Original research

The distribution of negative and positive relative accommodation and their relationship with binocular and refractive indices in a young population

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Abstract

Purpose: To determine the distribution of negative relative accommodation (NRA) and positive relative accommodation (PRA) and its relationship with binocular vision indices in a young population.
Methods: In this cross-sectional study conducted in a student population, samples were selected through multistage cluster sampling. 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) and accommodation, accommodation facility, PRA and NRA were evaluated in all participants.
Results: The mean age of the 382 participants was 22.5 ± 4.4 years (18–35 years). Mean NRA and PRA in the total sample was $+2.08 \pm 0.33$ diopter (D) and -2.92 ± 0.76 D, respectively. Mean NRA was highest in hyperopic ($P = 0.002$) and mean PRA was highest in myopic ($P = 0.003$) participants.

The multiple model showed that NRA had a direct relationship with accommodation facility and spherical refractive error, while PRA had a direct relationship with amplitude of accommodation (AA).
Conclusion: This study provides the normal range of the NRA and PRA and their relationship with accommodation facility, spherical refractive error, and AA in a sample of the Iranian population.

Introduction

Accommodation is a mechanism that affects visual clarity and binocular vision.[1] According to Hung et al, in emmetropization, both accommodation and vergence influence one another as well as refractive errors and binocular vision disorders.[2] A clear binocular single vision is the result of the interaction between accommodation and vergence systems.[2] Detection of functional visual disorders depends on the clinical analysis of accommodation and vergence and their interaction.[3] Accommodation has an important role in binocular vision through concepts such as accommodative convergence (AC), convergence accommodation (CA), AC over accommodation (AC/A), and CA over convergence (CA/C).[4,5]

In addition, evaluation of the 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) measure the maximum ability to stimulate accommodation while maintaining binocular single vision. These two tests can also help with indirect evaluation of fusional vergence.[6,7] Therefore, knowledge of their values in the normal population helps detect accommodative and vergence disorders. Few studies have addressed the normal values of these indices where their distributions vary in different groups defined by age and amplitude of accommodation (AA).[3,8] Another question is whether changes in these two indices are limited to fusional and accommodative disorders or can be related to refractive errors as well. In fact, evaluation of the relationship between refractive errors and relative accommodation can demonstrate accommodation facility in different types of refractive errors, which has not been investigated in any studies to date. Evaluation of the effect of AA and accommodation facility on relative accommodation while accounting for refractive errors provides researchers and therapists with comprehensive information on the functional status of patients' visual system and binocular vision.

Considering the prevalence of accommodation and fusional disorders, the importance of their correct diagnosis and treatment, and lack of similar studies in this regard, the present study was conducted to evaluate the distribution of PRA and NRA in a normal population and its relationship with associated factors.

Methods

In this cross-sectional study which was conducted in 2014, the target population was students of Mashhad University of Medical Sciences in Iran. Study samples were selected through multistage random cluster sampling and invited for a thorough optometric examination. For this purpose, a number of students proportionate to the total number of students in each major were selected with respect to years completed, and those willing to participate, reviewed and signed a written consent form and completed an interview to collect their demographics.

All examinations were performed separately by two skilled optometrists. First, visual acuity was tested using a Snellen E-chart. To evaluate uncorrected visual acuity (UCVA), the participant was asked to read or guess the letters in the lower line. If she/he was not able to see the first line, finger count, hand motion, and light perception were used in the mentioned order. For cases with UCVA worse than 20/25, their refractive error was first measured through auto-refraction (Topcon RM8800, Topcon Corporation, Japan) and refined through retinoscopy (Heine Beta 200 retinoscope, HEINE Optotechnik, Germany), and the best corrected visual acuity (BCVA) was determined using subjective refraction.

The red—green test was used as the end point to improve the precision of subjective refraction examinations. When patients found signs darker on the red background, a −0.25

diopter (D) lens was placed, and if the green background was preferred, a +0.25 D lens was added to achieve neutrality. If the two seemed equally dark, BCVA was recorded with regard to their preference in subjective refraction. The red—green test was also used for binocular balancing.

For cases with a UCVA equal to or greater than 20/25, binocular and accommodative tests were done without correction.

Near and distance dissociated phorias were measured using the alternate cover test at 40 cm and 6 m. The target was a letter on the Snellen chart one line above the corrected vision. To determine near associated phoria, measurements were made using the near Mallet unit with central and peripheral fusion lock. For convergence and divergence fusional reserves, we used the step method with the prism bar to measure the amounts of prism at blur, break, and recovery points at near and distance with base-out and base-in prisms, respectively. Near point of convergence (NPC) was measured by moving the accommodative target (a character one line above BCVA) closer to the eye until the patient reported diplopia or the examiner observed fusion break.

In measuring NRA and PRA with correction, the 20/20 on a high contrast near chart at 40 cm was set as the fixation target, and we changed the accommodation using minus and plus lenses for testing NRA and PRA, respectively. The lenses were added binocularly as 0.25 D steps until first slight sustained blur which is the endpoint of the test was appeared. At this point, letters are not as sharp and readable as the primary status. The total plus lenses added for NRA testing and minus lenses for PRA testing were recorded. NRA was tested before PRA to avoid any influence of accommodation on the measurements.

Monocular accommodation facility (MAF) and binocular accommodation facility (BAF) were measured with an accommodation target at 40 cm and ±2.0 D flipper lenses and each instance of clearing both the plus and minus lenses was counted as one cycle, and results were recorded in cycles per minute (cpm). BAF was measured using a target with suppression control. AA was measured monocularly using Donder's method during which the accommodative target (one line above near BCVA) was brought closer to the eye until sustained blur. Also, far and near vergence ranges were evaluated using a prism bar. All binocular and accommodative tests were performed according to their standard protocols.

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

In this study, refractive errors were defined based on the spherical equivalent (SE). An SE $\leq$ −0.5 D was defined as myopia and that of +0.5 D or more was considered hyperopia.

To categorize based on different types of phoria, any degree of esophoria at near or far was considered esophoria, and exophoria was defined as more than 2 prism diopter (pd) at far or more than 6 pd at near.[9,10]

Statistical analysis

Considering the high correlation between the fellow eyes, only right eye data was used in the analyses. To test the inter-examiner agreement, the kappa was determined for qualitative variables, and the intraclass correlation coefficient (ICC) was calculated for quantitative variables.

All examinations were conducted in the same place by 2 optometrists who had a high agreement in the measurement of refraction (86%), visual acuity (91%), cover test (87%), NRA (ICC = 0.891), and PRA (ICC = 0.907).

In this study, the mean and standard deviation (SD) of NRA and PRA were investigated. Simple and multiple linear regressions were used to evaluate their relationship with age, gender, refractive error, AA, and accommodation facility. One-way analysis of variance was used to evaluate the mean NRA and PRA in different types of refractive errors.

Finally, the relations of PRA and NRA with other studied variables were examined using multiple linear regression models. A significance level of 0.05 was used.

Results

In this study, 610 students were selected, 506 responded, and after applying the exclusion criteria, 124 individuals were excluded. Therefore, final analyses were done with data from 382 participants. The mean age of this sample was 22.5 ± 4.4 years (range, 18—35 years) and 280 (73.2%) were female. In this study, 145 individuals were myopic with a mean SE of −2.44 ± 2.45 D, and 52 were hyperopic with a mean SE of +0.79 ± 0.85 D. Those with a UCVA of 20/25 and better had a mean SE of +0.01 ± 0.46 D. As described in the methods section, cases with latent hyperopia were excluded.

Table 1 presents the mean and SD of NRA and PRA in the whole study population and according to sex, age, type of refractive error, and the presence or absence of phoria. The results of the study showed that although there was no significant difference in NRA between men and women (P = 0.483), PRA was significantly higher in women (P = 0.002). Moreover, NRA had no significant relationship with age (P = 0.052) although PRA decreased significantly with age from −3.00 in cases under 20 years of age to −1.55 in those over 30 years (P < 0.001).

The mean NRA was highest in hyperopic, and mean PRA was highest in myopic participants. Analysis of variance showed a significant difference in NRA (P = 0.002) and PRA (P = 0.003) among different groups of refractive error.

The mean PRA and NRA were not different between participants with and without phoria (P = 0.693 and P = 0.375, respectively).

Table 2 shows the relationship of NRA and PRA with mean AA, accommodation facility, and refractive error after adjusting for refractive error, sex, and phoria. In this model, age was removed from the model due to its high correlation with mean AA.

NRA had a statistically significant association with accommodation facility and spherical refractive error, and PRA

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

	n	NRA(D)	PRA(D)
		Mean ± SD	Mean ± SD
Total	382	+2.08 ± 0.33	−2.92 ± 0.76
Gender			
Male	102	+2.06 ± 0.36	−2.73 ± 0.89
Female	280	+2.09 ± 0.31	−3 ± 0.69
Age (years)			
≤20	135	+2.10 ± 0.29	−3.00 ± 0.72
21−25	202	+2.08 ± 0.32	−2.97 ± 0.67
26−30	29	+2.10 ± 0.27	−2.96 ± 0.69
>30	16	+1.89 ± 0.62	−1.55 ± 1.04
Refractive errors			
Emmetropia	185	+2.12 ± 0.26	−2.80 ± 0.68
Myopia	145	+2.00 ± 0.39	−3.09 ± 0.82
Hyperopia	52	+2.13 ± 0.30	−2.90 ± 0.77
Phoria			
No	303	+2.09 ± 0.3	−2.91 ± 0.63
Yes	79	+2.06 ± 0.36	−2.94 ± 0.88
Exophoria	40	+2.08 ± 0.33	−2.87 ± 0.69
Esophoria	39	+1.99 ± 0.46	−2.69 ± 0.91

D: Diopter.
NRA: Negative relative accommodation.
PRA: Positive relative accommodation.
SD: Standard deviation

had a statistically significant association with AA such that each 1 unit increase in AA increased PRA by 0.107 unit.

Discussion

Assessment of relative accommodation (NRA and PRA) helps detect accommodation disorders and conditions affecting visual clarity. Few studies have investigated the normal values of these indices.[8,9,11−14] The present study is one of the few studies worldwide that evaluated the distribution of these indices in a normal population and their relationship with variables like refractive errors, age, AA, and accommodation facility. Knowledge of normal values of these

Table 2
The association of negative relative accommodation (NRA) and positive relative accommodation (PRA) with other factors in multiple linear regression.

	Unstandardized Coefficients	Standardized Coefficients	P-value
NRA			
Sex	−0.001	−0.002	0.967
Amplitude of accommodation (AA)	0.002	0.019	0.696
Accommodation facility	0.023	0.391	<0.001
Phoria	−0.012	−0.019	0.686
Spherical error (diopter)	0.039	0.227	<0.001
Cylinder error (diopter)	0.058	0.084	0.092
PRA			
Sex	−0.196	−0.114	0.018
Amplitude of accommodation (AA)	−0.107	−0.367	<0.001
Accommodation facility	0.005	0.037	0.439
Phoria	−0.005	−0.003	0.944
Spherical error (diopter)	0.010	0.025	0.636
Cylinder error (diopter)	−0.067	−0.041	0.424

NRA: Negative relative accommodation.
PRA: Positive relative accommodation.

two parameters in a given population is necessary for the accurate diagnosis of accommodative and binocular vision disorders and following the appropriate management, because as mentioned before, NRA and PRA are important indicators of two important systems influencing binocular vision, i.e. accommodation and vergence.

The mean NRA and PRA was +2.08 ± 0.33 D and −2.92 ± 0.76 D in our study, respectively. According to Scheiman and Wick, mean PRA is −2.37 ± 1.00 D, and mean NRA is +2.00 ± 0.50 D; the maximum expectable normal NRA could be up to +2.5 D, but the maximum PRA depends on different factors. PRA usually stopped at −2.5 D by the examining physician to balance PRA and NRA values, while the true value of PRA could be even higher.[8] Our results were also in the same range. In addition to their effects on binocular vision disorders, factors like age and ethnicity affect relative accommodation values as well.[11] Age and ethnicity affect the AA,[12] phoria, and accommodation facility,[13] resulting in changes in the values of relative accommodation. In a study of 7–12-year-old children, PRA and NRA was −3.92 ± 0.8 D and +3.25 ± 0.8 D, respectively. The high AA and overlooking hyperopia in children as compared to adults can explain the difference between the results of this study and our findings.[11] In a study by Jorge et al. on a study population with a mean age of 20.6 ± 2.3 years, PRA was −2.21 ± 0.42 D, and NRA was +2.33 ± 1.40D.[14] The participants also had binocular vision disorders that affected the values of these parameters. These disorders were excluded in our study. In another study, PRA was −2.37 ± 1.12 D, and NRA was +2.00 ± 0.50 D, which are different from our results, but may be due to different AA. In this study, AA was about 5 D in all participants while mean AA was 10.15 ± 1.49 D in ours.[9]

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 significant relationship with NRA, while PRA decreased significantly with age. As presented in the results, PRA significantly decreased by 1.45 D from the under 20 to the over 30 age groups.

According to the conducted studies and considering the decrease in AA with age and the development of presbyopia,[15–17] this conclusion also applies to relative accommodation. A study showed that with an increase in age, due to physiologic changes of the eye and the Edinger–Westphal nucleus in the parasympathetic pathway of accommodation, dynamic accommodation changes are observed that affect dynamic accommodation and cause limitations.[18]

In 2008, a study on the PRA of 118 adults with a 3-year follow-up showed a significant increase of 0.66 ± 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.[14] These disorders were excluded in our study.

In our study, the mean PRA was higher in female participants; there are no similar studies to compare results, but this finding could indicate more active accommodation in women. It seems to be related to the later onset of presbyopia in women due to active accommodation, but this is not true considering inter-gender anatomical and functional differences.[19] Some studies have even reported a younger age of onset in women.[19] The age of onset of presbyopia is not only related to accommodation, but anatomical differences may be effective as well.[19,20] There are no studies describing the significant inter-gender difference and a more active accommodation in females.

This study determined the effect of accommodation and vergence on the amount of refractive errors correction. The values of PRA and NRA significantly varied by refractive error. PRA was highest in myopic participants. There is no study to compare these results. Young myopic individuals usually accept a more than required negative power.[21] 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 accommodation excess in pseudo myopic patients.[22] However, attention should be paid to the effect of phoria in this study because no significant relationship was observed between spherical error and PRA after it was removed, indicating that phoria was the reason for the observed relationship. On the other hand, NRA was highest in hyperopic participants. Plus acceptation 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 hyperopic individuals. Therefore, a more positive lens is acceptable in hyperopic individuals.[23] Nonetheless, latent hyperopia or uncorrected hyperopia may also be the reason for the relationship.[24] Our results showed that eliminating phoria had no effect on mean NRA or PRA. This relationship was also observed when phoria was excluded and phoria was not a confounder.

Considering the results of the present study, the functions of NRA and PRA are not similar and each one has a different effect. It should be noted that two different nervous pathways with different control centers are involved in stimulating and relaxing accommodation.[25] Therefore, the role of accommodation and visual acuity status is different in different refractive errors like hyperopia and true and pseudo myopia; accommodation is achieved through the parasympathetic pathway via the primary visual cortex and the Edinger–Westphal nucleus of the oculomotor nerve while relaxation is achieved through the sympathetic pathway via the hypothalamus and the superior cervical ganglion pathway.[25] Both pathways are involved in the facility test; however, considering the findings of this study, only NRA has a direct relationship with accommodation facility. It seems that this finding confirms the considerable relationship between relative relaxation accommodation and accommodation facility. Scheiman reported that young people had less infacility than children and regarded the resolution of this disorder with age as one of the reasons AA and PRA decrease with age; therefore, a direct relationship is found between accommodation facility and NRA.[26]

In addition to its use in evaluating accommodation facility, the facility test can be an orthoptic training method for the

treatment of accommodation and binocular vision disorders.[8] Vision therapy has a very important role in vergence and accommodation disorders. The aim of vision therapy is to maintain and restore appropriate academic and occupational functioning and minimize physical and physiological symptoms.[7] In all the disorders, stimulation and relaxation should be strengthened through orthoptic training in both accommodation and vergence systems. According to previous studies, when the person has a problem with the positive lens during the accommodation facility testing or has a low NRA value, the first step in vision therapy is to use the Flipper method which results in a higher NRA value.[14] Considering the results of our study, with more emphasis on accommodation relaxation in vision therapy, especially during facility training, the possibility of the improvement of disorders of AA, accommodation facility, and vergence increases. According to the results, PRA has a direct relationship with the AA. The results of the conducted studies by Kasthurirangan[27] and Abraham[28] indicate that AA decreases with age which results in decreased accommodation facility and PRA. Increasing AA has been mentioned as one of the first very important factors in the beginning of orthoptic training in the treatment of accommodation and fusional disorders.[29] Considering the obtained results and the direct relationship between the two parameters of AA and PRA, a marked increase in AA can be achieved through increasing the PRA. It should be noted that accommodation cannot be predicted based on only one of the parameters of age, sex, AA, refractive error, accommodation facility, or vergence conditions. For this reason, judgment based on only one of the above-mentioned factors may be misleading. Therefore, evaluation of the different aspects of accommodation along with NRA and PRA provides a comprehensive assessment in this regard. This is one of the few studies on relative accommodation and the first study to investigate the relationship between relative accommodation parameters and refractive errors.

This study has some limitations. The studied population included only students within a certain age range. Therefore, similar studies are recommended in children and adults over 35 years of age. Other limitations include the relatively low response rate and reduced sample size which calls for further studies with larger sample sizes.

The results of the study showed the different and important effects of NRA and PRA on various aspects of accommodation and refractive errors and also their different functions. Both NRA and PRA should be considered when evaluating vergence and accommodation systems and even during appropriate orthoptic training. Knowledge of normal values of these two parameters contributes to the accurate diagnosis of the type of disorder and differential diagnosis.

Acknowledgement

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