

Normative Data for Non-Strabismic Binocular Vision Parameters in a Nepalese Young Adults

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Purpose: To establish population-specific normative data for non-strabismic binocular vision (NSBV) parameters in Nepalese young adults and to evaluate their association with age and gender.

Materials and Methods: This cross-sectional analytical study included asymptomatic adults aged 18–35 years who underwent comprehensive ophthalmic evaluation and standardized accommodative and binocular vision assessments. The mean and standard deviation were used to describe the central tendency and dispersion of the study parameters, respectively. Intergroup comparisons were performed using ANOVA and independent t-tests.

Results: A total of 1,393 participants completed all NSBV assessments. The mean age of the participants was 25.04 ± 4.79 years. The mean values for key NSBV parameters were as follows: amplitude of accommodation, 8.75 ± 1.53 D; accommodative response (MEM), 0.50 ± 0.30 D; monocular accommodative facility, 9.98 ± 3.55 cpm; binocular accommodative facility, 6.39 ± 2.79 cpm; near point of convergence (break), 4.82 ± 1.50 cm; distance phoria, 0.19 ± 0.79 exophoria; near phoria, 2.96 ± 2.65 exophoria; and AC/A ratio, 2.61 ± 1.23 . Amplitude of accommodation showed a strong negative association with age ($AA = 16.20 - 0.30 \times \text{age}$; $R^2 = 0.85$; $p < 0.001$). Although gender differences were statistically significant for several parameters, the magnitude of these differences was small and not clinically meaningful.

Conclusion: This study provides the first large-scale normative clinical dataset of NSBV parameters in Nepalese young adults. Age significantly influences accommodative parameters, whereas gender-related differences are minimal. These population-specific normative values may support the screening, accurate diagnosis, and management of NSBVA and provide a contemporary reference for clinicians and researchers working with South Asian populations.

Keywords: Nepal, normative data, accommodation, binocular vision, non strabismic binocular vision anomalies

Introduction

Accommodative and binocular dysfunctions are a group of distinct visual disorders that affect binocularity and reduce the efficiency of the visual system, particularly during near tasks.¹ These dysfunctions are collectively referred to as non-strabismic binocular vision anomalies (NSBVA).² Several studies have suggested that the occurrence of NSBVA is relatively common. However, the reported prevalence of NSBVA varies widely across studies. A systematic review indicated that the prevalence of NSBVA ranges from approximately 0.1% to 33%, with higher rates typically observed in clinical or hospital-based populations compared to the general population.¹ Such variations may be influenced by study design, inclusion criteria, population characteristics, the range of clinical tests, and diagnostic criteria.³

These anomalies can lead to various vision-related symptoms such as headache, visual fatigue, loss of concentration, blurred vision, and diplopia, particularly during prolonged near activities or sustained digital device use,^{3,4} which may impair academic and occupational performance and reduce quality of life.^{4,5} Therefore, the diagnosis and treatment of these anomalies are important in the field of eye care and vision science. Accurate diagnosis and treatment of these

anomalies require a proper analysis of non-strabismic binocular vision (NSBV) parameters, which are measured using appropriate tests and compared with established normative values of the general population.⁶ Scheiman and Wick norms present expected values for NSBV parameters in White American children (7–12 years) and adults,⁷ which is most commonly used worldwide. However, normative values across different ages and the influence of gender on these values have not been studied.

Several studies have shown that using normative values from one ethnic population, without considering factors such as age and gender, to diagnose NSBVA in other ethnic populations is inappropriate.^{8–10} Population-defining variables such as race, ethnicity, and age are known to influence refractive status,^{11,12} which subsequently impacts binocular vision.^{13,14} Hussaindeen et al⁹ in Indian children, Alrasheed et al¹⁵ in Saudi young adults, and Darko-Takyi et al¹⁶ in Ghanaian school children reported significant differences in NSBV measures compared with Scheiman and Wick norms, indicating that ethnic, geographic, and environmental factors can influence binocular and accommodative function. Although various studies have reported normative values for NSBV parameters in different racial populations,^{8,9,11,14,16–18} only a few have focused on adult populations across different ages and genders.^{8,11} Accommodation gradually declines during early adulthood, while binocular stability and gender-related differences remain poorly understood in the literature. Therefore, establishing and evaluating age-, gender-, and ethnicity-specific normative values for NSBV parameters is essential to enhance the accuracy and clinical relevance of interpretation across diverse populations.

To date, no large-scale study has established age and gender-specific normative data for NSBV parameters in the Nepalese adult population, despite evidence suggesting ethnic variability in NSBV parameters. Addressing this gap, the present study is designed to establish normative data for NSBV parameters in a sample of the Nepalese adult population. It also aims to examine the relationship of these parameters with age and gender, and to compare the findings with normative NSBV data reported in other studies.

Methods

Ethical Consideration

This cross-sectional analytical study was conducted at the Tilganga Institute of Ophthalmology, Kathmandu, in 2022. The study adhered to the Declaration of Helsinki, and ethical approval was obtained from the Institutional Review Committee of the Tilganga Institute of Ophthalmology (Proposal number 10–2022). Written informed consent was obtained from all participants prior to the assessment of NSBV parameters, after the nature, purpose, and procedures of the study had been fully explained. The dignity and autonomy of all participants were respected and preserved throughout the study.

Sample Size Calculation and Sampling Technique

The estimated minimum sample sizes for each NSBV parameter were calculated using the formula $n = [Z_{1-\alpha/2}^2 \times SD^2] / d^2$, where $Z_{1-\alpha/2}$ is the standard normal variate at a 95% confidence interval ($P < 0.05$) = 1.96; SD is the standard deviation from a previous study in an adult population,⁸ and d is the absolute allowable error in estimating the values. Based on this approach, the minimum required sample size was 1,195 participants, which was considered sufficient to determine normative values for the parameters with the highest standard deviations, ensuring reliable and precise data ([Appendix Table A1](#)). To account for an anticipated 20% dropout rate, a minimum of 1,494 participants was required for comprehensive examination prior to the assessment of accommodative and binocular vision parameters.

Over a one-year period, all consecutive asymptomatic participants aged 18 to 35 years who met the inclusion criteria were recruited. Each participant underwent a comprehensive eye examination and specific tests to assess NSBV parameters, and findings were recorded in real time using a standardized data collection sheet.

Comprehensive Ophthalmic Examination

A comprehensive ophthalmic evaluation, including clinical history, refraction, anterior and posterior segment examinations, ocular motility assessed using the broad *H*-test, Worth four-dot test at both near and distance, and near stereopsis (Titmus fly test),⁷ was performed before the assessment of NSBV parameters. Participants were classified as asymptomatic if they had not experienced any vision-related symptoms, as defined by García-Muñoz et al⁴ in their scoping

review. Subjective refraction was conducted using the monocular fogging method, followed by binocular balancing to achieve the standard endpoint of maximum plus for best visual acuity. If a participant was found to have a significant refractive error for the first time (myopia ≥ -0.50 diopter sphere, hyperopia $\geq +0.50$ diopter sphere, or astigmatism ≥ 0.50 diopter), or if a change greater than 0.50 diopter occurred in the spherical or cylindrical component during refraction, glasses were prescribed, and the NSBV assessment was performed six weeks after the start of spectacle correction. Subsequently, a detailed assessment of accommodative and binocular vision parameters was conducted in the orthoptic department by multiple trained examiners following a standardized protocol. Inter-examiner reliability was evaluated in a subset of participants using the intraclass correlation coefficient (ICC), which demonstrated good agreement for the measured parameters (ICC > 0.80).

Accommodative and Binocular Vision Assessment

Ocular deviation was measured using the prism bar cover test at both near (40 cm) and distance (6 m),^{19,20} while the subject was instructed to fixate on a single letter of 6/9 visual acuity. For positive and negative step fusional vergences, the break and recovery points were measured at both near and distance using a horizontal prism bar with a target equivalent to 6/9 visual acuity.⁷ Negative fusional vergence (NFV) was measured before positive fusional vergence (PFV).⁷ Lag of accommodation was assessed using dynamic retinoscopy with the Monocular Estimated Method (MEM),²¹ while the subject fixated on an accommodative target of 6/9 size placed in free space at their habitual near reading distance. Monocular amplitude of accommodation (AA) was measured in primary gaze using push-up method.²² Near point of convergence (NPC) was measured by slowly moving the accommodative target of size 6/9 closer to the eyes until the patient reported diplopia or the examiner observed a fusion break.²³ The accommodative convergence to accommodation (AC/A) ratio was measured using the gradient method, near phoria was re-measured with and without the addition of -1.00 diopter lenses.⁷ Monocular and binocular accommodative facilities were assessed using ± 2.00 diopter flipper lenses at 40 cm.⁷ Each was measured for one minute, and the number of cycles per minute was recorded. Additionally, during the measurements, any difficulty experienced by participants while viewing through positive and/or negative lenses was also recorded. Positive and negative relative accommodation were measured using minus and plus lenses (increase 0.25 diopter steps), respectively, in the phoropter, with a 6/9 size accommodative target at 40 cm.⁷ The test continued until the subject reported sustained blur. Negative relative accommodation was measured before positive relative accommodation. All parameters were measured using standardized instruments for each specific test, with the same type and brand of equipment used for all participants, under consistent photopic lighting conditions (410 lux). Each parameter was measured three times, and the mean value was used for analysis. In cases of noticeable variability between readings, the measurement was repeated to ensure consistency prior to recording the final value.

Inclusion and Exclusion Criteria

All asymptomatic participants aged between 18 and 35 years²⁴ with unaided or best-corrected distance visual acuity of 6/6 and near visual acuity of N6 at 33 cm in each eye, were enrolled for the assessment of NSBV parameters. Exclusion criteria included the presence of NSBVA related symptoms,^{3,25} any ocular or systemic disease, contact lens use, anisometropia greater than 2.00 diopter, constant or intermittent strabismic deviation, use of systemic or topical medications affecting accommodation or binocular vision, and stereopsis less than 60 seconds of arc.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 20.0). Mean and standard deviation were used to describe the central tendency and dispersion of the study parameters, respectively. All of the study parameters showed a normal distribution during the normality test using Kolmogorov–Smirnov test ($p > 0.05$). Comparison of values between genders was carried out using the unpaired *t*-test. Comparisons among the three age groups were performed using one-way analysis of variance (ANOVA). When a significant difference was detected, post hoc pairwise comparisons were conducted using Tukey's honestly significant difference test, which controls for multiple comparisons. Phoria values were expressed using the conventional clinical sign convention, with negative values indicating exophoria and positive values indicating esophoria. Results were considered significant at p -value < 0.05 at a 5% level of significance.

Results

Out of 1,494 participants who underwent comprehensive ophthalmic examinations, 336 required spectacle correction (of whom 238 returned for NSBV assessment), and three participants had incomplete NSBV assessments and were excluded from the final analysis. Consequently, 1,393 participants completed the full NSBV evaluation and were included in the final analysis. The mean age of the sample was 25.04 ± 4.79 years, and 857 (61.5%) were male. Normative values for all NSBV parameters are presented in [Table 1](#).

Participants were categorized into three age groups: 18–23 years (Group 1), 24–29 years (Group 2), and 30–35 years (Group 3). Comparisons across these groups were conducted using one-way ANOVA ([Table 2](#)). Significant age-related differences were found for several accommodative measures (monocular amplitude of accommodation (AA), accommodative response, and accommodative facility) as well as for binocular parameters including NPC break and recovery, distance and near phoria, AC/A ratio, and relative accommodation. The mean monocular AA values for each age group are detailed in [Appendix Table A2](#). Linear regression analysis demonstrated a strong negative relationship between age and AA ($AA = 16.20 - 0.30 \times \text{age}$; $R^2 = 0.85$; $p < 0.001$), as illustrated in [Figure 1](#). This model demonstrated a strong goodness-of-fit and a steeper age-related decline compared with classical formulas reported in the literature.

Gender comparisons ([Table 3](#)) showed several statistically significant differences; however, the magnitudes were small and within the expected variability of these clinical tests. Males exhibited slightly higher values for monocular accommodative facility, PFV (distance and near), NFV (near), AC/A ratio, and relative accommodation, whereas females showed marginally higher phoria values at distance and near and larger NPC break and recovery values. Overall, these differences are unlikely to be clinically meaningful and should be interpreted with caution, as statistical significance may not reflect true functional disparities.

Table 1 Normative Data for Non-Strabismic Binocular Vision Parameters in Nepalese Young Adults. Values are Presented as Mean \pm SD (Minimum–Maximum). Data Represent Descriptive Normative Reference Ranges for Asymptomatic Young Adults

NSBV Parameter	Mean	Standard Deviation	Minimum	Maximum
NPC break	4.82	1.50	2.00	9.00
NPC recovery	7.16	1.62	4.00	11.50
Monocular amplitude of accommodation	8.75	1.53	4.46	13.08
Monocular accommodative facility	9.98	3.55	4.00	15.00
Binocular accommodative facility	6.39	2.79	3.00	13.00
MEM	0.50	0.30	-0.25	1.25
Distance phoria	-0.19	0.79	-2.00	2.00
Near phoria	-2.96	2.65	-6.00	4.00
Gradient AC/A ratio	2.61	1.23	1.00	7.00
PFV break distance	17.18	6.74	8.00	35.00
PFV recovery distance	13.08	4.92	6.00	25.00
PFV break near	25.20	9.47	10.00	45.00
PFV recovery near	19.01	7.62	6.00	35.00
NFV break distance	9.38	3.05	6.00	20.00
NFV recovery distance	6.54	2.40	4.00	18.00
NFV break near	17.03	5.53	8.00	30.00
NFV recovery near	13.27	4.49	6.00	25.00
NRA	2.24	0.57	1.00	4.00
PRA	-2.25	0.71	-4.00	-1.50

Abbreviations: NSBV, Non strabismic binocular vision; NPC, Near point of convergence; MEM, Monocular estimated method; AC/A, Accommodative convergence to accommodation ratio; PFV, Positive fusional vergence; NFV, Negative fusional vergence; NRA, Negative relative accommodation; PRA, Positive relative accommodation.

Table 2 The Distribution of NSBV Parameters by Age. Values are Presented as Mean \pm SD. Comparisons Were Performed Using One-Way ANOVA with Tukey Post Hoc Analysis

NSBV Parameter	18-23 years Group 1 (n=599) Mean \pm SD	24-29 years Group 2 (n=492) Mean \pm SD	30-35 years Group 3 (n=302) Mean \pm SD	p value	Post-hoc
NPC	4.65 \pm 1.49	4.93 \pm 1.52	5.00 \pm 1.47	<0.001*	Group 1 vs 2: 0.005 Group 2 vs 3: 0.783 Group 1 vs 3: 0.002
NPC recovery	7.01 \pm 1.56	7.29 \pm 1.67	7.30 \pm 1.65	0.005*	Group 1 vs 2: 0.014 Group 2 vs 3: 0.990 Group 1 vs 3: 0.028
Monocular amplitude of accommodation	10.11 \pm 0.90	8.37 \pm 0.71	6.71 \pm 0.60	<0.001*	Group 1 vs 2: <0.001 Group 2 vs 3: <0.001 Group 1 vs 3: <0.001
Monocular accommodative facility	10.50 \pm 3.58	9.62 \pm 3.55	9.58 \pm 3.42	<0.001*	Group 1 vs 2: <0.001 Group 2 vs 3: 0.986 Group 1 vs 3: 0.001
Binocular accommodative facility	6.87 \pm 2.94	6.08 \pm 2.66	5.98 \pm 2.57	<0.001*	Group 1 vs 2: <0.001 Group 2 vs 3: 0.871 Group 1 vs 3: <0.001
MEM	0.46 \pm 0.27	0.54 \pm 0.32	0.56 \pm 0.34	<0.001*	Group 1 vs 2: <0.001 Group 2 vs 3: 0.613 Group 1 vs 3: <0.001
Distance phoria	-0.31 \pm 0.84	-0.13 \pm 0.75	-0.08 \pm 0.72	<0.001*	Group 1 vs 2: <0.001 Group 2 vs 3: 0.638 Group 1 vs 3: <0.001
Near phoria	-2.66 \pm 2.43	-3.21 \pm 2.79	-3.16 \pm 2.80	0.001*	Group 1 vs 2: 0.002 Group 2 vs 3: 0.955 Group 1 vs 3: 0.021
AC/A	2.66 \pm 1.37	2.80 \pm 1.28	2.23 \pm 0.70	<0.001*	Group 1 vs 2: 0.122 Group 2 vs 3: <0.001 Group 1 vs 3: <0.001
PFV break distance	17.34 \pm 6.36	17.08 \pm 7.02	17.02 \pm 7.04	0.729	Group 1 vs 2: 0.801 Group 2 vs 3: 0.990 Group 1 vs 3: 0.771
PFV recovery distance	13.09 \pm 4.58	13.13 \pm 5.16	12.99 \pm 5.19	0.919	Group 1 vs 2: 0.988 Group 2 vs 3: 0.912 Group 1 vs 3: 0.952

(Continued)

Table 2 (Continued).

NSBV Parameter	18-23 years Group 1 (n=599) Mean±SD	24-29 years Group 2 (n=492) Mean±SD	30-35 years Group 3 (n=302) Mean±SD	p value	Post-hoc
PFV break near	25.56 ± 8.98	24.96 ± 10.69	24.89 ± 8.26	0.473	Group 1 vs 2: 0.552 Group 2 vs 3: 0.994
PFV recovery near	18.89 ± 7.47	19.06 ± 8.43	19.16 ± 6.48	0.873	Group 1 vs 3: 0.577 Group 2 vs 3: 0.982
NFV break distance	9.49 ± 2.91	9.44 ± 3.25	9.09 ± 2.98	0.161	Group 1 vs 3: 0.876 Group 1 vs 2: 0.967 Group 2 vs 3: 0.258
NFV recovery distance	6.66 ± 2.38	6.52 ± 2.56	6.34 ± 2.21	0.179	Group 1 vs 3: 0.156 Group 1 vs 2: 0.634 Group 2 vs 3: 0.563
NFV break near	17.27 ± 5.60	16.87 ± 5.94	16.85 ± 4.63	0.386	Group 1 vs 3: 0.156 Group 1 vs 2: 0.449 Group 2 vs 3: 0.999
NFV recovery near	13.45 ± 4.61	13.03 ± 4.69	13.34 ± 3.87	0.293	Group 1 vs 3: 0.522 Group 1 vs 2: 0.273 Group 2 vs 3: 0.601
NRA	2.19 ± 0.51	2.27 ± 0.61	2.30 ± 0.63	0.014*	Group 1 vs 3: 0.942 Group 1 vs 2: 0.084 Group 2 vs 3: 0.688
PRA	-2.36 ± 0.72	-2.22 ± 0.71	-2.09 ± 0.69	<0.001*	Group 1 vs 3: 0.020 Group 1 vs 2: 0.005 Group 2 vs 3: 0.088 Group 1 vs 3: <0.001

Note: *p < 0.05, statistically significant.

Abbreviations: NSBV, Non strabismic binocular vision; NPC, Near point of convergence; MEM, Monocular estimated method; AC/A, Accommodative convergence to accommodation ratio; PFV, Positive fusional vergence; NFV, Negative fusional vergence; NRA, Negative relative accommodation; PRA, Positive relative accommodation.

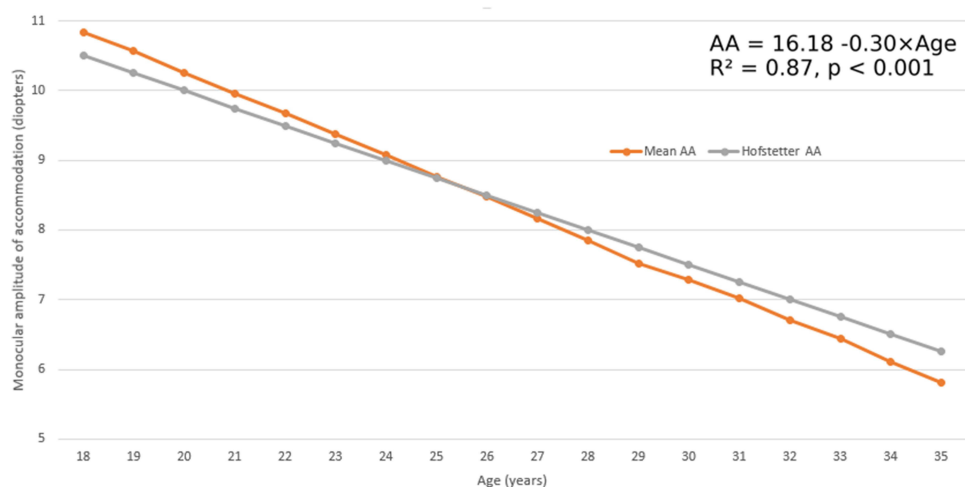


Figure 1 Comparison of age versus mean amplitude of accommodation (AA) between this study and Hofstetter's minimum.

Discussion

This study provides normative data for NSBV parameters in a large sample of Nepalese adults aged 18–35 years and, to our knowledge, represents the first large-scale reference dataset for this population. Establishing population-specific normative ranges is important for the accurate diagnosis and management of NSBVA. Although values may differ across studies due to variations in ethnicity, environmental factors, visual demands, and measurement techniques, such

Table 3 Distribution of NSBV Parameters by Gender. Values are Presented as Mean ± SD. Comparisons Were Performed Using Independent t-Tests

NSBV Parameter	Female n=536 Mean±SD	Male n=857 Mean±SD	t (df)	p value
NPC	5.12±1.68	4.64±1.36	5.82 (962)	<0.001*
NPC recovery	7.50±1.78	6.96±1.48	6.17 (980)	<0.001*
Monocular amplitude of accommodation	8.74±1.58	8.77±1.51	-0.36 (1391)	0.713
Monocular accommodative facility	9.35±3.50	10.39±3.54	-5.33 (1146)	<0.001*
Binocular accommodative facility	6.35±3.24	6.43±2.48	-0.52 (922)	0.601
MEM	0.50±0.26	0.51±0.33	-0.90 (1326)	0.364
Distance phoria	-0.34±0.97	-0.11±0.64	-5.45 (831)	<0.001*
Near phoria	-3.63±2.26	-2.54±2.79	-7.64 (1300)	<0.001*
Gradient AC/A ratio	2.40±0.98	2.75±1.36	-5.23 (1363)	<0.001*
PFV break distance	16.28±7.52	17.74±6.15	-3.95 (970)	<0.001*
PFV recovery distance	12.58±5.56	13.40±4.46	-3.01 (955)	0.003*
PFV break near	23.00±9.41	26.58±9.26	-6.95 (1391)	<0.001*
PFV recovery near	17.91±7.93	19.70±7.35	-4.27 (1071)	<0.001*
NFV break distance	9.38±3.56	9.39±2.69	-0.06 (911)	0.951
NFV recovery distance	6.44±2.75	6.60±2.16	-1.20 (940)	0.227
NFV break near	16±5.61	17.69±5.38	-5.61 (1391)	<0.001*
NFV recovery near	12.55±4.31	13.73±4.54	-4.83 (1180)	<0.001*
NRA	2.17±0.58	2.29±0.57	-3.84 (1131)	<0.001*
PRA	-2.14±0.74	-2.32±0.69	4.78 (1083)	<0.001*

Note: *p < 0.05, statistically significant.

Abbreviations: NSBV, Non strabismic binocular vision; NPC, Near point of convergence; MEM, Monocular estimated method; AC/A, Accommodative convergence to accommodation ratio; PF, Positive fusional vergence; NFV, Negative fusional vergence; NRA, Negative relative accommodation; PRA, Positive relative accommodation.

differences do not necessarily indicate clinically meaningful disparities between populations. Comparisons with previously published datasets (Table 4) are therefore presented descriptively, as formal statistical testing against external samples was not feasible. Accordingly, observed discrepancies should be interpreted cautiously and considered within the context of methodological differences rather than assumed population-level effects.

Starting with the accommodative tests, our regression model for monocular AA ($AA = 16.20 - 0.30 \times \text{age}$) aligns closely with the classic Donders formula ($AA = 15 - 0.25 \times \text{age}$),²² with both demonstrating a linear decline in accommodative amplitude with age. The slightly higher intercept and steeper slope in our model may reflect differences in sample characteristics or measurement methods; nevertheless, the overall trend is consistent with previous studies.^{8,26–28} Mean MAF values in this sample were slightly lower than those reported in earlier literature²⁹ and confirmed in subsequent studies.^{7,8} Based on these findings, values below 6.5 cycles per minute would indicate reduced performance on this test. For binocular accommodative facility (BAF), average values were comparable to those used as the gold standard.^{7,8} The lag values obtained were almost identical to those reported by Rouse et al²¹ and corroborated by later investigations.^{7,30,31} Finally, NRA and PRA values were also in line with established norms,⁷ although mean NRA was marginally lower than values reported in our sample and lower than that reported by Yekta et al.⁸ Despite minor discrepancies with previous reports, most accommodative parameters remained within clinically accepted normative ranges, suggesting limited impact on diagnostic interpretation.

Table 4 Comparing NSBV Parameter of the Present Study Compared with the Other Study. Values are Reported as Presented in the Original Studies. Comparisons are Descriptive Due to Methodological Differences Across Studies

NSBV Parameter	Present Study (Nepal, 18–35 y)	Contemporary Normative Studies		Classical Reference Standard
		Yekta et al, 2017 (Iran)	Abraham et al, 2015 (India)	Scheiman & Wick, 2008 (USA)
Sample size	1393	382	150	–
NPC break	AT 4.83 ± 1.51	AT 5.27 ± 3.60	FLRG 8.59 ± 3.19 (19–27 y) 9.52 ± 3.03 (28–35 y)	AT 5.00 ± 2.50
NPC recovery	AT 7.17 ± 1.62	–	FLRG 10.11 ± 3.2 (19–27 y) 11.92 ± 3.20 (28–35 y)	AT 7.00 ± 3.00
MAF	9.99 ± 3.56	11.00 ± 5.00	–	11.00 ± 5.00
BAF	6.40 ± 2.80	8.84 ± 4.47	–	10.00 ± 5.00
Accommodative response	MEM 0.51 ± 0.30	–	–	MEM +0.50 ± 0.25
Distance phoria	CT –0.20 ± 0.79	CT –1.15 ± 2.04	MTT –0.55 ± 2.12 (19–27 y) –0.40 ± 1.75 (28–35 y)	CT –1.00 ± 2.00
Near phoria	CT –2.96 ± 2.65	CT –5.02 ± 4.74	MTT –0.74 ± 3.58 (19–27 y) –2.17 ± 4.45 (28–35 y)	CT –3.00 ± 3.00
AC/A	Gradient 2.61 ± 1.24	Gradient 4.66 ± 1.59	–	NS 4.00 ± 2.00
PFV break D	PB 17.18 ± 6.74	PB 20.64 ± 7.47	–	PB 19.00 ± 8.00
PFV recovery D	PB 13.08 ± 4.92	PB 13.79 ± 5.56	–	PB 10.00 ± 4.00
PFV break N	PB 25.21 ± 9.48	PB 31.44 ± 6.73	–	PB 21.00 ± 6.00
PFV recovery N	PB 19.01 ± 7.62	PB 22.85 ± 6.04	–	PB 11.00 ± 7.00
NFV break D	PB 9.39 ± 3.05	PB 8.82 ± 2.82	–	PB 7.00 ± 3.00
NFV recovery D	PB 6.54 ± 2.41	PB 6.05 ± 2.51	–	PB 4.00 ± 2.00
NFV break N	PB 17.04 ± 5.53	PB 18.65 ± 4.97	–	PB 21.00 ± 4.00
NFV recovery N	PB 13.28 ± 4.49	PB 13.97 ± 3.79	–	PB 13.00 ± 5.00
NRA	2.24 ± 0.58	2.08 ± 0.33	–	2.00 ± 0.50
PRA	–2.25 ± 0.72	–2.92 ± 0.76	–	–2.37 ± 1.00

Note: Values are reported as presented in the original studies. Contemporary population-based normative datasets are shown separately from classical reference standards. **Abbreviations:** AC/A, accommodative convergence to accommodation ratio; AT, accommodative target; CT, cover test; D, distance; FLRG, fixation light with red and green filters; MTT, modified Thorington test; N, near; NFV, negative fusional vergence; NPC, near point of convergence; NRA, negative relative accommodation; NS, not specified; PB, prism bar; PFV, positive fusional vergence; PRA, positive relative accommodation; MAF, monocular accommodative facility; BAF, binocular accommodative facility.

For the binocular tests, slightly more exophoric distance phoria values were observed than those typically reported in the literature,^{7,8,32} although they more closely resembled findings from more recent studies.¹¹ At near, the disparity was greater, with the present results differing from both gold standard values⁷ and similar studies,¹¹ and matching only those reported by Cantó-Cerdan et al.³² These differences in phoria measurements contributed to discrepancies in the AC/A ratio, which also varied from values previously documented.^{7,8} Similar inconsistencies were found for NPC measurements, with both break and recovery values differing from those reported in the literature.^{7,8,11,26,33} Finally, fusional vergence values varied across all phases compared to gold standard ranges^{34,35} as well as other normative studies.^{7,8,11} Although differences were observed compared with commonly cited norms, these values largely fall within functional limits and are unlikely to alter clinical decision-making in routine practice.

Notably, many normative NSBV values cited in the literature were established decades ago,^{7,33} often using populations whose demographic characteristics and visual demands differ markedly from those of contemporary groups.^{9,14,17,18} In particular, the increase in digital device use and near-work tasks in recent years may influence NSBV performance.³⁶ For this reason, there is a growing need to re-evaluate normative values in modern populations and to acknowledge cultural and occupational differences that may affect binocular function. Although a universal standard may not be feasible, updated normative datasets would provide clinicians with more accurate benchmarks for current practice. These factors, including digital device use, near-work demands, and occupational visual load, may partially account for the patterns observed in the present sample and should be considered when interpreting normative values in modern populations.

Several statistically significant gender-related differences were observed; however, the magnitudes were small and unlikely to be clinically meaningful. Accordingly, effect sizes were not calculated, as the primary aim of this study was to provide descriptive normative data rather than to evaluate subgroup differences as hypothesis-driven outcomes.^{37,38}

Age-related differences were also apparent across NSBV parameters. This finding is consistent with the strong regression relationship identified in the Results, which demonstrated a predictable linear decline in accommodative amplitude across the studied age range. As expected, monocular AA declined progressively with age, from a mean of 10.11 diopters in the youngest group (18–23 years) to 6.71 diopters in the oldest group (30–35 years). Similarly, monocular and binocular accommodative facility decreased significantly with age, whereas lag values increased. Vergence parameters, however, remained relatively stable across age groups, with no significant changes in fusional reserves. As expected based on the AC/A relationship,³⁹ older groups showed increased near exophoria and reduced amplitude of accommodation, with AC/A ratios declining after the age of 30 years. Collectively, these findings confirm the age-related decline in accommodative performance, while vergence function appears relatively preserved in early adulthood.

From a clinical perspective, the normative database generated by this study provides population-specific reference ranges for eye care practitioners in Nepal. These values may enhance the accuracy of diagnosing NSBVA and guide management decisions, including vision therapy or ergonomic recommendations for individuals with visual discomfort. Clinicians should apply these findings as reference ranges rather than rigid diagnostic thresholds and interpret deviations in conjunction with symptoms, clinical findings, and individual visual demands. Future research should extend these normative data to broader age groups, including pediatric and older populations, validate diagnostic cut-offs using symptomatic cohorts, and explore regional differences within Nepal. Longitudinal studies would also help clarify changes in binocular function over time. These normative values are intended to support clinical interpretation and should not be used as standalone diagnostic criteria.

This study has several limitations that should be acknowledged. First, although the sample size was large, participants were recruited exclusively from individuals who independently sought eye examinations at a tertiary eye care center. This approach may introduce sampling bias by attracting individuals more likely to have visual concerns, even if asymptomatic at the time of testing. Second, the restricted age range of 18–35 years limits the generalizability of the findings across the lifespan. Third, environmental and occupational factors such as digital device use, near-work demands, and lifestyle habits were not assessed, although these may influence NSBV function. Finally, the cross-sectional design precludes causal inferences. Despite these limitations, the large sample and comprehensive assessment of accommodative

and binocular parameters using standardized procedures enhance the reliability of the findings and provide a valuable clinical reference for young adults.

Conclusion

This study provides the largest clinically based dataset to date on NSBV parameters in Nepalese young adults aged 18–35 years. While the hospital-based design may limit generalizability, these normative estimates, derived from a large sample assessed using standardized procedures, offer a valuable reference for clinical decision-making, including establishing screening thresholds and supporting accurate and reliable diagnosis and management of NSBVA. Although some parameters demonstrated statistically significant differences across age and gender, the magnitude of these variations was generally small, supporting the cautious but meaningful application of these values in clinical practice. These findings highlight the importance of demographic considerations when evaluating NSBV function. Future research should evaluate broader age groups, validate diagnostic cut-offs using symptomatic cohorts, and explore differences between urban and rural populations.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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No potential conflict of interest was reported by the authors.

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