Type of strabismus and changes to fusion measures

C. Lança
Lisbon School of Health Technology, Portugal

ABSTRACT: Introduction/*Purpose*: The aims of this study were to compare fusional vergence measurements between orthophoria, esophoria and exophoria and to determine the strength of correlations between fusional convergence and divergence, and angle of deviation. *Methods*: A cross-sectional study was performed in children with best-corrected visual acuity of 0.0 LogMar in either eye, compensated heterophoria within 10 prism dioptres, full ocular rotations, presence of fusional vergence and stereopsis (60 seconds of arc or better). Fusional amplitudes were compared between orthophoric and heterophoric children. The fusion reserve ratio (FRR) was used to assess the effect of the underlying angle of deviation and children with a FRR<2.0 were excluded from the study.*Results*: Five-hundred and thirty children (7.66±1.20 years) were recruited to this study. The most common heterophoria was exophoria (n=181, 34.2% for near; n=20, 3.8% for distance). Exophoric children had significant lower mean positive fusional vergences (exophoria-orthophoria: p=0.003; exophoria-esophoria: p=0.035) for near (19.54±5.23 base-out) compared with children with orthophoria (20.48±4.83 base-out) and esophoria (22.27±5.60 base-out). Smaller convergence fusion amplitudes were associated with larger angles of deviation at near (r_s=-0.115; p<0.008) and lower fusion reserve ratios were associated with larger angles of deviation at distance (r_s=-0.849; p<0.001) and at near (r_s=-0.821; p<0.001). *Conclusions*: Exophoric children have reduced convergence break points when compared with orthophoric and esophoric children. Vergence measurements, taking into consideration the baseline heterophoria, give important information about the ability of the patient to increase their vergence demand and maintain ocular alignment.

1 INTRODUCTION

Assessing the range of fusional vergence constitutes one of the most important diagnostic tools to provide information about the ability to maintain binocular vision.[1-3] Disparity vergence or motor fusion amplitude measurements should be used to quantify control of an underlying eye misalignment.[4,5] The prism bar or rotary prism is slowly increased until fusion cannot be maintained (break point). This simulates an increase in the strabismic angle and the break point estimates just how much deviation the patient can compensate before eye misalignment. Then the prism is slowly reduced until fusion is regained (recovery point). In the presence of a manifest deviation the testing is performed by first correcting the angle of deviation[3] with a prism bar, rotary prism, or on the amblyoscope[4] to then determine fusional vergence.

The degree and type of fusional vergence required for binocular viewing varies directly with the size and direction of the heterophoria.[6,7] Convergence fusion amplitudes have been found to correlate with control of the exodeviation.[8] However, type of deviation versus measured fusional vergence does not receive much attention in the literature. A difference has been reported between fusional vergence for eso versus exo deviations with a greater base-out range for esos and greater base-in range for exos.[13] However, the difference did not reach significance.

The purpose of this study has been to (1) compare fusional vergence measurements between orthophoria, esophoria and exophoria; (2) determine the strength of correlations between fusional convergence and angle of deviation.

2 METHODS

A cross-sectional study was performed with data from typically developing children between ages of 6 to 14 years. Inclusion criteria included a best-corrected visual acuity of 0.0 LogMAR in either eye, heterophoria within 10 prism dioptres with no decompensation to intermittent strabismus, full ocular rotations, presence of fusional vergence and stereopsis (60 seconds of arc or better). Each child had an orthoptic assessment in an emmetropic state (wearing habitual refractive correction, if required, to achieve inclusion criteria) conducted by the same orthoptist to avoid variability between examiners: distance visual acuity, ocular alignment, fusional amplitudes measured by the step method with prisms, stereoacuity, near convergence point and near accommodation point and ocular movements.

Exclusion criteria included children with manifest strabismus, microtropia or abnormal ocular motility.

The fusion reserve ratio was calculated (to assess the effect of the underlying angle of deviation) as fusional convergence divided by prism alternating cover test measurement. According to Sheard's criterion The fusion reserve should be twice the magnitude of the angle of deviation[9] corresponding to a fusion reserve ratio of 2.0.[8] Children with a fusion reserve ratio < 2.0 were excluded from the study.

3 RESULTS

Five-hundred and thirty children were included in this study. The mean age of the children was 7.66±1.20 (range 6 to 14) years. There were 280 females (52.8%) and 250 males (47.2%). The most common heterophoria was exophoria (n=181, 34.2% for near; n=20, 3.8% for distance). The median angle of deviation was 4PD (2 to 10PD) at near fixation (n=181) and 4PD (2 to 4PD) at distance (n=20) for exophoric children and 6PD (2 to 10PD) at near fixation (n=22) and 4PD at distance (n=1) for esophoric children.

Table 1 details the prism fusion range at near and distance fixation for orthophoria, esophoria and exophoria groups.

Table 1 – heterophoria and fusional amplitudes.

Heterophoria	Fusional amplitudes	Mean	Std. Deviation	Median
Orthophoria	Near PFV	20.48	4.83	20.00
	Distance PFV	13.10	3.22	12.00
	Near NFV	9.57	1.96	10.00
	Distance NFV	6.97	1.83	8.00
	Near PFV	22.27	5.60	20.00
	Distance PFV	14.00	0.00	14.00

Esophoria	Near NFV	9.64	2.11	10.00
	Distance NFV	6.00	0.00	6.00
	Near PFV	19.54	5.26	18.00
Exophoria	Distance PFV	12.60	2.44	12.00
	Near NFV	9.96	2.02	10.00
	Distance NFV	7.20	1.20	8.00

Legend: PFV – positive fusional vergence; NFV – negative fusional vergence;

The average fusional convergence and divergence for distance were 13.08±3.19 and 6.98±1.81, respectively. Near fusional convergence and divergence fusional values were 20.23±5.04 and 9.71±1.99, respectively.

Exophoric children had lower mean positive fusional vergences for near (19.54±5.23 base-out) and distance (12.60±2.44 base-out) compared with children with orthophoria and esophoria (Figure 1). This difference was statistically significant for near (exophoria-orthophoria: p=0.003; exophoria-esophoria: p=0.035). There were no statistically significant differences in other fusional amplitude measurements between the groups.

There was a significant but small inverse correlation between fusional convergence and angle (ie, smaller fusion reserves associated with larger angles) at near (r_s=-0.115; p<0.008). There was a strong significant inverse correlation between fusion reserve ratio and angle (ie, lower fusion reserve ratios associated with larger angles) at distance (r_s=-0.849; p<0.001) and at near (r_s=-0.821; p<0.001).

4 DISCUSSION

A shift towards base-out range was seen in esophoric children while a shift towards the base-in range was seen in exophoric children. This result is in accordance with other studies reporting a skewed vergence range in adults with exophorias having a bias towards the divergent range and the reverse for esophoric subjects.[7,10,11]

In the present study we observed that exophoric children had significant lower positive fusional vergences for near compared with children with orthophoria and esophoria. According to Dowley,[10] exophoric adults have a significant reduced base-out prism adaptive response when compared to orthophorics. The author hypothesized that exophoria exists due to a partial failure of convergence and esophoria due to a failure in divergence. When the exophorias diverge, exophoria may enhance the divergence movement because the natural tendency for the eyes to move outward to its phoria position.[7] When convergence is stimulated an inhibition of the natural tendency to diverge occurs, which results in a reduction of convergence peak velocity.

The present findings suggest that heterophoria has an important role within the vergence system and fusion measures should take these findings in consideration. Previous studies concluded that negative fusional vergence should be measured first to avoid affecting the vergence recovery because of excessive stimulation of convergence.[1,12-14] Other authors argue that the base of the prism should be placed in the direction opposite to that used to measure the deviation so as to increase the vergence demand.[4,13]

No correlation was found between distance fusional convergence and distance angle. The results of this study are in accordance with Hatt *et al.*[8] who studied a cohort of children with intermittent exotropia. Also similar to our results smaller fusion reserves were associated with larger angles and vice versa at near[12]. However, in the present study children had heterophorias with an angle of deviation ≤ 10DP and lower correlation strength. Lower fusion reserve ratios were associated with larger angles at distance and near.

5 CONCLUSIONS

In conclusion this study showed that exophoric children have reduced convergence break points when compared with orthophoric and esophoric children. Vergence measurements which take into consideration the baseline phoria provide important information about the ability of the patient to increase the vergence demand and maintain ocular alignment. For eso deviations, the base-in range should be measured first as an indicator of divergence control whereas for exo deviations, the base-out range should be measured first to indicate the convergence control.

REFERENCES

1. Fray KJ. Fusional amplitudes: exploring where fusion falters. *Am Orthopt J.* 2013;63:41-54. doi:10.3368/aoj.63.1.41.
2. Ciuffreda M, Ciuffreda K, Wang B. Repeatability and variability of near vergence rasnges. *J Behav Optom.* 2006;17(2):39-46.
3.Narbheram J, Firth A. Prism fusion range: blur point, break point, and recovery point. *Br Orthopt J.* 1997;54(2):2-6.
4. Arnoldi K. *Orthoptic Evaluation and Treatment.* (Wilson ME, Trivedi RH, Saunders RA, eds.). Berlin, Heidelberg: Springer Berlin Heidelberg; 2009. doi:10.1007/978-3-540-68632-3.
5. Arnoldi KA, Reynolds JD. Assessment of amplitude and control of the distance deviation in intermittent exotropia. *J Pediatr Ophthalmol Strabismus.* 2008;45(3):150-153; quiz 154-155. doi:10.3928/01913913-20080501-05.
6.Sreenivasan V, Irving EL, Bobier WR. Effect of heterophoria type and myopia on accommodative and vergence responses during sustained near activity in children. *Vision Res.* 2012;57:9-17. doi:10.1016/j.visres.2012.01.011.
7. Kim EH, Granger-Donetti B, Vicci VR, Alvarez TL. The relationship between phoria and the ratio of convergence peak velocity to divergence peak velocity. *Investig Ophthalmol Vis Sci.* 2010;51(8):4017-4027. doi:10.1167/iovs.09-4560.
8.Hatt SR, Leske DA, Mohney BG, Brodsky MC, Holmes JM. Fusional convergence in childhood intermittent exotropia. *Am J Ophthalmol.* 2011;152(2):314-9. doi:10.1016/j.ajo.2011.01.042.
9. Sheard C. Zones of ocular comfort. *Am J Optom.* 1930;7(1):9-25.
10. Dowley D. Heterophoria. *Optom Vis Sci.* 1990;67(6):456-460.
11.Rowe FJ. Fusional vergence measures and their significance in clinical assessment. *Strabismus.* 2010;18(2):48-57. doi:10.3109/09273971003758412.
12. Rosenfield M, Ciuffreda K, Ong E, Super S. Vergence adaptation and the order of clinical vergence range testing. *Optom Vis Sci.* 1995;72(4):219-23.
13. Noorden G von, Campos E. *Binocular Vision and Ocular Motility: Theory and Management of Strabismus.* 6th ed. St Louis: Mosby; 2002.
14. Cooper J. Clinical implications of vergence adaptation. *Optom Vis Sci.* 1992;69(4):300-7.

TRANSACTIONS

of the

37th European Strabismological Association (ESA) Meeting

October 1-4, 2015

Venice, Italy

Edited by

Daniela Eleonora Cioplean

Ophthalmology Clinic OFTAPRO
Bucharest, Romania