

Non-strabismic Binocular Vision Anomalies among Eastern Nepalese Children: A Cross-sectional Study

Priyanka Yadav,¹ Anita Gupta,¹ Purushottam Joshi²

¹Chitkara School of Health Sciences, Chitkara University, Rajura, Punjab, India, ²Mechi Eye Hospital, Birtamod, Jhapa, Nepal.

ABSTRACT

Introduction: Non-strabismic binocular vision anomalies are the most prevalent undiagnosed/misdiagnosed visual disorders seen in clinical practice in the school-aged population.

Methods: This was a planned cross-sectional research. The research included 995 individuals aged five to 18 from 15 schools in Nepal's eastern region. A cluster sampling approach was applied. A comprehensive binocular vision examination was performed on all participants to determine the prevalence for non-strabismic binocular vision anomalies.

Results: In the eastern region of Nepal, there were 501 (50.35%) non-strabismic binocular vision anomalies. The mean age of the participants was 12.97 ± 2.73 years. There were 465 (46.73%) males and 530 (53.27%) females among the subjects. Fusional vergence dysfunction was reported in 61 (6.13%) participants, accommodative infacility in 166 (16.68%), and convergence insufficiency in 251 (25.23%).

Conclusions: Aside from refractive error, non-strabismic binocular vision anomalies are among the most often encountered visual disorders in school children in clinical practice.



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Correspondence:

Name: Priyanka Yadav
Affiliation: Chitkara School of Health Sciences, Chitkara University, Rajura, Punjab, India.
Email: priyanka.vision2012@gmail.com
Phone no.: +977-9817888340



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INTRODUCTION

Binocular vision is the capability to see with both eyes at the same time. Impairment in this leads to conditions such as strabismus, amblyopia and non-strabismic binocular vision anomalies (NSBVA).¹⁻⁵ The prevalence of NSBVA was found to be 27.81% among medical students and 71.41% among engineering students in Nepal; 31.50% and 29.60% among rural and urban students of India; 28.52% among the South Korean population and 22.26% among Spanish students.⁶⁻¹¹ The prevalence estimates range from 2.25% to 33%, which may be owing to variance in the diagnosis cut-off and criteria.⁶

Various physiological and environmental factors like age, race, ethnicity, origin, ocular anatomy, refractive status, and testing techniques have been exposed to affect the analytic cut-off of binocular vision parameters.^{6, 10-12}

Since there has been limited study on the prevalence of NSBVA among Nepalese children below 18 years, it is essential to control the occurrence of these anomalies among school-going children in the country by determining its prevalence.

METHODS

This was a prospective, cross-sectional study conducted in

the eastern area of Nepal between December 2022 and June 2024. The study was approved by the Institutional Ethics Committee of Chitkara University (Reference No: EC/NEW/INST/2023/531/150) as well as Institutional Ethics committee of Mechi Eye Hospital and adhered to the declarations of Helsinki. Using a two-stage cluster sampling technique, fifteen schools were chosen in eastern region of Nepal and vision screening was performed on 6858 students. 995 students were chosen randomly from those students for comprehensive binocular vision assessment based on the inclusion criteria and sample size calculation. The students aged 5 to 18 years were enrolled in the study. The consent was taken from the government bodies as well as schools' authorities.

The sample size was calculated using Slovin's formula i.e. $n = N / (1 + Ne^2)$ where, n = Sample size; N = Population size (379, 368) and e = Margin of error (taken 5%). The normative data was estimated followed by the prevalence of non-strabismic binocular vision anomalies based on cut-off derived from the normative data. Students aged 5-18 years having best corrected visual acuity 6/6 for distance and near acuity N6 were included in the study whereas students having a self/guardian reported history of any types of ocular or head trauma, juvenile diabetes,

any types of intraocular or squint surgeries done earlier, any types of ocular abnormalities/strabismus (constant or intermittent)/amblyopia were excluded from the study.

Screening camps were conducted and vision screening as well as eye examinations were done which includes visual acuity testing, subjective and objective refraction and examination of anterior and posterior segment of eye. After the vision screening, all students who had best corrected visual acuity 6/6 and having no ocular abnormalities underwent a basic binocular vision assessment that included corneal reflex test, cover test, stereo acuity test and worth 4 dot test and then subjects passing the basic binocular vision assessment i.e. subjects with no constant or intermittent squint, no suppression, and a stereo visual acuity of forty seconds of arc were given a thorough binocular vision evaluation and accommodative assessment, that included near point convergence as well as phoria at distance and near, fusional vergence amplitude, vergence facility, near point of accommodation, accommodative response, and monocular and binocular accommodative facility. As a result, normative and non-strabismic binocular vision anomalies were identified. Scheiman and Wick proposed criteria for diagnosing non-strabismic binocular vision anomalies, which included convergence insufficiency, convergent excess, divergent insufficiency, divergent excess, basic esophoria, basic exophoria, and fusional vergence dysfunction, accommodative insufficiency, accommodative excess, and accommodative infacility which was followed in our study as well.¹² The flowchart showing steps of subjects' recruitment is mentioned below (Figure 1).

Each patient underwent a thorough eye examination and a binocular vision evaluation. This involved entering the participants' name, age, gender, levels of education, height, and weight on a BV proforma. The "GK FML World's measure" inch tape was used to measure height, and a weighing machine was used to assess weight. Each participant's complete medical history was gathered, including information on their usage of glasses, allergies, systemic disorders, ocular conditions, family history, and any traumatic experiences. Additionally, each participant was questioned about any prior ocular diagnosis and whether they had any supporting paperwork. They were also asked about their main ocular symptoms at the moment. Snellen's pocket vision screener was used to assess visual acuity from a three-meter distance. A modified Snellen's visual acuity chart was used to test near visual acuity from a distance of 40 cm away. Retinoscopy was done using a Heine retinoscope, a trial frames, and trial lenses. Subjective refractive was carried out using objective results. Subjects with latent hyperopia, or accommodative difficulties were evaluated with the fogging method and referred to the hospital if cycloplegia refraction was required.^{3,13,14} The anterior as well as posterior segments of the eye were examined, and those who showed any signs of ocular diseases were referred to the hospital.^{13,15}

The Hirschberg corneal reflex examination was used to identify the type and severity of tropia. To determine any variations and

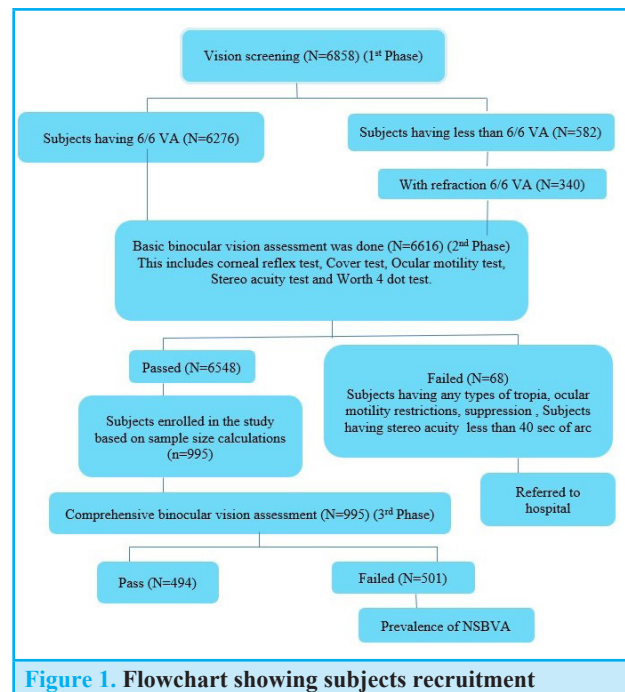


Figure 1. Flowchart showing subjects recruitment

their magnitude, both distant and near cover tests were performed, including the direct cover test, cover-uncover test, alternative cover test, and prism bar cover test.^{3,13,14} The Broad H test was used to assess ocular motility.^{3,14} The nearest point of convergence was examined using the RAF ruler, and all subjects' break & recovery points were noted. The magnitude of accommodation was also determined with an RAF ruler. Stereopsis was measured using a Lang stereo chart at a distance of 40 cm and with complete optical correction. Near & distance fusional vergences (negative and positive) were assessed utilizing the horizontal prism bar with base in or base out, correspondingly, and all participants' break and recovery points were recorded.^{3,13,14}

A fixation card and plus and minus trial lenses, respectively, were used to measure NRA (negative relative accommodation) and PRA (positive relative accommodation) at a distance of 40 cm. An accommodating rock card and ± 2 D accommodating flippers were used to test accommodative facility. Vergence flipper of 3D base in and 12D base out were used to measure vergence facility. The lead or lag of accommodation was shown by measuring accommodative response using the monocular estimation method. The gradient approach was used to calculate the AC/A ratio. A maddox rod, trial frame with a modified thorington chart positioned at 40 cm, and a pen torch with or without a -1D trial lens were used to assess phoria. The change in accommodation represented the gradient AC/A value. To detect any forms of suppression, the Worth 4 dot test was conducted utilizing an LED Worth 4 dot torch for both near and distance vision.^{3,13,15} Two skilled and knowledgeable optometrists conducted both basic and detailed binocular vision evaluations. Before the fieldwork, the inter-examiner reliability was also computed for every binocular vision measure.

After entering and carefully reviewing all the data in Microsoft

Excel, it was imported and analyzed using the Statistical Package for Social Sciences (SPSS for Windows, version 22.0, IBM-SPSS, Chicago, IL, USA). Descriptive statistics and frequency distribution were presented as mean and standard deviation.

RESULTS

A total of 6858 participants aged between five to eighteen years of age were screened in 15 schools and 995 participants were included in the study. The average age of the participants was 12.97 ± 2.73 years. The individuals' average height and weight were 38.66 ± 12.58 kg and 4.95 ± 0.57 feet, respectively. Among the participants, 465 (46.73%) were males 530 (53.27%) were females. Compound myopic astigmatism was noted in 34 (3.42%), simple myopia in 30 (3.02%) and mixed astigmatism in 2 (0.20%) (Table 1). There were 501 (50.35%) cases of non-strabismic binocular vision anomalies found. Of them, 251 (25.23%) had convergence insufficiency, 166 (16.68%) had accommodative infacility, and 61 (6.13%) had fusional vergence dysfunction (Table 2).

Table 1. Different types of refractive errors (n=995).

Refractive Errors	n(%)
Simple Myopia	30(3.02)
Simple myopic astigmatism	10(1.01)
Compound myopic astigmatism	34(3.42)
Simple hyperopia	5(0.50)
Mixed Astigmatism	2(0.20)

Table 2. Different types of non-strabismic binocular vision anomalies in Eastern Nepal (n=995).

Binocular Vision Status	n(%)
Normal binocular vision	494(49.65)
Overall NSBVD	501(50.35)
Convergence insufficiency	251(25.23)
Fusional vergence dysfunction	61(6.13)
Accommodative infacility	166(16.68)
Accommodative insufficiency	2(0.20)
Convergence insufficiency with accommodative insufficiency	11(1.11)
Convergence insufficiency with accommodative excess	6(0.60)
Convergence excess with accommodative insufficiency	4(0.40)

NSBVD: Non-strabismic Binocular Vision Dysfunction.

The initial normative values for binocular vision variables from the same demographic group were used as baseline data for these parameters. Near point of convergence break and recovery values in the convergence insufficiency group were 9.71 ± 2.22 and 10.80 ± 2.19 , respectively, and those in the normal binocular vision group were 6.13 ± 0.50 and 7.30 ± 0.76 , respectively. The monocular and binocular accommodative facility in the accommodative infacility group were 4.82 ± 1.17 and 4.90 ± 1.26 , respectively, and those in the standard normal binocular vision group were 13.36 ± 3.69 and 13.58 ± 3.86 , respectively. The fusional vergence dysfunction group had positive and negative fusional vergence break and recovery values for both

distance (DPFV Break: 9.31 ± 3.09 , DPFV Recovery: 7.31 ± 3.09 ; DNFV Break: 5.97 ± 3.15 , DNFV Recovery: 3.80 ± 3.22) and near (NPFV Break: 13.74 ± 4.03 , NPFV Recovery: 12.03 ± 3.26 ; NNFV Break: 10.49 ± 5.12 , NNFV Recovery: 8.79 ± 4.22), while the corresponding values in the normal binocular vision group were DPFV Break: 12.93 ± 2.69 , DPFV Recovery: 10.87 ± 2.70 ; DNFV Break: 9.89 ± 1.83 , DNFV Recovery: 7.82 ± 1.87 ; NPFV Break: 19.06 ± 3.43 , NPFV Recovery: 16.61 ± 2.71 ; and NNFV Break: 16.71 ± 3.44 , NNFV Recovery: 14.53 ± 3.32 (Table 3).

The distribution of non-strabismic binocular vision anomalies was 257 (25.83%) among males and 244 (24.52%) among females. The age groups were categorised as 5–11 years and 12–18 years, with 191 (19.20%) and 310 (31.16%) subjects, respectively.

DISCUSSION

Our study provides the first report of non-strabismic binocular vision anomalies among school-going children aged 5–18 years in the Eastern Nepalese community. The non-strabismic binocular vision anomalies was 50.35%, indicating that a considerable proportion of school children in Nepal's eastern area suffer from different kinds of accommodative and vergence abnormalities. The frequency of non-strabismic binocular visual abnormalities in Nepal is being reported for the first time in a population-based study. According to a recent study, 27.81% of medical students enrolled at a teaching hospital in Nepal had non-strabismic binocular vision abnormalities. Convergence insufficiency was most common, next to divergence excess and others.⁶ Similarly, accommodative insufficiency was found to be more common among Nepali engineering students (12.85%) than convergence insufficiency (11.42%).⁷ Medical and engineering students make up the study population in both investigations, indicating that the age range is beyond 20. The prevalence of non-strabismic binocular vision abnormalities was also discovered in a hospital-based research of the Nepalese population. Symptomatic participants with a best corrected visual acuity of 6/6 were enrolled in this study, which was conducted in a tertiary eye hospital in Nepal. Convergence insufficiency (18.2%) was the most prevalent anomaly, followed by fusional vergence dysfunction (3.9%) and accommodative infacility (6.06%). Similar to our study, this one also indicates that convergence insufficiency is the most common NSBVA. However, the study only included symptomatic participants, and the individuals' age ranged from 18 to 35, which is quite different from ours. The study was carried out in the central region of Nepal, and they used a modest sample size.¹⁶ Non-strabismic binocular vision abnormalities are seen in 29.6% to 76.5% of Indians, with convergence insufficiency being the most common anomaly.^{10,17-19} The majority of prevalence investigations carried out in India focused on university and college students.^{14,18} Non-strabismic binocular vision abnormalities were shown to be more common in the European population, with accommodative anomalies out numbering convergence anomalies, according to many studies.^{20,21} The age range and testing methodologies differed from those used in our study.

Table 3. Mean values of binocular vision parameters in convergence insufficiency (CI), accommodative infacility (AIF) and fusional vergence dysfunction subjects (n=995).

BV parameters	CI N=251	AIF N=166	FVD N=61	Normative reference N=494
Mean age, years	13.86±2.21	10.27±1.80	12.64±2.61	13.40±2.66
NPC-AT, cm				
Break	9.71±2.22	6.20±0.40	7.48±1.13	6.13±0.50
Recovery	10.80±2.19	7.25±0.44	8.97±1.44	7.30±0.76
AOA,D				
M/O	11.92±2.38	14.39±2.4	10.26±2.78	13.31±2.30
B/O	11.92±2.38	14.55±2.26	10.26±2.78	13.28±2.41
Near PFV, PD				
Break	19.61±3.06	19.71±3.66	13.74±4.03	19.06±3.43
Recovery	17.08±2.21	16.92±2.59	12.03±3.26	16.61±2.71
Near NFV, PD				
Break	18.63±2.69	18.17±2.57	10.49±5.12	16.71±3.44
Recovery	16.31±2.89	16.00±2.37	8.79±4.22	14.53±3.32
Distance PFV, PD				
Break	12.81±3.14	11.71±2.84	9.31±3.09	12.93±2.69
Recovery	10.74±3.09	9.71±2.84	7.31±3.09	10.87±2.70
Distance NFV, PD				
Break	11.29±1.42	9.96±1.99	5.97±3.15	9.89±1.83
Recovery	9.08±1.72	7.87±2.03	3.80±3.22	7.82±1.87
Accommodative facility, CPM				
M/O	13.41±4.47	4.82±1.17	13.21±5.07	13.36±3.69
B/O	13.86±4.34	4.90±1.26	12.56±5.44	13.58±3.86
Vergence facility, CPM	15.11±2.54	15.07±2.04	14.82±1.45	5.11±1.91
NRA	2.74±0.70	2.42±0.66	1.65±0.48	2.43±0.57
PRA	3.47±0.86	3.04±0.78	2.7±0.76	2.94±0.86
AC/A	5.22±0.42	5.12±0.29	5.31±0.26	5.22±0.29

CI: Convergence insufficiency; AIF: Accommodative infacility; FVD: Fusional vergence dysfunction; NPC-AT: Near point of convergence with accommodative target; AOA: Amplitude of accommodation; D: Dioptres; PFV: Positive fusional vergence; PD: Prism Dioptres; NFV: Negative fusional vergence; CPM: cycles per minute; NRA: Negative relative accommodation; PRA: Positive relative accommodation; AC/A: Accommodative convergence/accommodation ratio.

The variation in the prevalence and type of the most common anomalies can be due to differences in age range, testing techniques, or a variety of other biological variables such as the weather, gender, workplace setting, job, instruments used, and so on.¹⁰ Previously, several investigations were conducted in various regions of the world to determine the occurrence of accommodative and vergence anomalies. Comparison of prevalence of non-strabismic binocular vision anomalies among school students across different countries has been presented in Table 4. As a result, conducting a prevalence research among Nepalese school children was critical since undiscovered non-strabismic binocular vision defects have a negative impact on academic achievement.⁹ As a result, this study was conducted in order to uncover those abnormalities early on and handle them effectively, allowing school students to achieve high academic performance in the long run. As indicated (Table 4), when we analyze the prevalence of NSBVA in four nations throughout the world, we find that convergence insufficiency is most common in Nepalese, Indian, and Korean populations, whereas accommodative insufficiency is most common in Riopiedras. Similarly, it was subsequently followed by accommodative infacility among both Nepalese & Indian populations, with

accommodative insufficiency ranking second among Koreans. Convergence insufficiency was the second most prevalent ailment among Riopiedras. This demonstrates that the prevalence differs with ethnicity and race, as well as other biological variables and testing methods.

Limitations: Eastern Nepal currently organized as Koshi province encompasses fourteen administrative districts. The schools chosen for binocular vision assessment and data collection for the study were mainly from Jhapa and Illam and thus the occurrence of non-strabismic binocular vision anomalies could be variable if we consider all the districts of Eastern region.

CONCLUSION

Non-strabismic binocular vision anomalies are relatively common visual impairments found in school children after refractive error. Convergence insufficiency is the most prevalent types of non-strabismic binocular vision anomalies. Thus, screening of BV anomalies is an essential aspect of vision assessment among school children.

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Table 4. Comparison of prevalence of non-strabismic binocular vision anomalies among different countries

Binocular vision anomalies	Present study	Hussaindeen et al. ¹⁰ (Rural)	Hussaindeen et al. ¹⁰ (Urban)	Stefania M. Paniccia et al. ²¹	Jung Un Jang et al. ¹¹
Settings	Eastern Nepal	Tamilnadu, India	Tamilnadu, India	Santurce, Rio Piedras, Bayamon, Caguas, Hato Rey	South Korea
Population	Nepalese school children	Indian school children	Indian school children	Puerto Rican Pediatric Population	Korean primary school children
Age range	5–18 years	7–17 years	7–17 years	5–20 years	8–13 years
Sample size	995	358	562	593	589
Normal binocular vision (%)	49.65	70.4	68.5	—	71.5
Overall NSBVA (%)	50.35*	29.6*	31.5*	—	28.5*
Convergence insufficiency (%)	25.23**	63**	93**	12.6***	10.3**
Convergence excess (%)	0	6	10	9.1	1.9
Divergence excess (%)	0	0	2	1.3	—
Fusional vergence dysfunction (%)	6.13	3	5	4.7	—
Divergence insufficiency (%)	0	1	0	2.7	—
Basic esophoria (%)	0	1	0	5.1	—
Basic exophoria (%)	0	0	0	3.5	—
Vergence infacility (%)	0	0	2	—	—
Accommodative infacility (%)	16.68***	29***	64***	7.6	—
Accommodative excess (%)	0	3	0	5.1	1.2
Accommodative insufficiency (%)	0.20	0	1	39**	5.3***
Ill-sustained accommodation (%)	0	0	0	0.2	—

* marks overall NSBVA; ** most prevalent NSBVA; *** 2nd highest prevalent NSBVA; NSBVD = Non-strabismic Binocular Vision Dysfunction.

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