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Correlative Analysis of Accommodative Facility Testing Between the Non-strabismic Binocular Dysfunction Group and the Normal Population

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ABSTRACT

Background: Binocular vision anomalies and asthenopia symptoms, such as eye strain and headaches, often go undiagnosed in young individuals, especially in community eye screenings. These conditions can significantly affect academic performance and daily activities. This study explores the correlation between accommodative facility (AF) and binocular vision parameters while assessing the relationship between detecting non-strabismic binocular vision disorders (NSBVD) diagnosis and Convergence Insufficiency Symptom Survey (CISS) scores.

Methods: A random cluster sampling study was conducted on 105 participants aged 10–25 years. They were divided into two groups: regular (n=40) with AF≥11 cpm monocularly and ≥eight cpm binocularly, and NSBVD (n=65) with AF<11 cpm monocularly and <8 cpm binocularly. AF was measured using ±2D accommodative flippers with 20/40 accommodative rock cards for one minute. The Spearman correlation test analyzed relationships between AF and binocular vision parameters.

Results: A significant correlation was observed between AF and Negative Relative Accommodation (NRA), Negative Fusional Vergence (NFV), Vergence Facility (VF), and AF within the NSBVD group. CISS scores strongly correlated with binocular vision anomalies, reinforcing the role of AF testing in differentiating normal from NSBVD participants.

Conclusion: Monocular and binocular AF testing should be prioritized in clinical practice for NSBVD diagnosis. Our study supports AF testing as an effective screening tool in community eye services. The CISS questionnaire is crucial for detecting vergence dysfunction and identifying asthenopic symptoms affecting learning. Researchers can expand on these findings to enhance early screening strategies, improve interventions, and assess the impact of vergence dysfunction on cognitive performance.

Key-words: Pediatric Ophthalmology, Binocular Vision, Cerebral Visual Impairment, Visual Development, Refractive Errors in Children, Eye Screening

INTRODUCTION

The accommodative flipper is a widely used tool for detecting non-strabismic binocular vision disorders (NSBVD) by assessing AF; the visual system can shift focus between near and distant objects swiftly. This evaluation can be conducted either binocularly, where convergence plays a role, or monocularly, without the influence of convergence. In individuals with normal accommodative function, AF rates typically measure around seven cycles per minute (cpm) binocularly and 11 cpm monocularly [1].

When performed binocularly, AF testing simultaneously engages both positive and negative fusional vergence,

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making it a valuable method for assessing overall accommodative efficiency. The procedure is straightforward and takes approximately three minutes to complete [1].

Accommodative dysfunction is frequently observed in both pre-presbyopic and presbyopic populations, often manifesting as asthenopia (eye strain) and visual discomfort. Additionally, transient myopia induced by prolonged near-work has been associated with reduced AF, with excessive near-task engagement acting as a contributing factor. AF testing also offers valuable insights into NRA and positive relative accommodation (PRA), while difficulties in maintaining focus in pediatric cases may indicate underlying binocular vision disorders [1].

The evaluation is commonly performed using a ±2.00 diopter accommodative flipper, which stimulates an accommodative demand of 4.50 diopters at a 40 cm distance, with a 6/9 visual target as the fixation point. [2] Comprehensive NSBVD assessment typically includes multiple diagnostic tests, such as stereopsis, amplitude of accommodation (AA), near point of convergence (NPC), VF, and phoria measurements. While these evaluations provide critical diagnostic information, they require significant time and patient cooperation. In comparison, AF testing using an accommodative flipper presents a faster and more practical alternative, indirectly assessing AA, NRA, PRA, NFV, and positive fusional vergence (PFV), making it a reliable screening tool for early identification of potential NSBVD cases. [3]

MATERIALS AND METHODS

Study Design- This prospective comparative study was conducted over six months at a tertiary care hospital in Eastern India. It aimed to evaluate NSBVD in participants aged 10 to 25 (mean age 20±4 years).

Inclusion and Exclusion Criteria- Eligible participants had a best-corrected visual acuity (BCVA) of 6/6 at a distance and N6 at a distance, with no known ocular or systemic diseases. Individuals were excluded if they had a history of ocular or head injuries, juvenile diabetes, strabismus, amblyopia, or any previous intraocular/strabismus surgeries.

Study Procedure- Initially, each participant completed the CISS to assess NSBVD-related symptoms. Comprehensive orthoptic assessments were conducted under consistent lighting conditions (670 lux).[4] Participants underwent a detailed series of evaluations and were re-assessed one week after dilated refraction, provided they achieved BCVA of 6/6 at distance and N6 at near.

Optometric Examinations- The assessment process involved various diagnostic tests. Stereopsis was evaluated using the Random Dot Stereopsis Plate for both near and far distances, while suppression was measured simultaneously with the Worth Four Dot Test. The functionality of extraocular muscles was assessed using the Broad H Test. Phoria was measured at two distances: near (40 cm) and far (6 m), utilizing the Prism Bar Cover Test.

To determine the accommodative-convergence/ accommodation (AC/A) ratio, the heterophoria method was employed, with interpupillary distance measured using an IPD ruler. NPC was recorded with a Royal Air Force (RAF) Ruler, averaging three break-point measurements. The Near Point of Accommodation (NPA) was assessed through the push-up method to evaluate accommodative amplitude, both monocularly and binocularly.

Objective accommodation was gauged via dynamic retinoscopy (Monocular Estimated Method -MEM) at 40 cm with the patient's habitual prescription. Negative and positive relative accommodation (NRA & PRA) were measured using an N8 target at the same distance, incrementing +0.25 D until the patient experienced their first noticeable blur or diplopia for NRA, and decrementing -0.25 D for PRA.

Vergence testing was conducted using a horizontal base-out prism bar to assess Positive Fusional Vergence (PFV) and a base-in prism bar to assess NFV at 40 cm and 6 m. At the breakpoint, the patient reported experiencing double vision, which returned to single vision at the recovery point. Additionally, VF was measured binocularly at 40 cm with a 12 Base Out/ 3 Base In flipper and Lang fixation stick, recorded in cycles per minute. AF was evaluated at 40 cm with an N8 target using ±2.00 dioptre accommodative flippers. Vergence testing was performed using a horizontal base-out prism bar to evaluate Positive Fusional Vergence (PFV) and a base-in prism bar to assess NFV at distances of 40 cm and 6 meters. During the test, the patient reported

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experiencing double vision at the breakpoint, which returned to single vision at the recovery point.

Sample Size Calculation- One hundred five participants were randomly selected based on the study's design parameters and eligibility criteria, ensuring a representative sample for evaluating NSBVD.

Statistical Analysis- Data were analyzed using SPSS version 26.0. The Kolmogorov-Smirnov test assessed data normality, while the Spearman correlation test measured overall correlations. Comparisons between the NSBVD and regular groups were made using the Mann-Whitney U test. According to Scheiman Wick's criteria, participants were categorized into groups, with NSBVD defined by accommodative facility values below eight cycles per minute (cpm) binocularly and below 11 cpm monocularly.[5]

Ethical Considerations- The study received ethical approval from the Kalinga Institute of Medical Science (Ref No. KIIT/KIMS/IEC/1810/2024). All participants were provided with detailed information about the study procedures, and written informed consent and assent were obtained per the Declaration of Helsinki guidelines.

RESULTS

A total of 105 participants were enrolled—65 diagnosed with NSBVD and 40 classified as usual based on Scheiman and Wick's (2008) criteria. Within the NSBVD group, various dysfunctions were identified: convergence insufficiency (18), accommodative insufficiency (17), accommodative excess (13), accommodative infacility (9), fusional vergence dysfunction (7), and divergence insufficiency (1). Around 30% of individuals in the NSBVD group reported symptoms per the CISS, and a statistically significant difference in CISS scores was noted between the NSBVD and usual groups ($p<0.05$).

Table 1 summarizes the median and interquartile ranges for demographic and visual variables. The NSBVD group had a median age of 19 years compared to 21 in the usual group. Significant differences were found in binocular vision parameters, including near stereopsis, NPA, NRA, PRA, PFV, NFV, and VF.

Spearman's correlation in the NSBVD group showed a significant negative correlation between AF and refractive error, near stereopsis, and PRA. AF was positively correlated with AA, NRA, NFV, PFV, and VF. CISS scores were positively correlated with near stereopsis and negatively with AF, NRA, NFV, and PFV.

Table 1: Orthoptics parameters between normal individuals and those with NSBVD

Parameter	Normal (Median, 25th–75th Percentile)	NSBVD (Median, 25th–75th Percentile)	p-value (Significance)
Age (years)	21 (18–23)	19 (17–22)	0.304
Right Eye Refractive Error (D)	-0.13 (-0.56–0.00)	0.00 (-0.38–0.00)	0.126
Left Eye Refractive Error (D)	-0.19 (-0.50–0.00)	0.00 (-0.25–0.00)	0.066
Stereopsis (Distance) (arcsec)	60 (60–60)	60 (60–60)	0.078
Stereopsis (Near) (arcsec)	60 (60–60)	60 (60–60)	0.003
Near Point of Convergence (cm)	6.3 (6.0–7.0)	7.0 (6.0–8.0)	0.126
Minimum Amplitude of Accommodation (D)	9.88 (9.25–10.50)	10.00 (9.25–10.75)	0.332
Present Amplitude of Accommodation (D)	12.50 (12.00–14.28)	10.00 (8.33–12.50)	0.001
Cover Test (Distance) (Δ)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.721
Cover Test (Near) (Δ)	0.00 (0.00–0.00)	0.00 (-4.00–0.00)	0.010
Accommodative-Convergence/ Accommodation (AC/A) Ratio	6.0 (5.5–6.0)	6.0 (4.4–6.0)	0.064
Monocular Estimated Method (MEM) (D)	0.25 (0.00–0.25)	0.25 (0.00–0.50)	0.262
Negative Relative Accommodation (NRA) (D)	2.50 (2.50–2.50)	2.00 (1.75–2.25)	<0.001

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Positive Relative Accommodation (PRA) (D)	-3.00 (-3.00–-3.00)	-3.00 (-3.00–-2.00)	<0.001
Negative Fusional Vergence (Distance, Break Point/ Recovery Point) (Δ)	10 (8–12)/8 (6–10)	8 (6–8)/6 (4–6)	<0.001
Positive Fusional Vergence (Distance, Break Point/ Recovery Point) (Δ)	20 (16–25)/18 (14–20)	14 (10–16)/12 (8–14)	<0.001
Vergence Facility (cycles/min)	14 (13–16)	10 (8–12)	<0.001
Accommodative Facility – Right Eye (OD) (cpm)	12.0 (10.8–13.0)	3.0 (1.5–6.0)	<0.001
Accommodative Facility – Left Eye (OS) (cpm)	11.3 (11.0–12.8)	3.0 (1.5–6.0)	<0.001
Accommodative Facility – Both Eyes (OU) (cpm)	11.8 (10.3–13.0)	4.0 (1.5–6.0)	<0.001
Convergence Insufficiency Symptom Survey (CISS) Score	9 (8–13)	25 (20–27)	<0.001

These findings indicate that individuals with NSBVD exhibit reduced accommodative function, weaker fusional vergence, and poorer near stereopsis than normal individuals. The strong association, represented in Table 2, between elevated CISS scores and deficits in accommodative and vergence functions reinforces the importance of accommodative facility testing as an efficient screening tool for the early identification of non-strabismic binocular vision disorders.

Table 2: Correlation of Various Parameters with Accommodative Facility and CISS

Parameter	AF - Right Eye (OD)	AF - Left Eye (OS)	AF - Both Eyes (OU)	CISS Score
AF - Right Eye (OD)	1.000	0.930	0.883	-0.719
AF - Left Eye (OS)	0.930	1.000	0.905	-0.767
AF - Both Eyes (OU)	0.883	0.905	1.000	-0.742
CISS Score	-0.719	-0.767	-0.742	1.000
Age	0.057	0.146	0.127	-0.131
Right Eye Refractive Error	-0.244*	-0.246*	-0.202*	0.167
Left Eye Refractive Error	-0.248*	-0.259**	-0.218*	0.179
Stereopsis (Distance)	-0.140	-0.093	-0.166	0.093
Stereopsis (Near)	-0.271**	-0.287**	-0.246*	0.205*
Near Point of Convergence	-0.167	-0.150	-0.185	0.070
Minimum Amplitude of Accommodation	-0.038	-0.128	-0.125	0.191
Present Amplitude of Accommodation	0.315	0.289	0.264	-0.183
Cover Test (Distance)	0.029	0.004	0.021	0.010
Cover Test (Near)	0.189	0.231*	0.212*	-0.161
AC/A Ratio	0.180	0.247*	0.223*	-0.125
Monocular Estimated Method (MEM)	-0.128	-0.120	-0.132	0.035
Negative Relative Accommodation (NRA)	0.663	0.628	0.622	-0.499

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Positive Relative Accommodation (PRA)	-0.288	-0.287	-0.316	0.305
Negative Fusional Vergence (Distance - Break Point)	0.494	0.463	0.529	-0.399
Negative Fusional Vergence (Distance-Recovery Point)	0.538	0.512	0.562	-0.439
Negative Fusional Vergence (Near - Break Point)	0.194*	0.163	0.245*	-0.087
Negative Fusional Vergence (Near-Recovery Point)	0.167	0.150	0.235*	-0.093
Positive Fusional Vergence (Distance - Break Point)	0.554	0.570	0.568	-0.527
Positive Fusional Vergence (Distance-Recovery Point)	0.539	0.576	0.568	-0.514
Positive Fusional Vergence (Near - Break Point)	0.527	0.542	0.586	-0.542
Positive Fusional Vergence (Near - Recovery Point)	0.531	0.543	0.585	-0.541
Vergence Facility	0.587	0.558	0.620	-0.609

Fig. 1 compares the orthoptic parameters between the NSBVD group and the normal group. A comparison of the accommodative facility between normal and NSBVD groups, as demonstrated in Fig. 2, clearly shows that the NSBVD group shows low facility value monocularly and binocularly compared with the normal group. Fig. 3 shows a Comparison of CISS scores between the normal and NSBVD groups; a higher CISS score is found in the NSBVD group. The distribution of binocular vision dysfunction types in the NSBVD group is shown in Fig. 4, and convergence insufficiency has the highest prevalence, followed by accommodative insufficiency in the NSBVD group.

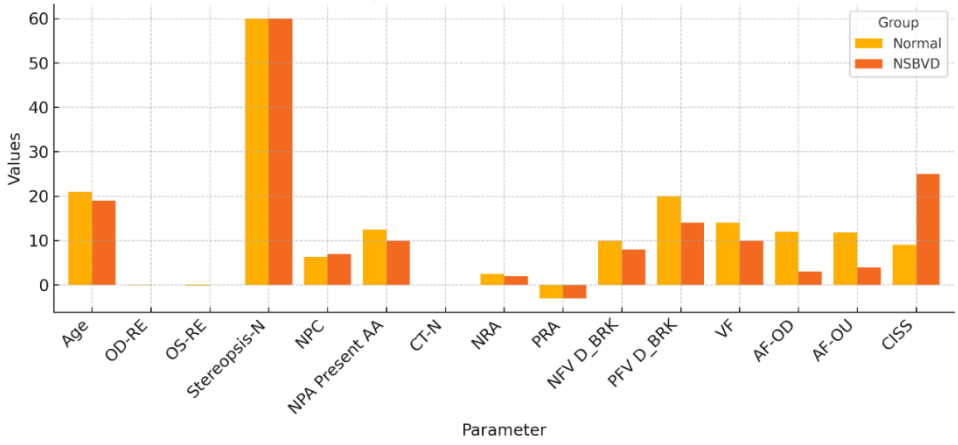

Fig. 1: Comparison of orthoptics parameter between normal and NSBVD group

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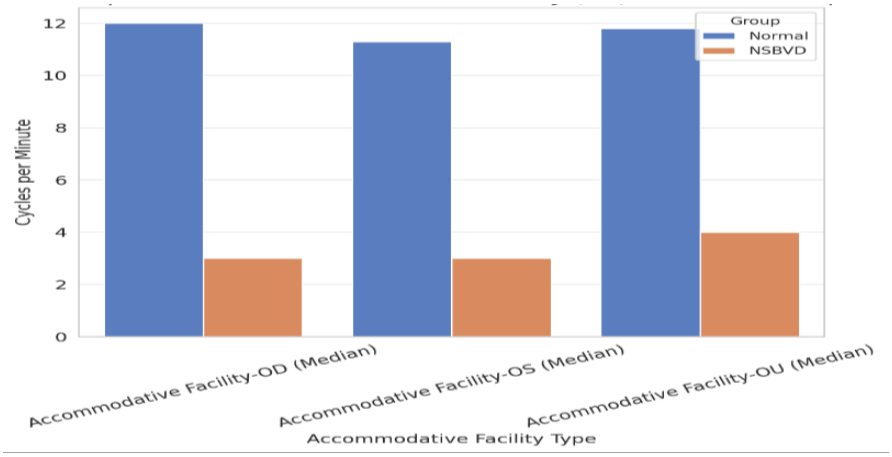

Fig. 2: Comparison of accommodative facility between normal and NSBVD group

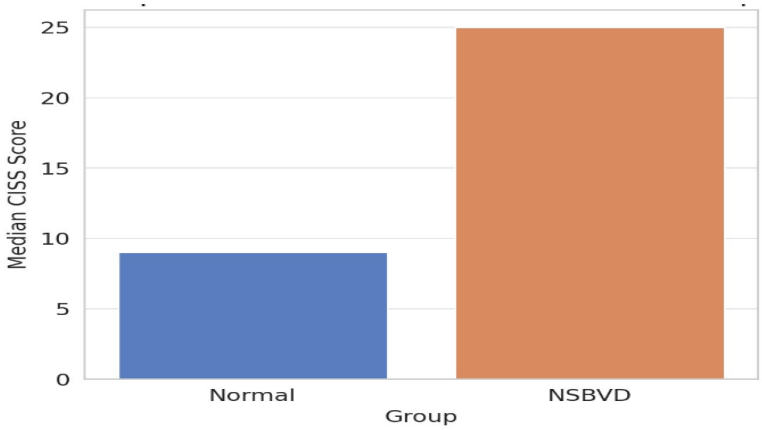

Fig. 3: Comparison of CISS score between normal and NSBVD group

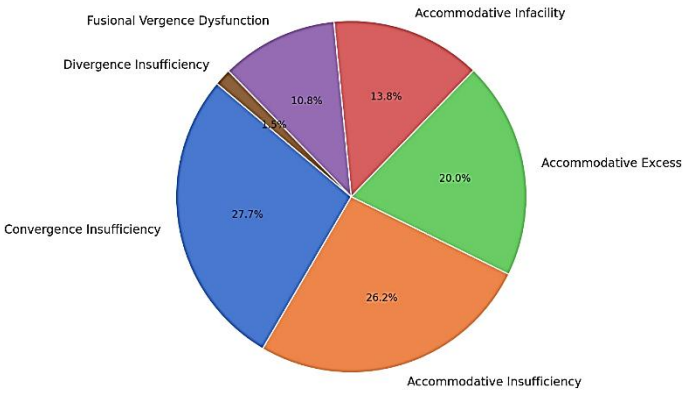

Fig. 4: Distribution of binocular vision dysfunction types in NSBVD group

DISCUSSION

Accommodative dysfunction can have significant psychological and emotional consequences, particularly in young individuals. [6] It has been linked to reduced academic performance, as visual stress and discomfort interfere with concentration on reading and other near tasks. Asthenopia, manifesting as headaches, blurred vision, and fatigue during prolonged work, strongly correlates with these disorders.

Our study classified participants into NSBVD and regular groups based on normative accommodative facility values established by Zeller *et al.* [3]. Our findings add to the growing body of research emphasizing that accommodative dysfunction plays a crucial role in visual symptoms and overall performance. Previous research, such as that by Levine *et al*. [7] indicates that monocular accommodative facility testing using a ±2.00 diopter flipper is highly effective for accurately assessing each

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eye's ability to switch focus between near and far objects without the influence of vergence.

Hussaindeen *et al*. [8], Siderov *et al*. [9] have developed a community-based screening protocol for NSBVD, incorporating latent squint testing for both distance and near, monocular accommodative facility testing, and NPC measurement using a penlight and red filter. These minimal test batteries have proven effective in identifying at-risk individuals and facilitating early intervention in community and school settings.

Additionally, Saikia *et al.* found that symptomatic individuals performed significantly worse on accommodative facility tests compared to asymptomatic peers, recommending that those with persistent asthenopic symptoms undergo a comprehensive orthoptic evaluation to rule out accommodative infacility. [10] Supporting this, Wajuihian's research demonstrated that compromised clinical measures of accommodation and vergence are strongly associated with visual symptoms. This finding aligns with our observations, where CISS scores correlated significantly with various visual function parameters. [11]

It is important to note that CISS scoring alone has limitations in identifying accommodative dysfunction, as it tends to focus more on vergence issues. Moodley's study highlighted that over one-fourth of school children assessed had some accommodation anomaly and cautioned that relying solely on visual acuity screening can overlook significant binocular vision anomalies, potentially leading to undiagnosed learning difficulties. [12] This underscores the necessity for comprehensive binocular vision assessments in school screening programs.

Maintaining clear and comfortable vision is essential for daily activities, academic performance, and overall quality of life. Even without vergence dysfunction, accommodative disorders can cause significant visual discomfort. The increasing use of digital devices has elevated the demand for near-vision tasks, which may be contributing to the rising prevalence of NSBVD. Our study found that accommodative facility testing was significantly associated with near stereopsis, PFV, NFV, NRA, PRA, and VF, highlighting the interconnected nature of binocular vision parameters and the importance of early detection in preventing long-term visual problems.

Moreover, our findings revealed a strong correlation between CISS scores and near stereopsis, suggesting that stereopsis testing could be a valuable screening tool for detecting NSBVD. These results align with the work of Cacho-Martinez *et al*., who confirmed the diagnostic accuracy of validated symptom questionnaires, convergence insufficiency testing, amplitude of accommodation, and monocular accommodative facility assessments in diagnosing accommodative dysfunctions. [13,14]

In India, digital penetration has increased dramatically over the past decade, rising from 14% in 2014 to over 52% in 2024. [15] With most internet users accessing online content via mobile devices, prolonged screen time and intensive near work have been linked to higher rates of asthenopia and accommodative dysfunction. Consequently, early screening for NSBVD is becoming increasingly important, especially among children and young adults with high digital device exposure. [16]

To ensure accuracy and consistency in our measurements, we adhered to standardized testing protocols recommended by Siderov *et al.* This approach minimized errors and reinforced the reliability of accommodative facility testing as a diagnostic and screening tool for NSBVD, particularly in populations facing near work demands. [17]

CONCLUSIONS

Our study highlights the importance of accommodative facility testing as an effective and comprehensive tool for assessing binocular vision. Incorporating monocular and binocular accommodative facility tests into routine vision screenings allows for early detection and timely intervention of NSBVD. This approach is particularly crucial in environments with high near-work demands, such as schools and workplaces, where it can help prevent long-term visual strain and improve overall visual health outcomes. Accommodative facility testing is a powerful and comprehensive screening tool that reflects key binocular parameters for detecting NSBVD. By incorporating monocular and binocular accommodative facility tests into routine vision assessments—especially for populations with high near-work demands—clinicians can achieve early detection and timely intervention, ultimately reducing long-term visual strain and significantly improving overall visual health outcomes.

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Data analysis and interpretation–Shoubhik Chakraborty, Shrutakirty Parida

Literature search– Shoubhik Chakraborty

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Critical review– Soumya Kanta Mohanty, Shovna Dash

Article editing– Shrutakirty Parida

Final approval– Soumya Kanta Mohanty, Shovna Dash

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