Original Article

THE RELATIONSHIP BETWEEN PUPIL SIZE AND REFRACTIVE ERROR

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Abstract

Background: It is a common conception that myopes tend to have larger pupil size and hyperopes smaller pupil size. This research was designed to investigate the effect of age, gender and refractive error on the pupil size of humans.

Methods: A total of six hundred (n=600) subjects made up of 280 (46.67%) males and 320 (53.33%) females within 10 to 65 years (mean age: 37±16.7 years) were used for this study. Retinoscopy was carried out on all subjects as well as their pupil size measurements taken under both ambient and dim illuminations.

Results: There was a statistically significant difference between pupil size and refractive error under both ambient and dim illuminations, ($p<0.05$).There was no statistically significant difference between the pupil size of males compared to females under both illuminations (unpaired t-test: $p>0.05$) and there was a relationship between pupil size and age with a regression line pupil size= 4.26 - 0.033age, for ambient illumination, and pupil size=6.44 - 0.047age for dim illumination.

Conclusion: Pupil size is dependent on refractive error but independent of gender.

Keywords: Pupil size, Ambient illumination, Dim illumination, Refractive error

Introduction

The pupil is defined as the opening that is located in the center of the iris of the eye and that which controls the amount of light that enters the eye. It appears black because most of the light entering the pupil is absorbed by the tissues inside the eye[1]. In an ametropic eye with accommodation relaxed, parallel rays of light fail to converge to a sharp focus on the retina. Categories of ametropia are myopia, hyperopia and astigmatism. This study is therefore designed to compare the pupil size of myopes, hyperopes and also emmetropes (which serve as the control).

It is a common conception that myopes tend to have larger pupil size and hyperopes smaller pupil size. From previous studies, not all researches that have been done support this conception. This study is therefore important to discover if myopes' pupil size are significantly larger and hyperopes' pupil size significantly smaller when compared with the control (emmetropes). Assessment of pupil size is critical in selecting patients for bifocal contact lens fitting or implantation with a bifocal intraocular lens because the annular design of bifocal intraocular and contact lenses requires the central zone to be smaller than the pupil size under photopic condition to allow both distance and near region of the lens to produce an adequate retinal image.

The size of the pupil is determined by the balance of two antagonist muscle of the iris: the sphincter muscle, which is under parasympathetic innervations resulting in miosis and the dilator muscle which is under sympathetic innervations.[2] "Scotopic pupil size of normal pediatric population using infra-red pupillometry" was a research carried out to determine scotopic pupil diameter in normal pediatric population. It was concluded that the scotopic pupil size of pediatric population increased with age until the age of 11 and then decreases again[3]. Pupillary size varies according to age, illumination, degree of mental stimulation or

fatigue and systemic condition such as diabetes and infection. Normal pupils should be isocoric. Lesions involving the efferent pathway or the iris substance will produce anisocoria. Many people will be found to have a difference in pupil size between the two eyes, this condition is called essential anisocoria and of no consequence[4]. Pupil size is determined by many factors including afferent drive from the retina, central processing unit in the brain stem, the balance of "tone" in the autonomous nervous system and local factors within the muscle of the iris. Any disturbance to these structures may result in an abnormal size, shape or activity of the pupil[2].

Materials and methods

This was a prospective case – control study carried out among black subjects who had refractive errors (ametropes) and those without (emmetropes). The subjects that were used for this study were patients who visited the Optometry Clinic, University of Benin and Faith Mediplex both in Benin City. Subjects who had other conditions that could affect pupil size were excluded such as those who had Diabetes mellitus, uveitis, glaucoma, neurological disorders like Horner's syndrome, Adie's pupil e.t.c. Subjects were randomly selected.

This study comprised of 600 patients with age range of between 10 to 65years: 200 emmetropes and 400 ametropes. The emmetropic subjects were used as control.

Personal data of patients which comprised of age and sex were noted. Diagnostic test for refractive error which was static retinoscopy was done on these subjects after the pupil size had been measured. The pupil size was measured under ambient and dim illumination. The patient was seated and instructed to look at the 6/60 letter on the Snellen's distance chart. The penlight was shone into the patient's right eye from the temporal side with the pupil meter directed in front of the pupil. The size of the pupil was then measured and the pupil diameter was estimated to the nearest half millimeter. The same procedure was repeated for the left eye.[4] Static retinoscopy was performed on the patient. The patient was trial framed with correct interpupillary distance set to match the patient's distance PD, vertex distance and nosepiece setting in place. The patient was instructed to keep both eyes open during the procedure.

Results

A total of six hundred (n=600) subjects made up of 280 (46.67%) males and 320 (53.33%) females within 10 to 65 years (mean age 37±16.7 years) were used for this study. Subjects were categorized by their spherical equivalent refractive error into emmetropes, myopes and hyperopes; (-0.50DS to +0.50DS for emmetropes, +0.75DS and above for hyperopes and -0.75DS and above for myopes). The number of emmetropes used were 200 (33.33%), 200(33.33%) myopes and 200(33.33%) hyperopes. Only the right eyes of the subjects were used for analysis to avoid duplication of results. The difference in mean pupil size under ambient illumination among emmetropes, myopes and hyperopes was statistically significant (ANOVA: $p<0.05$). Post hoc test (Duncan New Multiple range test-DMR) revealed that the myopes have larger mean pupil size, 3.44mm, followed by emmetropes with 3.08mm and 2.64mm for hyperopes (fig. 2). The mean difference between emmetropes and hyperopes was 0.44mm, 0.36mm between emmetropes and myopes and 0.80mm between myopes and hyperopes.

Similarly, the difference in mean pupil size under dim illumination, among the emmetropes, myopes and hyperopes was statistically significant (ANOVA: $p<0.05$) as shown in Fig. 3. Posthoc test (DMR) showed that myopes had larger mean pupil size of 5.27mm, followed by emmetropes with mean pupil size of 4.73mm and 4.10mm for mean pupil size of hyperopes; emmetropes and hyperopes with mean difference of 0.63mm, emmetropes and myopes with mean difference of 0.54mm while 1.17mm for mean difference of myopes and hyperopes. However, the difference in mean pupil size between males and females under ambient and dim illumination was not statistically significant: under ambient illumination (unpaired t-test: $t=0.13$, $p>0.05$) and dim illumination (unpaired t-test: $t=0.441$, $p>0.05$).This is shown in tables 1 and 2.

The degree of association between age and pupil size (ambient illumination) was statistically significant (Pearson's correlation coefficient: $r=0.77$, $p<0.05$) and the linear regression was also significant ($p<0.05$). The regression line is defined by the equation: pupil size = 4.26 – 0.033age. The linear regression line shows that the pupil size diameter under ambient illumination got smaller

with increasing age. Fig. 4 shows scatter plot of age and pupil size under ambient illumination. Similarly, the association between age and pupil size under dim illumination was significant ($r=0.81$, $p<0.05$) and the linear regression was also significant ($p<0.05$). The linear regression line is represented by the equation: Pupil size = 6.44 – 0.047age. The linear regression line shows that the pupil size diameter under dim illumination got smaller with increasing age. Fig. 5 shows scatter plot of age and pupil size under dim illumination.

Table 1: The mean pupil size and confidence interval of males and females under ambient illumination.

SEX	MEAN PUPIL SIZE ± SD	95% CONFIDENCE INTERVAL
Males (n=280)	3.04mm ± 0.75	2.87mm – 3.21mm
Females (n=320)	3.02mm ± 0.68	2.85mm – 3.19mm

Table 2: The mean pupil size and confidence interval of males and females under dim illumination.

SEX	MEAN PUPIL SIZE ± SD	95% CONFIDENCE INTERVAL
Males (n=280)	4.69mm ± 1.02	4.57mm – 4.81mm
Females (n=320)	4.76mm ± 0.89	4.65mm – 4.87mm

Fig. 1: Percentage of emmetropes, hyperopes and myopes in different age groups

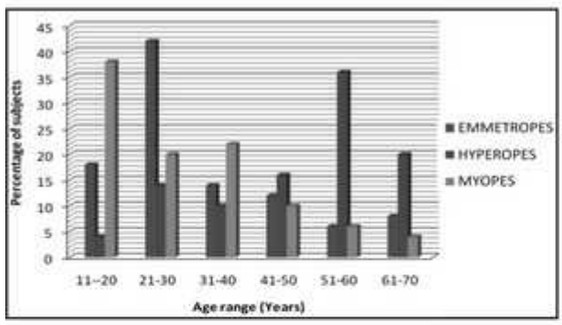


Fig 2: The mean pupil size of different refractive status under ambient illumination

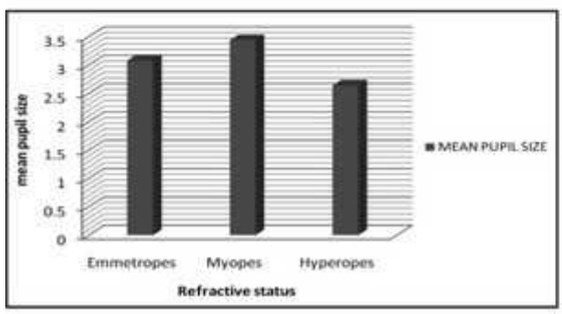


Fig. 3: The mean of pupil size of different refractive status under dim illumination

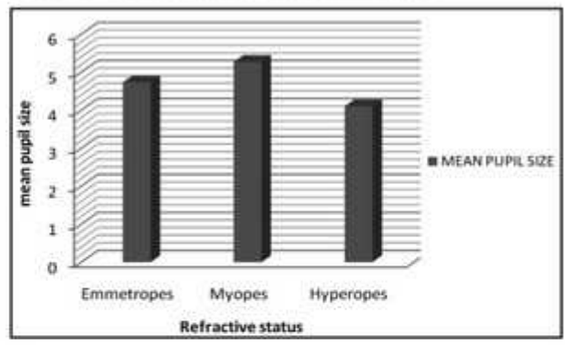


Fig. 4: Scattergram of age (years) versus pupil size (millimeters) under ambient illumination

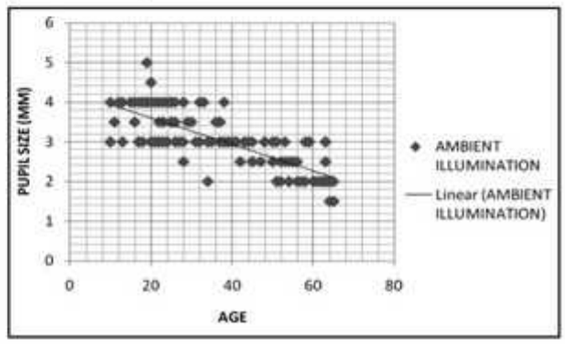
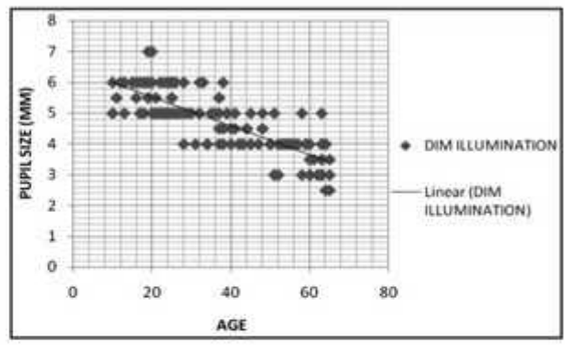


Fig. 5: Scattergram of age (years) versus pupil size (millimeters) in dim illumination



Discussion

A total of six hundred (n=600) subjects made up of 280(46.67%) males with mean pupil size of 4.76mm±0.88 and 320(53.33%) females with mean pupil size of 4.69mm±1.02 under dim illumination and for ambient illumination, males' mean pupil size was 3.04mm±0.75 and females' mean pupil size was 3.02mm±0.68. Individuals used for this study ranged between the ages of 10 to 65 years (mean age 37±16.7 years).

The results obtained in this study found a significant difference between the pupil size of myopes, hyperopes and emmetrope in both ambient and dim illumination, thereby supporting the general impression of myopes having a larger pupil size and hyperopes a smaller pupil size. This was also supported by some experimental evidence[5] but in contradiction to works done by Jones[6] and Netto *et al*[7]. The reason for this could be because hyperopes tend to accommodate more than myopes, this is because the far point of hyperopes recedes beyond infinity. Moreover, the relationship between accommodation and pupil size will result in relatively greater pupillary constriction, also it has been said that the anterior chamber of myopes is often deeper when compared with hyperopes and emmetropes which makes the pupil appear larger[5].

Furthermore, studies that are not in agreement with this findings carried out their experiments with all subjects wearing their refractive correction during measurement thereby making these individuals "artificial emmetropes". Moreover, most of these studies that are in contradiction with this work were carried out among the white race unlike this study which was carried out among black race in Africa.

Pupil size was found to decrease linearly with increasing age and the result was same in both dim and ambient illumination. This is in agreement with previous work done by Winn *et al*, where he stated that chronological age has a significant effect on the size of the pupil[8].This work is also in partial agreemment with the work done by Kohnen *et al* where it was stated that the scotopic pupil size of pediatric population increases with age until the age of 11 years and then decreases again[3]. Furthermore, from the work done by Netto *et al*, it revealed that there is an inverse correlation between pupil size and age.[7]Decrease in pupil size with increase in age is as a result of senile miosis. This is thought to be due to atrophy of the dilator muscle fibers. A potential disadvantage may be that higher levels of illumination are required in all settings to produce the same level of retinal luminance and subsequent visual acuity, thereby affecting visual performance.[9]

However, a smaller pupil size has several advantages: it serves to sharpen vision by reducing the amount of light scatter produced by the ocular lens which becomes less transparent with increase in age. Secondly, a smaller pupil size improves the visual depth of focus and thirdly, a smaller pupil may serve to protect the already vulnerable elderly retina from further phototic damage.

There was no significant difference between the pupil size of males as compared to females in both dim and ambient illumination. This is in accordance with the work done by Jones where in his result obtained between male and female subjects indicated that there was no significant difference in pupil sizes of these groups[6]. Jones also concluded that pupil size is independent of gender. However, Alexandridis stated that men usually have smaller pupil than women of the same age[10].

Conclusion

There was found to be a statistically significant difference between the pupil size of myopes, hyperopes and emmetropes both under ambient illumination and dim illumination. There was no statistically significant difference between the pupil size of males compared to females under both types of illuumination.

There was a relationship between pupil size and age under both types of illumination.

References

1. Cassin B. Solomon S. *Dictionary of Eye Terminology. 6th ed,* Florida. Triad publishing company: 1990:30 – 32.
2. Bremner FD. Pupil Abnormalities. *Arch of Ophthalmol. 2000;*103:384-387.
3. Kohnen E, Zubcov AA, Kohnen T. Scotopic pupil size in normal pediatric population using dynamic infrared pupillometry. *Arch. for clinical and exper. Ophthalmol. 2004;*10:18-23.
4. Grosvenor T. *Primary Eye care Optometry.* 4th Ed., Anomalies of Refraction. Butterworth Heineman, U.S.A. 2002:16-23.
5. Hirsch MJ, Weymouth FW. Pupil size in Ametropia. J. of Applied Physio. 1949;1: 646-648.
6. Jones R. Do women and myopes have larger pupil? *Invest. Ophthalmol. Vis. Sci.* 1990;31(7):1413-1415.
7. Netto MV, Ambriosio RJ, Wilson SE. Pupil size in refractive surgery candidate. J. of Refractive surgery. 2004;20:4.
8. Winn B, Whitaker D, Elliott DB, Phillips N. J. Factors affecting light-adapted pupil size in normal human subjects. Invest Ophthalmol. Vis. Sci. 1994;35:1132-1137. Smith, SC. Aging and Vision. J. of American Society of Ophthal. Registered nurses. 2008;33:16-19.
9. Alexandridis E. The pupil. 2nd ed., Springer-Verlag, New York. 1985:11-12.