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Research Article

Prevalence and Impact of Non-Strabismic Binocular Vision Disorders among College Students in Surat District, Gujarat: A Cross-Sectional Study

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Abstract*— *Objective: This study aimed to investigate the prevalence of Non-Strabismic Binocular Vision Disorders (NSBVD), including Convergence Insufficiency (CI) and Accommodative Insufficiency (AI), among college students in Surat, Gujarat, and to explore correlations with screen time and academic demands.
Methods: A cross-sectional study was conducted with 300 college students aged 18–25 years. Participants underwent binocular vision assessments, including Near Point of Convergence (NPC), Near Point of Accommodation (NPA), and fusional vergence testing. Data were analyzed using chi-square tests and descriptive statistics to determine the prevalence of NSBVD and its associations with screen time.
Results: The overall prevalence of NSBVD was 30% (95% CI: 25.1% - 34.9%). Convergence Insufficiency was the most common disorder, affecting 18% (95% CI: 13.8% - 22.2%) of students, followed by Accommodative Insufficiency (8%, 95% CI: 5.0% - 11.0%) and Accommodative Excess (4%, 95% CI: 2.0% - 6.0%). High screen time (>6 hours/day) was strongly associated with increased NSBVD prevalence, with 40% of participants in this group exhibiting symptoms of NSBVD, particularly CI (22%). No significant age or gender differences in NSBVD prevalence were observed.
Conclusion: The study identifies a high prevalence of NSBVD among college students, especially those with prolonged screen time. These findings highlight the need for routine visual health screenings, ergonomic interventions, and targeted vision therapy to alleviate visual strain and support academic performance. Prolonged screen exposure and academic pressures should be considered critical factors in the management of NSBVD in young adults.

Keywords— Non-Strabismic Binocular Vision Disorders, Convergence Insufficiency, Accommodative Insufficiency, Screen Time, College Students, Visual Health

1. Introduction

Non-Strabismic Binocular Vision Disorders (NSBVD) encompass a group of visual dysfunctions that impair the eyes' ability to coordinate effectively, impacting the quality of binocular vision and leading to symptoms such as eye strain, blurred vision, and headaches. These disorders include conditions like convergence insufficiency (CI), where the eyes have difficulty converging on a near object; accommodative insufficiency (AI), which reflects a reduced ability to maintain focus on close objects; and fusional vergence dysfunction, which impairs the eyes' ability to align images from each eye into a single, stable perception. NSBVD can profoundly affect activities that require sustained visual concentration and focus, such as reading, studying, and prolonged screen use [1].

College students are particularly at risk of developing NSBVD due to the unique visual demands they face. Academic tasks often require sustained near work for extended periods, and the increasing reliance on digital devices exacerbates these demands. Studies indicate that college students spend an average of 6-8 hours daily engaged in digital screen activities, including studying, reading, and recreational device use [2]. This high level of near-focus activity intensifies the demand on the binocular and accommodative systems, which, if not met, can lead to symptoms that disrupt visual comfort and function. Studies have shown that prolonged screen use not only increases the risk of digital eye strain but can also lead to a higher incidence of NSBVD, particularly CI, where the visual system struggles to maintain a single focus on near objects over time. Reduced blink rates, increased accommodative load, and sustained convergence demands during screen use contribute to this condition [3].

Global research has documented NSBVD prevalence rates among university students ranging from 27.8% to 62.2%, depending on factors like study intensity, screen exposure, and academic requirements. In particular, CI is often the most prevalent NSBVD, affecting approximately 37% of students in some regions (Shongmu & Akhtar, 2024) [4], a pattern that underscores the high visual demands within college environments. Similarly, studies from the United States report CI rates as high as 13% among students, linking this condition to the demanding academic workload of college students (Rouse et al., 1999) [5]. The consistency of these findings across different countries suggests that college life, with its heavy reliance on near work and screen use, places students at a significantly higher risk of developing NSBVD compared to other populations [6].

Despite the global data, there remains a notable gap in research on NSBVD among Indian college students, particularly in regions where academic demands are high and digital technology is increasingly integrated into study routines. Understanding the prevalence and impact of NSBVD in this context is essential for effective healthcare intervention, as visual discomfort and difficulties may interfere with academic success and quality of life for affected students.

To address this gap, the present study investigates the prevalence of NSBVD among college students in the Surat district of Gujarat, with a focus on common disorders like convergence insufficiency and accommodative insufficiency. This research seeks to provide valuable data on the specific visual challenges faced by Indian students, thereby informing tailored preventive and therapeutic interventions. Establishing a clearer understanding of NSBVD prevalence and its correlates in this population can support the development of regular screening programs and effective management strategies within educational institutions, ultimately promoting both visual health and academic performance among college students in India.

2. Related Work

Numerous studies have investigated Non-Strabismic Binocular Vision Disorders (NSBVD) in various populations, particularly focusing on the prevalence, associated risk factors, and management strategies.

"Digital Eye Strain: Prevalence, Measurement, and Amelioration" (Sheppard & Wolffsohn, 2018) [9]
Problem Statement: Digital eye strain caused by prolonged screen use has been linked to visual discomfort and binocular vision anomalies.
Objective: To assess the prevalence of digital eye strain and evaluate intervention strategies, such as the 20-20-20 rule, for improving visual health in screen users.

"Prevalence of Non-Strabismic Binocular Vision Dysfunction Among University Students" (Shongmu & Akhtar, 2024) [4]
Problem Statement: Academic demands and screen use increase visual strain, but prevalence data for NSBVD in student populations remain limited.
Objective: To identify the prevalence of NSBVD and its relationship with academic workload in North Indian university students.

"Computer Vision Syndrome: A Comprehensive Review" (Kaur et al., 2022) [3]
Problem Statement: The global rise in digital device usage has escalated cases of visual fatigue and associated binocular vision disorders.
Objective: To review the mechanisms of digital eye strain, its impact on accommodation and vergence systems, and potential interventions to mitigate its effects.

"Digital Screen Exposure and Its Association with Accommodative Dysfunction" (Iqbal et al., 2023) [7]
Problem Statement: Long screen hours have been implicated in reduced accommodative facility, yet quantitative data on this relationship remain scarce.
Objective: To quantify the effects of digital screen exposure on accommodative function among young adults.

"Visual Ergonomics and Binocular Vision: The Role of Screen Position and Lighting" (Rosenfield, 2016) [6]
Problem Statement: Poor ergonomic practices contribute significantly to visual strain and NSBVD, but specific recommendations remain underexplored.
Objective: To investigate the impact of screen positioning, ambient lighting, and posture on visual ergonomics and binocular vision performance.

"A Randomized Clinical Trial of Treatments for Convergence Insufficiency in Children" (Scheiman et al., 2005) [8]
Problem Statement: While CI is a prevalent binocular vision disorder, its optimal treatment methods remain debated.
Objective: To evaluate the efficacy of vision therapy compared to other treatments, such as base-in prism glasses, in managing CI.

"Non-Strabismic Binocular Vision Disorders Among Medical Students" (Shrestha & Kaiti, 2022) [1]
Problem Statement: Medical students face intense academic demands, yet little research has focused on their vulnerability to NSBVD.
Objective: To document the prevalence of NSBVD in medical students and its impact on academic performance and quality of life.

"Binocular Vision Dysfunctions in Adolescents: Prevalence and Risk Factors" (Sarkar & Bordoloi, 2021) [2]
Problem Statement: Adolescents are increasingly exposed to digital devices, yet their susceptibility to binocular vision dysfunctions is understudied.
Objective: To explore the prevalence of binocular vision dysfunctions in adolescents and analyze contributing lifestyle factors.

"Convergence Insufficiency and Reading Performance in Students" (Rouse et al., 1999) [5]
Problem Statement: CI's effect on academic tasks requiring sustained near vision, such as reading, is often overlooked.
Objective: To evaluate the relationship between CI and reading performance in school students, providing insights into its educational implications.

3. Experimental Method/Procedure/Design

Study Design
This was a cross-sectional observational study conducted at a tertiary eye care center in Surat, Gujarat, India, between August 2023 and April 2024. The study aimed to assess the prevalence and types of non-strabismic binocular vision disorders (NSBVD) among college students. The timing of the study was aligned with the academic calendar to ensure maximum participation, capturing a representative sample during periods of high academic workload and screen use.

Population and Sample Size Calculation
The target population comprised college students aged 18–25 years from various academic institutions in Surat, ensuring demographic and academic diversity. Based on an expected NSBVD prevalence of 31.5% in college populations with high visual demands, the sample size was calculated with a 95% confidence level and a 6% margin of error, requiring a minimum of 231 participants. To enhance reliability and account for potential non-responses, the sample size was increased to 300 students. This larger sample strengthens the study's statistical power and generalizability. Random sampling was employed to minimize selection bias, and students in allied health fields (e.g., nursing, physiotherapy) were excluded due to their unique visual demands. This approach supports a robust analysis of NSBVD prevalence and its associated risk factors.

Inclusion and Exclusion Criteria
Participants were eligible if they were aged 18–25, enrolled in college, and provided informed consent. Students were excluded if they had a history of ocular surgery, amblyopia, or strabismus. Those on medications affecting binocular or accommodative functions, or enrolled in allied health programs, were also excluded to minimize external influences on visual function. These criteria ensured that the sample reflected a typical student population without confounding variables.

Ethical Considerations
The study was approved by the Institutional Review Committee, adhering to the Declaration of Helsinki. All participants provided written informed consent after a detailed explanation of the study's objectives, procedures, and their rights, including the option to withdraw at any time without penalty.

Data Collection and Quality Control
Data collection occurred under controlled conditions to minimize variability. The testing environment was standardized with ambient lighting set to 400 lux, a level chosen to prevent any influence on visual performance. The consistency of measurements was ensured by experienced ophthalmologists and certified optometrists following established protocols. Equipment calibration, including that of the Royal Air Force (RAF) ruler and accommodative flippers, was performed bi-weekly to maintain accuracy. Inter-observer reliability was checked through periodic cross-checks to ensure consistency and minimize bias.

Preliminary Assessment and Visual History
Each participant completed a demographic questionnaire and a visual history form, which assessed lifestyle factors, screen time, and visual symptoms. Baseline distance visual acuity (VA) was measured using a Snellen chart at 6 meters, and near VA was assessed with a reduced Snellen chart at 50 cm, ensuring consistent refractive conditions for subsequent assessments.

Objective and Subjective Refraction
Objective refraction was conducted using static retinoscopy to estimate refractive error, followed by subjective refraction to determine best-corrected visual acuity (BCVA). The refractive correction determined during these tests was applied during all subsequent binocular and accommodative assessments, ensuring that visual deficits were not due to uncorrected refractive errors.

Binocular Vision and Accommodative Testing Protocols
The diagnosis of NSBVD involved a sequence of standardized tests to evaluate convergence, accommodation, and fusional vergence:
Near Point of Convergence (NPC): NPC measures the closest point at which the eyes can maintain convergence on a near object. This test is essential for diagnosing convergence insufficiency, as individuals with this condition struggle to bring their eyes together effectively when viewing nearby targets. NPC values were recorded as the average of three trials, capturing both the "break" point (where convergence is lost) and the "recovery" point (where convergence is regained).
Near Point of Accommodation (NPA): The NPA test determines the nearest point at which a participant can focus on a target without experiencing blur. By evaluating accommodation capabilities under both monocular and binocular conditions, this test provides valuable insights into accommodative insufficiency, a condition marked by reduced focusing ability on close objects. The NPA distance, measured in centimeters, indicates the participant's accommodative range.
Horizontal Phoria Measurements: Phoria tests measure latent misalignment of the eyes, with horizontal phoria indicating deviations when focusing on near or distant objects. These measurements were taken using the cover/uncover test and a prism bar, recorded in prism diopters. Horizontal phoria assessments help evaluate alignment tendencies and fusion capacity, critical in diagnosing NSBVDs that involve subtle misalignments.

Fusional Vergence Testing: This test evaluates the eyes' ability to maintain a single, stable perception while aligning images from each eye, which is essential for comfortable, clear binocular vision. Fusional vergence testing was conducted at both near and distance ranges using a prism bar to measure both negative (base-in) and positive (base-out) vergence capacities. Measurements of blur, break, and recovery points were recorded for each participant, providing a comprehensive understanding of their vergence adaptability.

Accommodative Facility and Amplitude: The accommodation facility was assessed using ±2.00 diopter flippers, measuring how efficiently participants could alternate focus between near and distance targets. The amplitude of accommodation was determined using the minus lens method, providing a measure of maximum accommodative power. Both tests help identify accommodative excess and deficiency by examining the participant's ability to sustain focus under changing demands.

Accommodative Convergence to Accommodation (AC/A) Ratio: Calculated using the gradient method, the AC/A ratio indicates the level of convergence per unit of accommodation. This ratio aids in diagnosing convergence-related dysfunctions, helping differentiate between convergence insufficiency and other accommodative or convergence issues.

Diagnostic Criteria and Quality Assurance

NSBVD diagnoses followed the Scheiman and Wick criteria, which involve specific combinations of primary and complementary diagnostic indicators. Convergence insufficiency, accommodative insufficiency, and other types of NSBVD were diagnosed by a qualified optometrist, with each case reviewed by the principal investigator for accuracy. Diagnoses were periodically cross-verified by an independent optometrist to ensure inter-rater reliability.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics Version 22. Descriptive statistics, including point estimates and 95% confidence intervals (CI), were calculated to determine the prevalence of NSBVD. Chi-square tests assessed associations between NSBVD prevalence and categorical variables such as age and gender. The Kolmogorov-Smirnov test was used to check for normality in continuous variables, and appropriate parametric (t-tests and ANOVA) or non-parametric (Mann-Whitney U and Kruskal-Wallis) tests were applied based on the data distribution. A p-value of < 0.05 was considered statistically significant. Subgroup analyses were performed to examine the influence of screen time and gender on NSBVD prevalence, as these factors have been shown to independently affect visual health. These methods ensured the robustness and reproducibility of the findings.

4. Results and Discussion

Demographic Characteristics of Participants

The study involved 300 college students aged between 18 and 25 years, with a nearly equal gender distribution: 151 females (50.3%) and 149 males (49.7%). The majority of participants (78%) were in the 18–22 age group, while the remaining 22% were aged 23–25 years. This balanced demographic distribution facilitates meaningful subgroup analyses based on age and gender, as presented in Table 1 and Figure 1.

Table 1: Demographics of Participants

Characteristic	Subcategory	Number of Participants (N = 300)	Percentage
Age	18–22 years	234	78%
	23–25 years	66	22%
Gender	Female	151	50.3%
	Male	149	49.7%

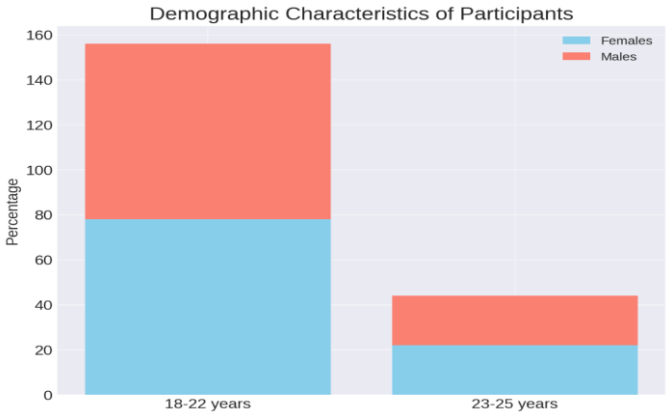

Figure 1: Showing Stacked bar chart showing age and gender distribution.

Prevalence of Non-Strabismic Binocular Vision Disorders (NSBVD)

The overall prevalence of NSBVD among the participants was 30% (95% CI: 25.1%–34.9%), with convergence insufficiency (CI) being the most common disorder. Specifically, 18% of the participants (54 students; 95% CI: 13.8%–22.2%) were diagnosed with CI. Accommodative insufficiency (AI) was observed in 8% of participants (24 students; 95% CI: 5.0%–11.0%), while accommodative excess (AE) was identified in 4% (12 students; 95% CI: 2.0%–6.0%). These findings are detailed in Table 2 and Figure 2.

Table 2: Prevalence of Non-Strabismic Binocular Vision Disorders (NSBVD)

Disorder	Number of Cases	Prevalence (%)	95% Confidence Interval
Overall NSBVD	90	30%	25.1% - 34.9%
Convergence Insufficiency (CI)	54	18%	13.8% - 22.2%
Accommodative Insufficiency (AI)	24	8%	5.0% - 11.0%
Accommodative Excess (AE)	12	4%	2.0% - 6.0%

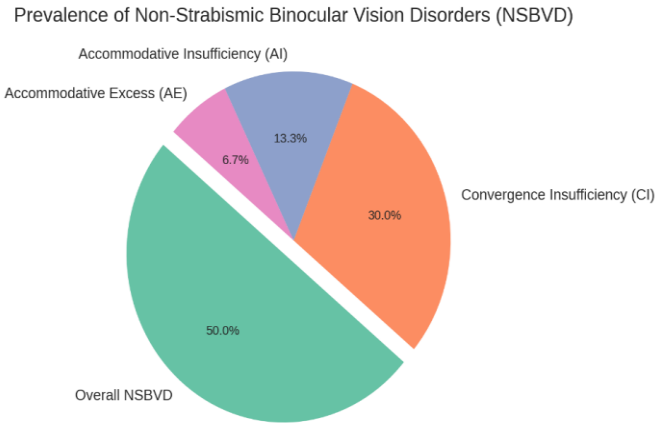

Figure 2: Showing pie chart representing the prevalence of different NSBVD types.

NSBVD Symptom Severity Distribution

Among the 90 students diagnosed with NSBVD, 40% reported mild symptoms, 35% experienced moderate symptoms, and 25% reported severe symptoms. Notably, 60% of students had moderate to severe symptoms, highlighting the urgent need for intervention. A chi-square test revealed a significant association between excessive screen time (>6 hours/day) and increased symptom severity ($\chi^2 = 17.70$, $p = 0.00014$), underscoring the importance of managing screen use to promote visual health. These findings are illustrated in Table 3 and Figure 3.

Table 3: NSBVD Symptom Severity Distribution

Severity Level	Number of Students	Percentage of Students
Mild	36	40%
Moderate	32	35%
Severe	22	25%

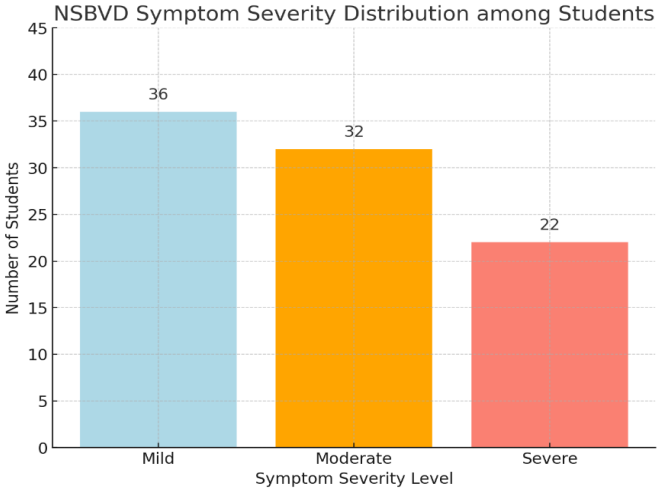

Figure 3: NSBVD Symptom Severity Distribution

Near Point of Convergence (NPC) and Near Point of Accommodation (NPA)

The NPC (near point of convergence) and NPA (near point of accommodation) measurements were evaluated to assess the participants' ability to converge and accommodate near objects, which are critical indicators of NSBVD. Among participants diagnosed with convergence insufficiency (CI), the mean NPC was 14.2 cm (SD = 2.1 cm), significantly higher than the normative value of approximately 10 cm ($t = 3.45$, $p < 0.01$), indicating reduced convergence ability.

For NPA, participants diagnosed with accommodative insufficiency (AI) exhibited a mean value of 15.0 cm (SD = 2.5 cm), which exceeded the typical range of 8–10 cm, further underscoring reduced accommodative capacity. The difference in NPA between participants with and without AI was statistically significant ($t = 2.98$, $p < 0.01$). These findings are detailed in Table 4 and Figure 4.

Table 4: Near Point of Convergence (NPC) and Near Point of Accommodation (NPA)

Measurement	Condition	Mean (cm)	Standard Deviation (SD)	Significance (p-value)
Near Point of Convergence (NPC)	Convergence Insufficiency (CI)	14.2	2.1	Higher than normative 10 cm ($p<0.01$)
Near Point of Accommodation (NPA)	Accommodative Insufficiency (AI)	15.0	2.5	Exceeds typical range 8–10 cm ($p<0.01$)

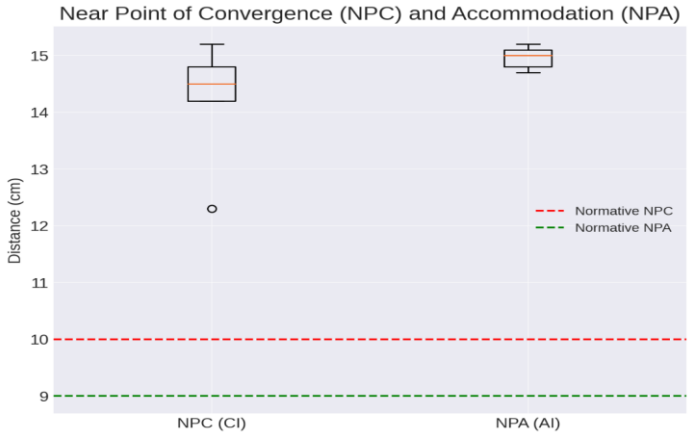

Figure 4: Showing box plot comparing NPC and NPA distances with normative values.

Horizontal Phoria and Fusional Vergence Testing

Horizontal phoria and fusional vergence tests were performed to evaluate latent eye misalignment and the ability to maintain single binocular vision. Among the participants, 15% (45 students) exhibited a near exophoria exceeding 6 prism diopters, indicating binocular dysfunction associated with convergence insufficiency (CI).

Fusional vergence testing revealed that participants with CI had a reduced positive fusional vergence (PFV) capacity, averaging 14.5 prism diopters at near distances, compared to 18.0 prism diopters in participants without CI. This difference was statistically significant ($t = 2.53$, $p = 0.01$), highlighting a potential link between decreased PFV and convergence insufficiency. These findings are presented in Table 5 and Figure 5.

Table 5: Horizontal Phoria and Fusional Vergence

Test	Condition	Metric	Result	Significance (p-value)
Horizontal Phoria	Convergence Insufficiency (CI)	Near Exophoria	>6 prism diopters in 15% of participants (45 students)	-
Positive Fusional Vergence (PFV)	Convergence Insufficiency (CI)	Mean PFV at Near Distance	14.5 prism diopters	Lower than non-CI (18 diopters, p = 0.01)

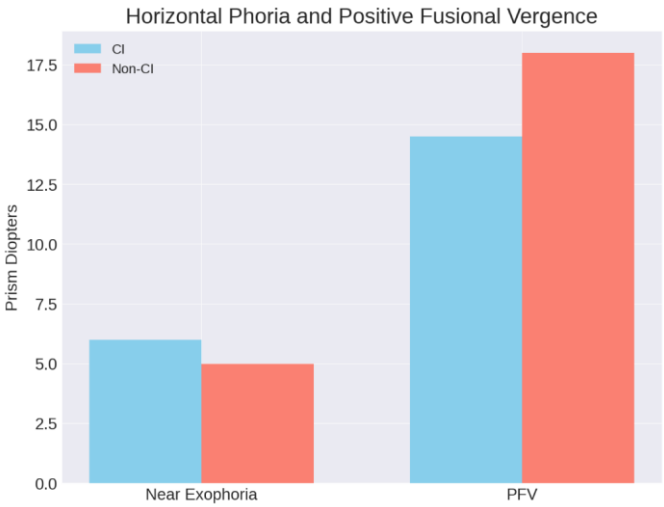

Figure 5: Showing clustered bar chart for phoria and fusional vergence between CI and non-CI groups

Accommodative Facility and Amplitude

Accommodative facility testing using ±2.00 D flippers revealed that participants with accommodative insufficiency (AI) had an average response rate of 8 cycles per minute, significantly lower than the average of 12 cycles per minute observed in participants without AI ($t = 3.21$, $p < 0.01$). This reduced response rate indicates difficulty in quickly alternating focus, a characteristic symptom of AI.

In terms of accommodative amplitude, participants with AI exhibited an average amplitude of 4.8 D (SD = 1.1 D), significantly below the expected value for their age group (mean = 6.5 D, $t = 4.02$, $p < 0.01$). These findings strongly support the presence of accommodative dysfunction in individuals diagnosed with AI, as detailed in Table 6 and Figure 6.

Table 6. Accommodative Facility and Amplitude

Test	Condition	Metric	Result	Significance (p-value)
Accommodative Facility	Accommodative Insufficiency (AI)	Average Response (Cycles/min)	8 cycles/min	Lower than non-AI (12 cycles/min, $p < 0.01$)
Accommodative Amplitude	Accommodative Insufficiency (AI)	Mean Amplitude (D)	4.8 D	Below age norm (6.5 D, $p < 0.01$)

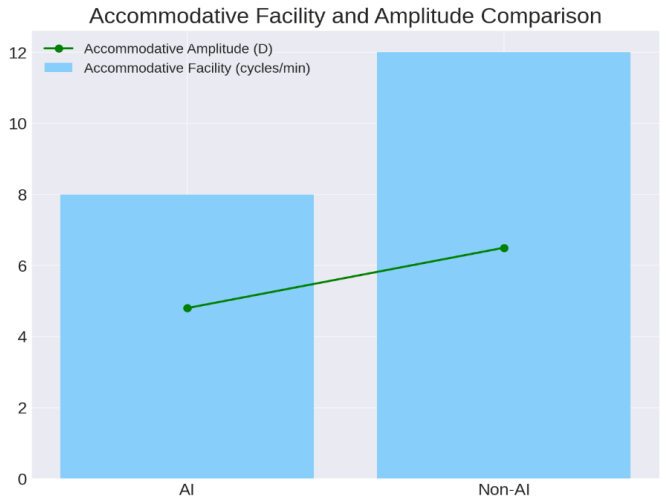

Figure 6: Showing bar chart and overlay line comparing facility and amplitude for AI and non-AI groups.

Accommodative Convergence to Accommodation (AC/A) Ratio

The mean AC/A ratio in participants with convergence insufficiency (CI) was 2.8:1, slightly lower than the normative value of approximately 4:1, indicating insufficient convergence in response to accommodation. The difference in the AC/A ratio between participants with and without CI was statistically significant ($t = 2.87$, $p < 0.01$), confirming an association between a lower AC/A ratio and convergence insufficiency. These results are presented in Table 7 and Figure 7.

Table 7. Accommodative Convergence to Accommodation (AC/A) Ratio

Condition	Mean AC/A Ratio	Normative Value	Significance (p-value)
Convergence Insufficiency (CI)	2.8:1	~4:1	Lower than norm ($p < 0.01$)

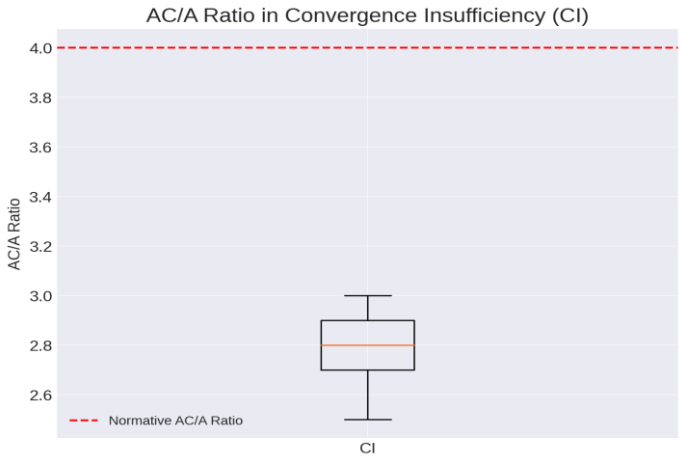

Figure 7: Showing box plot displaying AC/A ratios in CI participants with a normative reference.

Gender and Age Differences in NSBVD Prevalence

The prevalence of NSBVD was slightly higher in females (32%, 95% CI: 25.0%–39.0%) compared to males (28%, 95% CI: 21.0%–35.0%), although this difference was not statistically significant ($\chi^2 = 1.02$, $p = 0.31$).

Regarding age, participants aged 18–22 had a prevalence rate of 31% (95% CI: 25.0%–37.0%), while those in the 23–25 age group exhibited a prevalence of 26% (95% CI: 16.0%–36.0%). No statistically significant difference in NSBVD prevalence was found between the age groups ($\chi^2 = 0.79$, $p = 0.42$). These results are presented in Table 8 and Figure 8.

Table 8. Gender and Age Differences in NSBVD Prevalence

Category	Subcategory	Prevalence (%)	95% Confidence Interval	Significance (p-value)
Gender	Female	32%	25.0% - 39.0%	Not significant ($\chi^2 = 1.02$, $p = 0.31$)
	Male	28%	21.0% - 35.0%	
Age Group	18–22 years	31%	25.0% - 37.0%	Not significant ($\chi^2 = 0.79$, $p = 0.42$)
	23–25 years	26%	16.0% - 36.0%	

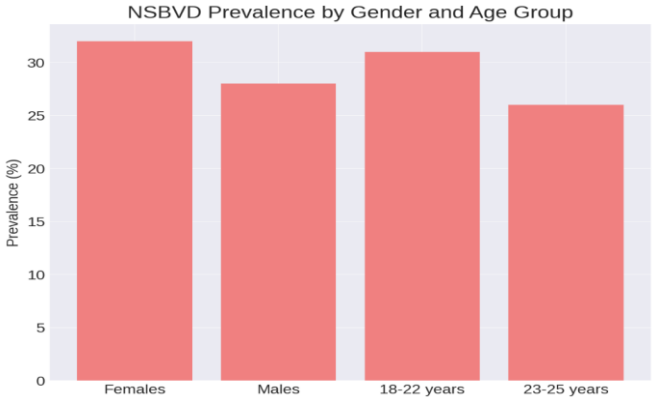

Figure 8: Showing Clustered bar chart for NSBVD prevalence by gender and age.

Correlation Between Screen Time and NSBVD Prevalence

Screen time was identified as a significant factor influencing the prevalence of NSBVD. Among participants who reported more than 6 hours of daily screen time (n = 155, 52% of the sample), 40% (62 students; 95% CI: 33.0%–47.0%) exhibited NSBVD symptoms. In contrast, only 15% (28 students; 95% CI: 10.0%–20.0%) of those with 6 hours or less of screen time showed similar symptoms. The association between high screen time and increased NSBVD prevalence was statistically significant ($\chi^2 = 22.58$, $p < 0.01$), with convergence insufficiency being particularly prevalent among high screen-time users, affecting 22% (34 students; 95% CI: 16.0%–28.0%) of this subgroup. These findings are shown in Table 9 and Figure 9.

Table 9. Correlation Between Screen Time and NSBVD Prevalence

Screen Time	NSBVD Prevalence (%)	Number of Cases	95% Confidence Interval	Significance (p-value)
> 6 Hours/Day	40%	62	33.0% - 47.0%	Statistically significant ($\chi^2 = 22.58$, $p < 0.01$)
≤ 6 Hours/Day	15%	28	10.0% - 20.0%	
Convergence Insufficiency (CI) in High Screen-Time Group	22%	34	16.0% - 28.0%	

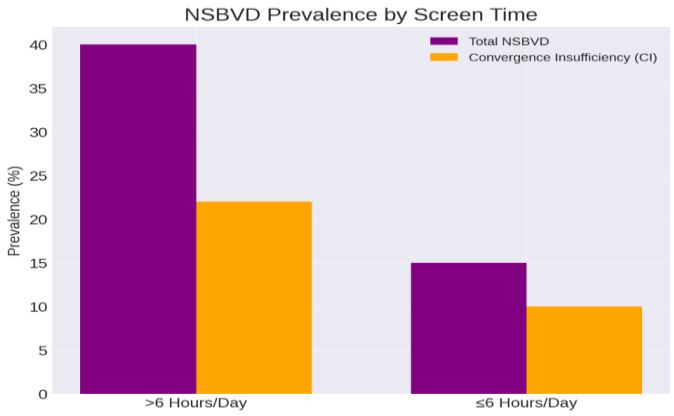

Figure 9: Showing side-by-side bar chart showing NSBVD prevalence in different screen-time groups.

DISCUSSION

This study identifies a notable prevalence (30%) of Non-Strabismic Binocular Vision Disorders (NSBVD) among college students in Surat, with Convergence Insufficiency (CI) being the most prevalent disorder, affecting 18% of the sample. Accommodative Insufficiency (AI) was diagnosed in 8% of participants, while Accommodative Excess (AE) affected 4%. These findings indicate a significant burden of NSBVD in a young adult population engaged in intensive academic work, where prolonged near tasks and screen time are common. The results suggest the importance of addressing visual health within academic environments, as it could have a direct impact on students' quality of life and academic performance.

Comparison with Existing Literature

Our findings align with global research, highlighting the increasing prevalence of NSBVD in populations with high visual demands, such as college students. For example, a study conducted in the U.S. reported a CI prevalence of 13%, which was associated with academic activities that involve prolonged near-focus tasks (Rouse et al., 1999) [5]. The range of CI prevalence in other studies varies widely, from 13% to 37%. A study in North India reported a CI prevalence of 37%, underscoring the impact of academic stress on visual health. Conversely, in Egypt, CI prevalence is reported to be lower, possibly due to lifestyle differences such as greater outdoor activity, which may reduce the risk of near-point visual strain (Iqbal et al., 2023) [7]. These regional differences highlight the role of cultural and environmental factors in influencing the prevalence of NSBVD, despite similar academic pressures across countries.

Screen Time as a Significant Factor

One of the most notable findings of this study is the strong correlation between extended screen time and an increased prevalence of NSBVD. Students who reported over six hours of screen time per day exhibited a 40% prevalence of NSBVD, compared to just 15% in those with lower screen time. This result is consistent with previous research that links sustained near-focus tasks, common in screen use, to visual dysfunction. Prolonged screen exposure places continuous accommodative and convergence demands on the visual system, which can lead to exhaustion and the

development of disorders such as CI (Rosenfield, 2016) [6]. Moreover, extended screen time often reduces blink rate, contributing to dry eye symptoms that exacerbate visual discomfort and further disrupt binocular vision. These findings suggest that managing screen time in academic settings could be a key intervention to reduce the risk of NSBVD in students.

Gender and Age Differences

Gender analysis revealed a slightly higher prevalence of NSBVD in females (32%) compared to males (28%), though this difference was not statistically significant. Previous studies have shown mixed results regarding gender differences in NSBVD prevalence. Some studies report a higher prevalence in females, which could be related to biological factors or gender-specific behaviors, such as more frequent screen use or greater susceptibility to visual strain (Sarkar & Bordoloi, 2021) [2]. Similarly, while younger participants (18-22 years) had a slightly higher prevalence of NSBVD than older students (23-25 years), this difference was also not statistically significant. This could be due to increased digital engagement or adaptation stress among younger students as they transition into more demanding academic environments.

Additional Factors Influencing NSBVD

Beyond screen time, other lifestyle factors such as academic stress, sleep quality, and physical ergonomics likely contribute to the prevalence of NSBVD in this population. Academic stress, commonly experienced by students, can cause muscular tension that affects ocular muscles, exacerbating visual strain. Higher levels of stress have been shown to affect both accommodation and convergence, potentially worsening NSBVD symptoms (Rosenfield, 2016) [6]. Similarly, poor sleep quality is a frequent issue among college students and can impair focus, increasing visual strain.

In addition, poor ergonomic practices, such as improper screen positioning and inadequate lighting, are associated with visual discomfort and may indirectly contribute to the development of binocular vision disorders. Research suggests that implementing ergonomic practices—such as optimal screen height, adequate lighting, and regular screen breaks—could reduce both visual and physical strain, particularly in high-risk groups like college students.

Mechanisms of NSBVD Development with Emphasis on Convergence Insufficiency

Convergence Insufficiency (CI) was the most prevalent disorder in our study and is particularly exacerbated by prolonged near-focus tasks and screen use. CI occurs when the visual system is unable to maintain proper eye alignment during close-up tasks, resulting in symptoms like eyestrain, headaches, and blurred vision. The physiological basis of CI involves poor coordination between accommodation (focusing) and convergence (eye alignment), which is especially stressed by activities requiring sustained near vision.

The findings from this study suggest that continuous accommodation and convergence demands during screen use lead to visual fatigue. Over time, the inability to maintain proper eye alignment during near work manifests as CI, indicating that students are particularly vulnerable to visual dysfunction due to the demands of digital device use (Rouse et al., 1999) [5]. Thus, both reducing screen time and implementing specific treatments for CI, such as vergence therapy, could provide relief and improve visual function in this population.

Clinical Implications and Recommendations

Given the high prevalence of NSBVD, particularly among students with extensive screen use, educational institutions should consider implementing routine binocular vision screenings and visual health programs. Regular screenings could help identify and manage conditions like CI, AI, and other NSBVDs early, ensuring that students' visual health does not interfere with their academic performance. Vision therapy has been shown to be effective in improving convergence and accommodative function, particularly for conditions like CI, and could benefit students with high visual demands (Scheiman et al., 2005) [8].

Additionally, integrating ergonomic interventions into the academic environment could reduce visual strain and prevent the development of NSBVD. Educational institutions could implement awareness programs focusing on proper screen use, such as maintaining appropriate distance, ensuring good lighting, and encouraging regular breaks. The 20-20-20 rule—taking a 20-second break to look at something 20 feet away every 20 minutes—has been widely recommended as an effective strategy to reduce digital eye strain (Sheppard & Wolffsohn, 2018) [9]. By incorporating such strategies, educational institutions can help prevent NSBVD, thereby enhancing students' academic performance and overall well-being.

5. Conclusion and Future Scope

The study revealed a significant prevalence of Non-Strabismic Binocular Vision Disorders (NSBVD) among college students in Surat, with 30% of participants affected, underscoring the substantial burden of visual dysfunctions in young adults with high academic demands. Convergence Insufficiency (CI) emerged as the most common disorder, affecting 18% of students, followed by Accommodative Insufficiency (AI) and Accommodative Excess (AE). The findings emphasize the strong association between prolonged screen time and increased prevalence of NSBVD, as students with over six hours of daily screen use were significantly more likely to exhibit symptoms. These results highlight the critical role of modern digital habits and academic pressures in exacerbating visual strain and dysfunction.

This research provides valuable insights into the prevalence and characteristics of NSBVD in a largely understudied Indian college population, offering a basis for targeted interventions. Routine binocular vision screenings and tailored visual health programs should be integrated into college health services to enable early identification and management of NSBVD. Ergonomic interventions, including

proper screen positioning, optimal lighting, and adherence to practices like the 20-20-20 rule, are recommended to mitigate visual strain. Vision therapy, particularly for CI and AI, can be an effective management strategy, improving binocular coordination and accommodative response among affected students. However, the study has certain limitations, including its cross-sectional design, which limits the ability to establish causal relationships, and its focus on a single geographic region, which may restrict generalizability to other populations.

The outcomes of this study are highly relevant in the context of increasing screen use and digital integration in education, providing evidence for the urgent need to address NSBVD in student populations. These findings hold practical applications for academic institutions, healthcare providers, and policymakers to promote visual health and enhance the academic performance and well-being of students. Future research should focus on longitudinal studies to explore the causal relationship between screen time and NSBVD, along with the role of additional factors such as stress, sleep patterns, and ergonomic practices. Exploring culturally specific interventions and preventive measures across diverse populations would further contribute to a comprehensive understanding and management of NSBVD in the digital age.

Data Availability

The data supporting the conclusions of this study are available from the corresponding author upon reasonable request. The data includes anonymized participant records, raw measurement values for binocular vision tests, and statistical analyses. Due to ethical considerations and participant confidentiality agreements, detailed individual-level data cannot be shared publicly. Access to the data will be granted for research purposes that comply with the ethical standards of the Institutional Review Committee and after appropriate approval.

Study Limitations

This study faced several limitations that may influence its outcomes. First, as a cross-sectional study, it provides a snapshot of NSBVD prevalence and its association with screen time but cannot establish causality or directionality in these relationships. Second, the study was geographically limited to college students in Surat, Gujarat, which may affect the generalizability of findings to other regions or populations with different academic or lifestyle demands. Third, reliance on self-reported screen time data may introduce recall bias, potentially overestimating or underestimating the actual duration of digital device usage. Additionally, participants from allied health fields were excluded to maintain population homogeneity, which may have limited the scope of visual demand variations in the sample. Lastly, the study did not explore other potential contributing factors, such as academic stress, sleep quality, and ergonomic practices, which could provide a more comprehensive understanding of NSBVD etiology.

Future studies addressing these limitations through longitudinal designs, diverse geographic sampling, and incorporation of additional lifestyle and environmental factors would provide deeper insights into the prevalence and management of NSBVD.

Conflict of Interest

The authors declare that they have no conflicts of interest. They affirm that there are no financial, personal, or professional relationships with any individuals or organizations that could inappropriately influence, or be perceived to influence, the outcomes of this research.

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Authors' Contributions

Dr. Ankit S. Varshney conceptualized and designed the study, conducted the literature review, and supervised the research process and analysis. Ms. Diana Ruguge contributed to protocol development, participant recruitment, data collection and the execution of binocular vision assessments. Mr. Hardeepsinh Mahida performed statistical analyses and assisted in interpreting the results. Ms. Ruguge drafted the initial manuscript, and Dr. Varshney and Mr. Mahida reviewed and edited the manuscript. All authors approved the final version of the manuscript for submission.

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