SciMedCentral JSM Ophthalmology

Research Article

Effectiveness of Unilateral or Alternating Methods Employed to Measure Phoria When Targets Get Deviated From Midline among School Children

Lavanya Kalikivayi, Ruksana Salim, Sajeev Cherian Jacob, and Venkataramana Kalikivayi

Ahalia School of Optometry, Palakkad, India
Ahalia Foundation Eye Hospital, Palakkad, Kerala, India

***Corresponding author**
Lavanya Kalikivayi, Asst.Professor, Ahalia School of Optometry, Palakkad, Kerala, 678557, India, Email: lavanyakalikivayi@yahoo.com

Submitted: 08 August 2020
Accepted: 20 August 2020
Published: 22 August 2020
ISSN: 2333-6447

Keywords
- Heterophoria
- Motor and Sensory mechanism
- Vergence
- Accommodation

Abstract

To maintain a clear vision in dynamic environment, both accommodative and vergence facilities are imperative, though they are asymmetrical between the eyes. This asymmetrical vergence leads to non strabismic anomalies in children. The position of the targets while measuring these phoria and the method of measurement employed plays an important role in concluding the amount of heterophoria present. The influence of this asymmetry and consequently the interactions between the motor and sensory mechanism in producing heterophoria were measured by alternate cover test (ACT), with reference to the amount of phoria measured independently in each eye through cover/uncover test (PBCT), and modified thorington test (MTT), in children. The results revealed a statistically significant difference in the measurement of heterophoria for distance between ACT, PBCT and by MTT both between the groups and within the groups with a $p < 0.00$. A statistically significant difference was found between ACT and PBCT with prism in front of the right eye for near with $p = 0.025$ and between ACT and MTT with Maddox rod in front of right eye for a near target with $p = 0.004$. Similarly, a statistically significant difference was found between ACT and PBCT with prism in front of the left eye for near with $p = 0.018$ and between ACT and MTT with Maddox rod in front of left eye for a near target with $p = 0.009$. This study emphasizes to measure heterophoria through cover/uncover test which is more pertinent with the dynamic spatial environment than ACT during school screening programs.

INTRODUCTION

Binocular single vision is defined as the perception of simultaneous vision with coordinated use of both eyes to produce a single vision when an individual's attention is on an object of regard. Proper development of motor and sensory mechanism along with a proper mental process is essential. Additionally, to maintain a clear vision in a dynamic environment, it involves both accommodative facility and vergence facility. Accommodation helps in focusing the objects at various distances and the vergence system helps in aligning the eye accordingly [1]. Unlike infants, as a child grows, blur is not the only stimulus for accommodation. It involves all the different types of accommodations along with fusional convergence in variable proportions depending on the viewing environment [2].

Another factor that requires consideration is, for a given stimulus at a particular distance, the amount of accommodative and associated vergence is asymmetrical between the eyes. When a target is moved nearer, it gets displaced off the midline, and the resultant adduction will be asymmetrical with dynamic properties of slow vergence and abnormalities of this vergence may contribute to non-strabismic anomalies in childhood [3].

Apart from non-strabismic anomalies, this asymmetry can cause physiological heterophoria. This heterophoria may lead to altered stereo acuity. The literature states that distance stereo acuity is achieved to adult levels by approximately 5 years [4]. In spite of stereo acuity development completion, children with heterophoria exhibit altered stereo acuity, more with esophoria than with exophoria [5,6].

Earlier studies revealed that a proper visual function and motor integration are important factors for good academic performance in a child [7]. It is an established fact that prevalence of non- strabismic anomalies of binocular vision are high among school children and hence screening of these along with refractive errors are important [8,9]. Another study stated that a significant increase in myopia occurs owing to the presence of head tilt in children while writing. This asymmetrical viewing angle between eyes lead to asymmetrical vergence and induced hyperopic defocus between the eyes [10].

All these led to the thought that the total phoria measured are not equally distributed between the eyes. Hence the aim of the study is to find out the impact of targets deviated from midline while measuring phoria among school children.

MATERIALS & METHODS

A cross-sectional study with 349 subjects between 7 and 18 years were enrolled in the study, of which 180 were girls and 169 were boys. All the subjects were selected by simple random sampling from a school in Kerala.

Subjects without symptoms, with a best corrected visual acuity of < 0.2 logMAR (6/9), for distance and N6 for near in both the eyes, normal ocular motility, and no manifest deviation were included in the study. Subjects with ocular pathology, previous ocular surgeries, nystagmus, amblyopia, and contact lens wear were excluded from the study.

The study followed the tenets of the Declaration of Helsinki and got approved by the Institutional ethics committee. Informed consent was obtained from the school authorities and acceptance from the parents. Each child was explained before the commencement of procedures. All the procedures were executed by the same examiner who was well experienced as per optometric practice.

Vision assessment, objective and subjective refraction, ocular motility, the amplitude of accommodation using RAF ruler, and the near point of convergence were measured [11-14], Following these procedures, ocular deviation, and stereo acuity were measured as explained below.

A standard cover/uncover and alternate cover tests were performed followed by prism bar cover test (PBCT). The PBCT was performed for each eye separately and also together. The subject was given a target at 3 meters to fixate which was not precisely at midline. Initially, with the left eye fixating on the target, PBCT through cover/uncover test with an occlusion time of 2 seconds was done on the right eye and the strength of the prism with which no recovery movement of the eye undercover was noted. This was noted as the amount of phoria in the right eye. The same procedure was repeated in the left eye and recorded. Similarly, the entire procedure for both right and left eye was done for a near target at 40 cm [15], following which, the alternate cover test (ACT), with prisms was performed for both distance and near in a conventional way [16]. The occlusion time of 2 seconds was maintained while performing ACT too.

As PBCT was an objective method, Modified Thorington test (MTT), was performed for a subjective measurement which is more reliable than other subjective methods [17].

Similar to PBCT, MTT was also performed for each eye separately. A Maddox rod was placed in front of the right eye with horizontal orientation. Penlight was shone from behind the hole of the MTT card at 3 meters which was also not positioned exactly at midline. The subject was asked to report if the straight line produced by the Maddox rod was to the right or left to the spot. This value was recorded as the phoria of the right eye [18]. The same procedure was repeated with Maddox rod in front of the left eye and recorded as phoria of the left eye, and the whole procedure was executed for near at 40 cm too.

The stereo acuity was measured using a TNO random test as the measurement is devoid of monocular cues, and a more critical judge than other methods employed in stereo acuity measurements [19].

Descriptive statistics were computed for all the parameters. As a conventional practice, exophoria was expressed with a negative sign and esophoria with a positive sign. The limits of agreement (LOA), between the two different methods of heterophoria measurement (PBCT-objectively and MTT-subjectively) were found using Bland Altman plots, which defined LOA = mean difference ± 1.96 x standard deviation of the differences between two methods. MedCalc was used to fit the data and graphical representation. ANNOVA test for comparing the means of equal variance was used to compare the difference in phoria measured by ACT, PBCT, and MTT, for distance and near (SPSS16.0). Simple linear regression was performed to analyze the effect of heterophoria on stereo acuity.

RESULTS

Out of 349 children between 7 and 18 years, 51.5% (180), were girls and 48.5% (169), were boys. The mean age of the sample was 11.5 ± 3.01 years. The distributions of refractive errors were 3.44 % of hyperopia with a mean spherical equivalent of + 1.02 D ± 0.77, 15.76 % of myopia with a mean spherical equivalent of – 1.64 D ± 1.37 and 80.80 % of emmetropia.

The prevalence of heterophoria for distance was found in 92 subjects (26.36%), and that for near was in 174 subjects (49.86%). Out of this 92 and 174 subjects, the heterophoria measured through cover/uncover test with PBCT showed varied responses between the eyes. The distribution of these are represented in Tables 1 and 2 for distance and near respectively.

The agreement between PBCT and MTT for right and left eye separately was performed using Bland Altman analysis. The mean difference between the two methods for distance was found to be -0.4 (CI 6.5, -7.3), and -0.4 (CI 3.1,-3.9), in the right and left eye respectively. Likewise, the mean difference between the two methods for near was found to be 0.1 (CI 2.55, -2.35), and 0.1 (CI 2.2, -2.0), in the right and left eye respectively. This states that both methods were agreeable to each other and can be used to measure alternatively.

The mean phoria exhibited by ACT was 1.60Δ ± 0.51 exophoria for distance and for near was 1.69Δ ± 0.51 exophoria. The mean phoria measured through cover/uncover test with prisms in front of the right eye for distance was 0.56Δ ± 4.10 esophoria and that for near was 1.13Δ ± 3.53 exophoria. Similarly, the mean phoria measured through cover/uncover test with prisms in front of the left eye for distance was 0.87Δ ± 3.89 esophoria and for near was 1.05Δ ± 3.76 exophoria. The mean phoria measured by MTT with Maddox rod in front of the right eye for a distance target was 0.20Δ ± 3.73 esophoria and for a near target was 0.99Δ ± 3.41 exophoria. Concurrently the mean phoria measured by MTT with Maddox rod in front of the left eye for a distance target was 0.47Δ ± 3.73 esophoria and for a near target was 0.99Δ ± 3.70

Table 1: Distribution of heterophoria in each eye with prism bar cover test (PBCT) and modified thorington test (MTT) for 3m distance.

Heterophoria	PBCT Right Eye		PBCT Left Eye		MTT Right Eye		MTT Left Eye	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Orthophoria	35.00	38.04	7.00	7.61	35.00	38.04	16.00	4.98
Exophoria	25.00	27.17	39.00	42.39	25.00	27.17	35.00	10.90
Esophoria	32.00	34.78	46.00	50.00	32.00	34.78	41.00	12.77

Table 2: Distribution of heterophoria in each eye with prism bar cover test (PBCT) and modified thorington test (MTT) for 40cm.

Heterophoria	PBCT Right Eye		PBCT Left Eye		MTT Right Eye		MTT Left Eye	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Orthophoria	17.00	9.77	45.00	25.86	29.00	4.78	54.00	8.89
Exophoria	104.00	59.77	82.00	47.13	97.00	15.97	78.00	12.84
Esophoria	53.00	30.46	47.00	27.01	48.00	7.90	42.00	6.92

exophoria. The mean heterophoria measured through different methods for both distance and near is presented in Table 3.

The mean heterophoria measured by ACT, PBCT with prism in front of the right eye for distance and MTT with Maddox rod in front of the right eye for distance were compared by ANNOVA and was found to be statistically significant both between the groups and within the groups with $p < 0.00$. Similarly, an ANNOVA was performed between ACT, PBCT with prism in front of the left eye for a distance target and MTT with the Maddox rod placed in front of the left eye with a target at distance revealed a statistically significant difference both between the groups and within the groups with a $p < 0.00$.

On the contrary, the mean heterophoria measured by ACT, PBCT with prism in front of the right eye for near and MTT with Maddox rod in front of right eye for a near target when compared by ANNOVA was not statistically significant between the groups but was found to be statistically significant within the groups. A statistically significant difference of $p = 0.025$ was found between ACT and PBCT, and a statistically significant difference of $p = 0.004$ was found between ACT and MTT. There was no statistically significant difference between PBCT and MTT.

Comparably, an ANNOVA when performed between ACT, PBCT with prism in front of the left eye for a near target and MTT with the Maddox rod placed in front of the left eye with a target at near revealed no statistically significant difference between the groups whereas a significant difference was found within the groups with a $p = 0.018$ between ACT and PBCT, and a $p = 0.009$ between ACT and MTT. No statistical significance was found between PBCT and MTT.

The influence of heterophoria on stereo acuity was analyzed with a simple linear regression and was not statistically significant ($R2 = 0.04$).

DISCUSSION

The study revealed a significant difference in the heterophoria measured through ACT when compared with PBCT and MTT. These alterations state that the accommodation and associated vergence for a stimulus at a particular distance is asymmetrical between the eyes. Further, on proximal movement of the target, it gets displaced off the midline, and the resultant adduction will be asymmetrical with dynamic properties of slow vergence. It was reported in spite of both eyes sharing common substratum in a natural viewing environment, it is necessary to test each eye separately to identify specific defects for precise diagnosis [3].

A study on the influence of eye position signals on perceived visual direction [20], proposed that the egocentric visual direction (EVD), is connecting the retinal image and signals from eccentric points in regard to the position of the eye in the head. The oculomotor commands are generated by the amalgamation of neural signals from conjugate and convergent eye positions, which grant the brain to restore separate eye position for each eye.

The movement of the eye and angular shift for distance and near is mathematically represented in Figures 1 and 2

Table 3: Means of heterophoria for distance and near measured through different methods.

Measurement Method	Heterophoria (PBCT)		Heterophoria (Alternate cover-uncover test) Δ
	OD Δ	OS Δ	
Distance PBCT with Cover-Uncover test	0.56 (±4.1) ESO	0.87 (±3.89) ESO	1.60 (± 0.51) EXO
Distance MTT	0.20 (±3.73) ESO	0.47 (±3.73) ESO	
Near PBCT with Cover-Uncover test	1.13 (±3.53) EXO	1.05 (±3.76) EXO	1.69 (± 0.51) EXO
Near MTT	0.99 (±3.41) EXO	0.99 (±3.70) EXO	

PBCT: Prism bar cover test, MTT: Modified thorington test, Δ: Prism Diopter, EXO: Exophoria, ESO: Esophoria

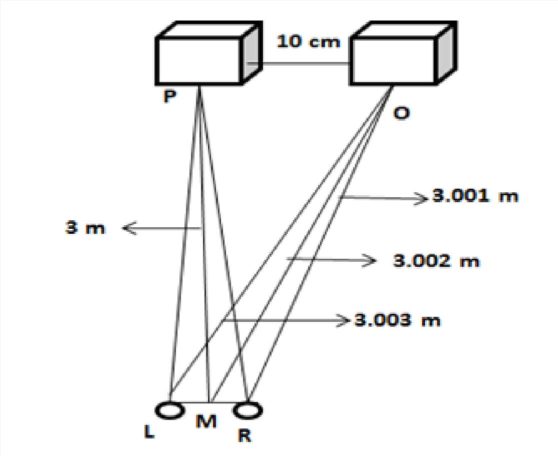

Figure 1 Mathematical representation of the eye movement associated angular shift for a target viewed at 3 meters distance.

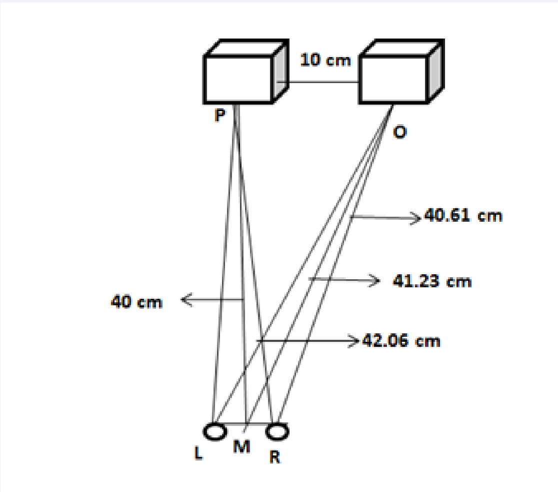

Figure 2 Mathematical representation of the eye movement associated angular shift for a target viewed at 40 meters distance.

respectively. The letters M, R, L in the figure are Midline for the right and left eye, P is the target placed exactly at midline and O is the target displaced by 10cm to the right side.

In a hypothecated example, the distance viewed by the right and left eye increase by 1mm and 3mm respectively if an object at 3 m is shifted to the right side by 10cm and vice versa if the shift is to the left side. The angle subtended by the right and left eye when viewing a target exactly at the 3m distance in the center is 85.89^0 i.e., ∠PLM/PRM is 4.11^0 inwards. The angular shift ∠OLM and ∠ORM with the displacement of the object by 10cm to the right side is 1.91^0 adducted and 5.73^0 abducted for the left and right eye respectively.

Similarly, when considered for an object placed at 40 cm for near, with a displacement by 10cm to the right side, the associated shift in the distance by the right and left eye is 6.1 mm and 20.6 mm respectively and vice versa if shifted to the left side. Similar to distance target, the angle subtended by the right and left eye when viewing a target exactly at a 40 cm distance in the center is 85.755^0 i.e., ∠PLM/PRM is 4.25^0 inwards. The angular shift ∠OLM and ∠ORM with a displacement of the object by 10 cm to the right side is 13.79^0 adducted and 14.11^0 abducted for the left and right eye respectively.

These calculations are helpful in understanding the asymmetry presented by each eye with minimal displacement, which are common during clinical examination settings. Generally, while performing a PBCT, the target is given to the patient to be held at 40cm, as the examiner holds both the occluder and the prism bar. A right or left side shift of the target is observed if the patient is right or left handed. Similarly, for distance, the target is not exactly placed at the midline of the patient. Further facial asymmetry and unequal distribution of inter pupillary distance (IPD), can contribute to varied heterophoria between ACT and cover/uncover measurements.

An earlier study reported that on quantitative analyses of the eye movements during cover/uncover test, the mean phoria after occlusion was $0.1^0 \pm 1.4$ esophoria for 3m distance and $1.6^0 \pm 2$ exophoria for near at 40 cm distance [21]. Whereas this study revealed a mean phoria of $0.71^0 \pm 1.99$ esophoria for 3 m distance and $1.09^0 \pm 1.82$ exophoria for near.

It was observed that 1.6Δ exophoria for distance with ACT altered to 1.43Δ esophoria with cover/uncover test. This drift can be attributed to the higher dissociation effect with ACT than cover/uncover test, while the tonic vergence of the fixating eye impacts the phoria of the other eye with cover/uncover test as opposed to ACT.

Conversely, for near, the 1.69Δ exophoria exhibited with ACT increases to 2.18Δ exophoria with cover/uncover test, which could be due to the equal disruption of accommodative convergence during ACT, whereas with cover/uncover test, the fixating eye exhibits more accommodation compared to the covered eye as observed with diagnostic occlusion.

From earlier studies, the prevalence of non-strabismic binocular vision anomalies among school children was 29.6% in rural India [8], hence it is appropriate to measure heterophoria through cover/uncover test which is more pertinent with the dynamic spatial environment than ACT during school screening programs. A study on the relationship between posture and myopia had stated that poor posture [22], principally neck angle had a significant relation to the degradation of unaided vision. Another study revealed that prolonged near reading of an hour or more, metamorphoses the resting postures of both accommodation and vergence [23]. The same study also alleged that changes in tonus accommodation are responsible for blurred distance vision after an hour of near reading and tonus vergence is responsible for visual fatigue. Besides the above rationale, the head tilts present when children are writing influence the increase in myopia as the asymmetrical viewing angle between the eyes impact the asymmetrical vergence and induced hyperopic defocus amidst the eyes [10]. Hence the importance of measuring phoria separately for each eye is befitting than measuring through ACT, as these motor mechanisms have an implication on the sensory mechanism in presenting heterophoria, thereby enhancing the cognition in children.

CONCLUSION

There is a significant difference in the measurement of heterophoria between cover/uncover test and ACT. Hence the importance of measuring heterophoria unilaterally for each eye through cover/uncover test cannot be more emphasized than measurements through ACT. These are beneficial in diagnosing non-strabismic binocular anomalies conclusively during school screening programs and routine clinical evaluations. These findings will be of value in children with myopia, to alter their reading and viewing posture appropriately for near in controlling the myopic progression. Unilateral measurements taken for each eye will be pragmatic for correction required when strabismic surgeries are performed monocularly. Further studies correlating these findings with the effect of AC/A ratio is recommended.

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Cite this article

Kalikivayi L, Salim R, Jacob SC, Kalikivayi V (2020) Effectiveness of Unilateral or Alternating Methods Employed to Measure Phoria When Targets Get Deviated From Midline among School Children. JSM Ophthalmol 7(1): 1072.