Original Article

Comparison of contrast sensitivity among strabismic and anisometropic amblyopes and its association with disease-related parameters

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Abstract:

PURPOSE: To evaluate and contrast the contrast sensitivity defects present in strabismic and anisometropic amblyopes. And to find out the association of contrast deterioration with the visual acuity of the amblyopic eye, the magnitude of strabismus, and the amount of anisometropia in both groups.

METHODS: This cross-sectional study was carried out in the orthoptics unit of a tertiary eye care facility between October 2021 and December 2021. There were 45 patients altogether. In the first phase, the patient's history and ocular examination data were recorded after informed consent. The Pelli-Robson chart was used to measure contrast sensitivity. In the second phase, results were interpreted using the SPSS (Statistical Package for the Social Sciences) version 26.0.

RESULTS: Strabismic amblyopes were 24 and anisometropic amblyopes were 21. A significant positive association existed between both groups' contrast sensitivity and visual acuity ($P = 0.000$). A moderately negative correlation between contrast and anisometropia was statistically significant ($P = 0.025$) in anisometropic amblyopes. However, no association ($P > 0.050$) existed between the contrast and magnitude of strabismus in any group.

CONCLUSION: The study concluded that contrast sensitivity decreases in both groups, whereas anisometropic amblyopes have poorer contrast than strabismic amblyopes. Excessively decreased contrast sensitivity among anisometropic amblyopes was solely because of the worst amblyopia in this group, whereas the magnitude of strabismus does not affect contrast sensitivity.

Keywords:

Amblyopia, anisometropic amblyopia, contrast sensitivity, strabismus

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Introduction

The global prevalence of amblyopia is between 0.2% and 6.2%.[1] Hess *et al*. reported that one-third of amblyopia is caused by anisometropia, one-third by strabismus, and one-third by a combination of these two.[2] Some other researchers have reported that anisometropia causes 50% of cases of amblyopia.[3] The efficiency of the eye to recognize even the smallest variations in luminance between areas without well-defined borders is known as contrast sensitivity.[4,5] In Strabismic amblyopes, contrast sensitivity deficits were less as compared to contrast deficits in anisometropic amblyopes.[6] Contrast sensitivity function (CSF) decreased only at high spatial frequencies in strabismic amblyopia, whereas CSF decreased in anisometropic amblyopes throughout the whole frequency range.[7,8]

In all previous research, the contrast sensitivity was determined by sine-wave gratings by varying their size, as used by Sjöstrand.[8-10] Apart from these gratings, chart-based tests are also available, including Pelli-Robson, Mars, and Bailey-Lovie charts.[11] Pelli-Robson is the most widely used chart among these. The

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testing distance for Pelli-Robson is 1 m with an illumination of 85 cd/m^2.[12] Some of these studies only measured comparisons of contrast among both groups, and some have tested the association of contrast with one or two factors separately for one group at a time. A combined comparison of contrasts among both groups and a simultaneous assessment of their association with certain disease-related parameters have not been done. Moreover, there are no data available on the association of contrast deficits with the magnitude of strabismus.

This study sought to identify and compare the contrast sensitivity deficiencies in strabismic and anisometropic amblyopes and simultaneously test the correlation of decreased contrast in both groups with other disease-related factors, including visual acuity, the magnitude of deviation, and anisometropia, to determine the possible cause of contrast deficits.

Methods

The cross-sectional research was carried out in the Orthoptics Division of a Tertiary Eye Care Facility. From July 2021 to December 2021, data were collected for 6 months. The total sample size was 45, computed by OpenEpi software which was developed by Dean AG, Sullivan KM, Soe MM and its development was supported in part by a grant from the Bill and Melinda Gates Foundation, Washington USA, to Emory University, Rollins School of Public Health, Atlanta, Georgia, USA, with a confidence interval of 95%, a level of significance of 5%, and a prevalence of amblyopia was 3%.[13] Consecutive sampling was utilized because it is the most suitable method for collecting data from patients in an outpatient department and is very similar to random sampling.

Patients between 5 and 18 years old were included. Amblyopes were selected with more than two lines of difference on the visual acuity chart in either eye. For strabismic amblyopes, patients with squint and amblyopia but anisometropia < 0.5DS were selected based on the criteria given by Choi *et al*.[14] For anisometropic amblyopes, patients with a greater difference in the refractive state of both eyes were selected according to the classification done by the American Academy of Ophthalmology, i.e., 1.0–1.5 D anisohyperopia or greater, 2.0 D or greater anisoastigmatism, and 3.0–4.0 D or greater anisomyopia.[15] Amblyopic patients meeting the above criteria were excluded from the study based on one of the following reasons: Patients with a history of ocular trauma, postoperative patients, patients with other ocular pathologies, i.e., cataract, corneal scar, and retinal pathologies; other types of amblyopia, including stimulus deprivation, bilateral hyperopic, or meridional astigmatic amblyopia; mentally handicapped patients; and illiterate patients, to ensure the validity of the results.

Data collected from the patients include sociodemographic data, a history about the age of onset of strabismus or anisometropia, and any previous treatment the patient had received. It was followed by the monocular visual acuity assessment of the patient with the best optical correction he or she has been using since their latest follow-up and was selected for sample only when their recent refractive prescription was similar to or slightly different from previous refractive correction. There were several patients with significant differences in the glasses they were using and glasses prescribed on the day of data collection were excluded from the study) with the LogMAR chart, and the amount of anisometropia was calculated from the difference in the spherical equivalent of the optical correction of the patient. After that, the orthoptic assessment was done, the type of strabismus was evaluated using the cover test and the magnitude of the strabismus was calculated by the prism cover test or prism reflection test. Contrast sensitivity was measured for both eyes separately using the Pelli-Robson chart. Data were noted on a structured pro forma and were then entered in SPSS by International Business Machines corporations (IBM), (New York, USA) for the analysis. Frequencies and percentages of categorical variables were computed. We calculated the continuous variables' mean and standard deviation (SD). The data were represented in graphs and tables. The distribution of the data was not normal but skewed for both groups ($P < 0.05$), where Shapiro–Wilk for strabismic amblyopes was $P = 0.00$ and for anisometropic amblyopes, it was $P = 0.025$. Therefore, a nonparametric test for comparison, "Mann–Whitney *U*-test" (because both samples were independent), was used to compare the contrast sensitivity in both groups, and Spearman's rank correlation coefficient was utilized to check the associations between the outcome variable and the independent variable. The test was applied to all applicable independent variables and outcome variables.

The study was carried out with the approval of the Institutional Review Board. All the participants were included after receiving informed consent from the attendants of the patients and the patients themselves. Moreover, it was ensured that all the information would be kept confidential, would be used for academic purposes only, and would be discarded safely after the completion of the research.

Results

This study included 45 patients in total. The mean (n) age was 9.98 (SD = ±3.58), ranging from 5 to 18 years. The majority of them were females $n = 24$ (53.3%). Patients from urban areas were $n = 23$ (51.1%) and students were $n = 43$ (95.6%). Details are discussed in Table 1. The mean age at the onset of strabismus and anisometropia was 2.73 (SD = 2.88). Most of the subjects have the congenital onset of strabismus and anisometropia $n = 16$ (35.6%). Out of total amblyopes, strabismic amblyopes were $n = 24$ (53.3%) and anisometropic amblyopes were $n = 21$ (46.7%). Out of 45, strabismic amblyopes who did not need glasses (emmetropes) were $n = 5$ (11.1%) and the remaining $n = 19$ (42.2%) were using spectacles with anisometropia ≤0.5D. However, all anisometropic amblyopes were using spectacles $n = 21$ (46.7%). The mean calculated vision of the amblyopic eye, the magnitude of deviation, and

Table 1: Patient demographics

Variables	Options	Mean (%)
Gender	Male	21 (46.7)
	Female	24 (53.3)
Residence	Rural	22 (48.9)
	Urban	23 (51.1)
Occupation	Student	43 (95.6)
	N/A	2 (4.4)

N/A: Not available

Table 2: Patient's examination

	n	Mean (±SD)
Visual acuity of the amblyopic eye		
Strabismic amblyopes	24	0.302 (±0.21)
Anisometropic amblyopes	21	0.21 (±0.2)
Magnitude of deviation		
Strabismic amblyopes	24	8.83 (±42.48)
Anisometropic amblyopes	21	8.90 (±38.56)
Refractive error		
Strabismic amblyopes	24	0.05 (±0.43)
Anisometropic amblyopes	21	−0.38 (±3.62)

SD: Standard deviation

the amount of anisometropia in both groups are shown in Table 2. All the subjects had associated strabismus: Phoria or tropia, but esotropia was present in the maximum number of subjects, $n = 25$ (55.6%), followed by exotropia $n = 11$ (24.4%), exophoria $n = 5$ (11.1%), esophoria $n = 3$ (6.7%), and vertical deviations $n = 1$ (2.2%). The amblyopic eyes of both groups have a mean contrast of 1.75 (±0.63), and that of the nonamblyopic eyes of both groups is 2.12 (±0.25).

The nonparametric Mann–Whitney *U*-test was used to examine the contrast sensitivity of anisometropic and strabismic amblyopes. Results showed a significance of $P = 0.039$ (<0.050), rejecting the null hypothesis (H_0) and accepting the alternate hypothesis (H_1), which states that the contrast sensitivity among both groups is not the same. The test revealed that contrast sensitivity in strabismic amblyopes (median = 2.25, $n = 24$) differed significantly from anisometropic amblyopes (median = 1.65, $n = 21$). A comparison of both groups showed that strabismic amblyopes have a mean rank of 26.54, which is higher than the mean rank of anisometropic amblyopes, which is 18.95. From the results of the rank table, we concluded that strabismic amblyopes have high contrast sensitivity compared to anisometropic amblyopes, who have decreased contrast sensitivity, and that amblyopia is more likely to be strabismic than anisometropic in eyes with full contrast sensitivity. Figure 1 shows the rank table of the Mann–Whitney *U*-test.

Spearman's Rank Correlation Coefficient is used as a nonparametric correlation test. The association of contrast sensitivity in both groups of amblyopes was separately checked with the amblyopic eyes' visual acuity, the magnitude of deviation, and anisometropia. For strabismic amblyopes, it was observed that contrast sensitivity and visual acuity had a

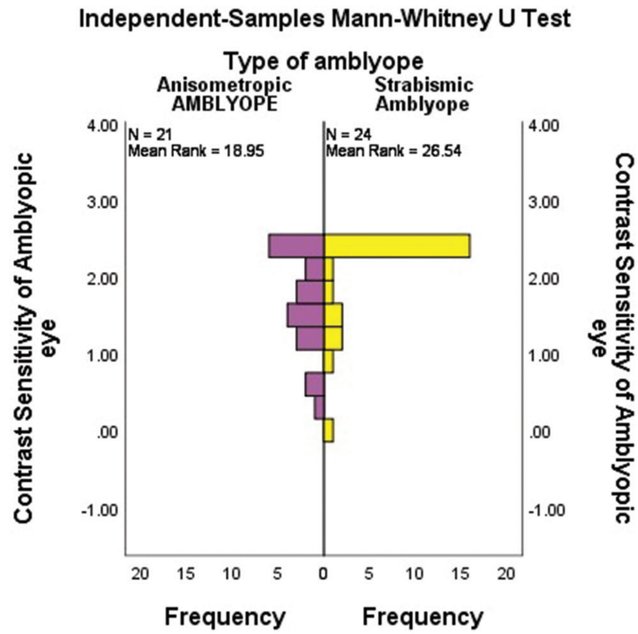

Figure 1: Mann–Whitney *U*-test rank table: On the horizontal axis, is the number of patients, and on the vertical axis is the contrast sensitivity values of the Pelli-Robson chart. Strabismic amblyopes have a maximum frequency (i.e., 16) of patients with a contrast sensitivity of 2.25 (threshold sensitivity value at the Pelli-Robson chart) in the amblyopic eye while the frequency of anisometropic amblyopes was less in the 2.25 region (only 6 patients)

significant and strong positive correlation ($r = 0.705$, $P = 0.000$). A very weak negative association ($r = -0.091$, $P = 0.671$) was found between contrast sensitivity and magnitude of deviation, and a very weak positive correlation ($r = 0.085$, $P = 0.692$) was found between contrast sensitivity and degree of anisometropia; however, both these results were not statistically significant ($P > 0.05$). Details are depicted in Table 3. However, there was a strong positive correlation between contrast sensitivity and visual acuity in the amblyopic eye of anisometropic amblyopes ($r = 0.709$, $P = 0.00$). A moderately negative correlation ($r = -0.300$, $P = 0.187$) was found between contrast sensitivity and the magnitude of deviation, but it was not statistically significant ($P > 0.05$). Whereas a moderately significant positive association between contrast sensitivity and anisometropia was found among anisometropic amblyopes ($P = 0.025$, $r = 0.486$). Details are shown in Table 4.

Discussion

The objectives of the study were to evaluate and compare the contrast sensitivity of strabismic and anisometropic amblyopes. Results showed that contrast sensitivity decreased in both groups but more in anisometropic amblyopes. Our study revealed that the mean contrast sensitivity of all amblyopic eyes in both groups was 1.75 (±0.63), and that of the nonamblyopic eyes was 2.12 (±0.25). The higher mean of nonamblyopic eyes showed that they have better contrast

Table 3: Spearman's correlation of strabismic amblyopes

Spearman's rho (strabismic)		
Contrast sensitivity and visual acuity	**Contrast sensitivity of amblyopic eye**	**Visual acuity of amblyopic eye**
Contrast sensitivity of amblyopic eye		
Correlation coefficient	1.000	0.705**
Significant (two-tailed)	-	0.000
n	24	24
Visual acuity of amblyopic eye		
Correlation coefficient	0.705**	1.000
Significant (two-tailed)	0.000	-
n	24	24

**Correlation is significant at the 0.01 level (two-tailed)

Spearman's rho (strabismic)		
Contrast sensitivity and magnitude of deviation	**Contrast sensitivity of amblyopic eye**	**Magnitude of deviation**
Contrast sensitivity of amblyopic eye		
Correlation coefficient	1.000	−0.091
Significant (two-tailed)	-	0.671
n	24	24
Magnitude of deviation		
Correlation coefficient	−0.091	1.000
Significant (two-tailed)	0.671	-
n	24	24

Spearman's rho (strabismic)		
Contrast sensitivity and anisometropia	**Contrast sensitivity of amblyopic eye**	**Anisometropia**
Contrast sensitivity of amblyopic eye		
Correlation coefficient	1.000	0.085
Significant (two-tailed)	-	0.692
n	24	24
Anisometropia		
Correlation coefficient	0.085	1.000
Significant (two-tailed)	0.692	-
n	24	24

sensitivity than amblyopic eyes. A previous study by Levi and Harwerth on the contrast sensitivity function among strabismic and anisometropic amblyopes also demonstrated similar results in amblyopic eyes; the contrast sensitivity function was diminished in both groups compared to nonamblyopic eyes.[16]

The findings of our research have shown that anisometropic amblyopes have significantly reduced contrast sensitivity compared to strabismic amblyopes when the contrast sensitivity of amblyopic eyes in both groups was compared. The mean contrast sensitivity of the amblyopic eye of strabismic amblyopes was 1.89 (±0.62), which is higher than that of anisometropic amblyopes, i.e., 1.59 (±0.63) Sjöstrand and Campos *et al*., separately studied, reported similar results that CSF was reduced only at high frequencies among strabismic amblyopes, while it was affected over the whole frequency range among anisometropic amblyopes.[7,8] Abrahamsson and Sjöstrand studied contrast sensitivity and visual acuity in children with strabismic and anisometropic amblyopia and showed similar results that at the same level of visual acuity, the contrast of anisometropic amblyopes was less than that of strabismic amblyopes.[9]

The study determined the association of the contrast sensitivity of the amblyopic eye of both groups with the visual acuity of amblyopes, the magnitude of strabismus, and the amount of anisometropia. When assessed for correlation, decreased contrast sensitivity (CS) of the amblyopic eye was associated with decreased visual acuity (VA) in both groups, owing to a significant, i.e., $P = 0.000$ ($P < 0.01$), strong positive correlation between CS and VA in both groups. A previous study by Rogers *et al*. supports this finding.[17] Both of these studies partly contradict the study by Abrahamsson and Sjöstrand also demonstrated that there was a clear association between contrast sensitivity and visual acuity in anisometropic amblyopes but stated that no such relationship was found in strabismic amblyopes.[9] Our study found no significant relationship between contrast sensitivity and the magnitude of strabismus in both groups, i.e., $P = 0.67$ for strabismic amblyopes and $P = 0.19$ for anisometropic amblyopes ($P > 0.05$).

The present study also found a significant ($P < 0.05$) moderate positive correlation between contrast sensitivity and the degree of anisometropia among anisometropic amblyopes only ($P = 0.025$, $r = 0.486$). This shows that contrast sensitivity in anisometropic amblyopes was better even

Table 4: Spearman's correlation of anisometropic amblyopes

Spearman's rho (anisometropic)		
Contrast sensitivity and visual acuity	**Contrast sensitivity of amblyopic eye**	**Visual acuity of amblyopic eye**
Contrast sensitivity of amblyopic eye		
Correlation coefficient	1.000	0.709**
Significant (two-tailed)	-	0.000
n	21	21
Visual acuity of amblyopic eye		
Correlation coefficient	0.709**	1.000
Significant (two-tailed)	0.000	-
n	21	21
**Correlation is significant at the 0.01 level (two-tailed)		
Contrast sensitivity and magnitude of deviation	**Contrast sensitivity of amblyopic eye**	**Magnitude of deviation**
Contrast sensitivity of amblyopic eye		
Correlation coefficient	1.000	−0.300
Significant (two-tailed)	-	0.187
n	21	21
Magnitude of deviation		
Correlation coefficient	−0.300	1.000
Significant (two-tailed)	0.187	-
n	21	21
Contrast sensitivity and anisometropia	**Contrast sensitivity of amblyopic eye**	**Anisometropia**
Contrast sensitivity of amblyopic eye		
Correlation coefficient	1.000	0.486**
Significant (two-tailed)	-	0.025
n	21	21
Anisometropia		
Correlation coefficient	0.486**	1.000
Significant (two-tailed)	0.025	-
n	21	21

**Correlation is significant at the 0.05 level (two-tailed)

in the presence of anisometropia, and glasses even helped this group in their contrast sensitivity. As per the results of the Spearman association, we concluded that amblyopia is the main cause of reduced contrast sensitivity. These results partially resemble those of Pang *et al.*, who found that the peak CSF of amblyopic eyes was shifted towards the lower spatial frequencies (1.5 cycles/degree) despite the worst CSF at a middle frequency, which was because of anisometropia.[18] Bradley and Freeman also found CSF reduction at a high-spatial frequency and that it was associated with the amount of anisometropia.[19] Anisometropia affected CSF either at the middle[18] or higher spatial frequency.[19] Since Pelli-Robson provides the measurement of low spatial frequency CS (0.5–1 cpd) when measured at the standard 1 m. Hence, the present study basically determined the contrast at lower spatial frequencies, and anisometropia did not worsen the contrast; instead, the results were quite surprising that anisometropia seemed to improve the contrast in this group.

Conclusion

The contrast sensitivity of the amblyopic eyes of anisometropic amblyopes was significantly reduced compared with that of strabismic amblyopes when compared with each other. A significant positive association between visual acuity and contrast sensitivity was found between both groups, showing that decreased vision or amblyopia causes contrast deficits. A statistically significant correlation between contrast sensitivity and anisometropia was observed among anisometropic amblyopes only, which shows that anisometropia does not decrease contrast sensitivity at lower spatial frequencies but rather enhances it. However, we found no significant correlation between contrast deficit and the magnitude of strabismus in any group.

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Conflicts of interest

There are no conflicts of interest.

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