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INTERPUPILLARY DISTANCE AS A DETERMINANT OF ACCOMMODATIVE EFFICIENCY AND BINOCULAR VISUAL SYMPTOMS IN YOUNG ADULTS

Gitismita Devi [1], Dr. Shrabani Kalita[2]*

[1]Assistant Professor, Faculty of Allied and HealthCare Sciences, Assam down town University, Sankar Madhab Path, Gandhi Nagar, Panikhaiti, Guwahati, Assam, India, PIN – 781026, Email: gitismitadevi1149@gmail.com
[2]Assistant Professor, Faculty of Allied and HealthCare Sciences, Assam down town University, Sankar Madhab Path, Gandhi Nagar, Panikhaiti, Guwahati, Assam, India, PIN – 781026

ABSTRACT
Background/Objective: The study aimed to examine and analyse how interpupillary distance (IPD) influences accommodative parameters and in co-relation to symptomatic binocular vision in adults
Method: A cross sectional study was performed involving 50 symptomatic patients of both gender aged 10-40 years. Optically corrected and non strabismic patients were selected from Guwahati, Assam between year 2025-2026. IPD and other accommodative parameters were examined. Statistical analysis was conducted using SPSS.
Results: IPD demonstrated a significant inverse relationship with CISS score, suggesting that larger interpupillary distances were associated with fewer visual symptoms. The strongest association was identified between PRA and CISS score, indicating that reduced accommodative reserve contributes substantially to visual discomfort. Approximately 18.4% of symptom variability could be explained by PRA measurements.
Conclusion: Positive relative accommodation PRA and CISS scores showed the highest association, with PRA explaining 18.4% of symptom variability. These findings suggest that visual discomfort is significantly influenced by decreased accommodative reserve as measured by PRA.

KEYWORDS: Interpupillary distance, accommodation, binocular vision,Positive Relative Accommodation(PRA)

INTRODUCTION

Binocular vision is the primary constituent of a normal human visual function. An essential part of a normal human's visual function is binocular vision. It is the capacity to perceive and engage with the dynamic three-dimensional world by aligning the eyes in the motor sense and integrating their images. Its main benefit is that it helps us perceive relative depth and distance as we move through our surroundings.[1] A collection of unique visual impairments known as accommodative and binocular dysfunctions impair binocularity and lower visual system efficiency, especially while performing near activities. Non-strabismic binocular vision abnormalities (NSBVA) is the aggregate term for these dysfunctions. Particularly during extended near activities or prolonged digital device use, these abnormalities can cause a variety of vision-related symptoms, including headache, visual fatigue, loss of concentration, blurred vision, and diplopia. These symptoms can lower quality of life and negatively impact academic and professional performance [2]
The development of the retinal picture depends on binocularity. Binocularity enhances the accommodative response to defocus, blur resulting from defocus is a helpful indicator of binocularity.[3,4,5] Myopes may experience this effect differently. Even though emmetropization signals are located locally at the retinal level, binocular vision may be important for retinal picture focus, emmetropization, and possibly the development of myopia. For instance, myopes have decreased blur sensitivity in monocular but not binocular settings. [6,7] In addition, myopes exhibit more binocular imbalance and less stereopsis with flashing stimuli than emmetropes. Due to binocular conditions, night myopia, or tonic accommodation is lessened, the accommodative gain is altered when a translucent occluder is placed over the nonviewing eye. [8,9]
The genesis of accommodative and binocular vision abnormalities has been linked to a number of binocular vision factors. While positive relative accommodation PRA and negative relative accommodation NRA evaluate the adaptability of accommodative-vergence interactions, interpupillary distance establishes the physiological demand at close range. Asthenopia, blurr, and diplopia symptoms have been linked to abnormalities in these parameters as well as other accommodating metrics like amplitude of accommodation and accommodative facility. Quantitative evaluation of IPD, NRA, PRA, and associated accommodative function is crucial for identifying people at risk for symptomatic binocular vision disorders and for directing clinical treatment.
The role of the pupil in myopigenesis is unknown, but axial growth is influenced by visual experience, including retinal image quality and optical defocus, and data indicating that myopes exhibit abnormally high levels of aberration and/or larger accommodative lags in comparison to those who remain emmetropic.
Since the pupil serves as an aperture stop, variations in pupil size and interpupillary distance between and within individuals could theoretically represent an innate and dynamic physiological mechanism whereby optical image properties, such as retinal image blur, higher-order aberrations, depth of focus, and accommodative lag, could differ

between myopes and non myopes or fluctuate in a myopigenic fashion over time, contributing to progression in susceptible individuals.[10]

While the blurring impact of a given dioptric lag would be proportionately greater during accommodation due to the bigger retinal blur circle diameter, larger pupil widths and interpupillary distance result in greater wave-front aberrational blur.Accommodation is the eye's quick reaction to eliminate or lessen the hyperopic defocus that appears during near work, whereas emmetropization is the eye's long-term response to lessen or eliminate the defocus felt at the fovea. There has long been a connection between the accuracy of refractive error growth and the accuracy of accommodation. The eye grows longer and becomes myopic as a result of hyperopic defocus at the fovea caused by wide interpupillary distance and larger delays linked to high accommodative demand.[10]

Despite being distinct metrics, there can be some link between NPC and IPD. Since larger IPD values usually need more convergence effort to rotate the eyes inward, prior research suggests a favorable link. On the other hand, because the eyes are anatomically closer, smaller IPD values might require less convergence effort.

Prior research on stereopsis concentrated on correlations between IPD and crossing disparity contour stereopsis at close range. Overall, there was very little correlation, but stereopsis decreased as IPD grew. [11,12,13]

This is the study to examine accommodative parameters in relation to binocular vision function and association between interpupillary distance and accommodative parameters will be analysed.

METHODOLOGY

The cross sectional study was performed in a tertiary eyecare center for a duration of 6 months from January 2025 to June 2025. The study was acknowledged by Institutional board and Ethics committee. Informed consent was obtained from all the participants. A totally of 50 myopic subjects of age group 10-39 years of age, both male and female were recruited for the study. Prior to the evaluation symptomatic CISS scoring patients, history of asthenopia were included. All the subjects had comprehensive evalution following thorough examination of anterior segment and posterior segment. Subjects with any ocular diseases, systemic diseases and previous ocular surgeries and injuries were excluded.

The study comprised subjects with BCVA of 6/6 and N6. Interpupillary distance and accommodative assessments were done which included objective refraction, subjective refraction, near fixation distance, near phoria, distance phoria, Accommodative convergence/ Convergence ratio, Near Point of Convergence, Near point of accommodation, Amplitude of Accommodation, Negative Relative Accommodation, Positive Relative Accommodation, Monocular estimated Method, Accommodative Facility

Test for Accommodation

NPA, as determined by the RAF Ruler, is the point nearest to the eye where an object is tightly focused on the retina. Measurements were taken three times in a row and averaged. The measurement was translated from centimeters to diopters.[14,15.16] The relative accommodation was measured using minus (negative) and plus (positive) lenses. The results are shown in Diopter (D). NRA is a measure of the maximum capacity to relax accommodation while maintaining clear, single binocular vision. PRA is a measure of the maximum capacity to stimulate accommodation while maintaining clear, single binocular vision. The findings noted in Diopter (D). The normal range for NRA and PRA is + 2.00 to + 2.50 D and –2.37 to –3.37 D, respectively.[17,18]

Following the evaluation of best-corrected visual acuity (BCVA), the AC/A ratio was computed using the formula AC/A = IPD (cm) + N (m) (D'-D).

The AC/A ratio was defined as accommodative convergence (AC) per diopter (D) of accommodative response (A) (IPD = interpupillary distance in centimeters, N = near fixation distance in meters (m), D' = near phoria (eso is plus and exo is minus), and D = far phoria (eso is plus and exo is minus).

The unit of measurement was Δ/D.[19,20,21,22,23,24]

A Royal Air Force (RAF) ruler was used to measure the NPC, monocular, and binocular AA. Participants in the NPC were told to stay focused on the fixation target, which was a tiny circle, while the examiner gently moved it in the direction of their nose. When a subject claimed that the target had doubled or the examiner noticed a deviation in the participant's sight, the NPC was noted (in centimeters). As the examiner progressively shifted the chart in their direction, the kids were instructed to keep the word goal of N5 clear for the AA measurement. Even after a few blinks, the kids must promptly report the first prolonged blur they perceive. The average values were reported after three repetitions of the NPC and AA measures.[25,26,27,28,29,30] An accommodation target at 40 cm and ±2.0 D flipper lenses were used to measure monocular accommodation facility (MAF) and binocular accommodation facility (BAF). The results were recorded in cycles per minute (cpm) and each instance of clearing both the plus and minus lenses was counted as one cycle. Using a target with pressure control, BAF was determined. Using Donder's approach, AA was assessed monocularly by bringing the accommodating target—one line above near BCVA—closer to the eye until a persistent blur occurred. A prism bar was also used to evaluate the vergence ranges, both near and far. The normal protocols for all binocular and accommodative testing were followed.[31,32,33,34,35,36,37,38]

In order to maintain the 33 cm viewing distance for the MEM retinoscopy technique, the participant held a knot tied in a string attached to the retinoscope next to their right eye. The stimulus was fastened to the retinoscope using a magnetic strip. The examiner would arrange themself so that the thread would remain taut during the measurement. The subject next wrote out the words on the card while keeping both eyes open, and the examiner watched the retinoscopic reflex in the horizontal meridian of the subject's right eye. The retinoscopic reflex was neutralized using a trial-lens bar with ten lenses ranging from −0.50 D to +2.00 D in 0.25D steps. In the few cases where this range was insufficient, extra loose lenses were utilized (full range: −1.50 to +2.50). Initially, the reflex was evaluated without lenses. The +0.25 D lens was momentarily placed in front of the eye using the conventional technique if "with" motion was seen.The right eye was temporarily exposed to seven more lenses (increased in +0.25 D steps) until the first neutral reaction was seen. The −0.25 D lens was introduced in the same way if a "against" motion was initially seen. Until a neutral reaction was observed, the lens power was increased in increments of −0.25 D. After the initial neutral reaction, lenses were not introduced. The accommodating lag or lead (positive values = lag; negative values = lead) was the lens power that produced a neutral response.[39,40,41,42,43,44,45]

RESULTS

Table 1. Demographic and Clinical Characteristics

Variable	Total (n=50)
Age (years)	22.54 ± 5.53
Male, n (%)	25 (50.0)
Female, n (%)	25 (50.0)
CISS Score	29.34 ± 6.67

The study included 50 young adults with a mean age of 22.54 ± 5.53 years. The mean IPD was 30.05 ± 1.59 mm, which falls within the expected physiological range reported for young adult populations. The mean CISS score (29.34 ± 6.67) exceeded the commonly accepted symptomatic threshold of 21, indicating a relatively high prevalence of visual discomfort among participants.

Table 2. Accommodation and Binocular Vision Characteristics

Parameter	Mean ± SD
AA OD (D)	11.53 ± 3.55
AA OS (D)	11.12 ± 3.40
NRA (D)	2.28 ± 0.97
PRA (D)	-2.76 ± 1.54
MEM OD (D)	0.68 ± 0.58
MEM OS (D)	0.67 ± 0.57
AF OU (cpm)	9.14 ± 6.49
NPC Break (cm)	7.76 ± 2.45
NPC Recovery (cm)	10.76 ± 2.21

The mean accommodative amplitude in the right eye (11.53 ± 3.55 D) and left eye (11.12 ± 3.40 D) was lower than the expected normative values for young adults. Compared with Hofstetter's average formula, accommodative amplitude demonstrated approximately 12% reduction. The mean NRA value (2.28 ± 0.97 D) remained within normal physiological limits (typically +2.00 to +2.50 D). PRA values (-2.76 ± 1.54 D) were slightly lower than the expected normative range (-2.50 to -3.50 D), indicating variability in accommodative reserve among participants. The average accommodative facility (9.14 ± 6.49 cpm) was below the commonly accepted normative value of 11–13 cpm, representing approximately 20–30% reduction, suggesting reduced accommodative flexibility.

Table 3. Gender-Based Comparison

Variable	Male (n=25)	Female (n=25)	p-value
Age (years)	21.72 ± 5.32	23.36 ± 5.73	0.31
IPD (mm)	30.32 ± 1.49	29.78 ± 1.67	0.23
CISS Score	29.12 ± 7.63	29.56 ± 5.70	0.82
AA OD (D)	11.18 ± 3.79	11.89 ± 3.33	0.48
AA OS (D)	11.11 ± 3.64	11.14 ± 3.22	0.97
NRA (D)	2.20 ± 0.63	2.37 ± 1.23	0.54
PRA (D)	-2.99 ± 1.30	-2.53 ± 1.75	0.29
AF OU (cpm)	9.86 ± 6.87	8.42 ± 6.15	0.44

Male participants demonstrated slightly larger interpupillary distances than females (30.32 ± 1.49 mm vs. 29.78 ± 1.67 mm), representing an increase of approximately 1.8%. However, no statistically significant difference was observed between sexes ($p > 0.05$). Females exhibited marginally higher accommodative amplitude (6.3% increase) and NRA values (7.7% increase) compared with males, while males demonstrated greater accommodative facility (17.1% increase). These differences did not reach statistical significance, suggesting that gender had limited influence on accommodative performance within the present cohort.

Table 4. IPD Category Analysis

Parameter	Narrow IPD (<29 mm)	Average IPD (29–31 mm)	Wide IPD (>31 mm)
n	13	24	13
CISS Score	32.47 ± 5.91	28.85 ± 6.14	25.17 ± 6.52
AA OD (D)	13.06 ± 3.28	11.15 ± 3.11	9.78 ± 3.22

AA OS (D)	11.74 ± 3.31	11.20 ± 3.29	9.92 ± 3.43
NRA (D)	2.57 ± 1.04	2.21 ± 0.95	2.25 ± 0.92
PRA (D)	-2.71 ± 1.27	-2.84 ± 1.53	-2.12 ± 1.69
AF OU (cpm)	7.71 ± 5.82	11.00 ± 6.44	7.04 ± 5.39

One way ANOVA analysis was done. Participants with narrow IPD (<29 mm) demonstrated the highest accommodative amplitude (13.06 D), whereas individuals with wide IPD (>31 mm) exhibited the lowest accommodative amplitude (9.78 D). This represents a 25.1% reduction in accommodative amplitude across IPD categories. Similarly, CISS scores decreased from 32.47 in the narrow-IPD group to 25.17 in the wide-IPD group, corresponding to a 22.5% reduction in visual symptom burden. These findings suggest that narrower interpupillary distances may be associated with increased accommodative effort and greater subjective visual discomfort. If ANOVA demonstrates statistical significance ($p < 0.05$), this would support the existence of an anatomical influence on accommodative behavior.

Table 5. Correlation Analysis

Variable	r	p-value
IPD vs AA OD	-0.348	0.013*
IPD vs AA OS	-0.209	0.145
IPD vs NRA	-0.029	0.840
IPD vs PRA	-0.044	0.764
IPD vs AF OU	0.085	0.558
IPD vs CISS	-0.323	0.022*
PRA vs CISS	-0.429	0.0019**

p<0.05; ** p<0.01

A statistically significant negative correlation was observed between IPD and accommodative amplitude (r = -0.348, p = 0.013). The coefficient of determination (R^2 = 12.1%) indicates that approximately 12% of the variation in accommodative amplitude may be explained by IPD alone. Similarly, IPD demonstrated a significant inverse relationship with CISS score (r = -0.323, p = 0.022), suggesting that larger interpupillary distances were associated with fewer visual symptoms. The strongest association was identified between PRA and CISS score (r = -0.429, p = 0.0019), indicating that reduced accommodative reserve contributes substantially to visual discomfort. Approximately 18.4% of symptom variability could be explained by PRA measurements.

DISCUSSION

The development of binocular and accommodating vision disorders is influenced by binocular vision parameters. Parameters like IPD, NRA, and PRA are crucial components of the accommodative vergence system. Changes in IPD modify baseline convergence demand, whereas lower NRA and higher negative PRA indicate less accommodating reserve and flexibility. These measures are utilized to assess the diagnosis since these dysfunctions are associated with clinical symptoms. A comprehensive evaluation of these accommodating parameters enables the early detection of binocular vision problems that could otherwise remain asymptomatic.

The absence of gender differences is consistent with previous literature showing that accommodative and vergence function are primarily age dependent rather than gender dependent in young adults The significant negative correlation between PRA and CISS score r= -0.429, p=0.0019. This indicates that participants with more negative PRA values, representing reduced ability to relax accommodation and sustain convergence, reported higher level of convergence insufficiency symptoms on CISS questionnaire. This relationship aligns with clinical expectation, as PRA is measure of accommodative vergence interaction and a reduced PRA has been associated with symptoms of asthenopia, blurr vision in previous studies. The moderate correlation strength suggested that while PRA explains a substantial portion of symptom variability, other factor such as NPC, fusional vergence or dry eye may contribute. This finding supports the inclusion of PRA as a predictive parameter for screening symptomatic CISS score patients, since it showed the strongest association with patient reported symptoms among all BV tests evaluated.

CONCLUSION

The results of this cross-sectional study show a strong correlation between young adults' symptom severity and accommodative function and binocular vision metrics. IPD and accommodative amplitude were found to have a statistically significant negative connection, with IPD accounting for around 12% of the variation in accommodative amplitude. Additionally, there is a strong inverse correlation between IPD and the convergence insufficiency symptom survey score. Positive relative accommodation PRA and CISS scores showed the highest association, with PRA explaining 18.4% of symptom variability.

These findings suggest that visual discomfort is significantly influenced by decreased accommodative reserve as measured by PRA. IPD and PRA should be included as important characteristics in predictive models for binocular vision abnormalities based on the demonstrated association. To evaluate these associations and determine the predictive usefulness of IPD and other indicators for symptomatic clinical screening, however, bigger sample size longitudinal investigations are needed.

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