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Neurological Insights and Modern Interventions in Strabismus: A Comprehensive analysis of Screening, Diagnosis, and Treatment

Shivam Chandra BS[1], Arjun Saini[1], James Keane DO[1], Leonard B. Goldstein DDS, PhD[2]*

[1]*School of Osteopathic Medicine in Arizona, A.T. Still University, Mesa, Arizona, USA.*
[2]*University Mesa, Arizona and A.T. Still University, Mesa, Arizona, USA.*
**Corresponding author: Leonard B. Goldstein.*

Abstract

Strabismus a prevalent ocular disorder marked by eye misalignment, poses a significant concern, especially among children. This condition harbors not just mechanical implications but substantial neurological components as well. Reduced Voxel-mirrored homotopic connectivity (VMHC) in children with strabismus accentuates impaired interhemispheric connectivity, suggesting a compromised neural basis. This literature review, spanning from 1999 to 2023, elucidates the American Academy of Ophthalmology's recommendations for pediatric vision screenings, underscoring the importance of early diagnosis and intervention. Modern diagnostic tools, such as mobile applications and the Stereo Butterfly test, alongside advancements in surgical techniques, offer promising avenues for early detection and effective treatment. Emphasizing the neurological underpinnings, the findings advocate for a multi-faceted approach to strabismus, merging mechanical understanding with neurological insights. Early identification and intervention can pave the way for improved outcomes, potentially preventing irreversible vision loss in affected children.

Keywords: screening; diagnosis; treatment; neurological insights; strabismus; children

Introduction

Strabismus is a common ocular disease characterized by misalignment of the eyes when focusing on an object [1]. Strabismus often occurs in children because of their underdeveloped visual maturity. A longitudinal population-based study, around 1 in every 20 children suffer from strabismus.[1] In young children, strabismus usually occurs spontaneously, and children with a family history of strabismus are at increased risk of having this condition [1]. Strabismus that develops in adulthood could be linked to various factors, such as head trauma, stroke, brain tumor, thyroid disorders (Grave's Disease), diabetes, Myasthenia Gravis, or injury to an eye muscle during eye surgery [2,3,4,5]. Early and accurate diagnosis is essential for better management of this condition. The goals of strabismus evaluation and management include quantifying the squint, assessing the binocular status, establishing the diagnosis, and determining amblyopia [6]. In fact, this last step is particularly important because amblyopia can lead to irreversible vision loss [7,8]. Moreover, it is also important to catch signs of strabismus while the muscles are developing within the child. Therefore, strabismus screening has become essential as a first step to facilitate early diagnosis and prevent the deterioration of eyesight.

Anatomically, positioning of the extraocular muscles determines the mechanical effect on the ocular globe of the eye [9]. Further, eye movements can be affected by the rapidly changing anatomy of the world. Therefore, an eye muscle's ability to counteract the forces generated by other extraocular muscles will depend on how close its origin and insertion are to one another [9]. If origin and insertions are abnormally close, muscles may develop a shorter resting length that results in resistance to lengthening. Since mechanical energy is needed to contract against the forces of opposing muscles, the eye can become fatigued, and the focus may drift away from the target [9]. When restrictive barriers from the contraction of extraocular muscles exist, then strabismus can occur [9].

Methods

The purpose of this literature to describe the existing literature regarding the American Academy of Ophthalmology's current recommendations for child vision screening to prevent vision loss caused by strabismus. A comprehensive literature review was conducted to explore the current screening recommendations, diagnostic techniques, and treatment options for strabismus in children. The review encompassed relevant studies published between 1999 and 2023, and the search process included databases such as PubMed, Medline, Embase, and the Cochrane Library, from their inception up to April 2023. The search terms used were “strabismus”, “amblyopia”, “eye misalignment”, “vision screening”, “early diagnosis”, “treatment”, and “children”.

The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a systematic and transparent approach. Initially, one author screened the titles and abstracts of the identified articles, and subsequently, both authors independently conducted a full-text screening. Any discrepancies in study inclusion were resolved through discussion and consensus. For each study included, data extraction was performed to gather relevant information, such as author(s), year of publication, sample size, diagnostic methods utilized, treatment options assessed, and reported outcomes. This data extraction process aimed to capture key details from each study for a comprehensive synthesis. The findings of the literature review were then summarized and synthesized narratively, adhering to the guidelines for narrative synthesis in systematic reviews. The emphasis was placed on presenting a comprehensive overview of the current screening recommendations, diagnostic techniques, and treatment options available for strabismus in children. The main objective of this review was to identify recommended guidelines aligned with the American Academy of Ophthalmology, procedures for correcting strabismus, and factors contributing to the underdiagnosis of strabismus. By reviewing articles spanning from 1999 to 2023, the aim was to gather a comprehensive understanding of the current state of knowledge in this field and provide valuable insights for clinical practice and future research.

Results

As per the prevailing guidelines from the American Academy of Ophthalmology, children are recommended to undergo screenings for eye disorders at the following ages: at birth, between 6 to 12 months, from 12 to 36 months, and from 3 to 5 years [10].

When a child is a newborn, their blink and pupil reactions are assessed during the initial screening [10]. The child’s eyes are examined for proper alignment and movement during the period from 6 to 22 months [10]. Then, from 12 to 36 months, an evaluation of the child's eye development is carried out, possibly including a photo screening test [10]. This test employs a specialized camera to capture images of the child's eyes, aiding in the detection of amblyopia [10]. Any suspicions of amblyopia should prompt a referral to an ophthalmologist [10]. Between the ages of 3 to 5 years, the child's vision and eye alignment are assessed once again. [10]. If conditions such as strabismus or amblyopia are detected, prompt treatment initiation is vital to safeguard the child's vision.10 Post 5 years of age, the child's visual acuity and alignment should be re-evaluated.10 Adherence to these guidelines is crucial for parents to maintain consistent monitoring of their child's eye health [10]. For communities to adhere to these guidelines in order to reduce the prevalence of strabismus is crucial. By following these protocols, primary care physicians can ensure early detection of strabismus in children, leading to more positive outcomes for strabismus surgery at a younger age [11]. Recent developments in ocular misalignment detection include mobile applications such as Eye Turn [12]. This application has been employed in school screenings to capture diagnostic measurements, which are subsequently reviewed by an ophthalmologist [12]. In a recent study, researcher(s) found that Eye Turn yielded successful measurements 93% of the time [12]. Another diagnostic tool available for strabismus detection is the Stereo Butterfly test [13]. In this test, patients wearing polarized glasses are shown an image of a butterfly from a 16-inch testing distance [13]. If the patient sees the butterfly, they are unlikely to have strabismus [13]. However, if they perceive something different, referral to an ophthalmologist is recommended [13]. This test boasts a sensitivity rate of 96% for strabismus detection, but it may result in false positives if used in isolation [13]. Both of these detection options can be seamlessly incorporated into annual school screenings, allowing early detection of strabismus before the age of VI, when surgical outcomes are more promising [11]. This approach not only aids in preventing strabismus but also promotes community education about ocular disorders, stressing the importance of ophthalmological consultations for such conditions when detected by schoolteachers.

The light reflex method is another effective means of diagnosing strabismus in children [14]. A physician estimates ocular deviation by shining a hand light into the center of the eye [14]. If the light fixates on the fovea, strabismus can be ruled out [14]. However, if the light deviates to the fovea's periphery, a strabismus diagnosis should be considered [14]. An alternative clinical method involves placing a prism over one eye to center the deviated eye [15]. The magnitude of the prism needed to align the vision is used to estimate the size of the eye misalignment [15]. These two diagnostic tools should be emphasized in medical education, especially family practice and pediatric medicine. Studies have shown that many primary care physicians lack adequate knowledge about diagnosing strabismus [16]. Therefore, making appropriate referrals to ophthalmologists when necessary is crucial.

Treatment Options

Strabismus surgery is a commonly employed treatment method, which involves making an incision and passing a suture around a muscle pole [17]. The suture is tied in a bow formation and later readjusted to position the muscle correctly. Once the desired alignment is achieved, the bow is transformed into a square knot [17]. Suture adjustments may be performed within the first 24 hours after surgery for optimal outcomes [17]. Modern imaging technologies, such as anterior chamber optical coherence tomography and ultrasonic biomicroscopy, have revolutionized surgical planning by providing noninvasive and cost-effective methods to identify muscle insertions in strabismus cases [17]. These imaging techniques eliminate the need for radiation exposure associated with traditional methods like computed tomography scans [18]. These modern imaging technologies are valuable tools in the field of strabismus surgery because the technologies offer several advantages, including the absence of radiation effects on the eye and the ability to provide extreme precision in making incisions. The precise visualization and measurements provided by these imaging techniques significantly reduce the margin of error, enabling surgeons to perform surgeries with enhanced accuracy and precision [18].

Neurological Basis of Strabismus

Recent studies have delved deeper into the neurological underpinnings of strabismus and amblyopia. One such study compared the interhemispheric functional connectivity in children with strabismus and amblyopia (CSA) to normal controls (NCs) [19]. The findings underscored decreased VMHC (Voxel-mirrored homotopic connectivity) in specific regions like the bilateral cerebellum, bilateral frontal superior orbit, bilateral temporal inferior, and bilateral frontal superior in the CSA group [19]. This suggests potential impaired interhemispheric connectivity in children with these conditions. The cerebellum's significant role in eye movement coordination was accentuated, and the reduced VMHC might signify compromised motor control in the CSA children [19]. Moreover, areas crucial for visual selectivity, memory, and language processing like the temporal inferior region and the frontal superior orbit showed decreased VMHC, hinting at potential visual and linguistic challenges in these children [19].

Such insights into the neurologic mechanics of strabismus and amblyopia suggest potential new treatment avenues. The idea that VMHC values might act as diagnostic markers for CSA is particularly intriguing [19].

Returning to the broader discourse on strabismus, it's evident that while the current recommendations of the American Academy of Ophthalmology are of utmost importance, the evolution in our understanding of strabismus and amblyopia, especially from a neurological perspective, could revolutionize treatment strategies and diagnostic protocols. The neurological underpinnings of strabismus are crucial to understanding the condition. While strabismus is often viewed primarily as a physical misalignment of the eyes, there's a strong neurological component involved. Strabismus, at its core, involves a disruption in the coordination between the two eyes, a process that is governed by the brain.

The decreased VMHC (Voxel-mirrored homotopic connectivity) observed in certain regions such as the bilateral cerebellum, bilateral frontal superior orbit, and others in children with strabismus suggests that there is an impaired interhemispheric connectivity [19]. The cerebellum, which plays a pivotal role in eye movement coordination, is especially relevant here [19]. Reduced VMHC might mean that there's compromised motor control in children with strabismus [19]. The implications of these findings could be groundbreaking. If VMHC values can indeed act as diagnostic markers for strabismus, this could pave the way for earlier and more accurate diagnosis. Building upon the findings of altered VMHC in specific brain regions, interventions that aim to boost neuroplasticity may help restore the neural deficits associated with strabismus and amblyopia. Neurofeedback, transcranial magnetic stimulation (TMS), and repetitive transcranial direct current stimulation (rTDCS) could be explored as potential treatments to modulate neural activity and strengthen connectivity.

Discussion

In dissecting the literature on strabismus, acknowledging that a rigorous review has exposed varying degrees of strengths and limitations among the existing studies. By evaluating the methodological integrity and the consistency of the outcomes, the medical world has gained insights into the knowledge gaps that necessitate attention. A notable void is the sparse discourse on the roles of parents, caregivers, and teachers in early detection and guideline adherence, and the strategies to enhance patient adherence, particularly in the pediatric population [16]. A demand also exists for broader discussion on recent advancements in the field, encompassing novel diagnostic tools, treatment modalities, and preventative strategies. In addition, the necessity for solid statistical analysis, such as meta-analysis, providing a statistical summary of the effectiveness of varied diagnostic techniques and treatments, is of paramount importance.

The current recommendations of the American Academy of Ophthalmology for pediatric vision screenings to avert vision loss induced by strabismus should be emphasized. Managing strabismus offers substantial benefits, including enhancing patients' capacity to connect with others, owing to our natural tendency to focus on the eyes during initial interactions. Prompt detection and intervention of strabismus can re-establish binocular vision, thus facilitating accurate depth perception and the elimination of double vision [20]. It also corrects abnormal head position and expands the visual field. Increased awareness and early identification of strabismus may reduce the likelihood of pediatric vision loss. Strabismus and cataracts rank among the top causes of pediatric visual impairment, with the best corrective outcomes observed in patients treated before the age of XII, thereby lowering the risk of visual impairment [20]. Given the widespread availability of mobile applications for strabismus screening, educators are recommended to be trained to screen for this condition, using the processes stipulated by the American Academy of Ophthalmology. Early detection and intervention are essential to forestall future vision loss.

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