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Evaluation of convergence, accommodation and fusional vergence in pre-presbyopes with asthenopia

Authors:
Saif H. Alrasheed[1,2]
Saeed Aljohani[1]

Affiliations:
[1]Department of Optometry, College of Applied Medical Sciences, Qassim University, Buraydah, Saudi Arabia

[2]Department of Binocular Vision, Faculty of Optometry and Visual Sciences, Al-Neelain University, Khartoum, Sudan

Corresponding author:
Saif Alrasheed,
s.rasheed@qu.ed.sa

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Background: Pre-presbyopes may suffer from ocular symptoms such as asthenopia of near work.

Aim: This study aimed to evaluate near points of convergence, amplitudes of accommodation, and fusional vergence among pre-presbyopes with asthenopia symptoms.

Setting: The study was conducted at El-Walidain Eye Hospital, Khartoum, Sudan in 2022.

Methods: The study was a hospital-based prospective, including 107 pre-presbyopes aged 35–40 years who complained of asthenopia symptoms. Clinical examinations included an assessment of amplitude of accommodation, near point of convergence and fusional vergence.

Results: The findings showed receded in near points of convergence and a decrease in the accommodation was highly significantly associated with increased age among emerging presbyopes with asthenopia symptoms (p = 0.0001). Conversely, positive and negative fusional vergence amplitudes were not significantly correlated with age with p = 0.109 and p = 0.355, respectively. Positive and negative fusional amplitudes were not significantly different between males and females ($p > 0.05$). Esophoria was more common in pre-presbyopia 62 (57.4%) and exophoria 45 (43.6) with p = 0.503.

Conclusion: The pre-presbyopes presented with low accommodation amplitude and receded near point of convergence, but without significant changes in positive and negative fusional vergence amplitudes.

Contribution: This study added by demonstrating how early presbyopia altered accommodation amplitude and near point of convergence significantly while having no significant impact on amplitudes of positive and negative fusional vergence.

Keywords: presbyopia; accommodation anomalies; symptoms; insufficiency; fusional vergence; esophoria.

Introduction

Presbyopia is a global health problem affecting the quality of life because it impairs near vision and binocular functions of individuals.[1,2] It is defined as an age-related decrease of amplitude of accommodation (AoA) that results in impairment of near vision.[1] The common belief is that presbyopia is because of a gradual thickening and loss of flexibility of the natural crystalline lens. The condition is commonly on account of the natural crystalline lens changing shape and losing elasticity.[2] Presbyopia is called early, emerging, or premature when the symptoms occur before the age of 40 years.[1,2]

Early onset presbyopia has a variety of ocular symptoms, including headache, reduced reading performance, and asthenopia after intensive close work without significant effect on near and distance visual acuity (VA).[2,3] Accommodation insufficiency is usually found when the AoA is lower than the expected finding for the age. The aetiology for under accommodation is extreme fatigue, influenza, high stress, and systemic condition such as anaemia, multiple sclerosis, and diabetes mellitus (DM).[4] The pathophysiology for under accommodation is accumulation of proteins in the lens, resulting in lens rigidity and loss of flexibility over time. These changes similarly occur in the muscle fibres surrounding the lens causing less elasticity.[4,5]

Age-related changes in near-visual functions can be influenced by various factors, besides a decrease in the AoA. These factors include binocular vision functions, contrast sensitivity (CS), lighting conditions, and pupillary size.[6,7]

Previous studies[8,9,10] have found that the ability to accommodate decreases as children and adults grow. Additionally, Woo[9] reported that near VA is significantly worse compared to distance VA, even in children with mild or moderate visual impairment (VI), primarily because of the impact of poor vision on accommodation amplitude. Insufficient accommodation from presbyopia causes blurred input to the vision area in the cortex because of reduced high spatial frequencies. Therefore, near visual functions such as VA, visual field, colour vision, and CS are reduced.[11,12,13] Blurred input to the visual cortex because of weaker and slower neuronal responses results in the reduction of binocular vision functions and CS. Therefore, CS and binocular vision functions are limited by the combined response of the receptive fields of simple cells in the visual cortex.[14,15,16]

The impact of ageing on the development of accommodation has been studied extensively in children and young adults. However, more knowledge is needed regarding the effect of age on fusional vergence amplitude and the near point of convergence (NPC).[17,18] In fact, the accommodative response may become increasingly essential during early presbyopia as greater accommodation is needed for near vision.[18] Scientific literature[19,20,21,22] proposes that changes in the eye vergence system affect the ability to keep the binocular vision and affect near activities. This is because the ciliary muscle plays a significant role in accommodation, and the medial rectus muscle responsible for the convergence of both muscles has the same nerve innervation.[19,20,23] Both functions, accommodation and fusional vergence, work together to maintain comfortable binocular vision at the near task.[19,24,25] Thus, the current study was conducted to evaluate the NPC, AoA, and fusional vergence among pre-presbyopes with asthenopia symptoms.

Research methods and design

Study design

This was a hospital-based prospective cross-sectional study designed to assess binocular vision functions (NPC, amplitudes of accommodation, and fusional vergence reserve) among participants with early presbyopia complaining from asthenopia symptoms. The study was conducted at El-Walidain Eye Hospital, Khartoum, Sudan, in 2022.

Study size and study population

This study used a non-probability sampling technique to sample 107 early presbyopia participants (87 females and 20 males) from El-Walidain Eye Hospital who had asthenopia symptoms. The mean age was 38.29 ± 1.88 years, ranging from 35 to 40 years.

Participants

All the participants complained of ocular symptoms such as blurred vision, soreness, tired eyes, and headache after near work. The inclusion criteria for the study were participants aged from 35 to 40 years who complained of asthenopia (headache, sore eye, ache, pain, irritation, burning, discomfort, fatigue, and eyestrain). All participants had unaided distance vision of 6/6 with no ocular pathology, with refraction less than ± 0.75 D for the sphere and 0.25 D for cylinder. Participants with high refractive error, anterior and posterior segment pathology, strabismus, and systemic diseases were excluded from the study.

Data sources and measurement

The study commenced with screening phase to ensure that all participants satisfied the inclusion criteria. A general and ocular case history was conducted to rule out systemic and ocular conditions. Objective and subjective refraction was assessed of all participants. External eye examinations were conducted by slit lamp to assess outer eye disorders. Fundus examination was conducted by an ophthalmoscope to rule out any posterior eye conditions. The distance VA was assessed using Snellen's tumbling E chart with E, at a standard distance of a 6-m.

The AoA was measured by the push-up method using a Royal Air Force (RAF) ruler. In the present study, the participants with refraction error less than ± 0.75 D sphere were instructed to wear their full distance refractive correction, and then the target (line of letters) was moved until the blur of the target was reported. The measurements of AoA were repeated three times for the right, left eye and both eyes, respectively and the average value was taken.

The NPC was also assessed by using RAF Rule; the patient focussed on the target (line), the examiner moved the target towards the participant until double vision was reported, then the examiner took the average of three measurements.

The cover test was conducted to find out if manifest or latent strabismus existed. The degree of latent strabismus (heterophoria) was measured using Maddox Wing at near and Maddox Rod for distance fixation.[22] Positive and negative fusional vergence amplitudes were measured by a prism bar using an accommodative target equivalent to the vision of 6/6 at 40 cm (about 1.31 ft) to the break point. To control the effect of convergence stimulation, negative fusional vergence was assessed first, and then positive fusional vergence after 5 min.

Bias control

In the present study to control the bias of data collection, one qualified optometrist performed all the clinical measurements. Moreover, the examiner took the average of three measurements for NPC, accommodation amplitude, and positive and negative fusional vergence amplitudes.

Statistical methods

The data entry was performed by the examiner using an Excel sheet and analysis was made by Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL, United States). Before analysis, the information was revised for data entry errors and/or missing values. The data for every participant were analysed descriptively using standard deviations, mean, variants, and percentages. The association between measures was determined using cross-tabulations, and chi-squared analysis and significance levels were established at $p < 0.05$.

Ethical considerations

Ethical permission to conduct the study was obtained from the Al-Neelain University Ethical Board (approval No. 22-04-10), and the study was conducted in line with the Declaration of Helsinki guidelines. Informed consent was obtained from all the participants, and the purpose of the study and any associated risks following eye examinations were explained to facilitate better understanding of the study procedure. The data were saved confidentially, and no personal information was collected during the process. All the participants participated freely; they could withdraw from the study at any time without giving justifications.

Results

This study comprised of 107 early presbyopes who complained of asthenopia symptoms. There were 87 females and 20 males, of age 35 to 40 years, with a mean age of 38.29 ± 1.88 years. One-Sample Kolmogorov-Smirnov Test showed that the clinical features for the patients with asthenopia symptoms were distributed normally with a $p = 0.0001$ as shown in Table 1.

The mean and standard deviation of NPC among pre-presbyopes was 15.84 ± 1.31 cm. The mean and standard deviation of binocular accommodation amplitude was 5.01 ± 0.88 D. Moreover, positive and negative fusional amplitude among patients were 41.00 ± 3.77, base-out, and 9.42 ± 1.20, base-in pd, respectively, as shown in Table 2.

Association between age, near point of convergence, accommodation, and fusional vergence among early presbyopes with asthenopia symptoms

The receded NPC was highly significantly associated with increased age among emerging presbyopes with asthenopia symptoms, $p = 0.0001$. However, a decrease in accommodation amplitude was extremely associated with age in patients who complained of asthenopia symptoms ($p = 0.0001$). The positive and negative fusional vergence were not significantly associated with age among patients who complained of asthenopia ($p = 0.109$) and ($p = 0.355$) respectively, as shown in Table 3.

There is no significant difference in NPC and AoA among males and females with asthenopia, $p = 0.412$ and $p = 0.413$, respectively. Positive fusional amplitude and negative fusional amplitude were not significantly different for males and females ($p < 0.05$) as shown in Table 4.

Esophoria was more common in early presbyopes 62 (57.4%) than exophoria 45 (43.6%); the difference was not significant ($p = 0.503$). Associations between near latent strabismus or heterophoria, near the point of convergence, accommodation amplitude, and fusional vergence ranges among early presbyopes with asthenopia symptoms were not statistically significant ($p > 0.05$), as shown in Table 5.

TABLE 1: One-sample Kolmogorov-Smirnov tests.

Statistics	Age (Years)	NPC (cm)	AoA (Dioptre)	PFV (Prism dioptre, pd)	NFV (Prism dioptre, pd)
N	107	107	107	107	107
Normal parameters†,‡					
Mean	38.29	15.84	5.00	41.39	9.42
s.d.	1.88	1.31	0.88	3.77	1.20
Most extreme differences					
Absolute	0.23	0.25	0.23	0.28	0.41
Positive	0.18	0.25	0.23	0.20	0.30
Negative	-0.23	-0.16	-0.13	-0.28	-0.41
Kolmogorov-Smirnov Z	2.36	2.55	2.39	2.89	4.19
Asymp. Sig. (2-tailed)	0.00	0.00	0.00	0.00	0.00

NPC, near point of convergence; AoA, amplitude of accommodation; PFV, positive fusional vergence; NFV, negative fusional vergence; s.d., standard deviation; Asymp. Sig., asymptotic significance.
†, Test distribution is normal.
‡, Calculated from data.

TABLE 2: Descriptive statistics of clinical characteristics for early presbyopes with asthenopia symptoms.

Clinical characteristics	*N*	Minima	Maxima	Means	s.d.
Age (Years)	107	35.00	40.00	38.30	1.88
NPC (cm)	107	14.00	18.00	15.84	1.31
AoA (Dioptre)	107	3.50	7.00	5.01	0.88
PFV (Prism dioptre)	107	30.00	45.00	41.00	3.77
NFV (Prism dioptre)	107	6.00	14.00	9.42	1.20

NPC, near point of convergence; AoA, amplitude of accommodation; PFV, positive fusional vergence; NFV, negative fusional vergence; s.d., standard deviation.

Discussion

Age-related decline in the AoA is the primary reason for early presbyopia. However, various factors, besides reduced accommodation, can also impact near vision.[5] These factors include latent strabismus types and severity, proximity of convergence points, and fusional vergence amplitudes.[6,7] Hence, the present study was conducted to assess the NPC, AoA, and fusional vergence reserve in pre-presbyopes with asthenopia symptoms. The present study showed that the recession in NPC and a decrease in AoA were highly significantly associated with pre-presbyopes suffering from asthenopia symptoms (p = 0.0001). These agreed with previously published studies[23,24,25] showing that accommodation functions decline with age and are commonly associated with ocular symptoms such as tired eyes, eyestrain, redness, irritation, blurred vision, headaches, and double vision.

In the Reindel et al.[25] study, the average NPC was found to be 13 ± 5.0 cm, which is lower than our findings of 15.84 ± 1.31 cm. This difference could be attributed to the lower average age of participants in the Reindel et al. study compared to our present study. Both findings clearly showed recession in NPC; these agreed with Spierer and Hefetz[26] who conducted a study to assess changes in the heterophoric condition of 100 normal subjects over 20 years. They reported that there was a significant recession in NPC as well as a significant decrease in accommodation amplitude.[26] However, some authors[24,25] reported that the increase in near points of convergence in recent years might be because of the common use of digital devices resulting in the high prevalence of computer vision syndrome. The current study revealed no significant difference in NPC and AoA among males and females suffering from asthenopia symptoms with p = 0.412 and p = 0.413, respectively.

In the present study, pre-presbyopes with asthenopia symptoms have receded NPC ranging from 14 to 18 cm with a mean of 15.84 ± 1.31 cm, which was associated with ageing (p = 0.001). The study revealed a strong association between receded NPC and decreased accommodation which was highly significant at p = 0.0001. Several authors[12,13,14,15,16,17,18] reported that most of the patients with convergence insufficient have accommodative insufficient.

TABLE 3: Association between age, near the point of convergence, accommodation, and fusional vergence among early presbyopes with asthenopia symptoms.

Clinical features	*N*	Mean	s.d.	95% Confidence interval for mean		*p*
				Lower bound	Upper bound	
NPC						**0.000**
35–36	24	15.04	0.62	14.78	15.31	-
37–38	24	15.00	1.10	14.53	15.47	-
39–40	59	16.51	1.22	16.19	16.83	-
AoA						**0.000**
35–36	24	6.10	0.68	5.82	6.39	-
37–38	24	5.06	0.54	4.84	5.29	-
39–40	59	4.53	0.61	4.37	4.69	-
PFV						0.109
35–36	24	42.08	3.59	40.57	43.60	-
37–38	24	40.00	4.66	38.03	41.97	-
39–40	59	41.68	3.33	40.81	42.55	-
NFV						0.355
35–36	24	9.67	1.52	9.02	10.31	-
37–38	24	9.17	1.31	8.61	9.72	-
39–40	59	9.42	0.99	9.17	9.68	-

Note: Bold text is used for significant results (p < 0.05).
NPC, near point of convergence; AoA, amplitude of accommodation; PFV, positive fusional vergence; NFV, negative fusional vergence; s.d., standard deviation.

TABLE 4: Association between gender, near the point of convergence, accommodation, and fusional vergence among early presbyopes with asthenopia symptoms.

Clinical features	*N*	Mean	s.d.	95% Confidence interval for mean		*p*
				Lower bound	Upper bound	
NPC						0.412
Male	20	16.05	1.28	15.45	16.65	-
Female	87	15.79	1.32	15.51	16.07	-
AoA						0.413
Male	20	5.15	0.89	4.73	5.57	-
Female	87	4.97	0.87	4.78	5.16	-
PFV						0.852
Male	20	41.25	3.58	39.57	42.93	-
Female	87	41.43	3.83	40.61	42.24	-
NFV						0.460
Male	20	9.60	1.54	8.88	10.32	-
Female	87	9.38	1.11	9.14	9.62	-

NPC, near point of convergence; AoA, amplitude of accommodation; PFV, positive fusional vergence; NFV, negative fusional vergence; s.d., standard deviation.

TABLE 5: Association between near latent strabismus (phoria), near the point of convergence, accommodation, and fusional vergence among early presbyopes with asthenopia symptoms.

Clinical features	*N*	Mean	s.d.	95% Confidence interval for mean		*p*
				Lower bound	Upper bound	
NPC						0.445
Exophoria	45	15.96	1.45	15.52	16.39	-
Esophoria	62	15.76	1.21	15.45	16.07	-
AoA						0.349
Exophoria	45	4.91	0.82	4.67	5.15	-
Esophoria	62	5.07	0.91	4.84	5.30	-
PFV						0.558
Exophoria	45	41.64	4.30	40.35	42.93	-
Esophoria	62	41.21	3.35	40.36	42.06	-
NFV						0.188
Exophoria	45	9.60	1.25	9.22	9.98	-
Esophoria	62	9.29	1.15	8.99	9.58	-

NPC, near point of convergence; AoA, amplitude of accommodation; PFV, positive fusional vergence; NFV, negative fusional vergence; s.d., standard deviation.

The mean and standard deviation of accommodation amplitude in this study population (5.01 ± 0.88 D) measured by the push-up method is lower than the mean (8.04 ± 3.09 D) found in the study conducted by Reindel et al.[25] in the United States (US) population. Accommodation amplitude in the current study fell within the lower range, despite including a slightly older population and using the same method of measurement as in the previous study in the US.[25] The present study was conducted in the African population; the lower values could be because of the effect of the environment on accommodation, as cited in many previous studies.[1,2,3,4,5,6,7,8,9,10]

The present study showed that positive and negative fusional vergence were not significantly connected with age at $p = 0.109$ and $p = 0.355$, respectively. These results agreed with a study conducted by Alrasheed and Adlakhil[27] among Sudanese exophoric patients aged between 10 and 30 years; they showed no association between ageing and fusional vergence amplitudes.[27] However, other previously published studies[22,28] reported that positive and negative fusional vergence at near distance were decreasing significantly with ageing. Furthermore, the current study showed that positive and negative fusional amplitudes were not significantly different between males and females ($p > 0.05$).

In our study, esophoria was more common in pre-presbyopes 62 (57.4%) than exophoria 45 (43.6%) with $p = 0.503$. In this study, we attributed the high prevalence of esophoria among pre-presbyopes to the ageing effect on fusional vergence and accommodation, resulting in a change in latent strabismus. Additionally, the current study showed that the association between near heterophoria, near the point of convergence, accommodation amplitude, and fusional vergence in pre-presbyopes was highly significant ($p < 0.05$).

The current study has some limitations. The sample size included was small; this is because of the nature of the study and the narrow age range. During data collection, most of the patients seeking eye care services were females resulting in a high proportion of females represented in this study, which may have reflected some gender inequality in our report. Despite the stated limitations, the present study assessed the NPC, AoA, and fusional vergence in pre-presbyopes with asthenopia symptoms. We recommended that for future studies, it is better to include the difference between the break and recovery of NPC and fusional vergence to assess if the change is within norms or if it takes longer for pre-presbyopes to recover.

Conclusions

Premature presbyopia significantly affected accommodation amplitude and NPC, whereas no significant changes were noted for positive and negative fusional vergence. Pre-presbyopes who perform near activities experience asthenopia symptoms. This should encourage eye care professionals to develop effective management plans, such as vision therapy or exercises to relax or stimulate accommodation and fusional vergence amplitude to relieve ocular symptoms.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

S.H.A. contributed to conceptualisation, data curation, formal analysis, methodology, and validation and investigation. S.A. was involved in software, writing – original draft, and writing – review and editing.

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Data availability

The data are available at any time requested by the corresponding author, S.H.A.

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