

# Clinical Effectiveness of Facility and Accuracy of Accommodation in Diagnosis of Non Strabismic Binocular Vision Anomalies in Young Adults: A Prospective Cross-sectional Observational Study

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## ABSTRACT

**Introduction:** Orthoptic evaluation is highly recommended in children and young adults to diagnose binocular dysfunctions. Binocular vision dysfunctions may hamper academic performance in children. Accommodative facility and accommodative accuracy are two orthoptic tests to evaluate accommodative flexibility and accommodative status of eye.

**Aim:** To investigate the effectiveness of facility and accuracy of accommodation in diagnosis of Non Strabismic Binocular Vision Anomalies (NSBVA) in young adults.

**Materials and Methods:** This prospective, cross-sectional observational study was conducted at Optsight Eye Care in association with Amity Medical School, Gurugram, Haryana, India, from August 2020 to August 2021. A total of 175 subjects (both symptomatic and asymptomatic) with normal anterior and posterior segment findings, and aged between 18-25 years were evaluated for accommodative facility test with the help of accommodative lens flipper  $\pm 2D$  and for accommodative status test with the help of monocular estimation method (dynamic retinoscopy). Both the tests were done over their best corrected visual acuity after refractive error correction and the Pearson

correlation test was applied to find out the correlation. Further, complete orthoptic examination was performed for all the subjects to correlate the abnormal findings from the two tests and conventional orthoptic tests. Independent sample t-test was applied to compare the accommodative facility between refractive groups.

**Results:** Out of 175 subjects, 84 (48%) of the subjects were found to have NSBVA which included 26 (14.86%) convergence insufficiency, 30 (17.14%) with accommodative insufficiency, 25 (14.29%) with convergence insufficiency secondary to accommodative insufficiency and 3 (1.71%) with accommodative infacility. A positive correlation between binocular accommodative facility and status of accommodation was found with a p-value  $<0.001$  ( $r=0.51$ ).

**Conclusion:** Status of accommodation and facility test can help to differentiate the accommodative and vergence problems making examination less time consuming. Both of these procedures should be a part of general routine eye examination protocol in the young adult group, so that detection of these anomalies become less time consuming and patient gets benefitted from early intervention.

**Keywords:** Binocular dysfunction, Convergence insufficiency, Orthoptic evaluation

## INTRODUCTION

Prevalence of Nonstrabismic Binocular Vision Anomalies (NSBVAs) are highly significant among young adults. The diagnosis of such anomalies is based on the evaluation of both accommodative and vergence parameters. A range of tests under near visual skills and visual perceptual skills are measured in a sequence at orthoptic clinics. But in general eye examination, ophthalmologists and optometrists do not perform the accommodative and vergence tests. Because of the latent nature of these anomalies, it's left undiagnosed and untreated. A quick referral to the orthoptic clinic will be beneficial to the patients, if some minimum orthoptic tests (accommodative and vergence parameters) can be added in general eye examination protocol.

The clinical standard of accommodative facility, an investigation of near visual skills, was explained by Zellers JA et al., [1]. It has been getting much attention in literatures recently. Clinical accommodative facility tests are commonly used as a count of visual fatigue and gives useful information in relation to accommodative and binocular dysfunctions [2-4]. This can be obtained while maintaining the constant angle of convergence (binocularly) and abolishing the convergence (monocularly).

The accuracy of accommodative response (accommodative status) is the actual amount of accommodation by the crystalline lens for

a given stimulus. It is usually the least accommodation required to obtain a clear image. It basically represents the relationship between the steady state accommodation and stimulus vergence. Individual's accommodative response to the near working distance stimulus can be more than, equal to, or less than the accommodative demand [5]. The lag of accommodation is the condition when a person's eye under accommodates at a stimulus than required accommodation where eye appears to focus farther than the stimulus. On the other hand, lead of accommodation is found with overaccommodation of eye where it appears to focus nearer than the stimulus. Monocular estimation method is considered a test of accommodative status function; binocular vision is also assessed. In normal condition, with a fixed near point stimulus in relation to accommodative system, a small lag of accommodation ( $+0.25$  to  $+0.5$  Dsph) is present. Predictions can be made that a greater variation in accommodative response from monocular to binocular conditions could be associated with an abnormal binocular accommodative response and thus perhaps greater possibility of symptoms.

Inclusion of these two orthoptic investigations in routine eye examination may provide important information for further management in lesser time. The aim of the study was to find out the effectiveness of the two orthoptic tests i.e., accommodative facility

and accommodative accuracy (status) in the diagnosis of NSBVAs in young adults.

## MATERIALS AND METHODS

This prospective, cross-sectional observational study was conducted at Optisight Eye Care associated with Amity Medical School, Amity University, Haryana, India, from August 2020 to August 2021. This study was approved by Institutional Ethical Board of Amity University, Haryana (AUH/EC/E/2017/51), and adhered to the tenets of Declaration of Helsinki.

Both symptomatic and asymptomatic subjects with best corrected visual acuity 6/6, N6 (both anterior segment and posterior segment within normal limit) were selected for the study from the general Outpatient Department.

**Sample size calculation:** According to a previous study the overall prevalence of accommodative and/or binocular dysfunctions was 13.15 per cent in university age group [6].

Formula used:

$$\text{Sample size} = \frac{Z_{1-\alpha/2}^2 p(1-p)}{d^2}$$

$Z_{1-\alpha/2}$  = Standard normal variate. The score depends on Confidence Interval (CI), for 95% CI it is 1.96

$p$  = Expected population proportion based on previous studies. Here it was 0.13

$d$  = Margin of error (generally 5% = 0.05)

The calculated sample size was 174. Authors selected total 175 subjects for the study.

**Inclusion criteria:** Healthy eyes (anterior and posterior segment normal), age group between 18-25 years, best corrected visual acuity 6/6 (20/20), insignificant refractive error (within  $\pm 0.75$ D spherical only), with or without asthenopic symptoms, no systemic illness were included in the study.

**Exclusion criteria:** Subjects with any abnormality in the anterior and posterior segment evaluation, age <18 and >25 years, amblyopia, strabismus, refractive error  $>\pm 0.75$  D and any amount of astigmatism were excluded from the study.

As a part of the study protocol, subjects were explained the procedures and written informed consent along with personal details were obtained.

### Study Procedure

This cross-sectional observational prospective study was conducted with 175 subjects (90 female and 85 male); age between 18-25 years. Each subject was asked about his or her chief visual complaints, medical and ocular history, medications, and hypersensitivities. Visual acuity both distance and near along with objective and subjective refraction for best corrected visual acuity was performed. General slit lamp examination was done for anterior and posterior segment assessment.

Accommodative Facility (AF) with flipper of +2/ -2D was measured both monocularly and binocularly in all subjects at 40 cm testing distance. In continuation, accommodative status was measured objectively with Monocular Estimation Method (MEM) technique and noted against AF.

In accommodative facility testing, the accommodation level was changed with the use of a lens flipper (usually  $\pm 2.00$  D). During this procedure, when sharp vision was attained at one level, the lens was flipped to produce accommodation to the other level. The number of cycles between both levels in a given time period, usually one minute, were recorded.

Accommodative status (accuracy to accommodative response) was measured in positive or negative lenses with the help of dynamic retinoscopy (MEM). It represented the individual's lag (value in plus)

or lead (value in minus) of accommodation to the near working distance stimulus.

Subjects with abnormal facility and status of accommodation along with normal subjects were further evaluated with detailed orthoptic work up to confirm the diagnosis. To detect and properly diagnose nonstrabismic accommodative and vergence anomalies, it is important to have a comprehensive package of accommodation and vergence tests as well as a systematic method for the analysis of accommodation and vergence findings. Preliminary orthoptic tests included cover test along with phoria measurement at near and at distance, near point of convergence, ocular motility, fusion (Worth 4-dot test) and stereopsis (titmus fly). Next Accommodative Convergence/Accommodation (AC/A) ratio was obtained with the gradient method, lateral and vertical fusional vergence at near and at distance (step vergence testing), vergence facility testing (12 prism diopters base-out and 3 prism diopters base-in), negative and positive relative accommodation, monocular and Binocular Accommodative Facility (BAF) (flippers with  $\pm 2.00$ -diopter lenses), MEM and amplitude of accommodation using the push-up with Royal Air Force (RAF) ruler were measured.

The diagnosis of NSBVAs was made based on the protocol suggested by Scheiman M and Wick B [7].

## STATISTICAL ANALYSIS

The data were entered into the excel sheet and analysed using the Statistical Package for the Social Sciences version 20.0 (SPSS Inc, Chicago, IL, USA). Continuous variables were expressed as mean  $\pm$  Standard Deviation (SD) and categorical variables were expressed as absolute numbers and percentages (n, %) with descriptive statistics. Pearson correlation test was applied to find out the correlation between BAF and accommodative status (MEM value). The comparison of AF in refractive error groups were tested with a parametric test i.e. independent samples t-test. Levene's test for equality of variances indicates about the equal or unequal variances across the two groups (emmetropia-myopia and emmetropia-hypermetropia) to further choice between "equal variances assumed data" or "equal variances not assumed data". The p-value <0.01 was considered as significant.

## RESULTS

On accommodative facility testing, out of 175 subjects (mean age  $20.31 \pm 1.92$  years); 91 were found with normal value both monocularly and binocularly. Overall, 41 (23.33%) and 43 (24.57%) had problem with monocular and BAF, respectively. A total of 37 (21.1%) lead and 44 (25.1%) lag of accommodation were noticed. All 84 (48%) subjects with abnormal facility and abnormal accuracy of accommodation (n=81) has been shown in the [Table/Fig-1]. Further all the subjects evaluated with detail orthoptic tests and surprisingly all 84 (48%) among 175 subjects were found with NSBVA [Table/Fig-2]. It included 26 (14.84%) convergence insufficiency, 30 (17.14%) with accommodative insufficiency, and 25 (14.28%) with convergence insufficiency secondary to accommodative sufficiency, 3 (1.71%) with accommodative infacility.

Tests	MAF problem n (%)	BAF problem n (%)	Total n (%)
Accommodative facility	41 (23.34%)	43 (24.57%)	84 (48%)
Lead of accommodation	7 (17.1%)	30 (69.77%)	37 (21.14%)
Lag of accommodation	31 (75.61%)	13 (30.23%)	44 (25.14%)

**[Table/Fig-1]:** Abnormal test findings (n=84).

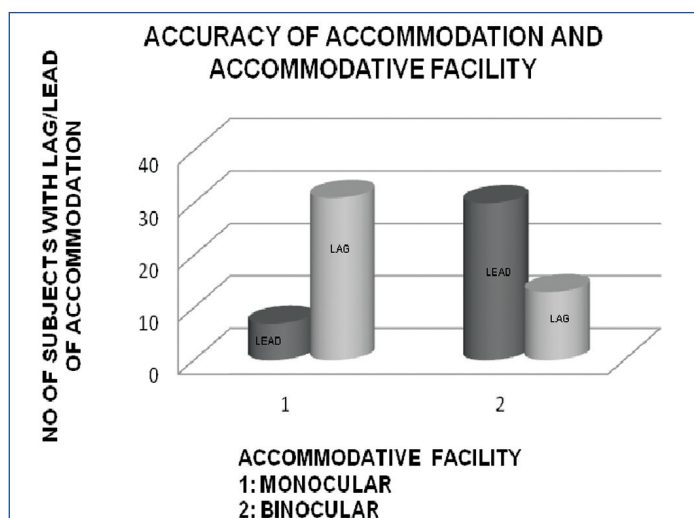
Among 84 abnormal accommodative facility subjects 81 also had problem with accommodative response (lag/lead).

\*Three (n=3; 7.3%) subjects showed normal status of accommodation; but the same three subjects showed abnormal accommodative facility); MAF: Monocular accommodative facility; BAF: Binocular accommodative facility

Dysfunction	n (%)
Normal	91 (52%)
Convergence insufficiency	26 (14.86%)
Accommodative insufficiency	30 (17.14%)
Convergence insufficiency secondary to accommodative insufficiency	25 (14.28%)
Accommodative infacility	3 (1.71%)
Total	175 (100%)

**[Table/Fig-2]:** Prevalence of binocular dysfunctions over the general population (N=175).

It was observed that 30 (69.77%) of the subjects who had lead of accommodation also had problem in BAF and 31 (75.6%) of subjects with lag of accommodation had issue with Monocular Accommodative Facility (MAF) [Table/Fig-1]. The graphical representation shows this finding together for both lead and lag of accommodation [Table/Fig-3].



**[Table/Fig-3]:** Status/accuracy of accommodation (lead/lag) in respect to monocular and binocular facility of accommodation.

Pearson correlation test found out a moderate positive correlation between BAF and accuracy of accommodation [Table/Fig-4] with a p-value <0.001 (r=0.5135). Out of 175 subjects 99 were emmetropic, 56 were myopic and 20 were hypermetropic. It showed significant BAF mean difference in emmetropic subjects (mean=9.46) compared to myopic subjects (mean=5.33), where hypermetropia showed a mean of 7.7 [Table/Fig-5]. The study found a significant BAF mean difference in emmetropic subjects (mean=9.5) compared to myopic

subjects (mean=5.33) with equal variances assumed [Table/Fig-6]. There was no statistically significant facility difference between emmetropia and hypermetropia [Table/Fig-7].

Pearson correlation	Binocular accommodative facility (X variable)	Monocular estimation method value (Y variable)	p-value
(r)	Mean (M <sub>x</sub> )	Mean (M <sub>y</sub> )	2-tailed
0.513**	4.827	0.164	p<0.001

**[Table/Fig-4]:** Correlation of facility and accuracy of accommodation (n=84). \*\*Correlation is significant at the 0.01 level (2-tailed)

Refractive status of eye (N=175)	Mean±Std. Deviation
Emmetropia (n=99)	9.5±4.2
Myopia (n=56)	5.3±3.41
Hypermetropia (n=20)	7.7±4.4

**[Table/Fig-5]:** Group statistics (Binocular accommodative facility).

## DISCUSSION

Looking at the huge population of India and with a prevalence of binocular vision anomalies of about 30-34%, intervention in this area is largely anticipated [8-10]. The NSBVAs are considered as vision anomalies which affect clarity, binocularity, impair the comfort and effectiveness of visual performance. Clinical diagnostic signs associated with each type of anomalies (accommodative anomalies i.e. accommodative insufficiency, accommodative infacility, accommodative fatigue etc and vergence anomalies i.e. convergence insufficiency, divergence insufficiency, convergence excess, divergence excess etc) are different [11].

Few studies have reported that children who have binocular dysfunctions encounter anxiety, emotional and social problems [12-15]. Children with uncorrected NSBVAs may be misdiagnosed as being dyslexic [16-18]. Early diagnosis always plays an important role on prognosis. It is a time taking procedure to differentiate the signs of accommodative anomalies and vergence anomalies separately. In recent years, many researchers have reported about the clinical significance of testing the accuracy of accommodative response (accommodative status) and accommodative facility as well as amplitude in the young adult group population [19,20]. An important aspect is that a subject may experience asthenopic symptoms and have an accommodative anomaly even when the accommodative amplitude is normal [21].

Accommodative and vergence functions influence the test results of binocular examination. Monocular testing provides a direct evaluation of the dynamics of accommodative responses and binocular testing

Independent samples test	Levene's test for equality of variances		t-test for equality of means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean diff.	Std. error diff.	95% Confidence interval of the difference	
								Lower	Upper
Equal variances assumed	0.24	0.62	6.2	153	0.000	4.13	0.66	2.81	5.44
Equal variances not assumed			6.6	135.3	0.000	4.13	0.62	2.90	5.36

**[Table/Fig-6]:** The t-test assuming equal and unequal variances (accommodative facility in emmetropic and myopic subjects).

Independent samples test	Levene's test for equality of variances		t-test for equality of means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% confidence interval of the difference	
								Lower	Upper
Equal variances assumed	0.03	0.87	1.7	117	0.09	1.78	1.05	-0.29	3.9
Equal variances not assumed			1.65	26.5	0.11	1.78	1.08	-0.44	4.1

**[Table/Fig-7]:** The t-test assuming equal and unequal variances (accommodative facility in emmetropic and hypermetropic subjects).

of accommodative facility yields similar information but also reviews the interactive nature of the relation between accommodation and vergence, referred to as interactive facility [22,23]. Garcia A et al., observed less accommodative facility in prediagnosed 48 NSBVA patients, aged 10-30 years [24]. This study also reported an interesting finding that MAF provided more information about the anomalies of a patient. It showed the importance of the accommodative facility test in diagnosis of NSBVA.

In this study, it has been observed that reduced MAF correlated with accommodative related subject issues and reduced BAF mainly correlated with subject's vergence issues. This study found a positive relation between facility and status of accommodation. As a whole, the data support a relation between AF, status of accommodation and a dysfunction and there is a positive relation between lead of accommodation and BAF as well as lag of accommodation and MAF. Total 69.76% of subjects who had lead of accommodation also had problem in BAF and 75.6% of subjects with lag of accommodation had issue with MAF. These results suggest that performing accommodative facility and accuracy may play a vital role in the diagnosis of accommodative and binocular dysfunctions. The current study showed 48% of the subjects were found with NSBVA, where, 14.84% convergence insufficiency, 17.14% with accommodative insufficiency and 14.28% with convergence insufficiency secondary to accommodative insufficiency, 1.71% with accommodative infacility among the young adult (18-25 years) age group. Whereas, in another study Darko-Takyi C et al., found 21.9% and 12.4% nonstrabismic accommodative and vergence dysfunctions respectively in ages ranging from 19-27 years [25]. In specific type of disorders, they found accommodative fatigue 8.6%, AF 6.7%, accommodative insufficiency 4.7%, convergence insufficiency 1.9%, convergence excess 1%, and divergence insufficiency 2.9% which was not similar to the current findings. Another study by Atiya A et al., confirmed 55% of 75 ophthalmology trainee had a diagnosis of a nonstrabismic binocular vision dysfunction [26]. The mean age of the subjects included in that study was 29±3 years and 20% of them had convergence insufficiency, 19% had accommodative infacility, 12% had Intermittent Divergent Squint (IDS), while 4% had convergence excess. However, the age range of this was not similar to current age group study.

As this study was done with limited sample, hospital based setup and at a specific age group, screening of nonstrabismic anomalies on the judgement of these two tests was not commendable. Authors would prefer to suggest the two tests (accommodative facility and accommodative status/accuracy) as additional tests to include into routine eye examination protocol. Though, the mentioned tests did not measure the vergence component directly, but binocular accommodative tests also help in indirect assessment of vergence into some extent. Early provisional diagnosis may be possible at the preliminary level and patient can be referred to orthoptic clinic for all direct tests to get the final diagnosis.

Refractive error is one of the causative factors for variation of accommodative measurements. Another important current concern is myopia progression, where retinal defocus is a significant factor in myopia progression in young adults. O'Leary DJ and Allen PM, concluded that both these factors i.e. AF and the lag of accommodation affect the retinal defocus that distinguishes between progressive and stable myopia [27]. The association between myopia and near work is long established, but the search for accommodative problems related with myopia has resulted in some inconsistencies. In myopia, AF (dynamics of accommodation) is less for distance, whereas the accommodative dynamics for near remain unchanged [28,29]. In the same study, it observed no significant influence of refractive error on near MAF measurement [29]. The present study also could not give any specific result in near monocular but the BAF of myopic subjects compared to emmetropia was found significant ( $p < 0.01$ ). No significant difference was seen in AF between hypermetropia and emmetropia ( $p = 0.11$ ); both monocularly and binocularly. This

may be because numbers of myopic subjects were more than hypermetropic subjects. Study with a larger and equalled sample size will be able to help in finding the difference of monocular and binocular accommodative problems in greater detail according to type of ametropia.

### Limitation(s)

The evaluation was not done at community level. Further studies with a larger sample size and a community setup can guide the examiners to make a decision in screening program of NSBVAs.

### CONCLUSION(S)

Accommodative facility testing and status of accommodation always plays a vital role in diagnosing NSBVA as well as prediction of myopic changes in long duration studies. However, this study has also shown that status of accommodation and facility testing can help to differentiate the accommodative and vergence problems making examination less time consuming. Hence, it is suggested to include these two procedures in regular routine general eye examination, particularly in young adult age group. This will improve the referral system as well as help binocular dysfunction patient get the best management at the earliest.

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