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ORIGINAL ARTICLE – OPEN ACCESS

Evaluation of Stereopsis in Children with Corrected Anisometropia According to Type, Severity, and Presence of Amblyopia

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ABSTRACT

Objective: This study was designed to determine the level of stereopsis in anisometropic children with and without amblyopia who used corrective glasses and to investigate the effect of the type and magnitude of anisometropia on the level of stereopsis.

Materials and Methods: The medical records of 256 children with a diagnosis of non-amblyopic anisometropia or anisometropic amblyopia, and healthy controls were retrospectively reviewed for this study. Anisometropia was categorized into 3 groups: spherical equivalent-only anisometropia, astigmatic-only anisometropia, or combined anisometropia. The level of stereopsis was measured using the Titmus stereo test, compared between groups, and the correlation of the stereopsis with the magnitude of anisometropia was analyzed.

Results: Patients in the non-amblyopic anisometropia group had a similar stereopsis level when compared with the control group (55.2±41.03 and 47.2±19.8 seconds of arc, respectively; p=0.223). The level of stereopsis was significantly less in the anisometropic amblyopia group (279.4±120 seconds of arc) compared with the non-amblyopic anisometropia (55.2±41.03 seconds of arc) and control groups (47.2±19.8 seconds of arc) (p=0.008, p=0.006, respectively). A greater spherical equivalent difference between the eyes resulted in poorer stereopsis in the anisometropic amblyopia group, and combined anisometropia was found to be associated with poorer stereopsis levels in the nonamblyopic anisometropia (NA) group.

Conclusion: The NA patients had a similar level of stereopsis compared with controls while wearing corrective glasses. This result suggests that as long as patients have good visual acuity, stereopsis is preserved, and that refractive correction with glasses does not interfere with stereopsis in childhood anisometropia.

Keywords: Amblyopia, anisometropia, children, depth perception, stereopsis

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INTRODUCTION

Anisometropia is diagnosed when the refractive error differs between the two eyes. The condition may cause discordant binocular vision and cause amblyopia (1, 2). Guidelines have been developed to assess the degree of anisometropia to prevent the development of amblyopia (3).

Stereopsis refers to depth perception and the combined visual information received from both eyes (4). Good binocular visual acuity and healthy visual pathways are necessary for adequate stereopsis that allows both eyes to see the same object as one image and to create a perception of depth. Problems such as amblyopia, anisometropia, cylindrical refractive error, or aniseikonia, may result in reduced stereo acuity (4–7).

Amblyopia has been associated with reduced stereopsis, however, the results of studies of anisometropia without amblyopia differ in the literature. Lee et al. (8) reported that the stereopsis was worse and that the ratio of subjects with normal stereo acuity was also lower in nonamblyopic anisometropic patients while using their anisometropic glasses. In contrast, Jeon et al. (9) found that stereopsis in the nonamblyopic anisometropic group did not vary meaningfully from that of the nonanisometropic control group, but was worse in cases of amblyopic anisometropia.

The objective of the current study was to determine the level of stereopsis in anisometropic patients with or without amblyopia who wore corrective eyeglasses. The effect of the type and magnitude of anisometropia on the level of stereopsis was also investigated.

MATERIALS and METHODS

This study conformed to the Helsinki Declaration of principles, and approval was granted by the Istanbul Medipol University ethics committee on December 11, 2019 (no: 10840098-604.01.01-E.64942).

Table 1. Demographics and level of stereopsis by group

	NA group (n=100)	AA group (n=52)	Control group (n=104)	p
Gender (F:M)	47:53	29:23	48:56	0.492*
Female, %	(47)	(55.7)	(46.1)	
Age (years)	10.1±2.9	9.6±2.7	9.1±2.8	0.060†
	(5–16)	(6–17)	(5–16)	
BCVA_better	0.0005±0.005	0.0029±0.01	0.001±0.006ǂ	0.172†
(LogMAR)	(0–0.05)	(0–0.05)	(0–0.05)	
BCVA_worse	0.0045±0.01	0.24±0.18	0.001±0.006§	<**0.001**†
(LogMAR)	(0–0.1)	(0.1–0.8)	(0–0.05)	
SE_better (D)	0.93±2.41	1.41±3.34	0.23±1.76ǂ	<**0.001**†
	(-8.0/+6.0)	(-2.5/+5.75)	(-5.25/+4.5)	
SE_worse (D)	1.41±3.34	2.85±3.40	0.28±1.83§	<**0.001**†
	(-8.50/+8.25)	(-8.75/+7.50)	(-5.50/+4.50)	
SED (D)	1.13±0.80	2.43±1.83	0.10±0.12	<**0.001**†
	(0.25–5.0)	(0–8.0)	(0.0.5)	
C_better (D)	0.72±0.89	0.89±1.06	0.50±0.78ǂ	**0.016**†
	(0–3.50)	(0–4.0)	(0–4.0)	
C_worse (D)	1.41±1.43	1.81±1.55	0.68±0.95§	<**0.001**†
	(0–4.75)	(0–5.25)	(0–4.50)	
CD (D)	0.68±0.9	0.91±0.9	0.17±0.3	<**0.001**†
	(0–4.75)	(0–4.50)	(0–1.25)	
Stereopsis	55.2±41.03	279.4±120.0	47.2±19.8	<**0.001**†
(seconds of arc)	(40–400)	(40–3552)	(40–200)	

*: Pearson's chi-squared test; †: Kruskal-Wallis test; ǂ: Result of right eye; §: Result of left eye; AA: Amblyopic anisometropia; BCVA_better: Best-corrected visual acuity of the better eye; BCVA_worse: Best-corrected visual acuity of the worse eye; C_better: Cylindrical refractive error of the better eye; CD: Cylindrical refractive error difference; C_worse: Cylindrical refractive error of the worse eye; D: Diopter; F: Female; M: Male; NA: Nonamblyopic anisometropia; SE_better: Spherical equivalent of the better eye; SED: Spherical equivalent difference between eye; SE_worse: Spherical equivalent of the worse eye

The medical records of 256 children (age range: 5–17 years) with a diagnosis of nonamblyopic anisometropia (NA), anisometropic amblyopia (AA), and healthy controls without anisometropia who presented between January 2017 and January 2020 were retrospectively reviewed.

Inclusion Criteria

Anisometropia was defined as a spherical equivalent (SE) of ≥0.5 diopters (D) or ≥1.5 D cylindrical refractive error difference, and amblyopia was defined as a best-corrected visual acuity (BCVA) difference of ≥2 Snellen lines between the eyes (10). Anisometropia was categorized into 3 groups: the SE-only anisometropia subjects had an SE difference of ≥0.5 D in the absence of an astigmatic refractive error difference of ≥1.5 D between the eyes, astigmatic-only anisometropia was defined as an astigmatic refractive error difference of ≥1.5 D without an SE difference of ≥1.5 D between the eyes, and the combined anisometropia group included those with both an SE and an astigmatic refractive error intraocular difference of ≥1.5 D (10).

The axis was not taken into consideration while evaluating astigmatic anisometropia because all of the patients with a significant cylindrical refractive error had a cylindrical axis within 10° of symmetry. The control group comprised children without anisometropia with a Snellen chart visual acuity of 10/10 with correction of refractive error, if needed.

Exclusion Criteria

The exclusion criteria for the present study were a history of ocular surgery or trauma; abnormal eye alignment at a distance, near fixation, or other types of amblyopia; corneal abnormality; or optic disc or retinal disease.

Study Procedure

All of the participants underwent an ophthalmic examination (visual acuity testing using a Snellen chart, orthoptic screening, and slit-lamp and dilated fundus evaluation). The subjects' BCVA was converted into a LogMAR value. Cycloplegia was achieved by applying cyclopentolate 1% three times, and 30 minutes later, autorefraction was performed using an auto keratorefractometer (KR-8900; Topcon Corp., Tokyo, Japan).

Stereopsis was tested using a Titmus stereo test (Vectogram; Stereo Optical Co., Inc., Chicago, IL, USA).8 Gross stereopsis

Table 2. Anisometropia results by type in the nonamblyopic anisometropia and anisometropic amblyopia groups

	Nonamblyopic anisometropia group			
	SE Anisometropia (n=81)	**Astigmatic Anisometropia (n=14)**	**Combined Anisometropia (n=5)**	**p**
Gender (F:M)	43:38	3:11	1:4	0.043*
(Female, %)	(53)	(21.4)	(20)	
Age (years)	10.2±2.9	9.3±2.6	9.8±4.3	0.599†
BCVA_worse (LogMAR)	0.00±0.01	0.00±0.01	0.01±0.02	0.369†
Stereopsis (seconds of arc)	55.8±44.2	44.2±7.5	76±37.8	**0.015**†
	Anisometropic amblyopia group			
	SE Anisometropia (n=41)	**Astigmatic Anisometropia (n=8)**	**Combined Anisometropia (n=3)**	**p**
Gender (F:M)	21:20	5:3	3:0	0.245*
(Female, %)	(51.2)	(62.5)	(100)	
Age (years)	10.0±2.7	8.7±3.0	7.0±1.0	0.057†
BCVA_worse (LogMAR)	0.25±0.18	0.14±0.15	0.33±0.31	0.228†
Stereopsis (seconds of arc)	323.9±569.6	83.7±50.6	193.3±179.2	0.164†

*: Pearson's chi-squared test; †: Kruskal-Wallis test; BCVA: Best-corrected visual acuity; F: Female; M: Male; SE: Spherical equivalent

was evaluated by asking patients to pinch the tip of the wing in an image of a fly. Fine stereopsis was evaluated using circle patterns. The patients were asked to identify the one that appeared to come out closer to them. All of the patients wore polarized viewers over glasses with the appropriate refractive correction and all had used their glasses for at least 16 weeks. Refractive corrections were based on the cycloplegic refraction. Myopia and astigmatism were corrected in full, whereas hypermetropia was usually undercorrected by as much as 1.5 D. Patients who were prescribed glasses for the first time were re-evaluated after a 16-week refractive adaptation period, and this value was used in the analysis.

Stereoacuity was compared between groups (NA, AA, healthy controls), as well as the effects of SE and cylindrical power difference, BCVA, and type of anisometropia on stereopsis.

Statistical Analysis

All of the statistical analyses were performed using SPSS Statistics for Windows, Version 19.0 software (IBM Corp., Armonk, NY, USA). Pearson's chi-squared test was used to compare differences based on gender. Normality of the data distribution was assessed with the Kolmogorov-Smirnov test, and since the distribution was not normal, the Kruskal-Wallis test was used, followed by the Mann-Whitney U test with Bonferroni correction for post-hoc analysis to compare the groups in terms of age, BCVA, refractive error, anisometropia magnitude, and stereopsis level. The correlation of stereopsis with SE and cylindrical power differences and BCVA were evaluated using Spearman's correlation coefficient. $P<0.05$ was accepted as statistically significant.

RESULTS

The baseline characteristics and the stereopsis level for the 256 subjects (124 females, 132 males) according to representation in the NA (n=100), AA (n=52), and healthy control (n=104) groups are provided in Table 1. The patients' mean age was 9.6±2.9 years (range: 5–17 years). There was no significant difference in terms of gender and age distribution between groups (p=0.492 and p=0.060, respectively). The worse eye was the eye with a higher refractive error in the AA and NA group.

The mean SE of the better eye in the AA group was higher than that of the control group (p<0.001). However, the SE values of the better eyes were not significantly different in a comparison of the NA and the AA groups with the control group (p=0.401 and p=0.048, respectively). The mean SE of the worse eye in the NA and AA groups was significantly higher than that of the control group (p=0.009 and p<0.001, respectively), and the mean SE in the AA group was higher than that of the NA group (p=0.041). The mean SE difference between the eyes in the AA group was remarkably greater when compared to the NA group (p<0.001). The mean cylindrical refractive error of the better eye in the AA group was significantly higher than that recorded in the control group (p=0.025). There was no significant difference between the NA group and the AA and control groups (p=0.696 and p=0.147, respectively). The mean cylindrical refractive error of the worse eye in the NA and AA groups was significantly higher than that of the control group (p<0.001 for both), while it did not vary significantly between the NA and AA groups (p=0.325). There was no significant differentiation between the NA and AA groups in terms of cylindrical refractive error difference (p=0.411).

Table 3. Correlation between the level of stereopsis and spherical equivalent difference, cylindrical power difference and visual acuity of the worse eye

	SED	CD	BCVA_worse
NA+AA groups			
Stereopsis	r=0.381	r=0.176	r=0.642
	p<**0.001***	p=**0.030***	p<**0.001***
NA group			
Stereopsis	r=0.126	r=0.147	r=0.128
	p=0.212*	p=0.145*	p=0.206*
AA group			
Stereopsis	r=0.328	r=-0.078	r=0.608
	p=**0.017***	p=0.581*	p<**0.001***

*: Spearman's correlation; AA: Amblyopic anisometropia; BCVA_worse: Best-corrected visual acuity of the worse eye; CD: Cylindrical refractive error difference; NA: Nonamblyopic anisometropia; SED: Spherical equivalent difference between eyes

The mean level of stereopsis was significantly worse in the AA group than in the NA and control groups (p=0.008 and p=0.006, respectively). The stereopsis results of the NA group and the control group were similar (p=0.223).

When the results of stereopsis were compared among the 3 subtypes in the NA group, the combined anisometropia group had a significantly lower stereopsis levels compared with the astigmatic anisometropia and spherical anisometropia groups (p=0.012 and p=0.036, respectively). There was no significant difference between the spherical anisometropia and astigmatic anisometropia groups (p=0.707). There was also no significant difference between the 3 subtypes in the AA group (p=0.164) (Table 2).

There was a significant correlation between the level of stereopsis and SE difference, cylindrical power difference, and the BCVA of the worse eye in the total of anisometropic patients (NA+AA groups) (r=0.381, p<0.001; r=0.176, p=0.030; r=0.642, p<0.001, respectively). In the AA group, a greater SE difference between the eyes and decreasing BCVA resulted in worsening stereopsis (r=0.328, p=0.017; r=0.608, p<0.001, respectively). There was no significant relationship seen in the NA group (Table 3).

DISCUSSION

This study examined the stereopsis level of anisometropic patients who wore corrective glasses using the Titmus stereo test. The results showed that the patients in the NA group had a similar stereopsis level to that of the control subjects. The stereopsis was remarkably poorer in the AA group in comparison with the NA and control groups. Increased intraocular SE difference and decreased BCVA resulted in worsening stereopsis in the AA group, and the combined anisometropia subtype was found to be related to worse stereopsis in the NA group.

Anisometropia may lead to amblyopia secondary to a defocusing image at the fovea or active suppression mechanism (11). It has also been shown that anisometropia, even in the absence of amblyopia, may affect binocular vision and cause decreased stereopsis (8–15). Since decreased visual acuity may cause difficulty in the differentiation of stereoacuity test targets, it is not unexpected to find that the level of stereopsis correlates with the amount of anisometropia and depth of amblyopia. Chen et al. (12) evaluated the stereopsis level of previously untreated anisometropic amblyopia patients using the Lang stereoacuity test, and they found that larger degrees of anisometropia induced poorer stereopsis. They also noticed that when the anisometropia magnitude was <3D, 80% of patients retained some stereopsis of <1200 seconds of arc, but when the anisometropia magnitude was >3D, and especially >6D, 80% patients had an absence of stereopsis function.

Wallace et al. (10) evaluated 633 subjects from Pediatric Eye Disease Investigator Group studies with moderate anisometropic amblyopia to determine factors associated with pretreatment and posttreatment stereoacuity. They used the Randot Preschool Stereoacuity test to assess the stereopsis level, and they reported that better stereoacuity was associated with less anisometropia and better visual acuity. Jeon et al. (9), however, reported no significant relationship between the degree of anisometropia and the level of stereopsis in a study with 35 amblyopic anisometropia patients that used the Titmus stereo test. Similar to the results reported by Chen et al. (12) and Wallace et al. (10), we found that an increasing SE difference between the eyes and a decreasing BCVA resulted in worsening stereopsis in the AA group. Wallace et al. (10) noted that anisometropia due to astigmatism alone was associated with better stereoacuity in anisometropic amblyopia patients. In the current study, no significant difference was observed between the 3 types of anisometropia.

The literature reveals conflicting findings about the effect of NA on stereopsis. Jeon et al. (9) evaluated 72 NA patients using the Titmus stereo test and reported that the NA patients had a similar level of stereopsis to that of the patients in a control group. They also noticed that increased anisometropia magnitude was associated with poorer stereopsis. Lee et al. (8) studied the stereopsis level of 106 nonamblyopic patients wearing glasses for anisometropia using the Titmus-fly and Randot stereo test. Although they found better stereopsis levels in the isometropic patients compared with anisometropic patients, they thought that anisometropic patients wearing their glasses had a clinically near-normal stereopsis level and they reported no significant association between the anisometropia magnitude and stereopsis. Also, in the Pediatric Eye Disease Investigator Group study, even if their visual acuity deficit resolved, many children with AA had worse stereopsis compared with a nonamblyopic age-matched group (10). Similar to the findings reported by Jeon et al. (9), we did not observe a significant difference in the stereopsis level of NA or isometropic patients, and as reported by Lee et al. (8), there was no significant relationship between the stereopsis level and SE difference. Lee et al. (8) also analyzed the effect of type of anisometropia on stereopsis and found that the stereopsis did not significantly vary among subtypes of anisometropia (spherical, astigmatic, or mixed type). The combined anisometropia group had the poorest stereopsis result in the present study.

Aniseikonia, a condition in which the recognized retinal image size is different between eyes, should be considered when prescribing anisometropic glasses. Studies have demonstrated that a magnification difference between eyes of 3% to 5% begins to disrupt binocular vision and decrease stereopsis (16, 17). Both anisometropia itself and its optical correction can induce aniseikonia, and contact lens usage instead of glasses may provide less difference in image size (18). The results of the present study showed that nonamblyopic anisometropia with corrective glasses did not interfere with binocular functions or stereopsis. It may be that good stereopsis mostly depends on good visual acuity, and aniseikonia created by corrective eyeglasses is clinically well tolerated under normal viewing conditions.

There are some limitations to this study. First, there was a lack of information about the history of amblyopia treatment in the NA group. Subnormal stereopsis may persist after the resolution of visual acuity deficits with treatment of amblyopia, and this may have affected our outcomes. Second, we didn't know how old the patients were when they first began to wear glasses. We selected patients who had been wearing glasses for least 16 weeks for an adaptive refractive period. There might be a relationship between the level of stereopsis and time of first usage. Lee et al. (8) reported no significant relationship between the age at the time of prescription of the first pair of glasses and the level of stereopsis for anisometropic patients. In addition, the subgroups based on anisometropia type differed in size, which may have been a source of bias. Finally, use of the Titmus stereo test is another limitation as it may overestimate stereoacuity due to some monocular clues (19).

Studies with larger patient groups and in which patients can be evaluated for a longer period of time before and after using glasses will be helpful to greater understanding of the relationship between anisometropia and stereopsis. In addition, an evaluation of stereopsis after correction of anisometropia by refractive surgery in appropriate-age patients may be a valuable subject of further study.

CONCLUSION

In conclusion, the NA patients had a similar level of stereopsis to that of isometropic controls while wearing their corrective glasses, and the level of stereopsis was not correlated with anisometropia magnitude in the NA patients. This result indicates that as long as patients have good visual acuity, stereopsis is preserved, and refractive correction with glasses does not cause aniseikonia, which may interfere with stereopsis in childhood anisometropia. Therefore, we can recommend the use of glasses for the prevention and treatment of amblyopia to our anisometropic patients.

Ethics Committee Approval: The İstanbul Medipol University Clinical Research Ethics Committee granted approval for this study (date: 11.12.2019, number: 10840098-604.01.01-E.64942).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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