SSR Journal of Medical Sciences (SSRJMS)

OPEN ACCESS

Volume 1, Issue 1, 2024 Journal homepage: https://ssrpublisher.com/ssrjms/ ISSN: 3049-0375
Email: office.ssrpublisher@gmail.com

The Prevalence and Association of Refractive Errors in Pediatric Strabismus: A Prospective Observational Study

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Received: 25.10.2024 | **Accepted:** 26.10.2024 | **Published:** 29.10.2024

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Abstract **Original Research Article**

Background: Strabismus, or misalignment of the eyes, is a common pediatric condition that affects visual development and quality of life. Refractive errors such as myopia, hyperopia, and astigmatism are believed to contribute to strabismus. Early identification and treatment of these errors may help reduce the severity of strabismus. However, there is limited research on the prevalence of refractive errors in pediatric strabismus cases in South Gujarat, India, highlighting the need for further investigation.
Purpose: This study aims to determine the prevalence of refractive errors among pediatric patients with strabismus and explore the relationship between specific refractive errors and different types of strabismus (esotropia and exotropia) in a tertiary care center in South Gujarat, India.
Materials and Methods: A prospective, observational study was conducted from August 2023 to July 2024, involving 78 pediatric strabismus patients out of 1044 children at a tertiary care center in Surat. Data on refractive status (myopia, hyperopia, astigmatism) and strabismus type (esotropia, exotropia) were collected using vision charts, retinoscopy, autorefractometers, a trial lens set, prism bars, and occluders. Statistical analysis, including chi-square tests, assessed the association between refractive errors and strabismus types ($p < 0.05$).
Results: Among 1044 children, 78 patients (7.47%) were strabismic, out of which 86% had ametropia, while 14% were emmetropic. Hyperopia was strongly associated with esotropia (36.54%), whereas myopic astigmatism (28.84%) and astigmatism (23.72%) were linked to exotropia. Amblyopia was diagnosed in 26.92% of strabismic patients, with higher prevalence in exotropia cases. A significant association between refractive errors and strabismus was found ($p < 0.0001$).
Conclusion: The study highlights a strong link between refractive errors and strabismus, particularly hyperopia with esotropia and myopia/astigmatism with exotropia. Early detection of refractive errors could prevent or lessen strabismus, and further research with larger samples is recommended.

Keywords: Strabismus, Refractive errors, Pediatric, Esotropia, Exotropia, Amblyopia, Hyperopia, Myopia, Astigmatism

INTRODUCTION

Strabismus, a prevalent ocular condition, is characterized by the misalignment of the eyes, where they do not focus in the same direction simultaneously. This misalignment can lead to several visual dysfunctions, including diplopia (double vision), suppression of the image from one eye, loss of stereopsis (depth perception), and amblyopia (lazy eye). The condition is particularly concerning in pediatric patients, as it can affect visual development and overall eye health. [1] Globally, the prevalence of strabismus among children varies significantly, ranging from 0.14% to 5.65%, depending on the population studied and the diagnostic criteria used. [2]

Strabismus can be classified into various forms, with esotropia (inward turning of one or both eyes) and exotropia (outward turning of the eyes) being the most common. Both conditions can severely impact a child's visual development, quality of life, and social interactions. Children with strabismus often struggle with reading difficulties, a lack of visual focus, and may develop amblyopia if the condition is left untreated. Strabismus may be either congenital or acquired, with causes including refractive errors, congenital ocular defects, neurological disorders, and environmental factors. [3]

Refractive errors—such as myopia (nearsightedness), hyperopia (farsightedness), and astigmatism (irregular

curvature of the cornea)—are well-established risk factors for strabismus development. Hyperopia is particularly associated with esotropia due to the accommodative mechanism, where over-focusing to see near objects clearly leads to an inward eye-turning. Conversely, exotropia is more common in children with myopia or astigmatism, where inadequate focusing results in the eyes drifting outward. [4]

Several studies have highlighted the significant relationship between uncorrected refractive errors and the onset of strabismus in children. For instance, Ullah et al. (2020) [5] found that refractive errors were the leading cause of visual impairment among primary school children in Pakistan, with many also diagnosed with strabismus. Similarly, Zhale Rajavi et al. (2015) [6] reported a high prevalence of amblyopia among children with both refractive errors and strabismus, suggesting a strong interconnection between these visual disorders.

Early detection and correction of refractive errors using spectacles or contact lenses have proven effective in reducing the risk of strabismus or preventing its progression. However, despite the established association between refractive errors and strabismus, there remains a lack of comprehensive data from specific geographic regions, particularly in India. Most existing studies have been conducted in Western or Eastern populations, where factors such as environment, genetics, and lifestyle may differ, thereby influencing the prevalence and characteristics of these conditions. [7] [8]

Prevalence of Strabismus: The prevalence of strabismus in school-aged children has been reported to be approximately 1.92%, with esotropia identified as the most common type (1.15%) according to Bazuaye et al. (2022) [9]. In broader pediatric populations, the prevalence of refractive errors was found to be 29.5%, indicating a substantial number of children at risk of visual impairment (Choudhary et al., 2022) [10].

Association with Refractive Errors: Uncorrected refractive errors are a significant risk factor for developing strabismus, as they can lead to conditions such as amblyopia and other visual disabilities (Verma & Ghosh, 2024) [11]. One study noted that all children with strabismus also had refractive errors, with astigmatism being the most prevalent (1.27%) (Bazuaye et al., 2022) [9].

Importance of Early Screening: Early screening for refractive errors is essential to prevent complications like amblyopia and strabismus, especially in children before they reach a verbal age (Verma & Ghosh, 2024; Choudhary et al., 2022) [11] [10]. School-based educational initiatives can enhance awareness and encourage timely eye care interventions (Choudhary et al., 2022) [10].

While refractive errors are often a preventable cause of visual impairment, some children may develop strabismus without significant refractive issues, indicating that other factors, such as genetics or neurological conditions, might also contribute to the development of strabismus (Rachmah et al., 2023) [12]. Understanding these complex relationships is crucial for early detection and effective management.

Research indicates a strong association between pediatric strabismus and various refractive errors, particularly hyperopia. The high prevalence of these conditions highlights the need for early diagnosis and timely intervention to manage potential visual impairments. Regular eye examinations, public education, and the correction of refractive errors are essential strategies for addressing these issues. Comprehensive regional studies, especially in underrepresented areas like South Gujarat, India, are needed to better understand the patterns and prevalence of refractive errors and strabismus, which can lead to more tailored and effective public health strategies

Need for the Study and Research Gap

Strabismus and refractive errors are significant visual impairments that can adversely affect children's development, quality of life, and social interactions. Despite the known association between strabismus and refractive errors, most research has been concentrated in Western and East Asian countries. There is a lack of comprehensive data from specific regions, particularly in India, where environmental, genetic, and lifestyle factors may differ and influence the prevalence and characteristics of these conditions.

Existing studies have primarily focused on identifying risk factors, prevalence rates, and clinical outcomes, but there remains a need for region-specific data to understand the unique patterns of strabismus and refractive errors within different populations. Additionally, previous research often does not comprehensively address the impact of early screening, prevention, and management strategies tailored to specific demographic and regional characteristics. This gap in knowledge underscores the importance of conducting localized studies to develop effective, context-appropriate prevention and intervention strategies.

The purpose of this study was to investigate the prevalence of refractive errors among pediatric patients diagnosed with strabismus and explore the specific types of refractive

errors associated with different forms of strabismus (esotropia and exotropia). By identifying these associations, this research seeks to provide valuable insights for clinicians to improve early diagnosis and treatment strategies for pediatric eye care in South Gujarat.

MATERIALS AND METHODS

This study was a prospective, observational analysis conducted at a single tertiary eye care center. The objective was to assess the prevalence of refractive errors and their association with various types of strabismus in pediatric patients. The research was carried out at a specialized tertiary care center in Surat, India, focusing on pediatric eye care. The study spanned over a year, from August 2023 to July 2024.

The study population consisted of 1044 children, out of which 78 pediatric patients diagnosed with strabismus, with or without accompanying refractive errors. Patients were selected through purposive sampling, drawn from children who attended the outpatient department of the hospital. Inclusion criteria allowed the participation of children diagnosed with strabismus who were cooperative during the examination, and those with refractive errors, amblyopia, or squints, irrespective of gender and age group. Patients with other ocular conditions, such as retinal or optic nerve diseases, or those with postoperative complications or systemic diseases affecting eye health, were excluded from the study.

Each child underwent a comprehensive eye examination, including visual acuity testing and strabismus evaluation using cover tests. Instruments used included standard vision charts, a retinoscope, an auto-refractometer, a trial lens set, prism bars, and occluders. Refractive errors, such as myopia (nearsightedness), hyperopia (farsightedness), and astigmatism, were measured. The data recorded detailed the types of strabismus observed (esotropia—eyes turning inward, or exotropia—eyes turning outward) and their association with refractive errors. The primary goal was to identify any correlations between refractive issues and specific types of strabismus.

Demographic information was collected, and comprehensive ocular examinations were performed. These included best-corrected visual acuity (BCVA) measurement following cycloplegic refraction, slit-lamp examination, alternate prism and cover testing, and a dilated fundus examination. Amblyopia was diagnosed following the guidelines recommended by the American Academy of Ophthalmology (2017), and the spherical equivalent (SE) was calculated by adding the spherical power and half the magnitude of the cylinder power.

In this study, refractive errors were defined as hyperopia (≥ +1.5 diopters), further categorized into mild (≤ +2.0 D), moderate (+2.25 to +5.0 D), and high (> +5.0 D); and myopia (≥ -0.75 D), classified as mild (≤ -3.0 D), moderate (-3.25 to -6.0 D), and high (> -6.0 D). Strabismus was assessed using a unilateral cover/uncover test with a distant picture fixation target and a near figure puppet, conducted with or without spectacles. Any movement of the uncovered eye after occlusion of the test eye for 3 seconds was identified as strabismus. Strabismic amblyopia was diagnosed as misalignment without refractive errors or combined-mechanism amblyopia. Anisometropic amblyopia was defined by uncorrected refractive error differences greater than -3.00 D for myopia, ≥ +1.00 D for hyperopia, and ≥ ±1.50 D for astigmatism. Mixed amblyopia was identified as amblyopia caused by both strabismus and refractive errors.

Ethical approval was obtained from the institutional review board, and confidentiality was maintained for all participants.

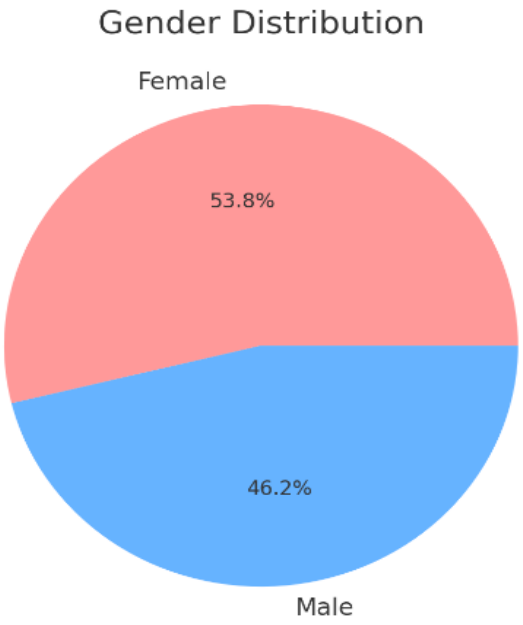
Data were analyzed using statistical methods, including the chi-square test and Fisher's exact test, to determine associations between refractive errors and different types of strabismus. A p-value of less than 0.05 was considered statistically significant, which facilitated the assessment of prevalence and correlations between these conditions.

RESULTS

The study evaluated 1044 children, out of which 78 patients (7.47%) were of pediatric strabismus, accounting for a total of 156 eyes, all diagnosed with strabismus. The data were analyzed for gender distribution, prevalence of refractive errors, types of refractive errors, associations between strabismus types and refractive errors, age-wise distribution of strabismus, and the presence of amblyopia. The key findings are presented below:

Gender Distribution

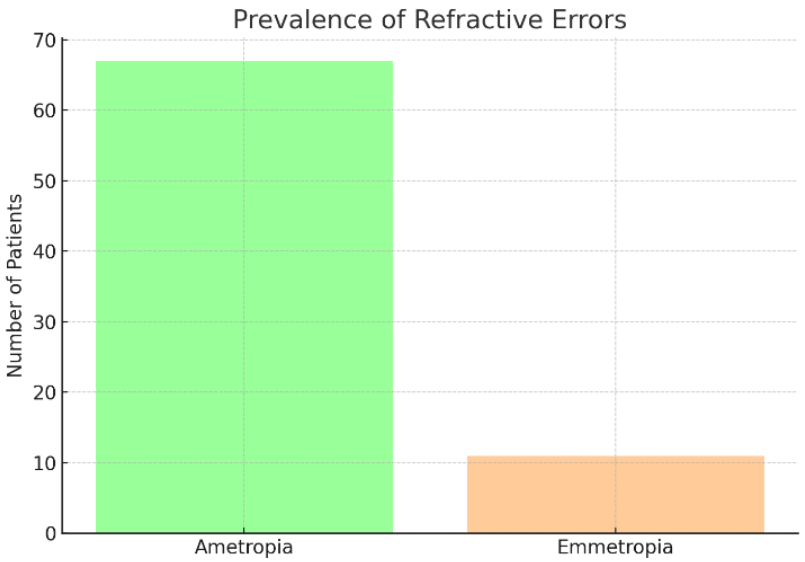
Of the 78 participants, 42 (54%) were female and 36 (46%) were male, indicating a slight predominance of female patients among the pediatric strabismus cases, as shown in Graph 1.



Graph 1: *Gender distribution of participants.*

Prevalence of Refractive Errors

Of the 78 patients, 67 (86%) had ametropia (refractive errors), while 11 (14%) were emmetropic (without refractive errors). This indicates a significant majority of children with strabismus also had co-existing refractive errors, suggesting a strong association between the two conditions. Bar Graph 2 displays the number of patients with various types of refractive conditions.



Graph 2: *Displays the number of patients with various types of refractive conditions.*

Types of Refractive Errors

Table 1 summarizes the distribution of various refractive errors. Myopic astigmatism was the most common refractive error among the participants, followed by astigmatism and Hyperopic astigmatism. This suggests that hyperopic and myopic astigmatism conditions were more frequently associated with pediatric strabismus cases in this study.

Table 1: The distribution of different refractive errors by eye.

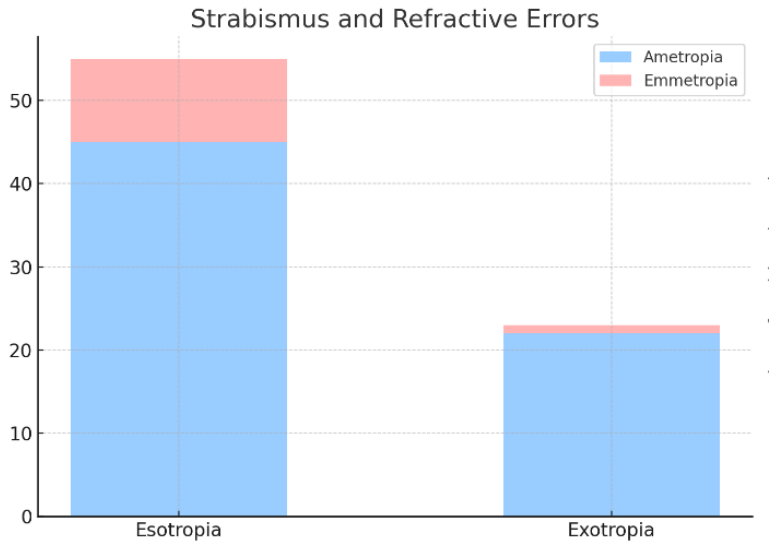
Refractive Error	Right Eye (RE)	Left Eye (LE)
Myopia	2	1
Myopic Astigmatism	19	23
Hyperopia	10	7
Hyperopic Astigmatism	17	19
Astigmatism	19	18
Emmetropia (No refractive error)	11	10

Association Between Strabismus Type and Refractive Errors

The association between different types of strabismus (esotropia and exotropia) and refractive conditions was analyzed, with the results summarized in Table 2. No statistically significant difference was found in the prevalence of esotropia versus exotropia among patients, regardless of whether they had refractive errors (p = 0.4892). Graph 3 compares the presence of esotropia and exotropia in patients with ametropia and emmetropia.

Table 2: The association between various types of strabismus (esotropia and exotropia) and refractive conditions.

Strabismus Type	Ametropia	Emmetropia	P-value
Esotropia	29	6	0.4892
Exotropia	38	5	



Graph 3: *Depicting the prevalence of esotropia and exotropia in patients with ametropia and emmetropia.*

Age-wise Distribution of Strabismus

The distribution of strabismus types (esotropia and exotropia) across different age groups, with and without refractive errors, is depicted in Table 3. No significant association was found between age and the type of strabismus (p = 0.1693), indicating that strabismus was similarly distributed across various pediatric age groups in the study population.

Table 3: The distribution of strabismus types (esotropia and exotropia) across various age groups, categorized by the presence or absence of refractive errors.

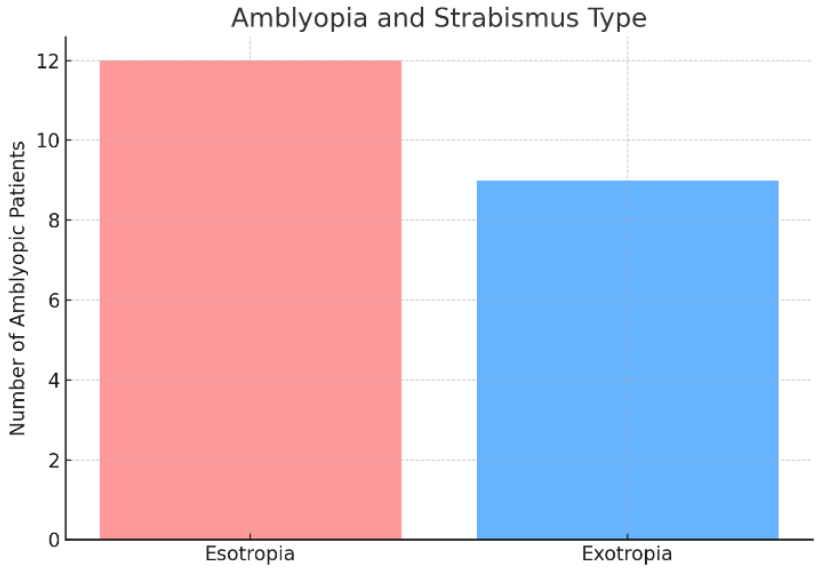
Age Group (years)	Esotropia (with refractive error)	Esotropia (emmetropic)	Exotropia (with refractive error)	Exotropia (emmetropic)	P-value
1-6	12	1	11	0	0.1693
7-12	14	4	19	2	
13-18	3	1	8	3	

Association of Amblyopia with Strabismus

Amblyopia, commonly known as "lazy eye," was observed in 26.92% of the patients. The analysis showed a stronger correlation of amblyopia with exotropia than with esotropia. There was a statistically significant association between amblyopia and the type of strabismus ($p = 0.0510$), with a higher prevalence of amblyopia in patients diagnosed with exotropia, as illustrated in Table 4 and Graph 4.

Table 4: The distribution of strabismus types (esotropia and exotropia) among patients with and without amblyopia.

Type of Strabismus	Amblyopic Patients	Non-Amblyopic Patients	P-value
Esotropia	5	27	0.0510
Exotropia	16	30	



Graph 4: *This bar chart illustrates the distribution of amblyopic patients across different types of strabismus.*

STATISTICAL ANALYSIS

Chi-square and Fisher's exact tests were used to analyze the associations between strabismus types, refractive errors, and amblyopia. The key findings were as follows: A strong association was found between ametropia (refractive error) and strabismus, with 86% of strabismic patients having refractive errors ($p < 0.0001$). Hyperopia and hyperopic astigmatism were significantly linked to esotropia, while myopic astigmatism was more commonly observed in patients with exotropia ($p = 0.0072$). Additionally, amblyopia was more frequently associated with exotropia than esotropia ($p = 0.0510$).

DISCUSSION

This study aimed to investigate the association between refractive errors and strabismus in pediatric

patients, while also exploring the distribution of refractive errors and their impact on different strabismus types. The findings of this study reinforce existing literature, underscoring the significant role that refractive errors play in the development of strabismus in children.

Gender Distribution

A slight predominance of female patients (54%) was observed in this study, aligning with previous research by Mohney et al. (2007) [13], which similarly found a higher occurrence of strabismus among females. Despite this trend, there is no strong evidence to suggest that strabismus disproportionately affects one gender. Other studies, such as those by Friedman et al. (1979) [14], have shown that the condition occurs at comparable rates among males and females. The minor female predominance seen here could be attributed to differences in health-seeking behavior, as girls may be more likely to report visual problems early. Nevertheless, strabismus remains a concern for both genders, highlighting the need for universal screening and early detection in pediatric populations.

Prevalence of Refractive Errors in Strabismus

The study revealed that a significant proportion of the pediatric patients with strabismus (7.47%), out of which (86%) exhibited refractive errors (ametropia), predominantly hyperopia and hyperopic astigmatism. This is consistent with findings from Chia et al. (2013) [15] and Robaei et al. (2006) [16], who also observed a strong correlation between refractive errors and strabismus, particularly in the case of hyperopia leading to esotropia. Uncorrected hyperopia can result in excessive accommodative effort, causing inward turning of the eyes (accommodative esotropia). The high prevalence of refractive errors in strabismic children emphasizes the importance of addressing refractive issues early to mitigate the risk of strabismus and other complications.

Association of Refractive Errors with Strabismus Type

The study identified a clear relationship between the type of refractive error and the form of strabismus. Hyperopia and hyperopic astigmatism were more commonly associated with esotropia, while myopic astigmatism was more prevalent among patients with exotropia. This finding is consistent with previous studies, such as Mohney (2001) [17], which also reported similar associations. Hyperopic children are prone to esotropia due to the increased accommodative effort required to focus, while myopic astigmatism may interfere with normal binocular function, leading to exotropia. The study underscores the importance of early correction of hyperopia and other refractive errors in preventing the development of strabismus.

Age-Wise Distribution of Strabismus

Although no statistically significant correlation between age and strabismus types was found, a notable trend emerged, with younger children (ages 1–6) more likely to present with esotropia, and older children (ages 7–12) more likely to exhibit exotropia. These trends mirror findings from Mohney and Huffaker (2003) [18], who reported similar age distributions. Esotropia often develops early in childhood when accommodative demands are high, while exotropia tends to appear later, possibly as a result of changing visual demands during school years. Despite the lack of statistical significance, these patterns suggest that age-related factors may influence the presentation of strabismus, warranting further research.

Amblyopia and Strabismus

Amblyopia, commonly known as "lazy eye," was observed in 26.92% of the strabismic patients, with a higher prevalence in those with exotropia. This finding is consistent with research by Robaei et al. (2006) [16], which also found a stronger association between exotropia and amblyopia compared to esotropia. The misalignment of the eyes in exotropia can lead to suppression of visual input from the deviating eye, causing amblyopia if left untreated. This highlights the critical need for early detection and intervention to prevent long-term visual impairment in children with strabismus and amblyopia.

Correlation with Other Studies

The results of this study align with those of numerous other investigations into the relationship between refractive errors and strabismus in pediatric populations. Studies such as those by Chia et al. (2013) [15] and Govindan et al. (2005) [19] have consistently demonstrated strong associations between hyperopia and esotropia, as well as between astigmatism and exotropia. The high prevalence of refractive errors observed in our study further supports the importance of addressing these visual issues to prevent or manage strabismus effectively.

Additionally, the association between amblyopia and strabismus is well-supported in the literature. Research by Ning-Yi Hsia et al. (2022) [20] underscores the increased risk of amblyopia in children with refractive errors and strabismus, especially when the refractive error remains uncorrected. These findings emphasize the need for early diagnosis and intervention to minimize the risk of amblyopia in strabismic children.

Clinical Implications

This study's findings have important clinical implications for the management of pediatric strabismus. Given the strong association between refractive errors and

strabismus, routine eye examinations should be part of pediatric care, especially for children presenting with strabismus. Correcting refractive errors early, particularly hyperopia, can help prevent or reduce the severity of strabismus, particularly accommodative esotropia. Moreover, timely intervention is crucial in preventing amblyopia, which can have long-lasting effects on a child's visual development.

Limitations and Future Research

A key limitation of this study is its relatively small sample size, which was drawn from a single eye care center. Future research should aim to include larger and more diverse populations to ensure broader applicability of the findings. Additionally, longitudinal studies are needed to examine how refractive errors and strabismus progress over time, and how early intervention affects long-term outcomes. Research into genetic and environmental factors that contribute to strabismus and refractive errors could also provide valuable insights into preventive strategies and management approaches.

CONCLUSION

In conclusion, this study reinforces the significant role that refractive errors, particularly hyperopia and astigmatism, play in the development of strabismus in children. Early detection and intervention are essential to prevent long-term complications, including amblyopia, and to ensure optimal visual outcomes in pediatric patients.

Key Findings:

Prevalence of Refractive Errors: The study found that most pediatric patients with strabismus also had co-existing refractive errors, with hyperopia and hyperopic astigmatism being the most prevalent. This supports existing research that identifies hyperopia as a major risk factor for esotropia. Uncorrected hyperopia creates an accommodative demand, leading to inward turning of the eyes and establishing a clear link between refractive errors and the onset of strabismus.

Association Between Refractive Errors and Strabismus Types: A distinct relationship between specific refractive errors and strabismus types was observed. Hyperopia and hyperopic astigmatism were predominantly associated with esotropia (inward turning of the eye), while myopic astigmatism and astigmatism were more frequently linked to exotropia (outward turning of the eye). These findings align with the understanding that refractive errors can disrupt normal focusing, causing misalignment of the eyes and leading to strabismus.

Amblyopia in Strabismic Children: A significant finding of the study is the high prevalence of amblyopia (lazy eye) in children with strabismus, especially those with exotropia. This underscores the critical importance of early intervention, as untreated amblyopia can result in permanent visual impairment. The study highlights the need for timely detection and treatment of both refractive errors and strabismus to prevent the onset of amblyopia and enhance visual outcomes.

Clinical Implications

The findings of this study have important clinical implications for pediatric eye care. Comprehensive eye examinations should be prioritized for children, particularly those showing signs of strabismus or refractive errors. Early diagnosis and correction of refractive errors can not only improve visual acuity but also reduce the risk of strabismus and amblyopia.

For children with hyperopia or astigmatism, corrective lenses should be prescribed promptly, especially when strabismus is present. In cases of accommodative esotropia, proper refractive correction often leads to significant improvement in eye alignment, potentially eliminating the need for surgical intervention. Regular follow-up is crucial to monitor the progression of strabismus and ensure optimal treatment outcomes.

Contribution to Literature

This study adds to the growing body of evidence supporting the role of refractive errors in the development of strabismus. While previous research has established this connection, the current study provides deeper insights into the types of refractive errors most commonly associated with different strabismus types. Additionally, it reinforces the importance of early detection and intervention in preventing long-term visual impairments, such as amblyopia, in children with strabismus.

Funding

Not applicable.

Data availability

All data generated or analyzed during this study are included in this published article. Further enquiries can be directed to the corresponding author.

Competing interests:

The authors declare no competing interests.

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