Original Article

Comparison of torsional amplitudes between emmetropes and myopes using after-image slides

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Purpose: To describe the influence of corrected refractive error on measured torsional fusional amplitudes (TA) by comparing the TA between emmetropes and spectacle corrected myopes, using the after-image slides of the synoptophore, as targets. **Methods:** Fifty emmetropes (Group I) and 50 myopes (Group II) with best-corrected acuity of 6/6 in each eye were included in the study. Near point of convergence (NPC), near point of accommodation (NPA), and horizontal fusional amplitudes (HFA) were assessed in all the subjects. After-image slides, both horizontally aligned, were used as targets (without the bright flashes). One of the slides was rotated inwards, till cyclo-diplopia was reported by the subject; the procedure was repeated with the slide rotated outwards. The sum of the two readings was taken as TA. NPC, NPA, HFA, and TA were analyzed. **Results:** There was no significant difference in the NPC, NPA, and HFA between the two groups. The emmetropic subjects had significantly better torsional amplitude (8.4 ± 1.4 degrees) compared to myopes (7.7 ± 1.5 degrees, $P = 0.03$). We postulate that this difference may be due to perceived image minification, which brings the edges of retinal image of the targets closer to the fovea, thus rendering the myopes lesser tolerant to cyclodiplopia than emmetropes. **Conclusion:** Refractive error, corrected with spectacles, influences the measured TA. Myopic subjects have lesser torsional fusional amplitude than emmetropes.

Key words: Cyclofusion, cyclotorsion, myopia, ocular torsion, torsional fusion amplitudes, torsional vergence amplitude

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Fusion is the ability of the brain to form a single composite mental image from two similar images perceived separately by the two eyes each lacking in a small detail. Fusional vergence aids sensory fusion by maintaining the image of objects of interest at the fovea of both the eyes. Measurement of vergence amplitudes evaluates the ability of the motor system to overcome induced misalignment of the visual axis; horizontally (convergence, divergence), vertically (sursumvergence, deosursumvergence), and torsionally (incyclovergence, excyclovergence).

While horizontal and vertical misalignments can be induced by prisms, torsional vergence measurements necessitate the use of synoptophore or similar haploscopic devices. A variety of targets and devices have been employed in the demonstration of cyclofusion and assessment of cyclofusional amplitudes since the nineteenth century.[1] However, torsional fusional amplitudes or cyclofusional amplitudes are seldom measured in routine clinical practice. The influence of refractive errors on the cyclofusional amplitudes is not much known.

The present study was done to assess the influence of refractive errors on torsional fusion amplitudes using the horizontal apertures of the after-image slides as images on a synoptophore. We proposed to use the after-image slides of the synoptophore, both oriented in a horizontal fashion, as images, to compare the torsional fusional amplitudes of emmetropes and myopes.

Methods

This descriptive, comparative study was done in a tertiary eye care hospital after approval by the Institutional Review Board. Patients aged 10 to 25 years and 6/6 BCVA were divided into 2 groups; Group I, emmetropes and Group II, myopes with refractive error > 1 diopter.

Patients above 25 years of age, those with previous history of ocular surgery or trauma, anterior or posterior segment pathology, manifest strabismus, no simultaneous perception, astigmatism of more than 0.5 cylinder, BCVA <6/6, anisometropia (difference of more than 1 D between the eyes), and/or any systemic disorders were excluded.

All patients underwent detailed evaluation including visual acuity assessment for near and distance, cover tests, extraocular motility assessment, orthoptic evaluation comprising measurement of near point of accommodation (NPA), and near point of convergence (NPC) with Royal Air Force (RAF)

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rule. Horizontal fusional amplitudes were measured with the synoptophore using the fusional slides.

The torsional fusional amplitude was measured in the following manner. The after-image slides [Fig. 1] were placed in the slide holders, such that both were horizontally oriented. The torsional position of one of the slides was changed by intorting the synoptophore arm to the right side of the observer, while the arm to the left remained fixed, and the point at which the patient appreciated diplopia was noted. This procedure was then performed with the same synoptophore arm extorted. Torsional range was calculated as the sum of extorsion and intorsion amplitudes, beyond which the patients reported torsional diplopia. An average of three readings were taken for each patient. In the myopic group, all tests were done with the patients using appropriate spectacles.

During these tests, the after-image slides were used as targets alone and were not used with bright flash lights as done during a routine after image test.

Results

One hundred patients (Group 1, 50 emmetropes and Group 2, 50 myopes) were included in the study. The demographic characteristics are summarized in Table 1. There was no statistically significant difference in the demographic characteristics between the groups.

The refractive error in the myopic group ranged from − 1 to − 7 D in either eye (mean RE: 2.75 ± 1.37 D; LE: 2.71 ± 1.41 D). In 44 subjects (88%) of this group, the refractive error was less than − 4 D. There was no significant difference in the refractive errors between the two eyes in the myopic group (paired t-test; $t = 1.013$; df = 49; $P = 0.316$).

The comparison of orthoptic parameters between both groups has been summarized in Table 2. There was no significant difference in the horizontal fusional amplitudes between the emmetropes and myopes. The torsional fusional amplitude was 8.38 ± 1.6 degrees in the emmetropes and 7.70 ± 1.5 degrees in the myopes [Table 2 and Fig. 2]; this difference was statistically significant.

The negative association between the average of the refractive errors of either eye and torsional fusional amplitudes did not reach statistical significance (Pearson correlation, $r = -1.4$, $P = 0.3$).

Table 1: Age and gender characteristics of the study participants

Parameter	Emmetropic group (Gr I)	Myopic group (Gr II)	Statistical significance
Age (in years) Mean±SD	19.42±3.54	19.84±2.83	t=−0.654, degree of freedom (df) = 98, P=0.514
Gender (M:F)	15: 35	22: 28	χ^2:1.53, df=1, P=0.22

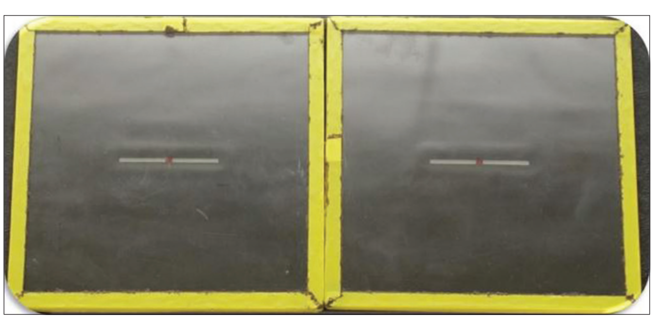

Figure 1: Picture of after- image slides used in the study

Discussion

Cyclorotation, which is the rotation of the eye around the anteroposterior axis, superior pole of the vertical tilting inwards in intorsion and outwards in extorsion, was described as early as 1868 by Ewald Hering.[2] The existence of "disjunctive cyclorotations" or "cyclofusion" – where the eyes perform simultaneous cyclorotations in opposite directions – was debated upon even then. Hering, and later many investigators, such as Kertesz, held the view that cyclofusion was predominantly sensory and that no motor cyclovergence occurred.[3] However, this was refuted by Crone[4,5] and other investigators such as Hooten *et al*.,[6] who demonstrated the motor component of cyclofusion, using appropriate wide-field complex stimuli and objective methods.

Cyclofusion assumes importance in the management of patients with cyclovertical muscle palsies, especially superior oblique palsy. Patients with good cyclofusional amplitudes may be able to avoid diplopia without head tilt, especially in mild cyclovertical muscle palsies. When torsional disparity exceeds the cyclofusional range, binocular vision may be adversely affected.[7]

The measured cyclofusional amplitudes may vary with the type of stimulus, the dissociativeness of the tests and the status of the extraocular muscles.[8] As early as in 1946, Ogle propounded that the amplitude of ocular cyclorotation following the rotation of a target depends, to a large extent, on the details of the target.[1] Various targets have been used to induce and study cyclofusion. Nagel used horizontal lines in a stereoscope,[1] Hering used vertical lines[2] in each

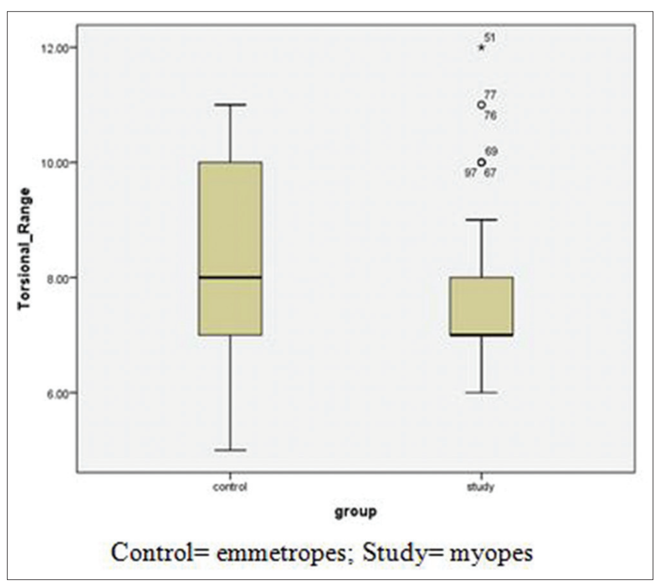

Figure 2: Comparison of torsional amplitudes among emmetropes and myopes enrolled in the study

Table 2: Comparison of orthoptic parameters between the emmetropes and myopes enrolled in the current study

Parameter	Emmetropic group (Gr I)	Myopic group (Gr II)	Statistical significance (unpaired *t*-test)
Near point of convergence	6.8±1.5 cm	6.72±1.26 cm	t=0.287 df=98; P=0.78
Near point of accommodation	7.3±1.7 cm	6.8±1.6 cm	t=1.27 df=98; P=0.21
Horizontal fusional amplitudes	11.8±2.1 deg	12.5±2.5 deg	t=−1.46 df=98; P=0.148
Torsional fusional amplitudes	8.38±1.6 deg	7.70±1.5 deg	t=2.199, df=98; P=0.030

df=degree of freedom (Group 1 number [50]−1+Group 2 number[50] −1=98)

half of the stereoscope, Kertesz[3] used horizontal lines in a synoptophore to study cyclofusion, while Crone,[5] and Hooten *et al*.[6] advocated the use of wide-field complex stimuli to demonstrate the motor component of cyclofusion. Sen *et al*.[9] used specially-designed slides on the synoptophore, whereas Sharma *et al*.[8] used special slides on a stereo projector. Use of 3D Landolt E chart by random dot stereogram for measuring cyclofusional amplitudes has been reported by Heckmann *et al*.[10] After-image test was used as a tool of measuring cyclodeviation by Sood and Sen.[11] In one of this study, Horizontal contours were found to have a greater effect on cyclovergence compared to the vertical ones.[5] In this study, horizontally-oriented lines of the after-image slides were used as the targets to elicit cyclofusion. Wide-angle complex stimuli were shown to elicit the motor component better than simple and smaller stimuli. However, these images have to be specially constructed to be employed in this process. We aimed to bring out the utility of commonly available after-image slides with horizontal line images in measuring cyclofusion. Moreover, since we aimed to study the difference in cyclofusion between emmetropes and myopes, and because the same slides were used in both the groups to assess cyclofusion, the effect of stimulus on the difference may be considered to be minimal.

Subjective methods of assessing cyclofusion had been in vogue since the last century. However, objective methods were required to study the motor component of cyclofusion in detail. Kertesz[3] used a marked contact lens, Crone[5] used synchronized photographs to study the conjunctival vessels in detail and Hooten *et al*.[6] used photographs and a thread lying on the anesthetized cornea to study cyclofusion. Perimetric analysis of the blindspot using phase difference haploscope was used by Herzau,[12] a scleral suction contact ring connected to a shaft attached to a eddy current motor to study the mechanical stiffness was used by Simonz *et al*.[13] and a Kratz linear pointer with cordimeter was used by Paris.[14] Though being useful to delineate the motor component of cyclofusion, objective methods would involve the use of sophisticated instruments and technology. In this study, though the motor and sensory component of fusion could not be clearly demarcated, we opine that this demarcation serves little purpose to a clinician. Nevertheless, it was also pointed out by Crone *et al*.[5] that objective and subjective measurements correspond well with each other.

Differences in cyclofusional amplitudes among patients with different refractive errors have not been well-studied. Several studies[15,16] suggest, that the fusional vergence and stimulus AC/A ratio measured with spectacle correction, before refractive surgery, may significantly differ after surgery. Thus, a patient with refractive error wearing optimal spectacle correction becomes technically different from an emmetrope, in the measurement of orthoptic parameters. The method of correction of the refractive error may have a role to play in this, though. In the current study, spectacle-corrected myopes were found to have significantly lower torsional fusional vergences than emmetropes [Table 2 and Fig. 2]. We postulate that this difference could be due to perceived minification of the images on the retina, rendering the edges of the horizontal lines closer to the fovea, thereby reducing tolerance to cyclodiplopia. Crone[5] and Guyton[17] have discussed the role of Panum's space, which becomes wider away from the fovea, in allowing sensory cyclofusion. Thus myopes, may have poorer tolerance to cyclodiploia, as compared to emmetropes, the peripheral Panum's space having greater tolerance to diplopia. We were not able to find conclusively whether the cyclofusional amplitudes decreased with increasing refractive error, since, the negative association between the value of the refractive error and the torsional range was statistically insignificant. This could probably be because most of the patients (88%) had a refractive error between 1 and 4 D and the fact that several optical, anatomical, physiological and perceptual factors play a role in the perceived image size.[18]

Table 3 summarizes the values of cyclofusional amplitudes recorded by various authors in the literature. The torsional amplitudes obtained in our study, that is, 8 deg (emmetropes) are akin to those reported by various authors who employed synoptophore based-line targets[3-9] as evidenced in Table 3. It is a well-accepted fact that in the measurement of cyclofusional amplitudes, varied results may be obtained.[19] Techniques which are more dissociative yield lesser fusional amplitudes, whereas more physiological tests tend to yield higher torsional fusional amplitudes.[8]

The advantage of this study is that, to our knowledge, the after image slides of the synoptophore, which are commonly available, have not been used for measuring torsional amplitudes, before. These slides would measure the sensory cyclofusion alone compared to other objective tests employed by various authors which measure sensory and motor cyclofusion separately. A potential disadvantage of using these slides is that there would be no dissimilarity between the two slides, as is normally evident in the fusion slides of the synoptophore. Moreover, these slides, unless modified, cannot be used to measure cyclodeviation. Another disadvantage of the study is that the axial length, corneal curvature and back vertex power of the spectacles of the subjects have not been measured. Though the torsional fusion amplitudes differed only marginally between both the groups and hence of questionable clinical importance in this study population, the lesser cyclofusional amplitudes among myopes may be clinically significant in patients with high refractive errors corrected with spectacles.

Table 3: Cyclofusional amplitudes calculated in the literature

Author	Value of cyclofusional amplitudes obtained
Lyle[18]	6 deg to 10 deg
Crone and Everhard[5]	8 deg
Sharma *et al.*[8]	13 deg incyclovergence and 12 deg excyclovergence
Sen *et al.*[9]	6 deg (horizontal lines) and 9 deg (vertical lines)
Guyton[17]	15 deg (8 deg – sensory, 6 – 8 deg – motor)
Heckmann[10]	3.6 deg (incyclofusion), 4.24 deg (excyclofusion)
Herzau[12]	7.5 – 17 deg (motor fusion excluded)
Kertesz[19]	8 deg to 10 deg

The after-image slides have been found to measure the torsional vergence ampltiudes, providing values consistent with similar studies found in the literature. Further studies comparing the torsional amplitudes between hypermetropes and myopes, between subjects corrected with spectacles and contact lenses, and among those with varying degrees of refractive errors may throw light on the mechanisms leading to decreased torsional fusional amplitudes in myopes.

Conclusion

After-image slides can be used to measure torsional amplitudes. Refractive errors, corrected with spectacles, influence measured torsional amplitudes.

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Conflicts of interest

There are no conflicts of interest.

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