# The effect of amblyopia on clinical outcomes of children with astigmatism

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**Burçin Çakır, Nilgün Özkan Aksoy, Sedat Özmen and Özlem Bursalı**

***Abstract***

**Background:** Amblyopia is more common in children with high astigmatism, but factors contributing to development of amblyopia and visual outcomes are not fully understood.

**Objective:** To evaluate the effect of amblyopia on the clinical outcomes in children with ⩾1.75 diopter (D) astigmatism.

**Methods:** We reviewed the medical records of children with ⩾1.75 D astigmatism with and without amblyopia (amblyopes group and non-amblyopes group). The mean age, gender, amount and type of ocular deviation, presence of convergence insufficiency (CI), stereopsis, time of initial spectacle use and follow-up time, differences in best-corrected visual acuity (VoD) and spherical equivalent (SE) between eyes were assessed and compared between the groups. Best-corrected visual acuity (BCVA), mean SE, astigmatism measurements were assessed and compared between amblyopic, fellow, and non-amblyopic eyes.

**Results:** The records included 68 eyes of 34 children with amblyopia and 56 eyes of 28 children without amblyopia. The mean age, gender, amount and type of ocular deviation, presence of CI, stereopsis, time of initial spectacle use, follow-up time, and the difference in SE did not differ between groups. In amblyopes, exodeviation was more common and statistically greater in near (33 cm) than at distance (6 m) ($p = 0.005$). The mean BCVA and astigmatism values were statistically different between amblyopic, fellow, and non-amblyopic eyes.

**Conclusion:** A greater near than distance exodeviation and higher mean astigmatism value were found in amblyopic children with astigmatism.

***Keywords:*** amblyopia, astigmatism, strabismus

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## Introduction

Astigmatism is a type of refractive error that may cause several visual problems, including impairment in acuity for grating stimuli, recognition acuity, contrast sensitivity, vernier acuity, stereo acuity, and amblyopia.[1–4] The astigmatic meridian that has greater optical blur may result in chronically reduced vision and meridional amblyopia may occur, which can be detected using grating acuity and vernier acuity.[5,6] Astigmatism-related amblyopia might occur with 2.00 diopter (D) of anisoastigmatism or more than 2D of astigmatism in both eyes.[7,8] With an astigmatism cut-off value of 1.0D, recent studies have reported the prevalence of astigmatism-related amblyopia (ARA) in children to be between 7% and 16.7%. Strabismus, oblique and high astigmatism were found to relate to amblyopia development.[9,10] In a study by Xiao and colleagues,[11] 91.9% of amblyopes were reported to have astigmatism of ⩾0.5D. The magnitude of the cortical deficits in amblyopes is closely related to the magnitude of the astigmatism, because amblyopes with ⩾1.75D of astigmatism have significantly poorer cortical processing compared with amblyopes with ⩽ 1.50D of astigmatism.[6]

Some reports focusing on the optimal time and methods for treating astigmatism in pediatric patients have been published.[12,13] According to Yap and Boon, spectacles are typically prescribed as the primary treatment of amblyopia. Secondary

Correspondence to:
**Burçin Çakır**
Sakarya Universiy,
Sakarya, Turkey.
**b_koklu@yahoo.com**
**Nilgün Özkan Aksoy**
**Sedat Özmen**
**Özlem Bursalı**
Sakarya University,
Sakarya, Turkey

treatments, such as occlusion therapy and vision therapy, may be prescribed in situations where the patients are less responsive to spectacle treatment.[5,14] The critical period for efficacious treatment of astigmatism, as it relates to and produces amblyopia, has not been established. The depth of amblyopia may certainly be affected by the severity of anisoastigmatism and degree of anisometropia in pediatric patients.[15,16] Although the optimal time of instilling spectacle correction is unknown, it is generally expected that the amblyopes would improve in approximately 4 months and some of them may take longer to respond to spectacle treatment.[17] Yap and Boon reported that a proportion of amblyopic children may need more time to respond to spectacle treatment.[14]

Children with strabismus often have refractive errors[18,19] Huynh et al. investigated associations of anisometropia and anisoastigmatism in a population-based on sample of 6-year-old children. Both of anisometropia and anisoastigmatism were found to correlate with amblyopia and exotropia.[20] Han et al. also found that astigmatism $\geqslant 1.0$D was correlated with clinically significant exodeviation. Abnormal binocular vision and strabismus (especially exotropia) tend to be more prevalent in those who have a history of childhood astigmatism, because the astigmatic blur may contribute to a breakdown of binocularity in cases of poor fusional control, resulting in strabismus. The majority of exotropia tends to manifest intermittently (more than 60%).[21] The potential ocular deviations that may accompany with astigmatism in childhood was not investigated in detail, previously. In our opinion, the influences of astigmatism on both eso- and exodeviations require additional investigations.

The objective of the current study was to assess clinical outcomes in amblyopic and non-amblyopic children with $\geqslant 1.75$D astigmatism and compare the type and amount of ocular deviations, refractive parameters, presence of stereopsis, convergence, and initial time of optical treatment between amblyopic and non-amblyopic children.

## Study participants and methods

This retrospective observational study was performed in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards, and was approved by the Sakarya University Ethical Board (approval number: 71522473/050.01.04/7). Written informed consent was provided by the parents of each child.

The medical records of children followed up in the Pediatric Ophthalmology Department at a tertiary university hospital (Sakarya University, Serdivan, Turkey) between 2013 and 2019 were retrospectively reviewed and the records of children with $\geqslant 1.75$ diopter (D) astigmatism were included in this study. The presence of astigmatism of $\geqslant 1.75$D was considered as the cutoff point of mild and moderate astigmatism. Yap and colleagues reported that amblyopes who have $\geqslant 1.75$D of astigmatism have significantly poorer cortical processing compared to amblyopes that have $\leqslant 1.50$D of astigmatism. We aimed to perform this study on children with moderate and severe astigmatism.[6] Patients with additional ocular, systemic diseases, and any strabismus or intraocular surgery history were excluded from this study. Subjects with and without amblyopia composed amblyopes and non-amblyopes groups, respectively. The mean age, gender, amount and type of deviation in near (33 cm) and distance (6 m) vision, presence of convergence insufficiency, stereopsis, time of initial spectacle use, and follow-up time were noted and compared between groups.

Best-corrected visual acuity (BCVA), mean spherical equivalent (SE) refractive error, astigmatism, and axe of astigmatism measurements were noted and compared between amblyopic, fellow and non-amblyopic eyes. The SE, astigmatism, BCVA differences (VoD) between amblyopic and fellow eyes were calculated and compared between groups. Correlations between VoD and difference in SE, astigmatism, and time of initial spectacle use were investigated.

Best-corrected visual acuity was measured by using the Snellen Chart and converted to decimals. To avoid crowding phenomenon, we asked for single letters in the Snellen Chart. Amount and type of deviations were assessed by the prism cover-uncover test in near (33 cm) and distance (6 m). The spherical equivalent was found by adding half of the cylindrical value to spherical value. Refractive errors were measured under cycloplegic conditions. Cyclopentolate hydrochloride 1% drops was administered twice, 5 minutes apart. After 30 minutes, measurements were done by using an auto refractometer (Tonoref 3; Nıdek Co., Ltd, Gamagori, Japan). Stereopsis was measured by using the Titmus test

**Table 1.** Characteristics of amblyopes and non-amblyopes groups.

| | Amblyopes (n = 34) | Non-amblyopes (n = 28) | *p* value |
|---|---|---|---|
| Mean age (year) | 10.11 ± 2.57 | 10.42 ± 2.25 | 0.61 |
| Gender (f/m) | 21/13 | 17/11 | 0.93 |
| Presence of Stereopsis (n) | 28 | 25 | 0.29 |
| Presence of CI (n) | 8 | 9 | 0.44 |
| Mean follow-up time (month) | 37.7 ± 30 | 46.50 ± 27.65 | 0.24 |
| Mean initial age of spectacle use (years) | 5.79 ± 2.49 | 6.07 ± 1.86 | 0.62 |
| VoD (line) | 3.23 ± 1.41 | 0.42 ± 0.50 | <0.001 |
| Difference in SE (diopter) | 0.44 ± 0.43 | 0.41 ± 0.45 | 0.55 |
| Difference in astigmatism (diopter) | 1.13 ± 0.91 | 0.70 ± 0.54 | 0.03 |

f/m, female/male; CI, convergence insufficiency; VoD, difference in best corrected visual acuity between eyes; SE, spherical equivalent.

(Stereo Optical, Chicago, IL). If the picture with the largest disparity (400 sec/arc) could not be seen, stereopsis was not considered to be present.

Amblyopia was specified as an interocular difference of two lines or more in a visual acuity table, (in our study, the Snellen chart),[22] and isometric amblyopia was defined as bilateral decrease in BCVA with high refractive errors such as ⩾5-6D myopia, ⩾4-5D, and ⩾2-3D astigmatism.

Convergence patterns were evaluated. Breaking the convergence in one eye or alternation of eyes when converging with a near point of 10 cm were considered as lack of convergence. Equal convergence in two eyes with a near point of 10 cm was accepted as normal eye convergence.

The spherical and cylindrical component of refractive error was fully corrected in patients with amblyopia. The hyperopic refractive error was corrected according to the results of dynamic retinoscopy and the type of strabismus, if present, in non-amblyopic patients. The refractive error was re-evaluated and corrected when necessary during the follow-up time.

SPSS statistical software (IBM SPSS Statistics, Version 24.0. Armonk, NY: IBM Corp.) was used for statistical analysis. Student' t-test was used for data comparisons, and multiple comparison correction was corrected by post hoc analysis. Correlations were assessed with Pearson correlation tests. $p < 0.05$ was assumed significant for all analyses.

## Results

Sixty-eight eyes of 34 subjects and 56 eyes of 28 subjects formed amblyopes and non-amblyopes groups, respectively. There was no statistically significant difference between groups in terms of gender, age, presence of stereopsis, convergence insufficiency, follow-up time and the mean initial time of spectacle use. While the mean difference in SE did not differ between groups, VoD and difference in astigmatism were statistically different between groups. In amblyopes, myopic astigmatism was present in 6 children (totally 12 eyes, 17,6 %) and in non-amblyopes, there were also 6 children (totally 12 eyes, 21,4%) with myopic astigmatism (p:0,71). Table 1 reveals these results in detail.

In amblyopes, 67.6% of subjects had ocular deviations, mostly latent exodeviation was present (47.05%). Esotropia was present in 20.5% of patients. In non-amblyopes, 60.7% of subjects had ocular deviations, mostly latent exodeviation was present (50%). Esotropia was present in 10.7% of these patients. There were no statistical differences in terms of presence and types of ocular deviation ($p = 0.57$, $p = 0.35$, respectively). Table 2 revealed ocular deviations in both groups.

**Table 2.** Types and amounts of ocular deviations in amblyopes and non-amblyopes groups.

| | Amblyopes (n) | Non-amblyopes (n) | *p* value |
|---|---|---|---|
| Presence of ocular deviation (n) | 23 | 17 | 0.57 |
| Exo/esodeviation (n) | 16/7 | 14/3 | 0.35 |
| Amount of near ocular deviation (PD) | 6.05 ± 7.05 | 4.42 ± 4.59 | 0.29 |
| Amount of distance ocular deviation (PD) | 3.17 ± 5.48 | 2.14 ± 4.71 | 0.43 |

PD, prism diopter.

**Table 3.** Comparisons of mean BCVA, SE, astigmatism, axe of astigmatism between amblyopic, fellow and non-amblyopic eyes.

| | Amblyopic eyes | Fellow eyes | Non-amblyopic eyes | *p-value* |
|---|---|---|---|---|
| Mean BCVA | 0.55 ± 0.15 | 0.83 ± 0.16 | 0.89 ± 0.06 | <0.001 |
| Mean SE (D) | 2.60 ± 1.70 | 2.12 ± 1.94 | 2.76 ± 1.58 | 0.66 |
| Mean astigmatism (D) | 3.52 ± 1.06 | 2.46 ± 1.14 | 2.77 ± 0.73 | <0.001 |
| Mean axes of astigmatism (degree) | 92.35 ± 10 | 90.88 ± 9.65 | 92.85 ± 6.99 | 0.68 |
| Myopic/hyperopic astigmatism (n) | 6 | 6 | 12 | 0.71 |

BCVA, best corrected visual acuity; SE, spherical equivalent; D, diopter; n, number of eyes.

When we performed statistical analysis in exotropic children in each group, we observed a statistically significant difference between near and distance deviations in amblyopes but no statistical difference was observed in non-amblyopes (0.005, p = 0.086, respectively). The mean differences between near and distance deviations were 2.88 ± 1.0 prism diopters (PD) and 2.38 ± 0.87 PD, in amblyopes and non-amblyopes groups, respectively.

There was a statistically significant difference between mean BCVA of amblyopic, fellow, and non-amblyopic eyes ($p < 0.001$). The mean SE of amblyopic, fellow, and non-amblyopic eyes were not statistically different ($p = 0.69$). The mean astigmatism values of amblyopic, fellow, and non-amblyopic eyes were found to be statistically different ($p = 0.001$). Table 3 reveals the details of the parameters mentioned above in amblyopic, fellow, and non-amblyopic eyes.

In amblyopes; the correlations between VoD and difference in SE was found to be statistically insignificant ($r = 0.896$, $p = 0.023$). There was a statistically significant positive correlation between VoD and difference in astigmatism (r: 0.546, $p = 0.001$).

## Discussion

In the present study, we observed a high rate of exodeviation especially at the near measurement in astigmatic children with amblyopia. Exodeviation has been found to relate with myopic refractive error,[23] meaning that additional myopic refractive error might be the cause of exodeviation. In our study, the number of children with hyperopic astigmatism was higher than the number of children with myopic astigmatism. Because of this, we believe that the effect of myopic refractive error on our results might have been minimal.

Recent studies which investigated the relationships between refractive errors and strabismus were enhanced on the diagnosis of tropia.[24–26] According to a meta-analysis, astigmatism was found to be a risk factor for both eso- and exotropia.[27] We observed latent exodeviation in astigmatic children especially in the amblyopic group when measured in near. This result might be important

for detecting an additional cause of asthenopic symptoms which might be seen in astigmatic children. In our knowledge, there was not a published study which was studied on the presence of exodeviation measured in near in astigmatic children.

The frequencies of convergence insufficiency in astigmatic children with and without amblyopia were found to be 23.0% and 32.0%, respectively. Statistically, a significant difference was not found between them thus amblyopia did not affect convergence insufficiency. However, these frequencies were higher than those reported in the general population. Trieu and Lavrich[25] reviewed convergence insufficiency and reported the prevalence of convergence insufficiency as 2–17%. In our opinion, this finding was also remarkable because this might increase asthenopic symptoms in children with astigmatism, too.

In this current study, while mean SE of amblyopic, fellow, and non-amblyopic eyes was not statistically different, the mean astigmatism of amblyopic eyes was higher than fellow and non-amblyopic eyes. Besides, the mean axes of astigmatism of amblyopic, fellow, and non-amblyopic eyes were not statistically different. The results from this current study suggest that astigmatism may be an important amblyogenic factor. However, the impact of cylindrical power on amblyopia might vary in children with either oblique or orthogonal astigmatism. Chou and colleagues[26] found that the cylindrical power in children with oblique astigmatism was lower than that in children with orthogonal astigmatism. In previous electrophysiological studies, Yap et al. found that amblyopic children with high magnitude of astigmatism have diminished peak amplitudes in the orientation-specific visual evoked potentials in all the meridians tested, rather than in just a single meridian.[6] The relatively small sample size in our study did not permit us to investigate this in detail.

In our study, the depth of amblyopia correlated with aniso-astigmatism. Therefore, we might say that aniso-astigmatism affected the depth of amblyopia. The impact of anisometropia on amblyopia was previously known, but further studies are needed on anisoastigmatism.[27–29]

The mean ages of amblyopes and non-amblyopes when they first worn spectacles were not statistically different. The optical correction in earlier ages (under 3 years) might have effect on amblyopia development and this possibility should be investigated with further studies.[5]

The major limitation of our study was relatively small sample sizes. Besides, more homogeneous groups including only hyperopic or myopic astigmatic amblyopic children might provide more accurate results. The mean values of stereopsis and the near point of convergence could not be evaluated because of the retrospective design of the study. On the other hand, studies focused on ocular deviation and convergence insufficiency in astigmatic children with or without amblyopia had not been conducted previously.

In conclusion, the presence of exodeviation was higher than the presence of esodeviation in children with $\geqslant$1.75D astigmatism regardless of whether they are amblyopic or non-amblyopic. On the other hand, amblyopic children had higher latent exodeviation measured in near than far. Both development and depth of amblyopia were affected by the disparity in astigmatism.

## Conflict of interest statement

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## ORCID iD

Burçin Çakır https://orcid.org/0000-0001-7816-0627

## References

1. Dobson V, Harvey EM, Clifford-Donaldson CE, *et al.* Amblyopia in astigmatic infants and toddlers. *Optom Vis Sci* 2010; 87: 330–336.
2. Freeman RD and Thibos LN. Contrast sensitivity in humans with abnormal visual experience. *J Physiol* 1975; 247: 687–710.
3. Mitchell DE, Freeman RD, Millodot M, *et al.* Meridional amblyopia: evidence for modification of the human visual system by early visual experience. *Vision Res* 1973; 13: 535–558.

4. Harvey EM, Dobson V, Miller JM, *et al*. Amblyopia in astigmatic children: patterns of deficits. *Vision Res* 2007; 47: 315–326.
5. Harvey EM. Development and treatment of astigmatism-related amblyopia. *Optom Vis Sci* 2009; 86: 634–639.
6. Yap TP, Luu CD, Suttle C, *et al*. Effect of stimulus orientation on visual function in children with refractive amblyopia. *Invest Ophthalmol Vis Sci* 2020; 1161: 615.
7. McKean-Cowdin R, Cotter SA, Tarczy-Hornoch K, *et al*. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of amblyopia or strabismus in Asian and non-Hispanic white pre-school children: multi-ethnic Pediatric Eye Disease Study. *Ophthalmology* 2013; 120: 2117–2124.
8. Multi-ethnic Pediatric Eye Disease Study Group. Prevalence of amblyopia and strabismus in African American and Hispanic children ages 6 to 72 months: multi-ethnic Pediatric Eye Disease Study. *Ophthalmology* 2008; 115: 1229. e1–1236.e1.
9. Rashad MA, Abd Elaziz KM, Fawzy SM, *et al*. Screening of primary school children for amblyopia and amblyogenic factors in Central Cairo, Egypt. *J Ophthalmol* 2018; 2018: 8425319.
10. Abrahamsson M, Fabian G, Andersson AK, *et al*. A longitudinal study of a population based sample of astigmatic children. I. Refraction and amblyopia. *Acta Ophthalmol (Copenh)* 1990; 68: 428–434.
11. Xiao X, Liu WM, Zhao WX, *et al*. Prevalence of astigmatism in 2023 children with amblyopia. *Zhongguo Dang Dai Er Ke Za Zhi* 2011; 13: 462–465.
12. Harvey EM, Dobson V, Miller JM, *et al*. Treatment of astigmatism-related amblyopia in 3-to 5-year-old children. *Vision Res* 2004; 44: 1623–1634.
13. Dobson V, Clifford-Donaldson CE, Green TK, *et al*. Optical treatment reduces amblyopia in astigmatic children who receive spectacles before kindergarten. *Ophthalmology* 2009; 116: 1002–1008.
14. Yap TP and Boon MY. Electrodiagnosis and treatment monitoring of children with refractive amblyopia. *Advances in Ophthalmology and Optometry* 2020; 5: 1–24.
15. Duman R, Atilla H and Çatak E. Characteristics of anisometropic patients with and without strabismus. *Turk J Ophthalmol* 2018; 48: 23–26.
16. Dobson V, Miller JM, Clifford-Donaldson CE, *et al*. Associations between anisometropia, amblyopia, and reduced stereoacuity in a school-aged population with a high prevalence of astigmatism. *Invest Ophthalmol Vis Sci* 2008; 49: 4427–4436.
17. Norris JH, Pilling RF and Hook J. An audit of the Royal College of Ophthalmologists strabismic amblyopia treatment protocol: a departmental review. *Strabismus* 2009; 17: 78–81.
18. Robaei D, Rose KA, Kifley A, *et al*. Factors associated with childhood strabismus: findings from a population-based study. *Ophthalmology* 2006; 113: 1146–1153.
19. Cotter SA, Varma R, Tarczy-Hornoch K, *et al*. Risk factors associated with childhood strabismus: the multi-ethnic pediatric eye disease and Baltimore pediatric eye disease studies. *Ophthalmology* 2011; 118: 2251–2261.
20. Huynh SC, Wang XY, Ip J, *et al*. Prevalence and associations of anisometropia and aniso-astigmatism in a population based sample of 6 year old children. *Br J Ophthalmol* 2006; 90: 597–601.
21. Han KE, Baek SH, Kim SH, *et al*. Prevalence and risk factors of strabismus in children and adolescents in South Korea: Korea National Health and Nutrition Examination Survey, 2008-2011. *PLoS ONE* 2018; 13: e0191857.
22. Zhao PF, Zhou YH, Wang NL, *et al*. Study of the wavefront aberrations in children with amblyopia. *Chin Med J (Engl)* 2010; 123: 1431–1435.
23. Zhu H, Yu JJ, Yu RB, *et al*. Association between childhood strabismus and refractive error in Chinese preschool children. *PLoS ONE* 2015; 10: e0130914.
24. Tang SM, Chan RY, Bin Lin S, *et al*. Refractive errors and concomitant strabismus: a systematic review and meta-analysis. *Sci Rep* 2016; 6: 35177.
25. Trieu LH and Lavrich JB. Current concepts in convergence insufficiency. *Curr Opin Ophthalmol* 2018; 29: 401–406.
26. Chou YS, Tai MC, Chen PL, *et al*. Impact of cylinder axis on the treatment for astigmatic amblyopia. *Am J Ophthalmol* 2014; 157: 908–914.
27. Mocanu V and Horhat R. Prevalence and risk factors of amblyopia among refractive errors in an Eastern European Population. *Medicina (Kaunas)* 2018; 54: 6.
28. Ostadimoghaddam H, Fotouhi A, Hashemi H, *et al*. The prevalence of anisometropia in population base study. *Strabismus* 2012; 20: 152–157.
29. Ardagil A, Yaylali S, Erbil H, *et al*. The prevalence of anisometropia aniso-astigmatism and amblyopia in neurofibromatosis type 1. *Eur J Ophthalmol* 2009; 19: 470–474.