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**Research Article**

# Anatomical and Physiological Determinants of Strabismus in Pakistani Children

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**ABSTRACT**

**Background:** Strabismus is a common pediatric ocular disorder characterized by misalignment of the eyes due to abnormalities in extraocular muscle coordination, neuromuscular control, and visual physiology. If left untreated, it may lead to amblyopia, impaired binocular vision, poor academic performance, and psychological distress in children. Anatomical, physiological, and systemic medical factors contribute significantly to the development and progression of pediatric strabismus. Early diagnosis and multidisciplinary management are therefore essential, particularly in Pakistan where pediatric ophthalmic screening remains limited.

**Objective:** To determine the anatomical and physiological basis of strabismus in Pakistani children and to evaluate its association with clinical and medical factors.

**Methodology:** This cross-sectional observational study was conducted in the Departments of Ophthalmology, at two tertiary care hospitals in Karachi and Lahore, Pakistan. A total of 120 children aged 2–15 years diagnosed with strabismus were included using non-probability consecutive sampling, 60 from each hospital respectively. Detailed ophthalmic examination including visual acuity assessment, Hirschberg test, cover–uncover test, ocular motility examination, cranial nerve assessment, and binocular vision testing was performed. Anatomical and physiological variables including extraocular muscle imbalance, refractive errors, neuromuscular dysfunction, orbital abnormalities, craniofacial anomalies, and associated systemic diseases were evaluated. Data were analyzed using SPSS version 26, and $p < 0.05$ was considered statistically significant.

**Results:** Among the 120 children studied, 68 (56.7%) were males and 52 (43.3%) were females, with a mean age of 7.9 ± 3.4 years. Esotropia was the most common type of strabismus observed in 64 (53.3%) children, followed by exotropia in 38 (31.7%) and vertical strabismus in 18 (15.0%) cases. Extraocular muscle imbalance was identified in 72 (60.0%) children, while refractive errors were present in 66 (55.0%) cases. Impaired binocular vision was observed in 58 (48.3%) participants, and associated neurological or systemic medical conditions were found in 29 (24.2%) children. A statistically significant association was observed between refractive errors and severity of strabismus ($p = 0.01$), as well as between neuromuscular dysfunction and impaired binocular vision ($p = 0.03$). Positive family history was reported in 34 (28.3%) children.

**Conclusion:** Pediatric strabismus in Pakistani children is strongly associated with anatomical abnormalities, altered visual physiology, and systemic medical factors. Esotropia and extraocular muscle imbalance were the predominant findings. Early multidisciplinary evaluation involving ophthalmology, physiology, pediatrics, and medicine may improve diagnosis, management, and prevention of long-term visual complications in children.

**Keywords**: Strabismus, Pakistani Children, Pediatric Ocular Disorder, Clinical and Medical Factors.

## INTRODUCTION

Strabismus is a common pediatric ocular disorder characterized by misalignment of the

visual axes of the eyes, resulting in impaired binocular vision and abnormal ocular motility [1]. The condition may present as esotropia, exotropia, hypertropia, or hypotropia and can be either constant or intermittent [1,2]. During childhood, proper ocular alignment is essential for normal visual development, and untreated strabismus may lead to amblyopia, impaired stereopsis, defective depth perception, and long-term visual disability [2].

The physiological maintenance of ocular alignment depends upon coordinated activity of the six extraocular muscles, intact cranial nerves III, IV, and VI, normal neuromuscular transmission, and effective cortical integration of binocular visual input [3]. You can insert the following concise 3-line summary into the second paragraph: The medial longitudinal fasciculus (MLF) is a brainstem fiber tract that coordinates the actions of cranial nerves III, IV, and VI and integrates ocular movements with vestibular function and conjugate gaze [3,4]. Clinically, strabismus may be classified as paralytic or non-paralytic; paralytic strabismus is characterized by impaired ocular movements and commonly causes diplopia, whereas non-paralytic strabismus is usually congenital and associated with preserved ocular motility [4]. Disturbances affecting these neural and muscular mechanisms can contribute significantly to ocular misalignment in children [3,4].

Anatomical abnormalities involving extraocular muscles, orbital structures, cranial nerves, and visual pathways may disrupt these mechanisms and contribute to the development of strabismus [4]. Recent evidence suggests that disturbances in vergence control, sensory fusion, and binocular visual processing also play a significant role in pediatric strabismus [3,4].

The prevalence of childhood strabismus varies globally, ranging from approximately 1% to 6% among different populations [5]. Refractive errors, family history, prematurity, low birth weight, developmental disorders, neurological diseases, and craniofacial abnormalities have been reported as major risk factors [6]. Epidemiological studies have further demonstrated that esotropia remains the most frequently observed subtype among children, followed by exotropia and vertical deviations [5].

Beyond visual impairment, strabismus has considerable psychosocial consequences. Children with visible ocular deviation may experience social stigma, reduced self-esteem, impaired interpersonal relationships, and poorer quality of life [7]. Recent systematic reviews have also reported associations between childhood strabismus and adverse psychological outcomes, including anxiety and depressive symptoms [8].

In Pakistan, strabismus remains an important pediatric eye health concern. A recent systematic review and meta-analysis reported a substantial burden of strabismus among Pakistani children despite improvements in ophthalmic services over the last two decades [9]. However, most local studies have focused on prevalence and clinical patterns, while limited data are available regarding the underlying anatomical and physiological determinants of the disorder [8,9].

A comprehensive understanding of the anatomical and physiological basis of pediatric strabismus is essential for timely diagnosis, multidisciplinary management, and prevention of long-term visual complications [3]. Therefore, the present study aimed to evaluate the anatomical and physiological determinants of strabismus among Pakistani children and to assess their association with relevant clinical and medical factors.

## MATERIALS AND METHODS

This cross-sectional observational study was conducted in the Departments of Ophthalmology, at two tertiary care hospitals in Karachi and Lahore, Pakistan, from January 2025 to December 2025. The study included 120 children (60 from each hospital) aged 2–15 years who were diagnosed with strabismus and presented to the Pediatric Ophthalmology Clinic during the study period. Participants were selected using non-probability consecutive sampling after obtaining informed consent from parents or legal guardians. Children with previous ocular surgery, traumatic eye injuries, or severe ocular pathologies unrelated to strabismus were excluded from the study. Detailed demographic and clinical data were collected using a structured proforma. Each participant underwent comprehensive ophthalmic evaluation including visual acuity assessment, Hirschberg test, cover-uncover test, alternate cover test, ocular motility examination, and binocular vision assessment. Anatomical variables such as type of strabismus, extraocular muscle involvement, refractive errors, craniofacial abnormalities, and orbital anomalies were recorded. Physiological parameters including binocular fusion defects and neuromuscular dysfunction were also assessed. Information regarding family history

and associated systemic or neurological disorders was obtained from medical records and clinical examinations. Data were entered and analyzed using SPSS version 26. Quantitative variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Associations between variables were analyzed using the Chi-square test, with a p-value <0.05 considered statistically significant.

## RESULTS

A total of 120 children diagnosed with strabismus were evaluated during the study period. The mean age of the participants was 7.9 ± 3.4 years, with males (56.7%) slightly outnumbering females (43.3%). The highest proportion of cases was observed in the 6–10 years age group (45.0%), followed by 11–15 years (28.3%) and 2–5 years (26.7%). Esotropia emerged as the predominant type of strabismus, accounting for 53.3% of cases, while exotropia, hypertropia, and hypotropia constituted 31.7%, 10.0%, and 5.0% respectively.

Analysis of anatomical and physiological factors revealed that extraocular muscle imbalance was the most common abnormality, identified in 60.0% of children. Refractive errors were present in 55.0% of participants, indicating a substantial contribution to ocular misalignment. Impaired binocular vision was observed in 48.3% of cases, whereas neuromuscular dysfunction was detected in 35.0%. Craniofacial abnormalities and orbital anomalies were found in 15.0% and 8.3% of participants, respectively. A positive family history of strabismus was documented in 28.3% of children.

Regarding associated medical conditions, neurological disorders were the most frequent comorbidity (13.3%), followed by prematurity (6.7%), developmental delay (4.2%), cerebral palsy (3.3%), and genetic syndromes (2.5%). Statistical analysis demonstrated a significant association between refractive errors and greater severity of strabismus (p=0.01). Furthermore, neuromuscular dysfunction showed a significant relationship with impaired binocular vision (p=0.03). These findings suggest that both anatomical abnormalities and physiological disturbances play important roles in the development and progression of pediatric strabismus in Pakistani children.

Table 1. Demographic Characteristics of the Study Population (n = 120)

| Variable | Frequency (n) | Percentage (%) |
|---|---|---|
| **Gender** | | |
| Male | 68 | 56.7 |
| Female | 52 | 43.3 |
| **Age Group (Years)** | | |
| 2–5 | 32 | 26.7 |
| 6–10 | 54 | 45.0 |
| 11–15 | 34 | 28.3 |
| **Mean Age (Years)** | 7.9 ± 3.4 | — |

Table 2. Distribution of Types of Strabismus

| Type of Strabismus | Frequency (n) | Percentage (%) |
|---|---|---|
| Esotropia | 64 | 53.3 |
| Exotropia | 38 | 31.7 |
| Hypertropia | 12 | 10.0 |
| Hypotropia | 6 | 5.0 |
| **Total** | **120** | **100** |

Table 3. Anatomical and Physiological Factors Associated with Strabismus

| Factor | Frequency (n) | Percentage (%) |
|---|---|---|
| Extraocular muscle imbalance | 72 | 60.0 |
| Refractive errors | 66 | 55.0 |
| Impaired binocular vision | 58 | 48.3 |
| Neuromuscular dysfunction | 42 | 35.0 |
| Craniofacial abnormalities | 18 | 15.0 |

| | | |
|---|---|---|
| Orbital abnormalities | 10 | 8.3 |
| Positive family history | 34 | 28.3 |

Table 4. Associated Medical Conditions in Children with Strabismus

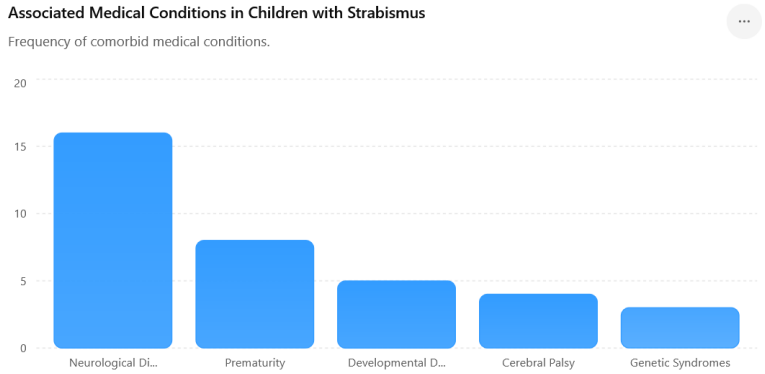
| Medical Condition | Frequency (n) | Percentage (%) |
|---|---|---|
| Neurological disorders | 16 | 13.3 |
| Prematurity | 8 | 6.7 |
| Developmental delay | 5 | 4.2 |
| Cerebral palsy | 4 | 3.3 |
| Genetic syndromes | 3 | 2.5 |
| No associated condition | 84 | 70.0 |

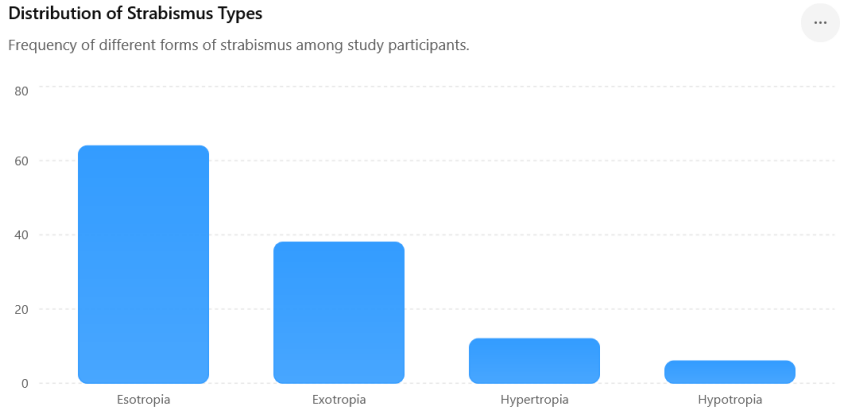
Table 5. Association between Refractive Errors and Severity of Strabismus

| Refractive Error | Mild n (%) | Moderate/Severe n (%) | Total | p-value |
|---|---|---|---|---|
| Present | 24 (36.4) | 42 (63.6) | 66 | |
| Absent | 34 (63.0) | 20 (37.0) | 54 | |
| **Total** | **58** | **62** | **120** | **0.01** |

Table 6. Association between Neuromuscular Dysfunction and Impaired Binocular Vision

| Neuromuscular Dysfunction | Impaired Binocular Vision n (%) | Normal Binocular Vision n (%) | Total | p-value |
|---|---|---|---|---|
| Present | 30 (71.4) | 12 (28.6) | 42 | |
| Absent | 28 (35.9) | 50 (64.1) | 78 | |
| **Total** | **58** | **62** | **120** | **0.03** |




## DISCUSSION

The present study investigated the anatomical and physiological determinants of pediatric strabismus among Pakistani children and demonstrated that esotropia was the most common subtype, accounting for 53.3% of all

cases. This finding is consistent with recent international literature reporting esotropia as the predominant form of childhood strabismus, particularly in younger children and in populations with a high prevalence of uncorrected hyperopia [10,11]. The predominance of esotropia observed in the current study may be attributed to accommodative mechanisms associated with refractive errors and developmental abnormalities affecting binocular vision.

A slight male predominance (56.7%) was observed in the study population. Similar gender distributions have been reported in recent pediatric ophthalmology studies, although most authors suggest that the occurrence of strabismus is generally comparable between males and females [12]. The highest frequency of cases was observed among children aged 6–10 years, likely reflecting increased detection during school-age years when visual demands become greater and ocular misalignment becomes more noticeable to parents and teachers [13].

One of the most important findings of this study was the high prevalence of extraocular muscle imbalance (60.0%). Normal ocular alignment depends on the coordinated action of six extraocular muscles under the control of cranial nerves III, IV, and VI. Disruption of this delicate neuromuscular balance can result in ocular deviation and impaired binocular vision [10]. Recent advances in neuro-ophthalmology suggest that abnormalities in central neural control mechanisms may be equally important as peripheral muscle dysfunction in the pathogenesis of pediatric strabismus [14].

Refractive errors were identified in 55.0% of participants and demonstrated a significant association with the severity of strabismus ($p=0.01$). This finding supports previous studies showing that uncorrected hyperopia and other refractive abnormalities increase accommodative effort and convergence, thereby predisposing children to ocular misalignment [11,15]. Early identification and correction of refractive errors may therefore play a crucial role in reducing the progression and severity of strabismus. The significant association observed in the present study further highlights the importance of routine pediatric vision screening programs.

Impaired binocular vision was observed in nearly half of the participants, while neuromuscular dysfunction was present in more than one-third of cases. Furthermore, neuromuscular dysfunction demonstrated a statistically significant association with impaired binocular vision ($p=0.03$). These findings are consistent with contemporary evidence suggesting that abnormalities in sensory fusion, vergence mechanisms, and cortical visual processing contribute substantially to the development of strabismus [14,16]. Defective binocular function may lead to suppression, amblyopia, and reduced stereopsis, thereby perpetuating ocular misalignment and visual dysfunction.

The present study also identified several associated medical conditions, with neurological disorders representing the most common comorbidity. Neurological diseases can interfere with ocular motor pathways, cranial nerve function, and cortical visual processing, thereby increasing the risk of strabismus [16,17]. Prematurity, developmental delay, cerebral palsy, and genetic syndromes were also observed among affected children. Similar associations have been reported in recent studies, which emphasize the multifactorial etiology of pediatric strabismus and the importance of multidisciplinary clinical assessment [17,18].

A positive family history was documented in 28.3% of participants, supporting previous evidence regarding the genetic contribution to strabismus development [18]. Genetic susceptibility may influence both anatomical and physiological pathways involved in ocular alignment, explaining the increased risk among children with affected relatives.

## CONCLUSION

The findings of this study have important clinical and public health implications. Early detection of refractive errors, binocular vision abnormalities, and neuromuscular dysfunction may facilitate timely intervention and prevent long-term visual complications. Community-based screening programs, school eye health initiatives, and increased awareness among parents and healthcare providers may significantly improve outcomes in affected children .

The present study has certain limitations. Being a single-center study with a relatively modest sample size, the findings may not be fully generalizable to the entire pediatric population of Pakistan. In addition, advanced neuroimaging and electrophysiological investigations were not performed, which may have provided further insight into the underlying pathophysiological mechanisms. Nevertheless, the study provides valuable local

data regarding the anatomical and physiological determinants of pediatric strabismus and highlights the need for further multicenter research.

**Authors' Contribution**

**Concept & Design of Study:** Shah Nawaz Channa**,** Zarka Sarwar
**Drafting:** Avais Ahmad**,** Beenish Sohail
**Data Analysis:** Faiza Habib**,** Bushra Hussain
**Critical Review:** Shah Nawaz Channa**,** Zarka Sarwar
**Final Approval of Version:** All authors approved the final version.

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