 2005b). A study conducted in Ethiopia among adults revealed that age, gender, and height were associated with biometric indices (Gessesse *et al.,* 2020). Additionally, a study in Nigeria reported that pupil size was dependent on refractive errors but independent of gender (AB Osaiyuwu, 2014). The discrepancies in results could be attributed to the fact that ocular biometric parameters can be influenced by many factors including race; environment and genetics (Gessesse, Debela and Anbesse, 2020). This is the main reason the researcher developed a curiosity to explore the relationship between ocular parameters and refractive errors.

MATERIAL AND METHODS

This was a cross-sectional study covering the period April to June of 2021. Systematic random sampling was used to recruit patients as follows; (i) patients who attended UTH's-EH aged 16 to 60 years consented to be study participants, (ii) those clinically diagnosed with REs or presenting with ocular disease or controlled systemic pathology. Patients with active ocular manifestations such as increased IOP and mature cataract or trauma and systemic pathology and those who had undergone intraocular surgery were excluded from the study.

Following patient recruitment according to inclusion criteria, refraction was done, at the same time obtaining k readings (including corneal dioptric power and corneal radius), and pupil size using an autokeratorefractometer. Secondly, k-readings were entered in an optilex machine and all the other biometric parameters (such

as lens thickness, axial length, anterior chamber depth and lens power) were computed automatically. Ethical review and approval were granted by University of Zambia Biomedical Research Ethics Committee and National Health Research Authority. All study participants consented prior to recruitment.

Statistical analysis was performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). For all the statistical analyses, the p-value <0.05 was considered statistically significant.

RESULTS

A total of 205 study participants were recruited in the study, with 64 (31.2%) males and 141 (68.8%) females. All participants were of black ethnic origin, and most of them had attained tertiary education and were in white-collar jobs (48.3%). Most patients (23.4%) were from high density areas. The sociodemographic characteristics of the study participants are presented in Table 1.

The proportions of different types of refractive errors were 66 (48.9%), 39 (28.9%), 19 (14.1%) and 11 (8.1%) for myopia, presbyopia, astigmatism, and hyperopia respectively.

Table 3 shows that ACD, AL, LP, LT, and PS were statistically significantly ($p < 0.05$) related to REs. Table 4 shows that ACD, AL, CDP was high in myopia compared to other, while LP varied greatly across all types of refractive errors. The mean values of ACD and AL were both longer in myopic study participants (2.7 mm and 23.9 mm respectively), with Lens thickness being much thicker in Presbyopia (3.95+/-0.65). Pupil size showed the highest mean SD of 4.39 mm in Myopia.

Linear regression analysis showed a strongly significant positive association between ACD, and Myopia as given in table 5 below [AOR 4.57, 95% CI (1.36, 15.40); p<0.014], AL with Myopia (AOR=1.74, p<0.002) and LT and Presbyopia (AOR=17.95, p<0.0001), when controlled for gender and Age. On the other hand, there was a negative significant association between CR and presbyopia (AOR=0.26, p<0.039), LP and myopia (AOR=0.76, p<0.0001), and PS and presbyopia (AOR=0.43, p<0.033).

The results reviewed a positive significant association between Astigmatism and Hyperopia in the age category. Myopia was significantly associated with age category 16-47 years. The results indicated that the odds of developing astigmatism, myopia, and hyperopia decreased with an increase in age, unlike presbyopia whose odds increased with an increase in age. Childhood-onset of ocular problems and inheritance were positively and significantly associated with Myopia.

Table 1: Descriptive characteristics of 205 study participants

Variables	**Refractive Error types**					**Total**	***p* value**
	None (n=70)	Astigmatism (n=19)	Hyperopia (n=11)	Myopia (n=66)	Presbyopia (n=39)		
Age (years)							<0.0001*
16 – 27	32	6	6	26	1	71	
28 – 37	26	6	3	19	4	58	
38 – 47	12	5	0	16	10	43	
48 – 60	0	2	2	5	24	33	
Residence							0.347
High density	15	4	5	17	7	48	
Medium density	46	15	5	37	26	129	
Low density	9	0	1	12	6	28	
Education							0.335
None	1	0	0	0	0	1	
Primary	0	1	2	3	4	10	
Secondary	25	5	4	19	13	66	
Tertiary	44	13	5	44	22	128	
Occupation							0.117
White collar job	27	11	3	34	24	99	
Business	9	1	1	4	6	21	
General worker	4	0	2	6	3	15	
Student	19	3	2	13	0	37	
Others	11	4	3	9	6	33	
Religion							0.720
Christian	66	19	10	64	37	196	
Islam	4	0	1	2	2	9	

Table 2: Medical and Clinical History of study participants

Variables	**Refractive Errors**					**Total**	*p value*
	None	Astigmatism	Hyperopia	Myopia	Presbyopia		
Onset of problem							0.466
On examination	3	0	0	1	1	5	
Childhood	10	3	2	20	10	45	
Adulthood	57	16	9	45	28	155	

Familial problem							0.038*
No	37	6	3	21	21	88	
Yes	33	13	8	45	18	117	
HIV status							0.067
Unknown	12	4	0	2	2	20	
Negative	54	14	10	60	32	170	
Positive	4	1	1	4	5	15	
Clinical features							0.052
None	68	17	11	55	29	180	
Hypertension	2	2	0	7	9	20	
Diabetes mellitus	0	0	0	2	0	2	
Glaucoma	0	0	0	2	0	2	
Others	0	0	0	0	1	1	

*Statistically significant at Pearson Chi-square *p* value of 0.05 (5%).

Table 3: Anatomical relationship of ocular biometrics by types of refractive errors

Variables	**Refractive Error types**					**Total**	*p value*
	None (n=70)	Astigmatism (n=19)	Hyperopia (n=11)	Myopia (n=66)	Presbyopia (n=39)		
ACD							0.023*
Normal	47	12	9	52	19	139	
Shallow	23	7	2	14	20	66	
AL							<0.0001*
Normal	60	15	7	48	33	163	
Short	8	4	4	4	5	25	
Long	2	0	0	14	1	17	
CR							0.286
Normal	65	17	10	59	37	188	
Short	0	0	0	4	2	6	
Steep	5	2	1	3	0	11	
CDP							0.717
Normal	55	14	7	46	28	150	
Low	3	1	1	2	0	7	
High	12	4	3	18	11	48	
LP							0.001*
Normal	20	6	2	28	12	68	
Low	0	0	0	10	1	11	
High	50	13	9	28	26	126	
LT							<0.0001*
Normal	50	12	7	45	14	128	

Thin	10	1	1	9	2	23	
Thick	10	6	3	12	23	54	
PS							0.026*
Normal	30	11	4	29	28	102	
Big	40	8	7	37	11	103	
REs Severity							<0.0001*
Normal Eye	71	0	0	0	0	71	
Mild	0	19	9	54	37	119	
Moderate	0	0	0	5	2	7	
Severe	0	0	1	7	0	8	
Visual acuity							<0.0001*
Normal	47	2	4	4	12	69	
Mild	22	15	7	32	23	99	
Moderate	1	2	0	22	3	28	
Severe	0	0	0	8	1	9	

Key: ACD = Anterior chamber depth, AL = Axial length, CDP = Corneal dioptric power, CR = Corneal radius, LP = Lens power, LT = Lens thickness, and PS = Pupil size. *Statistically significant at Pearson Chi-square *p* value 0.05 (5%).

Table 4: Variations of ocular biometrics in different refractive errors

Ocular biometrics	**Astigmatism**	**Hyperopia**	**Myopia**	**Presbyopia**
	Mean ± Standard deviation			
Anterior Chamber Depth	2.59±0.25	2.51±0.8	2.70±0.41	2.56±0.33
Axial Length	22.93±1.18	23.44±1.18	23.90±1.47	23.0±0.97
Corneal Radius	7.87±0.27	8.0±0.43	7.84±0.38	7.80±0.33
Corneal Dioptric Power	43.0±1.40	42.49±2.27	43.21±2.23	42.27±1.81
Lens Power	21.76±2.84	23.86±3.23	18.92±4.01	21.30±2.41
Lens Thickness	3.68±0.31	3.68±0.28	3.59±0.31	3.91±0.36
Pupil Size	4.29±0.93	4.32±0.88	4.39±0.86	3.95±0.65

Table 5: Linear regression for the association between refractive errors and ocular biometrics

	Univariate Logistic Regression					**Multivariate Logistic Regression**			
Variables compared	Coef.	*p* value	COR	95% CI for COR		*p* value	AOR	95% CI for AOR	
				Lower	Upper			Lower	Upper
ACD and Myopia	1.68	0.007	5.34	1.59	17.95	0.014	4.57	1.36	15.40
AL and Myopia	0.57	0.001	1.77	1.27	2.48	0.002	1.74	1.24	2.46
CR and Presbyopia	-1.33	0.041	0.27	0.074	0.95	0.039	0.26	0.072	0.933
LP and Myopia	-0.27	<0.0001	0.76	0.67	0.88	<0.0001	0.76	0.65	0.88
LT and Presbyopia	2.88	<0.0001	17.89	4.16	76.99	<0.0001	17.95	4,17	77.19
PS and Presbyopia	-0.77	0.008	0.46	0.26	0.82	0.033	0.43	0.20	0.94

Key: Coef. = Coefficient; AOR = Adjusted Odds Ratio; CI = Confidence Interval and COR = Crude Odds Ratio. The variables were controlled for Gender and Age categories.

Table 6: Univariate and multivariate logistic regression

Variables compared	*p* value	COR	**95% CI for COR**		*p* value	AOR	**95% CI for AOR**	
			Lower	Upper			Lower	Upper
Astigmatism and Age categories								
16 – 27	0.001	72	5.56	933	0.001	75.42	5.73	992.45
28 – 37	0.003	18	2.64	122.62	0.003	19.8	2.82	139.05
38 – 47	0.051	6	0.99	36.23	0.056	5.87	0.96	35.98
48 – 60	Ref							
Hyperopia and Age categories								
16 – 27	0.001	72	5.56	933	0.001	77.53	5.89	1021.02
28 – 37	0.038	9	1.13	71.96	0.034	9.69	1.18	79.42
38 – 47	1	0	0		1	0	0	0
48 – 60	Ref							
Myopia and Age categories								
16 – 27	<0.0001	124.8	13.59	1146.27	<0.0001	135.62	14.46	1272.37
28 – 37	<0.0001	22.8	5.37	96.81	<0.0001	27.05	6.07	120.63
38 – 47	0.001	7.68	2.21	26.7	0.001	8.18	2.3	29.08
48 – 60	Ref							
Onset of ocular problem and Myopia								
Childhood	0.033	2.53	1.08	5.95	0.038	2.51	1.05	6.01
Adulthood	Ref							
Inherited problem and Myopia								
No	Ref							
Yes	0.033	2.16	1.07	4.38	0.036	2.33	1.05	4.39

Key: AOR = Adjusted Odds Ratio; COR = Crude Odds Ratio; CI = Confidence interval and Ref = Reference category. Age categories were controlled for Gender and Onset of ocular Problem, while Onset of ocular Problem was controlled for Gender and Age. The reference category was Presbyopia.

DISCUSION

The mean values of ACD and AL were both longer in myopic study participants. This could be attributed to a genetic predisposition in the participants as there is a statistically significant correlation between RE and genetic origin (Wickremasinghe *et al.,* 2004; Zhang, 2015). These studies concluded that myopic eyes with a genetic origin tend to have a longer AL than those without a genetic inheritance of Myopia. The Lens was found to be much thicker in Presbyopia in the current study, which was directly related to nuclear lens sclerosis as most patients were above 38 years of age (Gessesse *et al.,* 2020). Pupil size showed the highest mean of 4.39 mm in Myopia, and this could be attributed to light scatter giving a blare image in Myopia. (AB Osaiyuwu, 2014). Axial length was more in men and could be attributed to men having on average greater physical height and hence tend to have bigger eyes than females (Gessesse *et al.,* 2020).

Bivariate analysis using Pearson's correlation showed a statistically significant correlation between CRC, LP, and LT with refractive errors. These all disappeared after controlling for age and gender in logistic regression analysis which suggests that confounding factors could have been at play (Fishers London, 1988). univariate and multivariate analysis showed a

significant positive association between ACD with myopia, AL with myopia, and LT with presbyopia. This is in support of previous studies in other areas such as the study conducted by Hashemi et alin 2015, (Zoraida et al., 2019). The only difference is that in the current study, CR was not significant, and could be due to a few cases of Astigmatism which is a unique type of RE more associated with CR. The current study did not cover VCD as it was considered a component of AL.

Kuo et al., 2011, found similar findings for ACD and AL-only differences is that they included CCT which the current study dropped due to challenges in methodology. Osaiyuwu et al., (2014) conducted a study in Nigeria designed to investigate the effect of age, gender, and refractive error on the pupil size of humans. It was found that there was a statistically significant difference between pupil size and refractive error but no difference in pupil size of males and female The current study did not show any statistical significance between males and females in terms of pupil size as gender was not matched but showed a significant correlation between pupil size and REs by chi-square. This means confounders could be at play for the positive correlation in Pearson analysis. In 2015, Hassan et al conducted a cross-sectional study in Iranian adults. The study found CP to have been the greatest contributing factor to SER together with AL. This different finding could be due to age differences in the inclusion criteria, ethnicity, and varying methodologies such as the definition of REs.

Logistic regression showed a positive association between inheritance and childhood-onset with Myopia attributed to a genetic predisposition (Wickremasinghe et al., 2004). In the current study, Astigmatism and hyperopia were prevalent mostly in two age categories, that is, 16 – 27 years and 28 to 37 years. This could be due to emmetropisation. Presbyopia increased with an increase in age due to nuclear lens sclerosis as most patients were above 38 years of age (Gessesse *et al.,* 2020).

Study Limitations

Firstly, the sample size was reduced from 323 to 205. due to escalating cases of COVID-19 and a directive from MOH to close all outpatient departments between June – July of 2021. Secondly, the pupil size was calculated manually using a ruler instead of an autorefractometer, which malfunctioned at some point during the study. Lastly, the measurement of Corneal Central Thickness (CCT) was a challenge since the Pachymeter had no batteries, which are often procured abroad. Hence CCT, was considered as part of AL.

Delimitations of the study

Young people below 16 years were excluded because of emmetropisation (Momeni-Moghaddam *et al.*, 2019) (Flitcroft, 2014), while those above 60 years were also excluded to avoid increase in refractive index of the lens associated with age (HV Nema *et al.*, 2012). Randomised systematic sampling was employed to prevent bias. This study did not include CCT as it was a limitation and VCD as it was considered as part of AL and could only be obtained by subtracting CCT, ACD and LT from AL (Hashemi *et al.*, 2012). RE were only considered > 0.25 for Myopia, Hyperopia and Astigmatism while Presbyopia was considered as ≥ 1.00. (Fisher, 1988). Ocular biometrics were normal in a range of ± 0.25mm to 0.50mm per specific parameter and according to (Hashemi *et al.*, 2012) no compensation was given apart from a benefit of a written prescription for treatment as routine.

CONCLUSION

Mean standard deviation for axial length, anterior chamber depth, and pupil size were greater in Myopia while that of lens thickness was greater in Presbyopia. Ocular biometrics related to refractive errors were

axial length, anterior chamber depth, and lens thickness. Axial length and anterior chamber depth are associated strongly with Myopia while lens thickness is more linked to Presbyopia. Age (16 and 47) years, inheritance, and childhood-onset associated strongly with Myopia while Presbyopia increased with increase in age.

Conflict of Interest

There was no form of conflicting interest in this study by the authors

Recommendations

Firstly, knowledge of variations in ocular biometrics, proportions, and types of REs obtained in this study, should be considered by interventional ophthalmology personnel practicing at UTHs EH for accurate diagnosis and treatment of refractive errors. Secondly, we recommend a matched study between males and females to be conducted as gender was not balanced in the current study.

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