



## Relationship of Negative, Positive Relative Accommodation and Negative, Positive Fusional Vergence in Ammetropes and Emmetropes in a Young Population of Nepal

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### Abstract

**Purpose:** This study aims to correlate accommodative, vergence parameters in myopia, hypermetropia and Emmetropia in young Nepalese population.

**Methods:** A cross sectional study design was conducted in subjects of Chitwan Eye Hospital, Bharatpur Nepal. All the samples underwent the measurement of uncorrected and corrected visual acuity and refraction. Then far and near cover tests were performed. The near point of convergence (NPC), accommodation, accommodation facility, negative relative accommodation (NRA) and positive relative accommodation (PRA) and vergence parameters for distance and near were evaluated in all participants. Statistical analysis was done using the one-way ANOVA and correlate bivariate in SPSS 16 Software.

**Results:** The mean age of the 108 participants was  $22.95 \pm 3.17$  years (18-35 years). The mean value of NRA was  $+2.88 \pm 0.74$  diopter (D) and PRA was  $-3.54 \pm 1.15$  (D) in total sample. Mean NRA and mean PRA was highest in hyperopic participants. The NRA was correlated with the Positive Fusional Vergence (PFV) distance in which significant ( $p < 0.040$ ) and it was also correlated with the Negative Fusional Vergence (NFV) near with significant difference at the level of 0.05 ( $p < 0.03$ ). But the NRA have no any statically correlation with the NFV distance in our study. The mean value of NFV in distance and near was  $10.14 \pm 3.40$  prism diopter (PD) and  $14.71 \pm 5.48$  prism diopter (PD), respectively. And the mean fusional value for PFV distance and near was  $21.58 \pm 10.65$  prism diopter (PD) and  $23.14 \pm 11.43$  prism diopter (PD), respectively.

**Conclusion:** This study provides the normal range of NRA and PRA in Nepalese population. The results found in this study provides the direct relationship between NRA and PFV in hyperopic participants. Both NRA, PRA and NFV, PFV should considered when evaluating vergence and accommodative systems and even during orthoptic training. This study also provides the normal values of two parameter contributes to the diagnosis of the type of disorder and differential diagnosis.

**Keywords:** Negative Relative Accommodation; Positive Relative Accommodation; Fusional Vergence; Refractive Errors

### Introduction

In order to maintain a clear single image when reading or doing near work, both accommodative and convergence system must be sufficient. If these mechanisms fails, these may lead to the accommodative and/ or vergence dysfunction in which patients may complain of several symptoms [1]. In adding, those who perform or do extended periods of close vision work, such as reading or the prolonged use of computers, are more likely to report the symptoms and signs associated with these vision disorders [2,3].

Accommodation is a mechanism that affects visual clarity and binocular vision. It can be defined as an increase in the refractive power of the eye for focusing near object of regard on the retina. Binocular single vision is the state of simultaneous vision, which is achieved by the coordinated use of both eyes, so that separate and slightly dissimilar images rising in each eye are appreciated as a single image by the process of fusion.

Refractive error, accommodative and vergence mechanism are all parts of our visual efficiency systems [4]. There is a close re-

relationship in between uncorrected refractive error, decreased visual acuity, sensory and motor fusions [5-9]. A clear vision is only obtained when the interaction in between accommodation and vergence system is optimum [10]. Our accommodation system maintains focus based on the type of refractive error and disparity of retinal images. At the same time our vergence system fuses the images located at the fovea of two eyes thus maintaining binocular single vision. Accommodation lag refers to the insufficient amount of accommodation i.e. the difference of accommodative demand and accommodative response. This accommodative lag in other words is directly the residual refractive error that has positive correlation with the symptoms of near related visual discomfort [11,12]. Accommodation and vergence have a great role in maintaining binocular single vision through their components [13,14] such as accommodative response, accommodative facility, amplitude of accommodation, near point of convergence, negative and positive relative accommodation, negative and positive fusional vergence. Myopia is the most common refractive error in young adults. Almost two billion people worldwide are affected by myopia and its prevalence is increasing at an alarming rate [15]. According to Hung, *et al.* in emmetropization, both accommodation and vergence influence one another as well as refractive errors and binocular vision disorders [10]. A clear binocular single vision is the result of the interaction between accommodation and vergence systems. Detection of functional visual disorders depends on the clinical analysis of accommodation and vergence and their interactions [16]. Accommodation has an important role in binocular vision through concepts such as accommodation convergence (AC), convergence accommodation (CA), AC over accommodation (AC/A) and CA over convergence (CA/C) [13,14]. Negative relative accommodation (NRA) measure the maximum ability to relax accommodation while maintaining clear, single binocular vision. While the Positive relative accommodation (PRA) measure the maximum ability to stimulate accommodation while maintaining clear, single binocular vision.

In addition, evaluation of accommodation changes in a stable vergence system helps better understand the roles of these two systems and accommodation facility. The two tests of positive relative accommodation (PRA) and negative relative accommodation (NRA) measures the maximum ability to stimulate accommodation while maintaining binocular single vision. These two tests can also help with indirect evaluation of fusional vergence. A vergence is the simultaneous movement of both eyes in opposite direction to obtain or maintain single binocular vision. While measuring Positive fusional vergence and Negative fusional vergence we used prism bar. While measuring the fusional vergence we encounter 3 points

- The blur point: The amount of vergence when no accommodation is used
- The break point: The total fusional vergence when the individual declines diplopia
- The recovery point: The amount of vergence when the individual regains single vision after diplopia.

In fact, evaluation of relationship between the relative accommodation and vergence parameters in different types of refractive errors which has not been investigated in any studies in Nepal to date. Evaluation of the effects of relative accommodation while accounting for refractive errors provides researchers and therapists with comprehensive information on the functional status of patient's visual system and binocular vision.

## Methods

In this cross-sectional study was conducted during the period of July 2019 to April 2020 at the clinic of Chitwan Eye Hospital, Bharatpur, Nepal. Full comprehensive eye examination was done for all subject followed by binocular vision (BV) evaluation. BV evaluation included the following measurements (Mitchell Scheiman and Wick, 2015).

The study involved 108 patients aged 18-35 years interested in evaluating binocular vision. Taking into consideration, all the subjects were recruited only after the informed consent. All subjects underwent a detailed ocular examination by clinically expert optometrists followed by the ophthalmologist. All the tests were done with best corrected spectacles. Detailed ocular examination included detailed ocular and systemic history, unaided visual acuity, automated refractometry followed by static and dynamic retinoscopy while subject was fixating on a non-accommodative target at 6-meter distance. Subjective acceptance was done monocularly followed by binocular balancing with the criterion of maximum plus with best corrected visual acuity. Prism dissociation method was used for binocular balancing. With informed consent from the patient, binocular vision works up was done to measure accommodative amplitude, accommodative vergence and binocular state over the best corrected spectacles.

The procedure involved stereo acuity measurement with Randot stereopsis test. There are ten presentations of three circles. Among these three circles, each subject was asked to select a circle appearing three dimensional to him/her (circle that appears to be popping out or appearing closest to him/her) when viewed wearing a polarized 3D viewing glasses. The stereo test uses stereo target as butterfly, animal and wirt circles which has stereo level from 2000 to 40 sec of arc. Polaroid glass were worn by the subjects and

maintained proper axis of polarization to avoid reflection on the surface. Subjects were asked to identify the stereoscopic insect/animal/circles. The last level of difficulty appreciated accurately was recorded as his/her stereo acuity in seconds of arc. Alternate cover test was done for distance and near to find heterophoria, 20/30 letter size targets were used for fixation while accessing phoria status for distance and near. All subjects' phoria status were identified as exophoria (out to in movement), esophoria (in to out movement) and hyper/hypo (upward and downward movement) and check the amount of phoria by prism bar.

Near point of convergence (NPC) was measured by using push up technique where an accommodative target of 20/30 size was moved closer to the face from 50 cm until it appeared constant double (distance from the eye to this point recorded as break point). It was further moved away from the face till it appeared clear and single (recorded as recovery point). NPC was measured in centimeters with blur, break and recovery point values. NPC was measured from subjects lateral canthal position to where subjects report diplopia or diverge (outward movement). Accommodative facility was measured by accommodative flippers +/-2.0D depending on the age of the patient. Subjects were asked to fix on 20/30 line at 40 cm. As soon as the letters appeared clear, subject was asked to flip the flipper to the other side until clarity was obtained to the other side. Once it was clear with the other side too, the same procedure was advised to repeat for a minute. The procedure was advised to repeat monocularly and then binocularly. Number of cycles per minute (cpm) was recorded in both monocular and binocular procedures.

Accommodative response (both monocular and binocular lag and lead of accommodation) was measured by monocular estimation method (MEM) retinoscopy at 40cm. While the subject was focusing on accommodative target at 40cm, retinoscopy was done on one eye at a time. Plus and minus lenses were added in-front of the eyes until neutralization was obtained in any meridian. It was repeated again for the other eye.

NRA and PRA was measured using 20/30 letter chart at 40 cm as a fixating target. Accommodation was changed using plus and minus lenses for testing NRA and PRA respectively. With the increment of 0.25D steps the lenses were added binocularly until first slight sustained blur was obtained. The first sustained blur where the letters are not readable was considered as the end point. Amount of plus lens to measure NRA and amount of minus lenses to measure PRA added binocularly was recorded. To avoid the influence of accommodation on the measurements, NRA (plus lenses with 0.25 increments) was measured before PRA as recommended by Scheiman and Wick [17].

Negative and positive fusional vergence was measured both for distance and near with prism bars as blur, break and recovery points. While the patient was fixing on a target of 20/30 line at 6 meter with full refractive correction, a gradually increasing horizontal prism bar was introduced in both eyes. Retinal disparity is created when prisms are gradually increased in-front of the eyes. This stimulates the vergence movements in order to eliminate these disparities and allow binocular single vision. Prisms (base in prisms and base out prisms for negative and positive fusional vergence respectively) were gradually added in front of the eyes until patient experienced blurred vision (recorded as 'blur'). Prisms were further added until patient experienced double vision (recorded as 'break') After attaining break point, prisms were gradually reduced until patient experienced single clear image through fusion (recorded as 'recovery' point). Negative fusional vergence was measured before positive fusional vergence to avoid excessive convergence stimuli [18]. For distance and near NFV and PFV, the procedure was performed at 6 meter and 40 cm respectively. We considered the break point as fusional vergence in our study.

Vergence facility was measured by using a 12PD base out and 3PD base in vergence flipper. While the patient was viewing at 20/30 target at a distance of 40cm, twelve prism diopter base out and 3 prism diopter base in prism was alternatively placed before one eye. The vergence flipper was flipped once the patient reported single and clear target. This procedure was repeated for a minute and total number of cycles per minute was recorded as vergence facility.

Exclusion criteria included a BCVA less than 20/25 in either eye, strabismus or previous strabismus surgery, any systemic or ocular disease affecting binocular vision and accommodation, use of systemic or topical medication affecting accommodation and binocular vision, and stereopsis less than 400 sec/arc.

In this study, refractive errors were defined based on the spherical equivalent (SE). An SE  $\leq$  -0.25 D was defined as myopia and that of +0.25 D or more was considered hypermetropia. Considering the high correlation between the fellow eyes, only right eye data was used in the analyses.

In this study, the mean and standard deviation (SD) of NRA and PRA were investigated. One-way ANOVA analysis of variance was used to evaluate the mean NRA and PRA and the fusional parameters with refractive errors.

## Results

In this study, 108 subjects were included out of which 59 (54.6%) were male and 49 (45.4%) were female. The mean age of

the sample was 22.95 ± 3.17 years. In this study, out of 108 subjects 30 were myopic (27.8%), 11 were hyperopic (10.2%) and 67 were emmetropia (62.0%). All the subject has a good stereopsis with the mean standard deviation of 41.57±7.12 sec of arc.

The mean value of NRA was +2.88 ± 0.74 D and PRA was -3.54 ± 1.15 D. The mean NRA in male patients was +2.78 ± 0.79 D and in female patients was +3.01 ± 0.86 D and the mean PRA in female patients was -3.77 ± 1.28 D and in male patients PRA was -3.38 ± 1.01 D.

Fig 5 and 6. Shows that the mean NRA was highest in hyperopic and mean PRA was almost equal in myopes and hyperopes. In our study the mean vergence facility was 12.05 ± 2.9 cpm. And the accommodative facility of right eye was 9.95 ± 4.51cpm, left eye was 10.00 ± 4.39 and with binocularly the accommodative facility was 8.64 ± 4.37 cpm. Accommodative response of the subjects according to refractive errors in myope the mean value of MEM was 0.516 ± 0.42D, in emmetrope the mean value was 0.35 ± 0.37D and hyperope the mean value was 0.386 ± 0.35D. The NRA was correlated with the PFV distance in which the significant (p < 0.040) and it also correlated with the NFV near in which significant difference at the level of 0.05 (p < 0.03). But the NRA have no correlation with the NFV distance which is not significant shows in our study. The mean value of NFV in distance and near was 10.14 ± 3.40 PD and 14.71 ± 5.48 PD, respectively. And the mean fusional value for PFV distance and near was 21.58 ± 10.65 PD and 23.14 ± 11.43 PD, re-

spectively. And the mean fusional value (recovery point) for NFV distance and near was 7.51 ± 2.80 PD and 11.38 ± 4.58 PD respectively. The mean value of fusional recovery point for PFV distance and near was 15.49 ± 7.56PD and 17.22 ± 8.45 PD.

	Number	NRA(D) Mean ± SD	PRA(D) Mean ± SD
Total	108	+2.88 ± 0.74	-3.54± 1.15
Gender			
Male	59	+2.78 ± 0.61	-3.38 ± 1.01
Female	49	+3.01 ± 0.86	-3.74 ± 1.28
Age (years)			
≤ 20	29	+2.67 ± 0.50	-3.23 ± 1.17
21-25	53	+3.07 ± 0.88	-3.79 ± 1.24
26-30	26	+2.75 ± 0.55	-3.38 ± 0.79
≥ 30			
Refractive Errors			
Myopia	30	+2.81 ± 0.61	-3.84 ± 1.23
Emmetropia	67	+2.88 ± 0.76	-3.36 ± 1.05
Hyperopia	11	+3.09 ± 0.97	-3.86 ± 1.37

**Table 1:** The distribution of negative relative accommodation (NRA) and positive relative accommodation (PRA) in a young population by sex, age and refractive errors.

	Number	NFV Distance (PD) Mean ± SD (Break)	NFV Near (PD) Mean ± SD (Break)	PFV Distance (PD) Mean ± SD (Break)	PFV Near (PD) Mean ± SD (Break)
Gender					
Male	59	10.44 ± 3.80	15.59 ± 5.28	20.35 ± 10.24	22.79 ± 10.49
Female	49	9.79 ± 2.86	13.65 ± 5.59	23.06 ± 11.05	23.57 ± 12.57
Ages Group					
≤ 20	29	11.24 ± 4.63	16.03 ± 6.85	15.17 ± 7.54	16.55 ± 10.14
21-25	53	9.88 ± 2.52	13.69 ± 4.86	26.64 ± 10.20	27.03 ± 10.84
26-30	26	9.46 ± 3.22	15.30 ± 4.75	18.4 ± 9.65	23.14 ± 11.43
Refractive Errors					
Myopia	30	9.26 ± 3.46	14.10 ± 4.23	19.30 ± 11.20	21.83 ± 10.42
Emmetropia	67	10.25 ± 3.05	15.26 ± 6.08	21.56 ± 9.81	23.08 ± 11.82
Hyperopia	11	11.90 ± 4.7	13.00 ± 4.40	27.90 ± 12.44	27.09 ± 11.83

**Table 2:** The distribution of fusional vergence in young population by age and refractive errors.

## Discussion

Assessment of relative accommodation (NRA and PRA) helps to detect accommodation disorders and conditions affecting visual clarity. Few studies have investigated the normal value of the NRA PRA [17,20-23]. These two parameters are vital indicators of important systems influencing binocular vision, i.e. accommodation and vergence.

The mean NRA and PRA was  $+2.88 \pm 0.74$  D and  $-3.54 \pm 1.15$  D in our study, respectively. According to the Scheiman and Wick, mean PRA is  $-2.37 \pm 1.00$  D, and mean NRA is  $+2.00 \pm 0.50$  D. In our study the NRA was high in hyperopia and the PRA was almost same in myopic and hyperopic subject. There is no such a difference in PRA with refractive errors. In 2008, a study on PRA of 118 adults with a 3 years follow-up showed a significance increase of  $0.66 \pm 1.35$  D during the study period. The authors stated that a decrease in PRA was expected and attributed this finding to decreased vergence break point in binocular disorders [24].

In our study the mean PRA was higher in female participants and the mean NRA was also high in female participants. But previous study shows that the PRA was high in female but NRA has no significant difference between men and women [24]. In a study by Jorge., *et al.* on study population with a mean age of  $20.6 \pm 2.3$  years, PRA was  $-2.21 \pm 0.42$  D, and NRA was  $+2.33 \pm 1.40$  D [23].

The relation of demographics such as age and gender with binocular vision parameters can help determine changes in accommodation and vergence within each category. In our study, age had no significance relationship with NRA and PRA, nonetheless in the study by Yekta., *et al.* it was shown, that the age has the relation with PRA. PRA decreases significantly with age but there is no substantial relation with NRA [24]. This study determined the effect of accommodation and vergence on the amount of refractive errors correction. The values of NRA and PRA significantly varied by refractive error. NRA was highest in hyperopic participants. Plus acceptance occurs when the acceptable power of the spherical lens for continuous near work is more than the calculated power. This finding is observed in individuals with a refractive status as well as plano and hyperopia individuals. Therefore, a more positive lens is acceptable in hyperopic subjects [25]. PRA was highest in myopes in another study but in our study there is not such a different, there is no any study to compare these results. Young myopic individuals usually accept a more than required negative power [26]. This improves the contrast of dark optotypes on a white background, and therefore results in vision with better details. The relationship between myopia and PRA could also be due to the accommodation excess in pseudo myopic patients [27]. In this study the mean value PFV distance and PFV near are higher in hyperopic. This mean there is a direct relationship of NRA and PFV in hyperopic participants. Scheiman and Wick, established for far distance reference

value of  $7 \pm 3$  PD for the break point NFV,  $4 \pm 2$  PD for the recovery point NFV,  $11 \pm 7$  PD for the break point PFV and  $7 \pm 2$  PD for the recovery point for general population [27].

Considering the obtained results and direct relationship between the two parameter NRA and PFV, it should be noted that accommodation cannot be predicted based on the age, sex, refractive errors, accommodative facility and or vergence conditions. For this reason, judgment based on only one of the above-mentioned reasons may be misleading. Therefore, evaluation of different aspects of accommodation along with NRA, PRA and fusional vergence provides the comprehensive assessment in this regard. This is the one of the few studies on relative accommodation and the first study to investigate the relationship between relative accommodation parameters, fusional vergence parameters and refractive errors.

This study has some limitations. The studied population included only the students within a certain age group. Therefore, similar studies are recommended in children and adults over 35 years of age. The sample size was small in our study and not equally distributed to the refractive errors. Cycloplegic refraction was not performed.

## Conclusion

The results found in this study provides the direct relationship between NRA and PFV in hyperopic participants. Both NRA, PRA and NFV, PFV should considered when evaluating vergence and accommodative systems and even during orthoptic training. This study also provides the normal values of two parameters and contributes to the diagnosis of the type of disorder and differential diagnosis.

It is medically necessary for the optometrist to diagnose the condition accurately, to discuss the diagnosis and risk and potentials benefits of existing treatment options with the patients, and to initiate treatment when appropriate. Management, including lenses, prisms, and vision therapy, is not age restricted. Vision therapy can give at any ages.

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