Original Article

The Impact of Induced Anisometropia on Binocular Vision

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ABSTRACT

Purpose: To assess the impact of induced anisometropia on binocular visual function.
Study Design: Quasi experimental study.

Place and Duration of Study: Optometry clinics of Qassim University, from January 2024 to June 2024.

Methods: The study included 60 subjects of 16-26 years. Anisometropic myopia was induced by plus lenses (+1DS, +2DS, +3DS) and anisometropic hypermetropia was induced by minus lenses (-1DS, -2DS, -3DS) keeping them emmetrope with normal binocularity. Subjects with squint, suppression and amblyopia were excluded. Clinical assessment included assessment of vision, refraction and near phoria with Maddox wing. Assessment of bifoveal fusion, suppression and diplopia was done using Worth four dot test and stereoscopic vision with Titmus fly test. Data was analyzed by using SPSS- v.25.

Results: There were 66.7% males and 33.3% females. Mean age was 22.37±2.81 years. A significant difference in stereo acuity was found in 1D (41.75±130.26 sec arc), 2D (233.77±172.09 sec arc) and 3D (399.267±181.31 sec arc) anisometropic myopia ($p<0.001$) as well as anisometropic hypermetropia ($p<0.001$). There was no significant difference in stereo acuity between males and females ($p > 0.05$). However, diplopia was higher in 3D of anisometropic hyperopia (73.3%) than anisometropic myopia (66.7%). Monocular suppression was present in 6.7% and 3.3% of 3D anisometropic hyperopia and anisometropic myopia respectively. Alternate suppression was present in 1.7% of eyes with 2D anisometropic hyperopia only.

Conclusion: Small degree of anisometropia significantly impact binocular vision. It affects bi-foveal fusion, leads to diplopia, suppression and reduction in stereopsis.

Key words: Anisometropia; Binocular vision; Bi-foveal fusion; Suppression; Stereoscopic vision.

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INTRODUCTION

Binocular vision is the ability of two eyes to see two similar images simultaneously and blend them into one with depth perception.[1] It needs a good and near equal visual acuity in both eyes. High anisometropia leads to amblyopia and reduction in binocular single vision.[2,3] Anisometropia affects babies and young children during their first 10 years of life during the period of visual development. When anisometropia is more severe, the visual cortex is unable to resolve differences in images (binocular summation) produced by the two retinas. It develops a preference for the clear image coming from one retina and suppresses the blurred image from the other retina.[4,5] Stereopsis is the ability to determine how far an individual or object is while seeing in three dimensions.[6] Binocular vision is required to perceive depth and monocular vision results in weak depth perception.[7]

Earlier studies have highlighted the impact of high degrees of anisometropia on binocular function, but there is a lack of research on its effects at lower degrees. Therefore, this study was conducted to

examine the influence of varying degrees of myopic and hypermetropic anisometropia on binocular visual function, with the aim of predicting amblyopia in eyes with low degrees of anisometropia.

METHODS

This quasi-experimental study was conducted at optometry clinics of Qassim University from January to June 2024. Sixty subjects of 16 to 26 years of age were enrolled. They were healthy young subjects with normal binocular vision (phoria at near ≤ 4Δ) and emmetropia in both eyes (SE≤ 0.50DS)and anisometropia of ≤0.25DS. Their unaided vision in both eyes was 6/6. Subjects with a history of ocular or systemic disease were excluded. Those with binocular vision problems such as squint, suppression, diplopia and amblyopia were also excluded. The sample size was calculated using convenience sampling. Anisometropia was induced for all participants by putting a spherical lens on a trail frame before the right eye. Anisometropic myopia was produced by using plus lenses (+1.00, +2.00, +3.00 diopter sphere) and anisometropic hypermetropia by using minus lenses (-1.00, -2.00, -3.00 diopter sphere). Data included demographic characteristics (age and gender), clinical history, assessment of vision by Decimal notation and objective refraction using auto-refracto-keratometer (Topcon RK-8900). Assessment of near phoria was done using Maddox Wing. Bi-foveal fusion, diplopia and suppression were checked by Worth four dot test and stereo acuity by Titmus fly test. Binocular vision was tested without lenses and then anisometropic myopia was induced. Binocular function was assessed after the use of +1.00DS, +2.00DS and +3.00DS. Similarly, hypermetropia was induced by using -1.00DS, -2.00DS, -3.00DS and binocular function was determined. Subjects took rest after each examination to avoid stress and to obtain a reliable result of examinations. For reliability of readings, three measurements were taken for each variable and an average was obtained. Data were analyzed by using SPSS-v 25. Descriptive statistics (frequencies, minimum, maximum, mean and standard deviation) were obtained. The mean values of study variables across all anisometropia groups were statistically analyzed to determine correlations at a 95% confidence level (CI). Statistical significance was set at $p < 0.05$. A one-way analysis of variance (ANOVA) was employed to compare the magnitude of stereopsis, while the Chi-square test was used to analyze data on bifoveal fusion, suppression, and diplopia among the study groups. Additionally, a paired sample t-test was conducted to compare the mean stereopsis values before and after lens correction.

RESULTS

Out of 60 healthy subjects with normal binocularity included 66.7% (40) males and 33.3% (20) females. Their mean age was 22.37±2.81 years. The mean of near phoria was 2.68±1.31Δ. Mean stereo-acuity before the use of lenses was 41.75±29.90 sec arc. Table 1 shows stereo acuity after induced anisometropic myopia and induced hypermetropia.

One way ANOVA yield no significant difference of stereoscopic vision between males and females ($p>0.05$) except in 3D anisometropic myopia. It was significantly different ($F=5.546$; $p=0.022$). Paired sample t-test revealed a significant decrease of stereo-acuity in all degrees of anisometropic myopia and anisometropic hypermetropia when compared to emmetropia ($p<0.001$). Multivariate regression analysis showed significant difference of stereo acuity after induced anisometropic myopia and anisometropic hypermetropia ($F=8.880$; $p=0.000$, $R=0.708$; $R^2=5\%$).

Table 1: *Magnitude of Stereoacuity in induced anisometropia.*

Stereo-acuity	All participants (n=60)		Male (n=40)		Female (n=20)		p-value[a]	p-value[b]
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD		
Baseline value	20 – 160	41.75±29.90	20 – 100	40.50±26.18	20 – 160	44.25±36.87	0.651	
Anisometropic myopia								
+1.00DS	20 – 600	134.85±130.26	20 – 600	139.35±135.78	20 – 400	125.85±111.57	0.709	<0.001
+2.00DS	40 – 600	233.77±172.09	50 – 600	242.58±180.99	40 – 600	216.15±155.66	0.579	
+3.00DS	40 – 600	399.27±181.31	50 – 600	436.83±173.90	40 – 600	324.15±176.35	0.022	
Anisometropic hypermetropia								
-1.00DS	20 – 600	131.97±144.25	20 – 600	132.75±140.01	20 – 600	156.11±13.40	0.953	<0.001
-2.00DS	25 – 600	249.60±166.58	25 – 600	259.65±163.97	50 – 600	229.50±174.19	0.513	
-3.00DS	50 – 600	392.55±183.34	100 – 600	397.33±181.06	50 – 600	383.00±192.19	0.778	

[a]Analysis of variance (ANOVA). [b]Paired sample t-test.

Table 2: *Clinical findings of binocular vision function.*

Binocularity	Fusion *n (%)*	Diplopia *n (%)*	Alternate suppression *n (%)*	Monocular suppression *n (%)*	*p-value* [a]	*p-value* [b]
Baseline value	60 (100)	0 (0.0)	0 (0.0)	0 (0.0)		
Anisometropic myopia						
+1.00DS	50 (83.3)	9 (15.0)	0 (0.0)	1 (1.7)	0.361	<0.001
+2.00DS	27 (45.0)	32 (53.3)	0 (0.0)	1 (1.7)	0.278	
+3.00DS	16 (26.7)	40 (66.7)	0 (0.0)	4 (6.6)	0.094	
Anisometropic hypermetropia						
-100DS	41 (68.3)	17 (28.3)	1 (1.7)	1 (1.7)	0.791	<0.001
-2.00DS	27 (45.0)	30 (50.0)	1 (1.6)	2 (3.4)	0.558	
-3.00DS	12 (20.0)	44 (73.3)	0 (0.0)	4 (6.7)	0.235	

[a]Paired sample t-test.
[b]Chi-squire test.

Binocular visual functions are revealed in Table 2. The one-way ANOVA test revealed a significant difference in anisometropic myopia and anisometropic hyperopia compared to isometropia ($p < 0.001$). The Chi-square test showed no statistically significant difference in binocular function outcomes between males and females across all degrees of anisometropic myopia and anisometropic hyperopia ($p > 0.05$).

DISCUSSION

The results indicated that anisometropia has a significant effect on stereo acuity ($p < 0.001$). An impairment in stereo acuity was observed, which increased with the degree of anisometropia, aligning with previous findings. A previous study reported that even low degrees of anisometropia can lead to abnormalities in binocular visual functions in young adults.[8] Uncorrected anisometropia can potentially impact binocularity in children and should be carefully considered when developing guidelines for correcting refractive errors.[9,10] According to another study, anisometropia affects 6% of students between 6 and 18 years of age.[11] Generally, spherical and cylindrical difference of greater than 1 D and 1.5 D can cause anisometropia and need correction.[12] Amblyopia is associated with anisometropia and it causes alterations in various parts of visual system.[13,14] Neuronal receptive fields, contrast sensitivity, grating acuity and depth perception are also affected by amblyopia.[15,16] In addition to amblyopia, the influence of anisometropia on binocular vision should be considered before prescribing spectacles in children during the critical period.[17-19] Previous study in healthy adults also reported that low spherical degrees of anisometropia can have significant adverse effects on binocular vision.[20] Foveal suppression, which is directly associated with the magnitude of anisometropia, may be attributed to loss of stereopsis. The studies suggested that the impact of anisometropia on stereo acuity should be considered in the empiric correction of anisometropia.[21,22] Clinically, many cases with low and moderate anisometropia complain of asthenopia despite their normal binocularity. These cases may have a higher risk of developing binocular vision anomalies and amblyopia.

The degree of stereo acuity impairment between males and females was not significantly different in both anisometropic myopia and anisometropic hypermetropia ($p>0.05$). In addition, anisometropic myopia had a greater impairment in stereoacuity than anisometropic hyperopia. The highest degree of impairment was found to be among the 3D anisometropic myopia (399.267 sec arc) followed by 3D anisometropic hyperopia (392.55 sec arc) ($F=8.880$; $P<0.001$).Previous studies in Egyptian and Chinese populations, reported that eyes with anisometropic hyperopia had a better stereo acuity than anisometropic myopia.[13,16] Eyes with 1D Anisometropic hyperopia had a better stereo acuity than those with 1D anisometropic myopia.

These results demonstrated that monocular blur has a lesser effect on stereo acuity than binocular blur. It seemed due to a better visual function obtained by isometropia when compared to anisometropia. In contrast, an anisometropic hyperopia usually accommodate to have a clear retinal image in the hyperopic eye and the fellow eye will be out of focus which will lead to reduction of high spatial frequencies in the retinal image.[15,17]

The study demonstrated a significant impact of anisometropia on binocular visual function ($p < 0.001$), with no significant differences between genders across all degrees of anisometropic myopia and hypermetropia ($p > 0.05$). All isometropic eyes exhibited good bifoveal fusion (100%) prior to the induction of anisometropia. In contrast, bifoveal fusion decreased substantially in eyes with 3D anisometropic hypermetropia (20%) and 3D anisometropic myopia (26.7%). A 2D difference in anisometropic myopia and hypermetropia resulted in the same bifoveal fusion percentage (45%), while a 1D difference had a lesser effect on bifoveal fusion. These findings align with those reported in previous studies.[5,10,13]

The break in bifoveal fusion will lead to either suppression or diplopia. The study revealed that diplopia was highly present in eyes with 3D anisometropic hypermetropia (73.3%) followed by eyes with 3D anisometropic myopia 66.7%). Considering these results, it is obvious that uncorrected anisometropia with different degrees has impact on binocular function. Good binocular vison requires clear and equal size retinal image to be perceived by the brain and blend them into single image with depth perception. In addition, diplopia and suppression significantly increase with the increase the degree of anisometropia when compared to isometropia. Earlier studies reported that anisometropia has effect on binocular function and the effect is more in cases with anisometropic hyperopia.[8,13,21]

Results of the current study indicated that early correction of anisometropia with the appropriate lenses would maintain binocular function to high level and prevent the occurrence of amblyopia.

The primary limitation of the current study was the extended duration of clinical examinations, which led to the withdrawal of some participants. However, a notable strength was the inclusion of relatively young subjects, ensuring well-established binocular vision and minimizing the influence of age-related changes.

CONCLUSION

The study concluded that small degree of anisometropia had significant impact on binocular visual function. It affects bi-foveal fusion and leads to diplopia, suppression and reduction in stereoacuity. Therefore, it would be recommendable to assess binocular function in anisometropia before and after prescribing optical correction.

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Patient's Consent: Researchers followed the guidelines set forth in the Declaration of Helsinki.

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval: The study was approved by the Institutional review board/Ethical review board **(**24-02-08**)**.

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Author's Designation and Contribution

Raghda Faisal Mutwaly; *Assistant Professor: Concepts, Design, Literature search, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Manuscript review.*