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Comparative assessment of pupillary oscillation and blinking rate between emmetropes and myopes

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ABSTRACT

Aim: Aim of this study was to investigate for a relationship between pupillary oscillations (PO) and blinking rate (B) in various vision deprived states such as in refractive errors (Myopes).
Materials and Methods: A case control descriptive study with 340 individuals, including 220 myopes and 120 emmetropes were compared for pupillary oscillation rate (PO), blinking rate (B) and Pupillary oscillation/blinking rate (PO/B) ratio bilaterally in normal as well as in individual subgroups of decreasing visual acuity, done under slit lamp in dim diffuse illumination.
Results: The pupillary oscillation rate (PO) was 49.23± 8.80 in right eye (POR) and 56.44 ±8.95 in left eye (POL) in the control group whereas it was 46.28 ±11.55 and 52.79 ±11.22 in the right and left eyes respectively of the cases. While PO/B ratio was 12.41±14.11 in the right eye and 14.33±15.9 in the left eye in control group, it was 7.13 ± 7.86 in the right and 8.18 ±9.07 in the left eye of the cases respectively. The blinking rate (B) was 8.62 ±6.06 in the control eyes and in the cases it was 11.69 ±7.91. The comparative analysis of all of the above parameters were statistically significant with $p < 0.001$ between cases and controls. POR = POL in 5.0%, POR > POL in 7.50% and POR < POL in 87.50%.
Conclusion: This study could be useful in non-verbal patients and comatose patients as diagnostic and prognostic tool, having an implication in different refractive errors and neurological diseases.

1. Introduction

In normal physiology, amplitude of both direct and consensual reflexes are same in both eyes. Two modifiable factors for good distant vision are pupillary constriction and blinking rate. [1] The question that arises is, are the parameters of pupillary reactions equal in between emmetropic and ametropic refractive errors i.e. those with Best Corrected Visual Acuity (BCVA) of 6/6 distant vision (DV) and N6 near vision (NV), or is there a difference between them.

This study would investigate for a relationship between pupillary oscillations(PO) and blinking rate (B) in various vision deprived states such as in refractive errors (Myopes).

2. Material and Methods

This case control descriptive study was conducted at Department of Ophthalmology of a tertiary care hospital over a period of one year in 2021. After a written, informed consent, as per the Declaration of Helsinki, 340 patients were included for one year and divided into two groups, controls and cases (refractive errors). A large population with different age groups (10 years to 40 years) of both

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gender was included. All emmetropic eyes (120 individuals) and the ametropic eyes (220 individuals) with myopic refractive errors with BCVA 6/6, N6 were included in the study. The refractive status was based on distant visual acuity followed by objective and subjective correction of refractive errors. The subjects were again sub-grouped according to decreasing uncorrected visual acuity such as Group 0 (6/6-perfect vision), group 1 (6/9 – 6/12), group 2 (6/18 -6/24), group 3 (6/36- 6/60), group 4 (<6/60). The normal eyes (Control group) were defined as individuals with unaided vision of 6/6 and N6.

The blinking rate (B) was calculated with the patient looking straight at a distance with both eyes without stress. Closure of the eyelids was considered as one blink.

Inclusion criteria for cases was fixed to patients with vision (< 6/6) but BCVA of 6/6, N6 with age groups between 10 to 40 years (male and female) who consented and were cooperative.

Exclusion criteria for cases were patients with decreased vision with BCVA < 6/6, amblyopia, dry eyes, other ocular pathology (anterior segment, posterior segment, orbital), traumatic disease, inflammations, non-consenting patients, uncooperative patients.

A thorough routine ophthalmological examination in both case and control group was done including visual acuity (VA), refraction, slit lamp examination and slit lamp biomicroscopy using a +90 D lens, indirect ophthalmoscopy, Schirmer's test, keratometry, biometry and tonometry. Blinking rate was tested by asking the individual to look without stress at a distance. The number of blinks per minute was calculated and considered as Blinking Rate.

The right and left eyes were examined. The right eye was seen first followed by left eye and alternate way was also done under dim diffuse illumination of the slit lamp. In the normal condition the pupil constricts on light exposure. Even in constricted state the pupil is in a dynamic state of miniconstriction and minidilatation under constant light exposure. One cycle of miniconstriction and minidilatation is taken as one pupillary oscillation. The total number of pupillary oscillations per minute is termed as pupillary oscillation rate (PO) in the right eye(POR) and left eye(POL) The patients with refractive errors were corrected by refraction and the individuals with BCVA 6/6, N6 were included. The spherical, cylindrical power, axis were also recorded for both eyes.

PO/B is the ratio of pupillary oscillation to the associated blinking rate in the right eye(PO/BR) and left eye(PO/BL).

PO/B was divided into 8 groups and the associated mean visual acuity was recorded. Group- 1 (0-3), Group-2 (3.1-6), Group-3 (6.1-9), Group- 4 (9.1-12), Group-5 (12.1-15), Group-6 (15.1-18), Group-7 (18.1-21) and Group-8 (>21). The visual acuity was converted to logmar visual acuity and was recorded. The statistical significance and the corresponding logmar visual acuity was documented with respect to PO/B in right eye (PO/BR) and left eye (PO/BL)

2.1. Statistical analysis

All continuous variables are presented by mean ± standard deviation and categorical variables are presented by frequency and percentage. For comparison of different groups student t – test and ANOVA used. A p value < 0.05 is considered as statistically significant. Data are analysed by IBM SPSS version 25.0.

3. Results

A total of 340 individuals (680 eyes), 220 cases and 120 control were enrolled for the study after consideration of inclusion and exclusion criteria.

Pupillary Oscillation rate in right eye (POR) and Pupillary oscillation rate in left eye (POL) are significantly more in control than cases. Blinking rate is increased in cases than normal controls. Pupillary oscillation/blinking rate right eye (PO/BR) and Pupillary oscillation/blinking rate left eye (PO/BL) are both higher in normal than that of cases. (Table 1)

One of the significant major finding was that the POR and POL was not same as believed earlier that direct and consensual pupillary reflex are equal in both eyes in all characteristics. This study clearly proves that POR was less than POL (POR<POL) in 82.72% individuals in cases and 87.5% in control. POR=POL in 5.0% of control and 6.38% in cases. POR>POL in 7.5% in control whereas 10.9% in cases. (Table 2)

In all the five groups variation between POR and POL was statistically significant. The blinking rate showed increasing trend from control to cases in contrast to pupillary oscillations which showed a decreasing trend in both right and left eye. The spherical equivalent was also significant in between the groups. PO/B (Pupillary oscillation/blinking rate ratio) was statistically significant between the groups. PO/B in control group was highest and decreased systematically with graded decrease of visual acuity in both right and left eye.(Table 3)

Dividing the PO/B values into 8 groups, group 1(0-3), group 2 (3.1-6), group3 (6.1-9), group 4 (9.1-12), group 5 (12.1-15), group 6 (15.1-18), group 7 (18.1-21), group 8 (>21), and comparing the visual acuity in respective groups showed a increasing trend in visual acuity. Spherical equivalent also showed a similar increasing trend in the various groups. Visual acuity decreased and spherical equivalent increased with decreasing PO/B.(Table 4)

4. Discussion

The pupillary dynamics was assessed on the basis of ratio between pupillary oscillation and blinking rate. The light reaction (direct light reflex) constricts the pupil and further continuous light exposure maintains the constriction

Table 1: Comparison of the normal and abnormal cases in relationship to pupillary oscillation (POR, POL), blinking (B) rate and POBR right and POBL left ratio in each of the eyes

	Control (n=120)	Cases (n=220)	P Value
Age	26.63 ± 7.05	22.69 ± 6.57	<0.001
POR (Pupillary oscillation in right eye)	49.23 ± 8.80	46.28 ± 11.55	0.015
POL (Pupillary oscillation in left eye)	56.44 ± 8.95	52.79 ± 11.22	0.002
B (Blinking rate/min)	8.62 ± 6.06	11.69 ± 7.91	<0.001
PO|BR (Pupillary oscillation to Blinking rate ratio in right eye)	12.41 ± 14.11	7.13 ± 7.86	<0.001
PO|BL (Pupillary oscillation to Blinking rate ratio in left eye)	14.33 ± 15.98	8.18 ± 9.07	<0.001

Table 2: Comparison between pupillary oscillations in right eye in comparison to left eye in control and cases

	Control (n=120)	Cases (n=220)
POR > POL	9 (7.5%)	24 (10.90%)
POR < POL	105 (87.5%)	182 (82.72%)
POR = POL	6 (5%)	14 (6.38%)

Note: Pupillary oscillations in right eye (POR), Pupillary oscillation in left eye (POL)

Table 3: Comparison of pupillary oscillation rate (POR, POL), blinking rate(B) and POBR ratio (pupillary oscillation rate to blinking rate ratio) between control and in between different decreased visual acuity groups

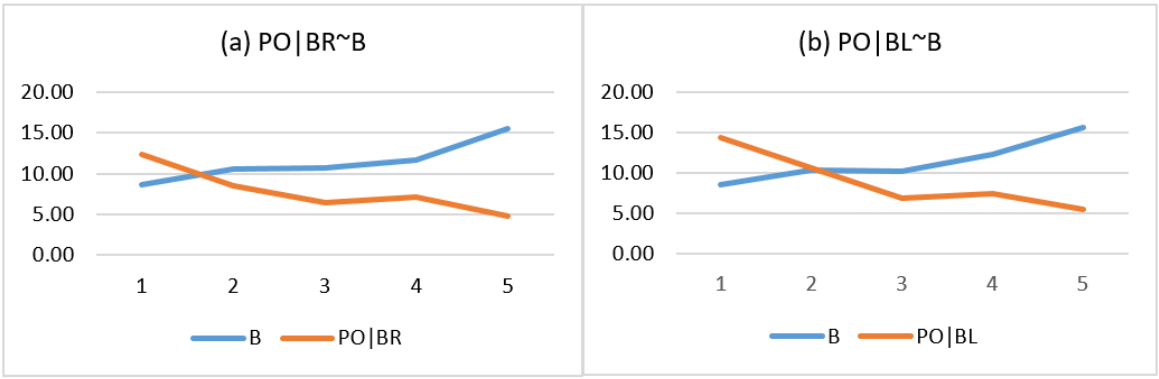
	Age	POR	POL	B	PO|BR	PO|BL
6|6	26.63 ± 7.06	49.23 ± 8.8	56.44 ± 8.96	8.62 ± 6.61	12.41 ± 14.12	14.33 ± 15.98
6|9 – 6|12	23.46 ± 7.03	45.41 ± 11.47	52.11 ± 11.43	10.53 ± 7.43	8.51 ± 9.95	10.61 ± 12.26
6|18 – 6|24	21.65 ± 6.42	47.33 ± 11.05	52.1 ± 10.76	10.75 ± 6.37	6.49 ± 4.66	6.89 ± 4.5
6|36 – 6|60	22.24 ± 6.53	45.16 ± 11.87	52.58 ± 11.87	11.72 ± 8.34	7.2 ± 8.21	7.45 ± 8.03
< 6|60	23.14 ± 5.74	48.66 ± 11.92	55.51 ± 10.41	15.51 ± 9.21	4.82 ± 4.21	5.54 ± 4.59
P Value	<0.001	0.055	0.015	<0.001	<0.001	<0.001

Table 4: Logmar visual acuity* and spherical equivalent correlation with pupillary oscillation by blinking rate ratio in right eye and left eye

PO|B	Visual Acuity* (Right Eye)	Visual Acuity* (Left Eye)	Spherical Equivalent (Right Eye)	Spherical Equivalent (Left Eye)
0-3 (n=84)	0.62 ± 0.48	0.61 ± 0.49	-2.3 ± 2.15	-1.09 ± 1.67
3.1 - 6.0 (n=124)	0.39 ± 0.41	0.39 ± 0.41	-1.23 ± 1.51	-0.47 ± 0.91
6.1 - 9.0 (n=39)	0.39 ± 0.43	0.38 ± 0.43	-1.27 ± 1.84	-0.51 ± 1.24
9.1 - 12.0 (n=27)	0.29 ± 0.4	0.26 ± 0.34	-0.73 ± 1.06	-0.37 ± 0.88
12.1 - 15.0 (n=17)	0.45 ± 0.4	0.44 ± 0.41	-1.22 ± 1.33	-0.66 ± 0.93
15.1 - 18.0 (n=5)	0.36 ± 0.13	0.36 ± 0.13	-1.21 ± 0.5	-0.55 ± 0.46
18.1 - 21.0 (n=12)	0.39 ± 0.45	0.37 ± 0.45	-1.26 ± 1.94	-0.72 ± 1.85
> 21.0 (n=32)	0.16 ± 0.32	0.14 ± 0.3	-0.38 ± 0.7	-0.21 ± 0.54
P value	< 0.001	<0.001	<0.001	<0.006

along with the cyclic tone of pupillary constriction and relaxation.[2] The study by MaxWarga, Holger Lindtke et al. prove that there is considerable inter and intra individual differences in the amplitude and frequency of pupillary oscillations on exposure to light, depending upon the intensity and duration of exposure to light.[3] Our study is done under slit lamp with very small amount of diffuse and dim illumination to both eyes alternately in the same setting and time (1 minute for each eye). The purpose of the eye is a clear and contrast vision. Hence, this pupillary reaction must also help in proper projection of a clarified image to the retina.[4] The pupillary oscillations are physiological and are found in both normal eyes (6/6, N6 vision) as well as eyes with abnormal vision of < 6/6. This study proves that with increased or better visual acuity, the pupillary oscillations are more in number than the decreased visual acuity cases.

Does that suggest that more pupillary oscillations provide a much better vision, whereas decreased pupillary oscillations a decreased vision? Previous literature proves that gross diminution of vision is often associated with RAPD, sluggish reactions and other pupillary abnormalities like Adie's pupil, tonic pupil, hippus, miotic or dilated fixed pupil are an indicator for other ocular or systemic diseases.[5–7] So are increased pupillary oscillation an



Graph 1: **a):** Pupillary oscillation by blinking rate ratio in relationship to blinking rate in right eye; **b)**: Pupillary oscillation by blinking rate ratio in relationship to blinking rate in left eye

indicator of better vision?

This study shows that in the visual acuity of 6/9 → <6/60 there is a graded decrease of pupillary oscillations in both right and left eye and a gradual significant decrease of pupillary reflexes from normal to abnormal eyes. Increased cortical activity like mindful meditation has proved that there is 53% increase of oscillation between pre- and post-meditation baseline. Thus, cortical state could be assessed by pupillary oscillations as shown by a study on spontaneous pupillary oscillations by Antonella pome, David C burr et al.[8–10]

The left eye physiologically seems to have more pupillary oscillations than the right eye with 85% of the total individuals having higher pupillary oscillations in left eye. Both patients and control have left pupillary oscillations more than right eye. Left eye having more oscillations that right eye in both cases and control proves it to be more physiological. This finding has not been documented in medical literature as far as now. The cause of this state is not clear or might be due to a left dominant brain. There is a slight increase of POR than POL in diseased than normal control emmetropic eyes.

Pupil constriction like pinhole restricts the passage of excessive or aberrant rays from periphery and helps in proper focusing on the object of desire.[11,12] The pupillary oscillations facilitate this phenomenon and help in proper focusing of the image of an object in the eye. Thus, when the image becomes unclear, blinking happens to abolish the improper image and genesis of the whole process starts again for a better image again until the next blink. This is a function of the macula, optic nerve and the cortical brain.[13] The two modifiable factors which regulate vision unaided are thus due to pupillary constrictions and blinking rate.[14] The relationship of pupillary oscillations to that of blinking is not widely studied. PO/B ratio or pupillary oscillation rate / blinking rate ratio indicates the number of pupillary oscillations per blink of the eye.

This study proves that the pupillary oscillation rate varies directly with visual acuity. In case of amblyopia there is a decreased visual acuity and alongside a decreased pupillary oscillation rate. After occlusion of sound eye, there is an improvement of vision and also an increase in oscillation rate in the amblyopic eye in the age group of 8-11years. This study was conducted by Hans SH, Kim JH et al. to assess the pupil cycle time in amblyopia occlusion therapy.[15] Pupillary oscillations normally decrease with decreasing visual acuity. This could be a manifestation of optic nerve function. The normal blinking rate is around 8-11 in number. Blinking rate increases in myopia, dry eyes, photophobia, vitamin A deficiency, inflammations and foreign body in eye.[16] It is seen that with decreased visual acuity the blinking rate increases. This increase of blinking rate is a protective measure for the structural and functional integrity of the cornea and conjunctiva. Decreased visual acuity such as due to astigmatic refractive error presents an abnormal image to the eye and blinking would help in avoiding this confusion of images and help in restoration of new better vision after each blink. Even though there is no strict relationship to the visual acuity but blinking rate is generally inversely proportional to visual acuity, increased visual acuity having decreased blinking rate and decreased visual acuity has increased blinking rate.

PO/B ratio proves that with decreasing visual acuity there is a certain pattern of decrease in PO/B ratio in both right and left eye. Increasing PO/B ratio pattern is definitely maintained in direct relationship with progressive increase of vision, emmetropic individuals with 6/6 vision having the highest PO/B. There is a definite matching pattern of progressive decrease in pupillary oscillation/blinking rate ratio with graded decrease of visual acuity. This pattern of PO/B ratio definitely seeks attention to the relationship between pupillary oscillations, blinking rate and visual acuity. In a moderate group of 680 eyes this maintenance of pattern of PO/B is quite striking. Evidence of this ratio is quite strong as both left and right eye show the pattern

equally.(Graph 1)

Normal controls have high PO/B ratio, where PO is the highest and B is the lowest. When there is development of abnormal image, the patient blinks in lesser time. In normal eyes, even though with long duration of vision, the blinking rate is decreased thus proving that more pupillary oscillations are associated per unit of blinking in controls than cases (refractive errors). Both the right and left eyes showed a matching pattern of visual acuity (logmar) fixed in a systematic pattern with various groups of PO/B ratio. Higher the PO/B ratio better the visual acuity (logmar) in bilateral eyes. There is increased oscillations in the left eye than the right eye with the same amount of PO/B ratio with corresponding better visual acuity in left eye. This also proves that left eye having better visual acuity has decreased amount of refractive power correction (spherical equivalent) than right eye with the same amount of PO/B ratio.

Both the right and left eye showed a decreasing pattern of visual acuity fixed in a systematic pattern with various groups of PO/B ratio. This could help in evaluation of visual assesment in nonverbal patients, uncooperative patients and patients with decreased mental functions if only oscillations and blinking rate is measured, so also in prognosis of cerebral, ocular (central and peripheral) causes of visual compromise.

5. Conclusion

Pupillary oscillation, blinking rate and ratio of PO & B help in understanding the physiology and pathology of vision of varied refractive errors in contrast to normal control eyes. Variation in PO and B found in different visual acuity is of statistical significance. But PO/B maintains a definite pattern of increase and decrease, with increased or decreased visual acuity respectively.

Thus, PO/B ratio can identify approximate visual acuity in patients who cannot cooperate in visual acuity testing and it can suggest the course, prognosis and follow up in different ocular or neurological(brain) diseases. This study needs to be done in a larger, wider, social and racial community with more inclusion criteria for better understanding of refractive error, visual compromise and other ocular conditions in different ocular and related systemic diseases.

6. Source of Funding

None.

7. Conflict of Interest

None.

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