Article • Developmental Delay and Oculo-Visual Deficits: Challenges and Interventions–A Narrative Review

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ABSTRACT

Visual skills play a critical role in early childhood development, influencing not only visual acuity but also other domains, such as language, fine motor control, and social interactions. Disruptions in visual development can result in oculo-visual deficits, which are common in children with developmental delays. These deficits include issues with visual perception, oculomotor control, binocular vision, and visuo-cognitive processing. Developmental delay is characterized by significant delays in two or more developmental areas, and when combined with oculo-visual deficits, comprehensive care is essential. The prevalence of developmental disabilities among children under 20 is estimated to be between 10.1% and 11.3%, with oculo-visual deficits affecting 68% to 86% of this population. Risk factors include prenatal, perinatal, and postnatal influences. Children with developmental delays often experience difficulties in motor coordination, balance, laterality, and visual performance. Early recognition and intervention are vital in addressing these deficits, as they significantly impact overall development and quality of life. A multidisciplinary approach involving eye care professionals, occupational therapists, and caregivers is essential for effective rehabilitation. Vision therapy can improve visual perceptual skills and overall quality of life by addressing oculomotor dysfunction, binocular vision, and accommodation issues. Prioritizing early detection and intervention can optimize developmental outcomes for children with oculo-visual deficits and developmental delays. This review explores the prevalence of these deficits and highlights the crucial role of eye care professionals in their identification, management, and rehabilitation, aiming to enhance the long-term well-being of affected children.

Keywords: developmental delay, early assessment, oculo-visual deficits, visual impairment, visual rehabilitation

Introduction

Among the major domains of developmental milestones, visual skills play a crucial role in early childhood development. Visual development is a highly complex maturation process involving structural and functional changes in both the eye and the central nervous system. Disruptions in this process can lead to oculo-visual deficits, which extend beyond general visual deficits, the latter primarily referring to refractive errors or visual function impairments. Oculo-visual deficits encompass a broader range of dysfunctions, including delays in visual perception, oculomotor control, binocular vision, and visuo-cognitive processing, all of which can impact overall development. Developmental delay is operationally defined as significant delay in two or more developmental domains: gross motor, vision, and fine motor; speech, hearing, and language; and personal and social activities of daily living. Developmental delay can be global, when multiple domains of developmental milestones are affected. If only one domain is impacted, it is considered an isolated developmental delay.[1] However, if one domain is

disproportionately delayed or atypical compared to others, it is classified as a specific developmental delay.[1] When the expected intellectual, behavioral, and visual milestones are not achieved within an appropriate time frame, the condition is referred to as developmental delay. If these delays persist due to an underlying disorder, they are classified as developmental disabilities.

Developmental disabilities encompass a group of conditions arising from impairments that affect a child's physical, cognitive, learning, or behavioral functioning. These conditions are closely linked to disruptions in neural processes, as they involve changes in neuronal synapses. Since the eye is directly connected to the brain through the optic nerve, visual development is significantly influenced by these neurological factors. As a result, children with developmental delays and disabilities often experience a higher prevalence of oculo-visual deficits, which complicate their overall development. UNICEF and Global Burden of Diseases (GBD) estimate the prevalence of developmental disabilities among individuals less than 20 years as 10.1% to 11.3%, respectively.[2] This trend reflects the increasing likelihood of visual deficits among children with developmental delay.[2] Vision loss, one of the most common oculo-visual deficits, further complicates the acquisition of other developmental skills. Vision plays a critical role in the development of language, interpreting facial expressions, and performing tasks that require eye-hand coordination. Normal visual development not only ensures the mastery of visual skills, but also supports the acquisition of other developmental domains. Eye movements, for example, are closely linked to fine motor control. Therefore, the presence of oculo-visual deficits not only adds to the developmental burden but also increases the risk of other comorbidities. Early recognition and intervention for these deficits are crucial to improving the quality of life for affected children.

The global burden of developmental delay is saddening. Developmental delay is estimated to be present in about 10% of the pediatric population.[3] However, epidemiological data on developmental disabilities are scarce.[4] In the US, 17% of children aged 3 to 17 years are diagnosed with developmental disabilities.[5] On a global scale, in 1990, there were 598.5 million under the age of five, with 53 million having developmental disabilities, which accounts for approximately 8.86% of the global child population. By 2016, the global child population under five had increased to 632 million, with 52.9 million children having developmental disabilities,[6] representing about 8.38% of the total population. Despite a gap of nearly 26 years, from 1990 to 2016, the global burden of developmental disabilities has remained relatively stable, with only a slight decrease in the percentage. This trend indicates that the global burden of developmental disabilities does not appear to be decreasing significantly. The increasing burden reflects the absence of any systematic global initiative aimed to curtail the increasing number of affected children. Moreover, nearly 95% of these children reside in low- and middle-income countries.[6] Roughly 250 million children are at risk of suboptimal development due to factors such as stunting or extreme poverty.[7,8] However, this figure only represents children at risk due to these factors and does not fully account for those with developmental disabilities. The actual prevalence and risk are likely much higher than these estimates suggest.

There is a significantly high prevalence of ocular morbidities in children with developmental disabilities compared to their age-matched counterparts. These children are at higher risk of visual impairment relative to the general pediatric population.[9] The type and severity of ocular disorders vary depending on the specific disability. Among the children with developmental disorders, vision loss is the most prevalent sensory disability, followed by hearing loss and intellectual disability.[6] The overall prevalence of oculo-visual deficits in children with developmental delay has been reported to range from 68% to as high as 86%.[10,12,13] There is a male preponderance, [10,11,14] which has been attributed to typical patterns of genetic inheritance.

The risk factors for oculo-visual manifestations are more or less similar to the overall risk factors for developmental delays. The prenatal risk factors include maternal intoxication with cigarettes, alcohol, and drugs; TORCH infections; genetic abnormalities; and metabolic disorders such as gestational diabetes and pregnancy-induced hypertension.[15] Perinatal factors such as birth complications, birth trauma (especially from vacuum or forceps delivery and caesarean-section), birth asphyxia, breech presentation, neonatal jaundice, seizures, etc. have also been strongly linked to oculo-visual deficits.[15] Additionally, post-natal factors,[16,17] including acquired accidental or non-accidental head trauma, anoxia, infections like meningitis, encephalitis, etc.,

contribute to the risk. Beyond medical risk, maternal age, medical conditions, and environmental factors like poverty and family environment have also been associated with increased risk for developmental delays.[18] According to Nielson et al., visual impairment in children was due to prenatal factors in 11% of cases, perinatal factors in 6%, and postnatal factors in 1.4%.[19]

Affected children typically have sensory impairments (hearing and vision loss), epilepsy or seizures, cerebral palsy, attention deficit hyperactivity disorder (ADHD), ASD, intellectual disability, or other learning disorders.[20] Almost all of these conditions have ocular manifestations, although the type and severity of oculo-visual deficits may vary. These manifestations may be amenable, treatable, or irremediable. Some of the oculo-visual deficits are easily treatable if corrected within the stipulated time, but due to delayed diagnosis and treatment, these deficits often impose life-long implications. Oculomotor abnormalities, particularly deficits in supra-nuclear gaze controls, are frequently observed in children with developmental delays. Impairments in saccades and pursuits can manifest as oculomotor apraxia in some cases.[21] When present, the disorder predominantly affects horizontal saccades, which may be asymmetric. Additionally, an accompanying head thrust, which first appears as the head control is establishing, often takes the head beyond the target of regard and is often accompanied by an exaggerated blink.

Vision impairment is a common finding in children with developmental delays. The most common causes for visual impairment in these children include refractive correction, strabismus, and amblyopia, all of which are mostly treatable. Amblyopia is one of the frequent causes of childhood visual impairment,[22] which is highly prevalent among children with developmental delays. Moreover, the etiology of amblyopia could influence performance on fine motor skills tasks due to hypothesized differences in visual neural development between those with a history of blur (anisometropia and form deprivation) and those with a history of ocular misalignment (strabismus).[23] The type and magnitude of refractive error as well as the type of strabismus differ depending on the type of developmental delay.

The visual signs in children with developmental delays are often masked or underdiagnosed because of the superimposed systemic signs and symptoms. As a result, the majority of oculo-visual signs go unrecognized in early years, by which time the critical windows for intervention may have passed, leading to further developmental setbacks. This delay in diagnosis, which consequently delays the interventions, can significantly impact a child's ability to thrive in social and educational settings. Scheiman et al.[24] have given the following visual signs and symptoms of oculomotor dysfunction (Table 1). However, the following visual warning signs can be a useful guide:

- Difficulty in following objects
- Rubs eyes frequently
- Turns, tilts, or holds head in an unusual position
- Difficulty in finding or picking up small objects
- Difficulty in focusing and maintaining eye contact
- Closes one eye when trying to look at distant objects
- Eyes appear to be crossed or turned
- Brings objects close to eye to see
- One or both eyes appear abnormal

Children with developmental delay need special care and attention, and these needs become even more critical when compounded by oculo-visual deficits and visual impairments. Visual handicap during childhood, particularly in children with developmental delay, has significant implications, as it affects not only visual development but also other areas of development. Ocular morbidities and visual impairment in these children are known to cause setbacks in various developmental domains.[25] This is because clear vision is essential for acquisition of other domains of development, such as learning,

Table 1. Signs and Symptoms in Oculomotor Dysfunction (Adapted from Scheimann M, Wick B. Clinical Management of Binocular Vision. Philadelphia: Lippincott Williams & Wilkins, 2002:370-91)[24]

Visual Signs & Symptoms (General)	Visual Signs & Symptoms (While Reading)
Poor fixation, locating, and tracking objects	Loss of place
Head or body movement while tracking	Skipping words or lines
Difficulty copying from far to near	Excessive head movement
Short attention span	Eyestrain or headache
Poor performance in sports	Slow reader
Motion sickness or dizziness	Uses finger to keep place
Poor visually guided coordination	Poor comprehension

language and speech, hearing, cognition, and social behaviors. Therefore, early diagnosis of oculo-visual deficits in children with developmental delay is crucial in order to be able to adequately support them.

A thorough ophthalmic examination is essential for evaluating children with developmental delays, even in the absence of apparent obvious ocular abnormalities observed by other healthcare professionals. Eye care practitioners should conduct a comprehensive assessment, including precise visual acuity measurement, detailed refraction (both cycloplegic and non-cycloplegic), anterior segment examination, pupillary evaluation, fundoscopy, and comprehensive binocular vision assessment. If necessary, additional tests like tonometry and visual field assessment should be performed to rule out underlying conditions that could affect visual function.

All treatable visual signs, such as refractive conditions, amblyopia, cataract, strabismus, and gaze/motility abnormalities, should be addressed to optimize the use of remaining functional vision. Early identification of such defects is crucial for instituting therapies in cases amenable to treatment. Accurate management of refractive errors is particularly important for managing visual impairment.[26] In cases where vision restoration is not possible, children should undergo visual rehabilitation. Vision therapy plays a significant role in rehabilitating children and enhancing overall quality of life for children with developmental disorders who have concurrent visual abnormalities. Along with motor and perceptual defects, refractive conditions are often concurrent with many systemic and ocular anomalies. Among these conditions, cerebral palsy (CP) presents a high prevalence of oculo-visual deficits. A meta-analysis by Heydarian et al. estimated ocular manifestation to range from 34 to 100% among patients with CP,[27] comparable to the finding of 78.05% by Bala et al.[28] These statistics remind the eye care professional to be vigilant on assessment of visual functions to detect subtle visual impairments early on. Although different literatures report varying frequencies of myopia prevalence among children with CP, most studies agree upon greater prevalence of myopia, followed by hypermetropia and astigmatism (12.9%, 8.6%, and 3.6%, respectively).[29] Many studies also agree that refractive conditions, strabismus, and nystagmus are the major culprits for subnormal visual functions in these groups.[27,28] Uncorrected refractive conditions are thought to be an important cause of poor academic performance and high dropout from school.[30]

During emmetropization, the crystalline lens and corneal curvatures mold themselves, thus compensating for the increasing axial length, but this natural phenomenon is disrupted in CP through neurological damage, leading to significant refractive conditions.[31] With the high prevalence of strabismus, greater load is owed to alternating exotropia.[32,33] While alternating exotropia is more commonly prevalent in CP, some studies report a higher prevalence of esodeviation,[34] with prevalence ranging from 9 to 54%.[34] Contradicting the theories of lesions in subcortical and cortical motor and visual circuits responsible for strabismus among children with CP, Herron et al. considered genetic factors to be responsible for horizontal deviations, with greater frequency of exotropia among Caucasians and eso-deviation among Asian and African populations.[35]

Autism Spectrum Ddisorder (ASD), a neurodevelopmental disability characterized by impaired communication, restricted interest, and repetitive behavior, affects approximately 27.6 per 1000 children aged 8 years.[36] Research indicates elevated risk of visual impairment in the presence of ASD.[37] Impaired neuronal migration in ASD has been linked to co-existing ocular conditions. For instance, 1 in 28 individuals with oculo-cutaneous albinism has been diagnosed with ASD.[38] The frequency of astigmatism in ASD is 14.1%, with lower prevalence of simple myopia and hyperopia (14.1% and 9.8%, respectively).[39] In contrast to these findings, some studies report greater prevalence of hypermetropia alongside astigmatism,[40,41] with variable rates of exotropia and esotropia. Amblyopia and anisometropia can also be frequently observed in children with ASD. As visual acuity seems to be equally affected in visually impaired children with and without ASD, other dimensions of vision need to be assessed. When done so, accommodative insufficiency, reduced stereoacuity, and diminished color vision and contrast sensitivity have been identified.[42] A meta-analysis even projected strabismus to be prevalent with an odds ratio of 4.72 in children with ASD.[42]

Beyond strabismus and refractive error, non-strabismic binocular vision anomalies are also commonly present in children with developmental delay. For instance, a greater prevalence of convergence insufficiency (CI) has been associated with ADHD,[43] and accommodative insufficiency has been associated with ASD.[44] An apparent three-

fold greater incidence of CI has been reported in the ADHD population.[43] This neurodevelopmental disorder impacting 8% of children and adolescents, with bipartite prevalence among boys, tends to affect physiological functioning of the eyes rather than the anatomical structures,[45] as evidenced by the absence of significant variation of RNFL thickness and ganglion cell complex.[46] Bellato et al. reported that children with ADHD exhibit reduced color vision and contrast functions, albeit the association with astigmatism for this was less pronounced than anticipated.[42] As neuronal synapse is essential for visual development, the faulty neuronal processing (neural ectoderm-derived retinal cells[46]) among ADHD patients aids in the alteration of the sensory or perceptual domain of vision[42] rather than anatomical disfigurement being responsible for motor anomalies and significant refractive error. Contrarily, the error in voluntary eye movement causing marked reduction in memory-guided saccades and visually guided saccades can also be linked to altered cerebellar function.[47] Hence, these neurological underpinnings are essential for conceptualizing the pathophysiology of ocular abnormalities in developmental disorders.

Oculomotor dysfunction in children with developmental delays is not uncommon.[48] Congenital cataract and sensory nystagmus is also common in children with developmental disorder.[6] Some children may also present with visual field defects. The major causes of visual impairment in children with developmental delays include, but are not limited to, cerebral visual impairment, cortical blindness, optic atrophy, retinal dystrophies, and congenital nystagmus.[19] Oculo-visual deficits may also manifest as glaucoma, proptosis, disc hypoplasia, microcornea, persistent hyperplastic primary vitreous (PHPV), iridocorneal endothelial syndrome, and cone dystrophy.[6]

Visual signs in developmental delay must not be confused with delayed visual maturation, which subsequently improves without any treatment. Misinterpreting these signs can lead to missed opportunities for early diagnosis and appropriate management. Therefore, routine ophthalmic screening should be an integral part of the multidisciplinary care approach for children with developmental delays, ensuring that visual impairments are promptly identified and managed to optimize their overall development. Collaborative efforts of occupational therapists and optometrists are indispensable for providing a better lifestyle for children with developmental delay, as motor coordination attaining body balance and laterality is essential for enhancing visual performance.[48] A child with developmental disabilities relying on their visual input rather than auditory input is believed to have better quality of life.[48] Thus, it is essential to provide visual rehabilitation through in-office vision therapy, with the aim of improving oculomotor dysfunction, binocular vision, and accommodation and uplifting the gross motor coordination of the children. Vision therapy can offer significant benefits enhancing visual perceptual skills but also improves overall quality of life in these children. However, vision therapy for children with developmental disabilities requires specific adaptations to accommodate their unique needs, behavior, and cognition.[49] Children with developmental delays may have physical limitations that can hinder their participation in vision therapy activities. Hence, therapists need to be creative in adapting activities to suit individual abilities. Moreover, therapy sessions may need to be sequenced differently based on the child's behavior and cognitive level. Initiating monocular activity followed by binocular therapy is expected to be effective for the disrupted motor coordination of children with developmental disabilities.[48] A proper visual environment is obligatory for adaptation, thus in-office vision therapy is suggested rather than home activities. Working on laterality and voluntary eye movement has proven to be effective in improving overall visual perceptual skill among patients with developmental disabilities.[48] Achieving progress in vision therapy for children with developmental delays may take longer compared to normally developing peers and hence will require more patience, consistency, and a highly individualized approach.

Conclusion

In conclusion, vision plays an integral role in a child's overall development, influencing not only vision, but also cognitive, motor, and social growth. Children with developmental delays often exhibit a high prevalence of oculo-visual deficits, which can significantly impact learning, coordination, and quality of life. Early detection and integrated intervention, such as vision therapy and multidisciplinary collaboration, become non-negotiable in addressing these challenges, where eye care professionals play a substantial role. It is important to recognize that these children are not fundamentally different; they simply require additional attention and care. With the right support and rehabilitation, their developmental

outcomes can be similar to that of their typically developing peers.

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