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ORIGINAL RESEARCH

Distribution and Patterns of Refractive Errors in a Pediatric Amblyopic Cohort Aged 3–5 Years: A Descriptive Study in a Pakistani Tertiary Eye Care Center

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Purpose: To assess the patterns and severity of different refractive errors in children aged 3 to 5 years presenting with established amblyopia in a tertiary care eye centre in Pakistan.

Patients and Methods: A cross-sectional study was conducted at a tertiary care eye center involving 178 children (aged 3–5 years). The study specifically included only those with refractive amblyopia; children with strabismic or sensory deprivation amblyopia were excluded. From each participant, only the amblyopic eye (or the eye with the worse visual acuity in bilateral cases) was analyzed to ensure statistical independence. All participants underwent a comprehensive ophthalmic examination, including cycloplegic refraction (using 1% cyclopentolate) and dilated fundus evaluation. Refractive errors were classified according to MEPEDS criteria, and data was analyzed using SPSS version 24.0.

Results: Among the 178 amblyopic eyes, astigmatism (53.4%) was common, particularly myopic astigmatism (n = 28, 15.7%) and hyperopic astigmatism (n = 27, 15.2%). Females were more likely to have myopia or astigmatism, whereas males were more likely to have hyperopia or astigmatism which may indicate some gender-specific patterns in amblyopia. Hyperopia was mostly low to moderate, while moderate astigmatism was more common than high astigmatism. These differences were also statistically significant ($p < 0.001$). Amblyopes with myopic astigmatism (n = 28, 15.7%) and hyperopic astigmatism (n = 27, 15.2%) exhibited the poorest visual acuity (mean LogMAR VA 1.05 ± 0.49 and 0.96 ± 0.46).

Conclusion: Astigmatic refractive errors are more likely associated with greater amblyopia severity, and even lower thresholds of refractive error have the potential to cause amblyopia. By establishing these amblyogenic patterns, our study provides the surveillance data essential for early intervention. These findings advocate for preschool screening to prevent irreversible vision loss, directly advancing the WHO SPECS 2030 goal of people-centered eye care.

Keywords: amblyopia, refractive errors, preschool children, Pakistan, WHO SPECS 2030

Introduction

Amblyopia, colloquially referred to as lazy eye, is defined as the best corrected visual acuity at 20/40 (0.3 log MAR) or worse, in the absence of any organic disease.[1,2] It is a disease of childhood with a worldwide prevalence of 1.36% (95% CI: 1.27–1.46%)[3] and is characterized by underdevelopment of visual system throughout the crucial stage of development.[4] The primary ocular changes that predispose to amblyopia are lack of visual stimuli (ptosis-induced pupil occlusion, optical media opacities, nystagmus, and others), refractive errors (high ametropia and/or anisometropia), and inconsistent images received by each eye (strabismus).[5] Prematurity, Apgar score, neonatal intensive care unit admission, and maternal smoking during pregnancy are all non-ocular risk factors for amblyopia.[6]

Early diagnosis of amblyopia is integral for successful treatment. As compared to older children, children younger than seven years are more likely to have a good response to treatment. US Preventive Services Task Force (USPSTF),

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supported by the American Academy of Family Physicians, recommends screening at least once, all children aged three to five years, for amblyopia or its risk factors.[7]

The Multi-ethnic Pediatric Eye Disease Study (MEPEDS) and Baltimore Pediatric Eye Disease (BPEDS), the two largest US population-based samples of preschoolers, calculated the risk of amblyopia for each type of strabismus and refractive error severity levels. The study found that unilateral amblyopia was associated with only esotropia (not exotropia), and there was a lower threshold level of refractive error associated with increased risk of amblyopia.[8]

Refractive errors can be classified into 3 types myopia, hypermetropia, and astigmatism.[9] A study conducted in Pakistan in 2025 reported hypermetropia to be the most common refractive error (36.9%) associated with amblyopia followed by myopia (26.9%%) and astigmatism (12.5%). At present, there is limited in-depth knowledge regarding the distribution of refractive phenotypes and their relationship with amblyopia severity—stratified as mild, moderate, and severe—within our population. Landmark studies like MEPEDS and BPEDS provide foundational benchmarks, they are typically conducted in resource-rich environments with universal screening protocols. In contrast, in a developing nation like Pakistan, where healthcare resources are centralized and community-wide screening is limited, hospital-based descriptive studies serve as a critical primary source of clinical intelligence. In line with the WHO SPECS 2030 agenda, this study aims to provide essential baseline surveillance data on the refractive patterns found in our pediatric amblyopic cohort. The rationale for focusing on severity stratification is to identify which specific refractive profiles correlate with profound vision loss, thereby allowing for more targeted clinical prioritization and realistic prognostic counseling for parents. By identifying the distribution of these errors across different severity grades, we can better optimize clinical workflows and improve visual outcomes in resource-constrained settings.[10]

Objectives

- To describe the distribution and frequency of various refractive error patterns specifically within the identified amblyopic eyes of children aged 3 to 5 years.
- To characterize the clinical profile of refractive phenotypes across different severity grades of amblyopia within this pediatric cohort in a tertiary care setting.

Operational Definitions

This study adhered to the MEPEDS definition of amblyopia.

- A best corrected visual acuity (BCVA) of less than 0.5 (equivalent to Snellen VA < 20/40, 0.3logMAR) is considered amblyopia.
- Unilateral amblyopia is defined as a two-line difference in BCVA between anisometropic eyes.[8]

Types of refractive errors will be classified as:

- If the refraction is −0.50 D or less, myopia will be taken into consideration. There are three categories for myopia: low (−0.50 to −2.99 D), moderate (−3.00 to −5.99 D), and high (−6.00 D or higher).
- Hyperopia will be defined as a refraction of ≥+0.5 D. Low hyperopia will be considered for refractions of +0.50 D to +2.99 D, and moderate hyperopia considered for refractions of +3.00 D to +5.99 and high hyperopia +6.00 or more.
- Astigmatism based on standard 0.25 D clinical increments will be defined as a cylinder of ≥−0.5 D. For a cylinder, low astigmatism will be taken into consideration between −0.50 and −1.00 D, moderate astigmatism between −1.25 and −2.50 D, and high astigmatism between −2.75 and −5.00 D.[6]

Materials and Methods

This was a cross-sectional study conducted in a tertiary eye care center. The study was conducted after approval by Al Shifa Trust hospital ethical committee (ERC-37/AST-24) on 18/09/2024 and was performed in accordance with the ethical standards of the Declaration of Helsinki. Non-probability sampling technique was used and all children aged 3 to

5 years old visiting the pediatric center of Al Shifa trust eye hospital from October 2024 to October 2025, who were diagnosed as having amblyopia as defined by MEPED criterion, were included in the study.

By WHO calculator with a confidence interval of 95% and a population proportion of 12.5%,[11] the sample size came out to be 169 but at the end of the study 178 children in total were included. This study analyzed a diverse clinical cohort of 178 children, including those from school screenings, community referrals, and parental self-presentations, reflecting a real-world distribution of pediatric amblyopia at a major tertiary center. The unit of analysis was restricted to one eye per participant (N=178); in bilateral cases, the eye with the poorest visual acuity was selected to provide a single, representative ocular profile for each child.

All children who had amblyopia due to any cause, other than refractive error, which includes strabismus, cataract, trauma, or found to have any ocular pathology were excluded from the study. Furthermore, participants were also excluded from the study if they failed to give consent or their data sets were incomplete.

Informed consent was taken from parents or legal guardian followed by history taking. Demographic information including name, age, and gender was recorded. Certified ophthalmologists and optometrists with experience treating children performed a thorough eye examination on the enrolled children. Monocular threshold visual acuity (VA) testing, using occlude over non tested eye, using the Snellen chart was part of the thorough eye exam. In the patient's medical record, the visual acuity and best corrected visual acuity (BCVA) (returning after 6 weeks with spectacles) were recorded in LogMar. Retinoscopy was done to measure cycloplegic refraction thirty minutes after the final drop of three 1% cyclopentolate drops spaced five minutes apart. A pupil diameter of at least 6 mm or the lack of the pupillary light reflex was required to verify cycloplegia. The results of an examination were used to assess a child's refractive error and amblyopia. To find additional potential causes of decreased VA, dilated fundus examination and anterior segment evaluation were also carried out. Statistical analysis was performed using SPSS version 24.0. Descriptive statistics were used to characterize refractive patterns. For subgroup comparisons between severity grades (mild, moderate, severe), the Chi-square test for independence was applied. A p-value of <0.05 was considered statistically significant

Results

The mean and age of participants was 4.28 (SD = 0.71), with near equal gender proportions (48.3% male, 51.69% female) (Table 1). Gender differences in refractive error patterns appear to be statistically significant (Table 2). Females

Table 1 Demographic Characteristics of Study Participants (n = 178 Amblyopic Eyes)

Variable	Category	n	%
Age (years)	3	27	15.2
	4	74	41.6
	5	77	43.3
Gender	Male	86	48.3
	Female	92	51.7

Abbreviation: VA, Visual Acuity.

Table 2 Refractive Error Type by Gender (n = 178 Amblyopic Eyes)

Refractive Error Type	Female n (%)	Male n (%)	Total n (%)	p-value (Test)
Myopia only	30 (16.9%)	15 (8.4%)	45 (25.3%)	0.005 (Chi-square)
Hyperopia only	10 (5.6%)	28 (15.7%)	38 (21.3%)	<0.001 (Chi-square)
Astigmatism only	20 (11.2%)	20 (11.2%)	40 (22.5%)	0.025 (Chi-square)
Myopic Astigmatism	14 (7.9%)	14 (7.9%)	28 (15.7%)	
Hyperopic Astigmatism	14 (7.9%)	13 (7.3%)	27 (15.2%)	

Abbreviations: n, number of eyes; %, percentage of eyes.

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Table 3 Refractive Error Severity in Amblyopic Eyes (n = 178)

Refractive Component	Severity	n (%)
Spherical Error		
Myopia	Low	20 (11.2%)
	Moderate	33 (18.5%)
	High	36 (20.2%)
Hyperopia	Low	14 (7.9%)
	Moderate	28 (15.7%)
No Spherical Error*	–	47 (26.5%)
Cylindrical Error		
Astigmatism	Low	51 (28.7%)
	Moderate	44 (24.7%)
Absent	–	83 (46.6%)

Note: * "No Spherical Error" represents eyes with isolated astigmatism.
Abbreviations: n, number of eyes; %, percentage of eyes.

Table 4 Refractive Error Patterns and Visual Acuity (VA) in Amblyopic Eyes (n = 178)

Refractive Error/Combination	n	%	Mean BCVA (LogMAR ± SD)
Myopia only	45	25.3	0.92 ± 0.45
Hyperopia only	38	21.3	0.71 ± 0.38
Astigmatism only	40	22.5	0.84 ± 0.41
Myopia + Astigmatism	28	15.7	1.05 ± 0.49
Hyperopia + Astigmatism	27	15.2	0.96 ± 0.46

Abbreviations: VA, Visual Acuity; SD, Standard Deviation; LogMAR, Logarithm of the Minimum Angle of Resolution.

were more likely to have myopia or astigmatism, whereas males were more likely to have hyperopia or astigmatism, indicating possible gender-specific patterns in amblyopia. There is no statistically significant difference between males and females in the proportion of eyes with combined versus single refractive errors ($p \approx 0.80$, Chi-square test).

Refractive error severity, when analyzed by individual component, showed that eyes with moderate and high myopia were more likely to be amblyopic. Hyperopia was mostly low to moderate, while moderate astigmatism was more common than high astigmatism (Table 3). These differences were statistically significant ($p < 0.001$).

Among the 178 amblyopic eyes, astigmatism was common, particularly myopic astigmatism (n = 28, 15.7%) and hyperopic astigmatism (n = 27, 15.2%), while isolated refractive errors were also observed. Visual acuity outcomes were strongly associated with refractive error type (Table 4). Amblyopes with particularly myopic astigmatism (n = 28, 15.7%) and hyperopic astigmatism (n = 27, 15.2%) exhibited the poorest visual acuity (mean LogMAR VA 1.05 ± 0.49 and 0.96 ± 0.46) and the highest proportion of eyes in the poor VA category. Eyes with hyperopia alone (n = 38, 21.3%) demonstrated the best visual outcomes (mean LogMAR VA 0.71 ± 0.38), whereas myopia-only (n = 45, 25.3%) and astigmatism-only eyes (n = 40, 22.5%) showed intermediate visual acuity (mean LogMAR VA 0.92 ± 0.45 and 0.84 ± 0.41). Differences between groups were statistically significant ($p < 0.001$).

Discussion

This study revealed several important findings with respect to pediatric amblyopes. First, astigmatism was the most common refractive error in our population. Second, there was some gender-specific pattern also observed, with males being more myopic and females hyperopic. In terms of severity of refractive error lower thresholds for hyperopia and astigmatism was observed, furthermore it was also seen that children with mixed refractive error had worse visual outcome than those with single refractive error.

Before interpreting our findings, therewere some limitation to our research, first was the difficulty in obtaining reliable Visual Acuity (VA) data from the youngest participants. This resulted in the exclusion of data from the majority of three-year-old children (only 15% contributing usable data), leading to 85% of our final analyzed cohort being four and five-year-olds. The second was the use of the Snellen chart for primary data collection, although all Snellen measurements were converted to the continuous log MAR scale for statistical analysis, our study may have underestimated the true magnitude of amblyopia. Lastly, while the sample size of 178 is robust for a descriptive distribution analysis in a tertiary setting, it may have limited statistical power for definitive subgroup analyses. Future multicenter studies with larger cohorts are required to provide a more powered analysis of these refractive phenotypes.

Our study found prevalence of myopia, hyperopia, and astigmatism as 25.3%, 21.3%, and 53.4%, respectively. When compared to the study done by Malik et al in Pakistan, where 150 amblyopic children were studied, the prevalence of myopia, hyperopia, and astigmatism was 8.6%, 36%, and 53.3%.[12] This is lower than our results, except for the hyperopia cases. Similar results were also seen in a study by Eslayeh AH where the most common refractive error was astigmatism (53.7%), followed by hyperopia (30.9%), and myopia (15.4%).[13]

In contrast to our findings, hypermetropia accounted for 36.9% of cases, myopia for 29.6%, and astigmatism for 12.5% of cases in a Pakistani study by Tauqeer et al where refractive errors were found to be the primary causes of amblyopia. Compared to our study, theirs found higher rates of hyperopia and myopia and lower rates of astigmatism.[11] Similarly, an Indian study conducted by Karunanithi found that amblyopia caused by hypermetropia was the most common (48.4%). This was also observed in studies conducted in Nepal by K Sapkota et al (336%), Sadia Sethi et al (60%), and Jing Fu et al.[14–17]

The refractive distribution in our study population exhibits a notable variance when compared to the established baseline proportions reported in the landmark MEPEDS and BPEDS cohorts (Table 5). While those population-based studies identified hyperopia as the predominant driver of preschool refractive risk, 25.3% of the amblyopic eyes in our study presented with a myopic pattern. This represents a roughly six-fold increase over the 3.98% prevalence reported for Asian children in the MEPEDS data. Most significantly, astigmatism was identified as the primary refractive phenotype in our clinical setting, occurring in 53.4% of amblyopic eyes. This stands in contrast to the 6.3–8.3% prevalence observed in Western pediatric cohorts. These findings suggest a distinctive refractive profile in South Asian tertiary care settings.[8]

In a Chinese study on amblyopia, there was a higher prevalence of high hyperopia, followed by moderate hyperopia whereas in our study, the highest was low astigmatism, followed by moderate astigmatism.[18] Another study in Tibet found a significant correlation between amblyopia and astigmatism (≤−2.00 D, OR 6.76, 95% CI 2.56–17.85) and hyperopia (≥+2.00 D, odds ratio [OR] 8.22, 95% CI 3.42–19.72).[19] Additionally, another study by Aljohani et al found a high degree of hyperopic astigmatism in meridional amblyopia and ametropic amblyopia, and hyperopic astigmatism was significantly linked to amblyopia.[20] Our findings revealed an equal proportion of both hyperopic and myopic astigmatism with poorer mean BCVA than other refractive errors. While pure myopia is rarely a primary cause of bilateral amblyopia—as noted in the PEDIG ATS-7 study—the addition of a cylindrical component significantly alters the risk profile. Unlike symmetric spherical errors, uncorrected astigmatism of 1.50 D or more creates a constant meridional blur that cannot be fully neutralized by the eye's accommodative system. This inability to achieve a sharp retinal image, even with robust accommodation, likely explains the larger prevalence of amblyopia and reduced BCVA observed in our astigmatic cohort compared to those with isolated spherical errors.[21]

In contrast to the 2022 meta-analysis, which reported a significantly higher overall prevalence of amblyopia in boys, our recent data showed no statistical difference between genders in the overall frequency of amblyopia ($p > 0.05$).[3]

Table 5 Comparative Refractive Proportions

Refractive Category	Current Study n (%)	MEPEDS/BPEDS n (%)
Total Myopic Pattern	25.3%	1.2–4.0%
Total Hyperopic Pattern	21.3%	13.5–25.7%
Total Astigmatism	53.4%	6.3–8.3%

However, we identified a significant disparity in the underlying refractive error type: males demonstrated a clear majority of hyperopic amblyopia, while females exhibited a predominance of myopic amblyopia.

A slight male predominance in amblyopia cases (63.64% male vs. 36.36% female) was also observed in a study conducted in India, although the difference was not statistically significant. This study also noted that high hypermetropia (farsightedness) was the most common error and was also more frequently observed in males, which is consistent with our findings.[22] However, Tauqeer et al observed no significant difference in the type of refractive error (hypermetropia or myopia) between genders.[11] There may be some environmental or behavioral factors attributable to these patterns, the exact mechanism underlying this refractive disparity remains speculative and requires more extensive research.[23,24]

Conclusion

Astigmatic refractive errors are likely significantly associated with greater amblyopia severity, and thresholds lower than previously established may contribute to amblyopia. The WHO 2030 agenda for Vision, emphasizes increasing Effective Refractive Error Coverage (eREC) to prevent permanent visual impairment. Our findings in 178 children aged 3–5 years capture a vital window—the critical period for visual development. By identifying amylogenic refractive patterns in preschoolers, this research provides the "Surveillance" data necessary to intervene before refractive errors progress into irreversible amblyopia, directly supporting the SPECS 2030 goal of early, people-centered eye care in Pakistan.

AI Statement

During the preparation of this work, the author used Gemini in order to review literature relevant to this study. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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Disclosure

The authors declare that they have no competing interests for this work.

References

1. Brin TA, Chow A, Carter C, Oremus M, Bobier W, Thompson B. Efficacy of vision-based treatments for children and teens with amblyopia: a systematic review and meta-analysis of randomised controlled trials. *BMJ Open Ophthalmol*. 2021;6(1):e000657. doi:10.1136/bmjophth-2020-000657
2. Vodenčarević AN, Halilbašić M, Međedović A, et al. Refractive errors in children: analysis among preschool and school children in Tuzla city, Bosnia and Herzegovina. *Medicinski Glasnik*. 2021;18(1). doi:10.17392/1153-21
3. Hu B, Liu Z, Zhao J, et al. The global prevalence of amblyopia in children: a systematic review and meta-analysis. *Front Pediatr*. 2022;10:819998. doi:10.3389/fped.2022.819998
4. Wong AMF. Amblyopia (lazy eye) in children. *Can Med Assoc J*. 2013;186(4):292. doi:10.1503/cmaj.130666
5. Zagui R. Amblyopia: types, diagnosis, treatment, and new perspectives. *Am Acad Ophthalmol*. 2019;25:2–4.
6. Mocanu V, Horhat R. Prevalence and risk factors of amblyopia among refractive errors in an Eastern European Population. *Medicina*. 2018;54(1):6. doi:10.3390/medicina54010006
7. Jonas DE, Amick HR, Wallace IF, et al. Vision screening in children aged 6 months to 5 years: evidence report and systematic review for the US preventive services task force. Carolina Digital Repository (University of North Carolina at Chapel Hill); 2017. doi:10.17615/m1xv-7k5.
8. Tarczy-Hornoch K, Varma R, Cotter SA, et al. Risk factors for decreased visual acuity in preschool children. *Ophthalmology*. 2011;118(11):2262–2273. doi:10.1016/j.ophtha.2011.06.033

9. Omar R, Wong MES, Majumder C, Feizal Knight V. Distribution of refractive error among Chinese primary school children in a rural area in Pahang, Malaysia. *Malays Fam Physician*. 2022;17(1):29–35. doi:10.51866/oa1251
10. World Health Organization. Report of the 2030 targets on effective coverage of eye care. World Health Organization; 2022.
11. Tauqeer S, Karim S, Khan MN. Frequency of the factors leading to amblyopia in children. *Ann PIMS-Shaheed Zulfiqar Ali Bhutto Med Univ*. 2025;21(1):214–217. doi:10.48036/apims.v21i1.1349
12. Malik N, Masud H, Basit I, Noor P. Frequency of refractive error and amblyopia in strabismus in pediatric age group. *Pakistan Armed Forces Med J*. 2021;71(2):405–408. doi:10.51253/pafmj.v71i2.3109
13. Eslayeh AH, Omar R, Md Fadzil N. Refractive amblyopia among children aged 4–12 years in a hospital-based setting in Gaza Strip, Palestine. *Med Hypothesis Discov Innov Ophthalmol*. 2021;10(3):107–113. doi:10.51329/mehdiophthal1428
14. Karunanithi S, Venugopal S. Prevalence of refractive amblyopia among children aged 5–12 years attending a tertiary care centre in south India. *Int J Med Public Health*. 2025;15:1514–1517. doi:10.70034/ijmedph.2025.4.271
15. Sapkota K, Pirouzian A, Matta N. Prevalence of amblyopia and patterns of refractive error in the amblyopic children of a tertiary eye care center of Nepal. *Nepal J Ophthalmol*. 2013;5(1):38–44. doi:10.3126/nepjoph.v5i1.7820
16. Sethi MJ, Sethi S, Iqbal R. Frequency of refractive errors in children visiting eye out patients department agency headquarter hospital landi kotal. *Gomal J Med Sci*. 2009;7(2).
17. Fu J, Li SM, Li SY, et al. Prevalence, causes and associations of amblyopia in year 1 students in Central China. *Graefes Arch Clin Exp Ophthalmol*. 2013;252(1):137–143. doi:10.1007/s00417-013-2451-z
18. Wu J, Wang N. Prevalence and characteristics of amblyopia, strabismus, and refractive errors among patients aged 3–16 years in Shanghai, China: a hospital-based population study. *BMC Ophthalmol*. 2024;24(1). doi:10.1186/s12886-024-03477-8
19. Meng Z, Fu J, Chen W, et al. Prevalence of amblyopia and associated risk factors in tibetan grade one children. *Ophthalmic Res*. 2020:1–10. doi:10.1159/000511264
20. Aljohani S, Aldakhil S, Alrasheed SH, Tan QQ, Alshammeri S. The clinical characteristics of amblyopia in children under 17 years of age in Qassim Region, Saudi Arabia. *Clin Ophthalmol*. 2022;16:2677–2684. doi:10.2147/opth.s379550
21. Wallace DK, Chandler DL, Beck RW, et al. Treatment of bilateral refractive amblyopia in children three to less than 10 years of age. *Am J Ophthalmol*. 2007;144:487–496. doi:10.1016/j.ajo.2007.05.040
22. Patel S, Singh H, Singh K, et al. The prevalence of amblyopia in school-going children less than 18 years of age presenting at eye OPD in a tertiary care hospital in Bhopal. *Eur J Cardiovasc Med*. 2025;15:541–546.
23. Klinker CD, Schipperijn J, Kerr J, Ersbøll AK, Troelsen J. Context-specific outdoor time and physical activity among school-children across gender and age: using accelerometers and GPS to advance methods. *Front Public Health*. 2014;2. doi:10.3389/fpubh.2014.00020
24. Lingham G, Mackey DA, Lucas R, Yazar S. How does spending time outdoors protect against myopia? A review. *Br J Ophthalmol*. 2020;104(5):593–599. doi:10.1136/bjophthalmol-2019-314675