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Correlations between intermittent exotropia, stereoacuity and ocular torsion

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ABSTRACT

Aims: To objectively measure anatomical ocular torsion in intermittent exotropia (IXT), correlate with the amount of exo-deviation and stereoacuity.

Methods: We enrolled 84 participants from 8 to 35 years. Revised Newcastle control scores were obtained. Deviation was measured using prism cover test. Titmus stereo test was used for stereopsis. Dominant eye was identified using a hole in the card test. Anatomical ocular torsion was obtained using Spectralis SD-OCT. Any sorts of pathological conditions affecting ocular motility were excluded.

Results: The anatomical torsion of left or right eyes or their relative difference among different IXT groups was not found statistically significant (p-value >0.05). Newcastle Control Scale score was lowest 1 (1-2) in the convergence insufficiency group, 4 (2-8) in the divergence excess group and highest 5 (3-6) in the basic group (p-value <0.000). The amount of exodeviation positively correlated with different Newcastle Control Scales scores but no correlations were found between anatomical ocular torsion and neither stereopsis, nor the amount of near and distance exo-deviations.

Conclusion: This study could not establish significant correlations between anatomical ocular torsion measured objectively with OCT and the severity of deviation or stereoacuity. The revised Newcastle Control Scale was remarkable in monitoring the progression of IXT.

Keywords: Cyclodeviation, intermittent exotropia, ocular torsion, revised newcastle control score, stereoacuity

INTRODUCTION

The anatomical cyclo-position of an eye around its visual axis is called ocular torsion.[1] According to Donder's law, the eye assumes an invariable and involuntary angle of torsion, independent of the path taken in achieving that position of gaze.[2,3] But ocular torsion also occurs due to an imbalance between the vertically acting muscles.[4] This torsional disparity between two eyes can hamper fusion and stereopsis.[5] Significant cyclovertical deviations can be found in anisometropia, uncorrected astigmatism, orbital anomalies and neuromuscular or innervational anomalies.[6] Similarly, such deviations are also in cases with intermittent exotropia (IXT), although IXT is a horizontal form of strabismus.[1] Any cyclo-disparity is likely to mask under the significant sensory component of sensory cyclofusion where motor cyclovergence need not play.[2,6] Nevertheless, it is fair to assume cyclo-disparity as an obstacle for obtaining or maintaining binocular single vision in intermittent exotropia.[1] Subjective tests like the double Maddox-Rod test, Lancaster red-green test, Bagolini test, synoptophore, etc., are widely used to assess this disparity.[6,7] However, these measurements are be constrained by sensory adaptation to fundus torsion over time, particularly if cyclotorsion appears during early childhood.[2,8,9] These incomitant deviations have large inter-observer variability as well.[6]

Direct observation of the fundus, iris photography, fundus OCT, and fundus photography have been proposed to objectively assess ocular torsion.[1,7,10] For the purpose of this study, we used Spectralis SD-OCT. Fovea and Bruch's membrane orifice centroid is automatically traced, and ocular torsion is revealed relative to the acquired image frame horizontal axis (**Figure 1**).[11-13] We used cover tests and prism

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cover tests with prescribed glasses to measure and group IXT into convergence insufficiency (CI), divergence excess (DE), and basic types. We also used the revised Newcastle home and clinical control scores to mark the presentation of IXT and stereoacuity to observe the status of binocular single vision.

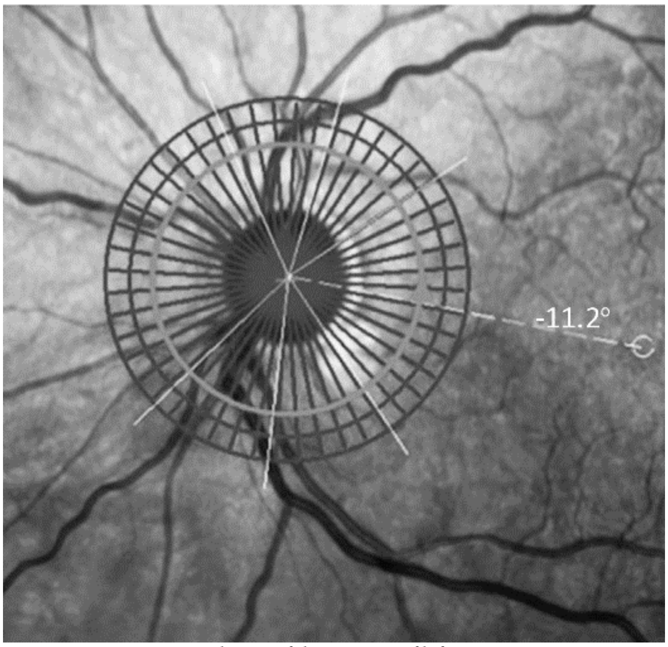

Figure 1. Automatic revelation of the amount of left eye extorsion in SDOCT

SDOCT: Spectral domain optical coherence tomography

measure the amount of IXT using a prism bar. With the amount of deviation at near and distance, we segregated the participants into different groups of intermittent exotropia. The groups with greater than 8 PD of exo-deviation at near than at a distance was termed the convergence insufficiency (CI) group, while the reverse one was called divergence excess (DE) group. If greater than 8 PD of exo-deviation was present at both distances with less than 8 PD difference, it was termed the Basic group. We also enrolled less severe cases with less than 8 PD of deviation as control group. Stereoacuity was measured using the Titmus stereo test. The dominant eye was determined using a hole in the card test in conjunction with the near point of convergence test.

Table 1. Scoring of Intermittent exotropia based on Revised Newcastle Control Score[6,19]

Home control score	
0	Deviation is never seen
1	Deviation is seen <50% of time fixing at distance
2	Deviation is seen >50% of time fixing at distance
3	Deviation is seen >50% of time fixing at distance and near
Clinic control (near/distance)	
0	Immediate realignment after dissociation
1	Realignment with aid of blink or refixation
2	Remains manifest after dissociation/prolonged fixation
3	Manifest spontaneously
Total score	Home Score+Near Score+Distance Score

METHODS

The study was carried out with the permission of the Institutional Review Committee, Institute of Medicine, Tribhuvan University, Kathmandu, Nepal (Date: 17.08.2022, Decision No: 147(6-11)E2, 079/080). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

This observational study was conducted at B.P. Koirala Lions Centre for Ophthalmic Studies, Kathmandu, Nepal. We enrolled participants with different types of intermittent exotropia from 8 to 35 years old having visual acuity of 6/9 or better. We avoided children below 8 years of age because of poor application of orthoptic tests on them. Sample size was calculated after considering the prevalence rate of intermittent exotropia 5.16%.[14] Neurological paralytic squints, mechanical squints, myogenic squints, alphabet pattern strabismus, dissociated vertical deviations, developmental disabilities, previous history of strabismus surgery, myopia or hypermetropia >3.00 D, anisometropia >1.5 D, and astigmatism >1.5 D were all excluded from the study. Other conditions, such as nystagmus, albinism, microphthalmia, retinopathy of prematurity, congenital cataracts, etc., were also excluded. To avoid any sorts interobserver errors, all the tests were administered by the principal researcher himself.

Participants were asked about the frequency of onset of strabismus at home to determine the revised Newcastle Home Control Scale (NHCS) scores and cover tests were performed at both near (33 cm) and distance (6 meters) fixation distances to obtain the revised Newcastle Clinical Control Scale scores as Newcastle Near Control Scale (NNCS) and Newcastle Distance Control Scale (NDCS) scores (Table 1). Prism cover tests were also done at both distances to

We used spectralis spectral domain optical coherence tomography (SDOCT) (Heidelberg Engineering GmBH, Heidelberg, Germany) for the measurement of disc to fovea angle as ocular torsion. The patient with their refractive correction was required to sit maintaining the appropriate head, chin and canthus positions. During optic nerve head-radial and circle (ONH-RC) scans, the patient first fixates on the inner central target whereby machine completes foveal scans and captures grayscale photograph. Later patient fixates on the nasal target whereby the machine completes optic disc scans. Now on earlier greyscale map, exact foveal location, center of optic disc and angle between them is traced. No mydriatics or cycloplegics were used.

We used SPSS version-26 for analysis. p-value <0.05 is considered statistically significant. We used Spearman's correlation when at least one of the variables is ordinal like stereopsis, Newcastle scores, prism cover test etc. and Pearson's correlation only when both the variables are continuous like ocular torsion. Correlation coefficient which is not significantly different from 0 indicated no correlation and if significantly different from 0 and <0.2, it is considered weakly correlated. Likewise, 0.2-0.5 is considered moderately correlated and the value of >0.5 is considered strongly correlated.

RESULTS

A total of 84 participants with age of 8 to 35 years were enrolled; 20 controls had orthophoria or below 8 PD of phoria at any distance, 27 had CI type of IXT, 16 had DE type of IXT, and 21 had the Basic type of IXT. The mean age of respective groups was 20, 19, 16 and 21 years. Only 18% of individuals had left dominant eyes. (Table 2).

Table 2. Average age, gender count, and dominant eyes count				
	Control	**CI**	**DE**	**Basic**
Age (years, mean±SD)	20±7	19±7	16±7	21±9
Male (count)	7	8	6	8
Female (count)	13	19	10	13
Right eye dominant (count)	18	23	11	17
Left eye dominant (count)	2	4	5	4

CI: Convergence insufficiency, DE: Divergence excess, SD: Standard deviation

On observing the Newcastle Control Scale Scores, each score in the control group was obtained 0 (0-0). The total median score was lowest in the CI group i.e., 1 (1-2), followed by 4 (2-8) in the DE group and it was highest i.e., 5 (3-6) in the basic group. The total score in the CI group was derived from the Newcastle Near control Scale (NNCS) score alone. To the DE group, Newcastle Home Control Scale (NHCS) score and Newcastle Distance Control Scale (NDCS) scores contributed. Meanwhile, to the basic group, all of three Newcastle Control Scale Scores contributed (Table 3). The difference in Newcastle scores of different groups was found statistically significant (0.000, Pearson's chi-squared test).

Table 3. Median and 95% Confidence Interval of Newcastle Scores					
	Control	**CI**	**DE**	**Basic**	**p-value***
NHCS Score	0 (0-0)	0 (0-0)	1.5 (1-3)	1 (0-2)	0.000
NNCS Score	0 (0-0)	1 (1-2)	0.5 (0-2)	2 (1-2)	0.000
NDCS Score	0 (0-0)	0 (0-1)	2 (1-3)	2 (1-2)	0.000
Total score	0 (0-0)	1 (1-2)	4 (2-8)	5 (3-6)	0.000

Pearson's chi-squared test, NHCS: Newcastle Home Control Scale, NNCS: Newcastle Near Control Scale, NDCS: Newcastle Distance Control Scale, CI: Convergence insufficiency, DE: Divergence excess, p-value of <0.05 indicates statistically significant finding

The median stereopsis (seconds of arc) in different groups are found as, 40 (40-40) in control group, 40 (40-80) in CI group, 45 (40-140) in DE group and 40 (40-60) in the basic group. We found no significant differences in stereopsis among these groups (p-value-0.65, Chi-square test). The mean amount of deviation of different groups at near and distance fixations is shown in Table 4. The amount of deviation fits with the nature of each group respectively (p<0.001, chi-square test).

Table 4. Mean amount of deviation of different groups at near and distance fixations				
	Control	**CI**	**DE**	**Basic IXT**
Near (PD)	-1.1±1.8	-16.4±7.7	-13.1±7.4	-19.8±7.1
Distance (PD)	0±0	-5.3±5.9	-26.9±8.6	-19.5±7.5

A negative value means exo-deviation and a positive value implies eso-deviation, CI: Convergence insufficiency, DE: Divergence excess, IXT: Intermittent exotropia, PD: Prism diopters

The anatomical ocular torsion of different IXT groups is shown in Table 5. The differences were not found statistically significant (p-value: >0.05, 1-way ANOVA). Within an individual, left eye was found more extorted by an average of 3.4±4.3 degrees than the right eye (p-value: <0.000, T test). There was no statistically significant difference in ocular torsion in terms of dominant eye (p-value: >0.05, T test).

On performing different correlations we found that, Newcastle Home Control Scale (NHCS) score correlated strongly with near prism cover test (PCT) [n (71)=.521, p=0.000] and distance PCT [n (71)=.756, p=0.000] (Figure 2). Stereopsis was moderately correlated with near PCT [n (71)=.377, p=.001] (Figure 3) and NNCS [n (71)=0.376, p=.001] (Figure 4) but not correlated with NHCS [r (71)=.155, p=0.197]. We couldn't find any correlations between ocular torsion of neither eye with any of age, Newcastle score, stereoacuity and amount of prism deviation for near as well as distance (Table 6). We also couldn't find the correlation between the torsion of two eyes [n (71)=.127, p=0.291]. Rather, we found a strong positive correlation between the amount of near and distance exo-deviation [r (71)=.725, p=0.000] (Figure 5).

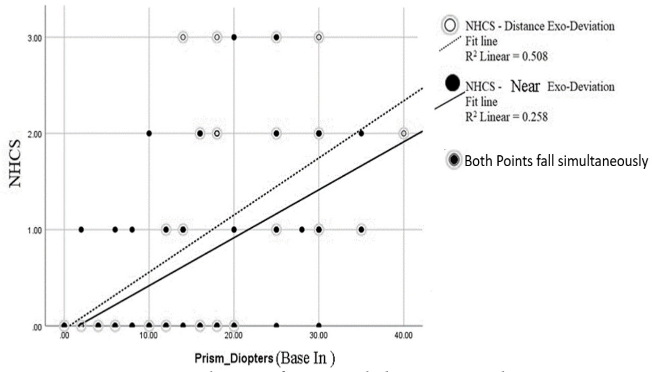

Figure 2. Positive correlation of near and distance exo-deviation in prism diopters with Newcastle Home Control Scale Score

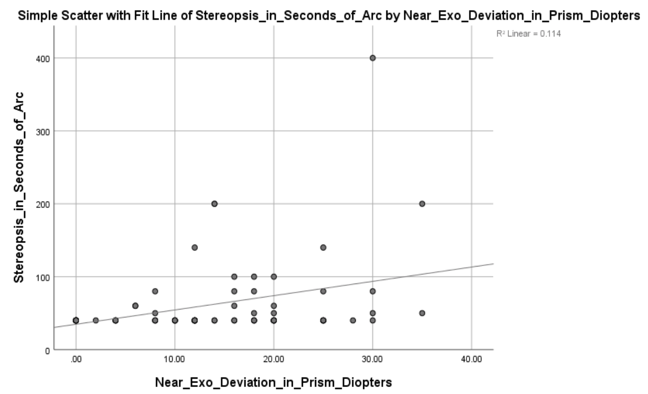

Figure 3. Positive correlation between near exo-deviation in prism diopters and stereoacuity

Table 5. Mean ocular torsion (in degrees) of left and right eyes of different groups					
	Control	**CI**	**DE**	**Basic IXT**	**p-value***
Right eye	-4.3±2.7	-4.9±2.8	-6.1±2.3	-4.7±3.2	0.6
Left eye	-7.6±2.7	-7.5±3.4	-10.8±4.0	-8.5±4.0	0.1
Average	-5.98±1.82	-6.21±2.44	-8.43±2.63	-6.64±2.49	0.1
Difference, p-value**	3.3±4.1, 0.007	2.7±3.8, 0.001	4.7±3.8, 0.01	3.8±5.2, 0.003	0.63

**The negative value indicates extortion, One-Way ANOVA test, Paired sample T test between right and left eye, CI: Convergence insufficiency, DE: Divergence excess, IXT: Intermittent exotropia, p-value of <0.05 indicates statistically significant finding

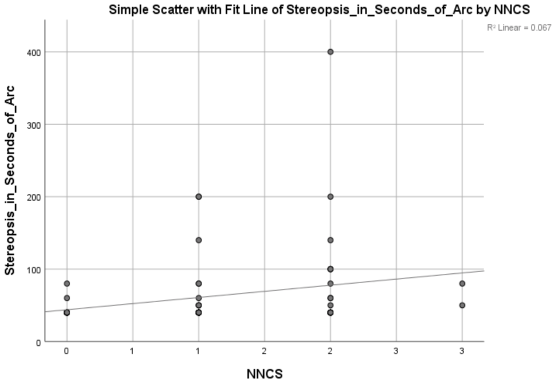

Figure 4. Positive correlation between Newcastle Near Control Scale Score and stereopsis

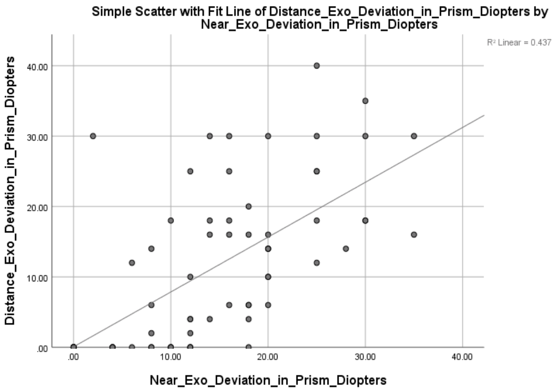

Figure 5. Positive correlation between near exo-deviation and distance exo-deviation in prism diopters

DISCUSSION

This study objectively measured ocular torsion in IXT and investigated potential correlations with the deviation severity and stereo acuity. Contrary to the initial hypothesis, the study did not reveal a significant relationship between objectively measured ocular torsion and stereoacuity or the severity of intermittent exotropia indicated by prism cover test amounts. On the other hand, stereopsis was found to correlate with the amount of near deviation. Thus, while the amount of near deviation has an influential role on stereopsis but the lack of clear correlation with anatomical ocular torsion measured with OCT method challenges the presumed impact of torsion on binocular vision perception.

Kang et al.[7] found that, the findings of ocular torsion measured using fundus photography and OCT correlated with each other. Si et al.[12] also showed the usefulness of OCT in the measurement of ocular torsion. Although the amount of ocular torsion measured is comparable to our study, the implications on binocular vision were besides the scope of these studies. On the other hand, Georgievski et al.[5] adjusted synoptophore targets to present varying degrees of torsional disparity and demonstrated that torsional disparity of 6 degrees or more significantly degrades horizontal fusional vergence and stereopsis. The test is completely sensory and has no link to anatomical torsion.

Morton et al.[8] discusses the usefulness of fundus photography in diagnosing vertical strabismus and found that fundus torsion strongly correlates with oblique muscle dysfunction. Kushner et al.[11] shared that objective and subjective torsion have different roles. Objective torsion can be useful in motility pattern caused by oblique or vertical muscle dysfunction where subjective torsion is mostly meaningless. But at other instances, the measurement of subjective torsion is to consider torsion as a part of the treatment plan. They also suggested that those who develop torsion during their childhood may not report to the subjective test. And there may or may not be correlation in between these two tests. Anatomically, torsional angle has a wide range of normal variation that doesn't hinder fusion. When vertical prisms were placed, in about 80 % of asymptomatic cases, the vertical deviation was induced for a short interval and it is considered as the manifestation of previously physiologically compensated deviation.[15,16] In contrast, when vertical prisms were placed in the symptomatic cases, they didn't develop vertical deviations indicating that there were no prior compensated deviations which would decompensate.[6,17] This bizarre nature comprising of wide normal range, compensation and decompensation, etc. indirectly indicates that anatomical torsional angle amid subjective findings is just an arbitrary value within a certain range.

Lee et al.[18] demonstrated that vertical deviation and extorsion measured with fundus photography decreases significantly after horizontal muscle surgery in patients with IXT and unilateral inferior oblique muscle overaction. Although they associated objectively measured vertical and cyclo deviations with IXT, the improvement in stereoacuity following surgery was found insignificant which stills questions the subjective implications of such deviations on IXT.

While using optical coherence tomography (OCT) for objectively assessing ocular torsion, we have a greater advantage of locating the fovea and drawing the disc margins because OCT utilizes cross sectional images to plot them in the grayscale picture of retina taken in the primary position of gaze and is automatic. However, lack of correlations between ocular torsion and the severity of exodeviation-measured with prism cover tests and Newcastle Control Scale scores or stereoacuity raises the question about the role of anatomical torsion in non-strabismic binocular vision disorders. Therefore, this study questions the possibility of interchangeably using subjective and objective methods

Table 6. Spearman's correlation coefficient between ocular torsion and stereopsis, Newcastle Scores near and distance deviation

	Age	Stereopsis	NHCS	NNCS	NDCS	Near deviation	Distance deviation
Torsion OD	.066	.058	-.024	-.157	-.081	-.054	.000
p-value	.582	.629	.846	.190	.503	.653	.998
Sample size	71	71	71	71	71	71	71
Torsion OS	.123	.049	-.173	-.026	-.094	.069	.176
p-value	.305	.687	.149	.830	.436	.568	.142
Sample size	71	71	71	71	71	71	71

NHCS: Newcastle Home Control Scale, NNCS: Newcastle Near Control Scale, NDCS: Newcastle Distance Control Scale, p-value of <0.05 indicates statistically significant finding of measuring ocular torsion and cyclodeviations as also described by Kushner et al.[11]

Limitations

Although ocular torsion measurement using OCT demonstrates higher interobserver agreement over fundus photo methods, the use of an inner target disrupts sensory fusion, and the machine used in this study lacks a mechanism to control for fusion. We also felt that the subjective ways of measuring cyclodeviations and symptom scores would further support the findings of this study.

CONCLUSION

While this study objectively measured ocular torsion in intermittent exotropia, it did not establish significant correlations between anatomical torsion and the severity of deviation or stereo acuity. It claims the futility of objective ways of measuring anatomical torsion in non-strabismic binocular vision disorders. The revised Newcastle Control Scale was found remarkable in monitoring the progression of the intermittent exotropia.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Institutional Review Committee, Institute of Medicine, Tribhuvan University, Kathmandu, Nepal (Date: 17.08.2022, Decision No: 147(6-11)E2, 079/080).

Informed Consent

Informed consent was taken from either the patients or their guardians before data collection. Anonymity was maintained. No additional risk of any type was introduced to the patients during this study.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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