Evidence-Based Clinical Practice Guideline

Comprehensive Pediatric Eye and Vision Examination

AMERICAN OPTOMETRIC ASSOCIATION

OPTOMETRY: THE PRIMARY EYE CARE PROFESSION

The American Optometric Association represents approximately 39,000 doctors of optometry, optometry students and paraoptometric assistants and technicians. Optometrists serve individuals in nearly 6,500 communities across the country, and in 3,500 of those communities are the only eye doctors. Doctors of optometry provide two-thirds of all primary eye care in the United States.

Doctors of optometry are on the frontline of eye and vision care. They examine, diagnose, treat, and manage diseases and disorders of the eye. In addition to providing eye and vision care, optometrists play a major role in an individual's overall health and well-being by detecting systemic diseases such as diabetes and hypertension.

The mission of the profession of optometry is to fulfill the vision and eye care needs of the public through clinical care, research, and education, all of which enhance the quality of life.

Disclosure Statement

This Clinical Practice Guideline was funded by the American Optometric Association (AOA) without financial support from any commercial sources. The Evidence-Based Optometry Guideline Development Group and other guideline participants provided full written disclosure of conflicts of interest prior to each meeting and prior to voting on the quality of evidence or strength of clinical recommendations contained within this guideline.

Disclaimer

Recommendations made in this guideline do not represent a standard of care. Instead, the recommendations are intended to assist the clinician in the decision-making process. Patient care and treatment should always be based on a clinician's independent professional judgment, given the patient's circumstances, and in compliance with state laws and regulations.

The information in this guideline is current to the extent possible at the time of publication.

COMPREHENSIVE PEDIATRIC EYE AND VISION EXAMINATION

Developed by the AOA Evidence-Based Optometry Guideline Development Group

Approved by the AOA Board of Trustees February 12, 2017

243 N. Lindbergh Blvd., St. Louis, MO 63141-7881

TABLE OF CONTENTS

EVIDENCE-BASED CLINICAL GUIDELINES

A. WHAT IS THE EVIDENCE-BASED PROCESS?

As a result of the Medicare Improvement for Patients and Providers Act of 2008, Congress commissioned the Secretary of Health and Human Services to create a public-private program to develop and promote a common set of standards for the development of clinical practice guidelines (CPGs). These standards address the structure, process, reporting, and final products of systematic reviews of comparative effectiveness research and evidence-based clinical practice guidelines.

The Institute of Medicine (IOM), now the Health and Medicine Division of the National Academies of Sciences, Engineering, and Medicine (NASEM), in response to a request from the Agency for Healthcare Research and Quality (AHRQ), issued two reports in March 2011: *Clinical Practice Guidelines We Can Trust and Finding What Works in Health Care: Standards for Systematic Reviews*.

In *Clinical Practice Guidelines We Can Trust*,[1] the IOM redefined CPGs as follows

> *"Clinical practice guidelines are statements that include recommendations intended to optimize patient care that are informed by a systematic review of the evidence and an assessment of the benefits and harms of alternative care options."*

The report states that to be trustworthy, guidelines should:

- Be based on a systematic review of existing evidence
- Be developed by a knowledgeable, multidisciplinary panel of experts and key stakeholders
- Consider important patient subgroups and preferences, as appropriate
- Be based on a transparent process that minimizes conflicts of interest and biases
- Provide a clear explanation of the logical relationships between alternative care options and health outcomes
- Provide a grading of both the quality of evidence and the strength of the clinical recommendation
- Be revised as appropriate when new evidence warrants modifications of recommendations.

Based on the IOM/NASEM reports, the American Optometric Association (AOA) Evidence-Based Optometry (EBO) Committee developed a 14-step process to meet the new evidence-based recommendations for trustworthy guidelines.

AOA's 14 Steps to Evidence-Based Clinical Practice Guideline Development
1. **Guideline Development Group:** Evidence-Based Optometry (EBO) Committee selects a multidisciplinary panel of experts, including patient and public representatives, for the Guideline Development Group (GDG).
2. **Transparency and COI:** GDG manages all conflict of interest (COI), which is documented by AOA staff.
3. **Clinical Questions*:** GDG explores and defines all clinical questions through a Question Formulation Meeting and defines search criteria.
4. **Search for Evidence:** AOA Staff sends clinical questions for query (outside researchers) and provides all papers to the Guideline Development Reading Group (GDRG). There should be no inclusion of Systematic Review (SR) writers in the GDRG.
5. **Grade Evidence and Clinical Recommendations:** Two clinicians from the GDRG read and grade papers, randomly selected according to the pre-designed evidence search criteria. They state clinical recommendation(s) from each paper and grade the strength of each.
6. **Articulate Clinical Recommendations*:** GDRG reviews all clinical recommendations and articulates each for inclusion in the guideline during an "Articulation of Recommendations" meeting and identified gaps in medical research are documented.
7. **Write Draft:** AOA Staff sends the Articulation results to the writer for development of draft 1.
8. **Draft Review and Edits*:** GDG reads draft 1, discusses and edits.
9. **Rewrite/Final Drafts:** AOA Staff sends the draft results to the writer for writing/revisions for draft 2, then sends to medical editor for copy editing, then a final review is completed as necessary.
10. **Approval for Peer Review:** AOA Staff or EBO Committee Chair sends the Peer Review draft to AOA Board of Trustees for approval to post for peer and public review. This draft is posted on the AOA website, the review period is announced, and comments are solicited.
11. **Final Document Produced:** GDG reviews all peer review comments and revises the final document (includes peer review comments, documents why a peer review comment was not included, or identifies further gaps for review when preparing the next edition).
12. **Final Draft Approval and Legal Review:** AOA Staff or EBO Committee Chair sends to the AOA Board of Trustees and AOA Legal Counsel for approval that the GDG followed the evidence-based process as outlined by the IOM and AOA EBO Committee (same management of COI).
13. **Post Guidelines:** AOA Staff posts the evidence-based guideline to AOA website and submits it to the National Guideline Clearinghouse for public use, accompanied by AOA's written process and documents.
14. **Schedule Reviews:** GDG reviews all previously identified gaps in medical research and any new evidence, and revises the evidence-based guideline every 2 to 5 years. ***Denotes face-to-face meeting*

B. HOW TO USE THIS GUIDELINE

The following table provides the grading system used in this guideline for rating evidence-based clinical statements. Grades are provided for both quality of the evidence and strength of clinical recommendations.

Key to Quality of Evidence and Strength of Clinical Recommendation Grading	
Grade	**Quality of Evidence Levels**
A	Data derived from well-designed, randomized clinical trials (RCTs); systematic reviews; meta-analyses; or diagnostic studies (Grade A) of relevant populations with a validated reference standard. Grade A diagnostic studies do not have a narrow population or use a poor reference standard and are not case control studies of diseases or conditions.
B	Randomized clinical trials (RCTs) with weaker designs; cohort studies (retrospective or prospective); or diagnostic studies (Grade B). Grade B diagnostic studies have only one of the following: a narrow population, or the sample used does not reflect the population to whom the test would apply, or uses a poor reference standard, or the comparison between the test and reference standard is not blinded, or are case control studies of diseases or conditions.
C	Studies of strong design, but with substantial uncertainty about conclusions or serious doubts about generalizations, bias, research design, or sample size. Nonrandomized trials; case control studies (retrospective or prospective); or diagnostic studies (Grade C). Grade C diagnostic studies have at least 2 or more of the following: a narrow population, or the sample used does not reflect the population to whom the test would apply, or uses a poor reference standard, or the comparison between the test and reference standard is not blinded, or are case control studies of diseases or conditions.
D	Cross sectional studies; case reports/series; reviews; position papers; expert opinion; or reasoning from principal.
Strength of Clinical Recommendation Levels	
Strong Recommendation: The benefits of the recommendation clearly exceed the harms (or the harms clearly exceed the benefits in the case of a negative recommendation) and the quality of evidence is excellent (Grade A or B). In some clearly identified circumstances, a strong recommendation may be made on lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits strongly outweigh the harms. *This recommendation should be followed unless clear and compelling rationale for an alternative approach is present.*	
Recommendation: The benefits of the recommendation exceed the harms (or the harms exceed the benefits in the case of a negative recommendation) but the quality of evidence is not as strong (Grade B or C). In some clearly identified circumstances, a recommendation may be made on lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits strongly outweigh the harms. *This recommendation should generally be followed, but remain alert for new information.*	
Option: The benefits of the recommendation exceed the harms (or the harms exceed the benefits in the case of a negative recommendation) but the quality of evidence is low (Grade D) or well-done studies (Grade A, B, or C) show little clear advantage of one approach versus another. In some clearly identified circumstances, an option may be elevated to a recommendation even with lesser evidence when high-quality evidence is impossible to obtain and the anticipated benefits strongly outweigh the harms. *There should be an awareness of this recommendation, but a flexibility in clinical decision-making, as well as remaining alert for new information.*	

Clinical Notes and Statements

Quality of evidence grades (A, B, C, or D) are shown throughout the guideline for clinical notes and statements. For example, a clinical note or statement with a quality of evidence grade of "B" is shown as "(Evidence Grade: B)".

Evidence-Based Action Statements will be highlighted in an "Action" box, with the quality of evidence, level of confidence, and clinical recommendation grading information listed. For example:

<table>
<tr><td colspan="2">EVIDENCE-BASED ACTION STATEMENT: Parents/caregivers and children should be educated about potential risks for eye injuries at home, at school, and during sports and recreational activities and advised about safety precautions to decrease the risk of ocular injury.[193,199] Prevention of eye injuries in children should focus on the use of protective eyewear, parental supervision, and on education about both the risks of eye injury and the benefits of protective eyewear.[194]</td></tr>
<tr><td colspan="2">Evidence Quality: Grade B: Retrospective cohort studies
Level of Confidence: Medium
Clinical Recommendation Strength: Strong Recommendation. This recommendation should be followed unless clear and compelling rationale for an alternative approach is present.</td></tr>
<tr><td colspan="2">Evidence Statements: It is important to discuss eye safety issues with children/ parents/caregivers.[193] (Evidence Grade: B),[199] (Evidence Grade: B)

Prevention strategies should focus on the use of protective eyewear, parental supervision, and on childhood education about both the risks of eye injury and the utility of protective eyewear.[194] (Evidence Grade: B)</td></tr>
<tr><td>Potential Benefits: Reduction in eye injuries in children</td><td>Potential Risks/Harms: None</td></tr>
<tr><td colspan="2">Benefit and Harm Assessment: Benefits significantly outweigh harms</td></tr>
<tr><td colspan="2">Potential Costs: Direct cost of counseling as part of a pediatric eye and vision examination</td></tr>
<tr><td colspan="2">Value Judgments: None</td></tr>
<tr><td colspan="2">Role of Patient Preferences: None</td></tr>
<tr><td colspan="2">Intentional Vagueness: Specific type/form of counseling is not stated, as it is patient specific</td></tr>
<tr><td colspan="2">Gaps in Evidence: None identified</td></tr>
</table>

The Action Statement profile provides additional information related to the development and implementation of the clinical recommendation. The following is an explanation of the categories listed in the profile:

Evidence Quality – The quality of evidence grade (A, B, C, or D) or the aggregate quality of evidence grade (if multiple studies were available for review) and the type/method of research study or studies reviewed.

Level of Confidence – The consistency of the evidence and the extent to which it can be trusted specified as high, medium, or low.

Clinical Recommendation Strength – The grade (Strong Recommendation, Recommendation, or Option) assigned to the implementation of the clinical recommendation made in the Action Statement.

Evidence Statements – The clinical statements derived from research studies reviewed that support the Action Statement.

Potential Benefits – Favorable changes which would likely occur if the Action Statement was followed.

Potential Risks/Harms – Adverse effects or unfavorable outcomes that may occur if the Action Statement was followed.

Benefit and Harm Assessment – A comparison of the relationship of benefits to harms specified as "benefits significantly outweigh harms" (or vice versa) or a "balance of benefits and harms."

Potential Costs – Direct and indirect costs refer to the costs of the procedure, test, or medication; time spent counseling the patient; administrative time; parent/caregiver time off from work, etc.

Value Judgments – Determinations made by the Guideline Development Group in the development of the Action Statement relating to guiding principles, ethical considerations, or other priorities.

Role of Patient Preference – The role the patient has in shared decision making regarding implementation of the Action Statement specified as large, moderate, small, or none.

Intentional Vagueness – Specific aspects of the Action Statement that are left vague due to factors such as the role of clinical judgment, patient variability, concerns over setting legal precedent, etc.

Gaps in Evidence – Areas identified during searches and evaluations of the research that show gaps in available evidence.

Consensus-Based Action Statements, based on consensus by the Guideline Development Reading Group, are also highlighted in an "Action" box, but without any quality of evidence or strength of clinical recommendation grading information listed. For example:

CONSENSUS-BASED ACTION STATEMENT: At the conclusion of a comprehensive pediatric eye and vision examination, the diagnosis should be explained to the patient/parent/caregiver and related to the patient's symptoms, and treatment plans and prognosis discussed.
Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.
Benefit and Harm Assessment: Implementation of this recommendation is likely to increase patient/parent/caregiver understanding of any diagnosed eye or vision problems and improve compliance with any recommended treatment. The benefits of this recommendation were established by expert consensus opinion.

I. INTRODUCTION

Eye and vision problems in children are a significant public health concern. An estimated one in five preschool children have vision problems.[2-8] In the United States, about one in four school-age children wear corrective lenses.[9] Since eye and vision problems can become worse over time, early diagnosis and treatment are essential to optimize children's eye health and vision and to prevent future vision loss.

Eye and vision disorders can lead to problems in a child's normal development,[10,11] school performance,[12-16] social interactions,[17] and self-esteem.[17-19] Vision disorders that occur in childhood may manifest as problems well into adulthood, affecting an individual's level of education, employment opportunities, and social interactions.[20]

Early recognition of visual disorders is especially important in children with developmental and intellectual disabilities.[21,22] Children with disabilities are reported to have significantly more eye and vision problems (e.g., strabismus, refractive errors, and nystagmus) than children without these disabilities.[22-27] The increasing severity of the disability may be related to a higher prevalence of vision problems.

This Evidence-Based Clinical Practice Guideline for the Comprehensive Pediatric Eye and Vision Examination describes procedures for evaluation of the eye health and vision status of infants and children. It contains recommendations for timely diagnosis and, when necessary, referral for consultation with, or treatment by, another health care provider. Other guidelines developed to address treatment of specific eye and vision conditions can be found at *AOA Clinical Practice Guidelines web page*.

The recommendations in this guideline were developed to assist doctors of optometry and ophthalmologists involved in providing eye and vision examinations for infants and children. Others who assist in providing coordinated patient care for specific services, as well as patients, parents, and caregivers, may also gain insight from this document.

A. GUIDELINE OBJECTIVES

This Guideline can help achieve the following objectives:

- Recommend an optimal timetable for comprehensive eye and vision examinations for infants and children (newborn through 18 years of age)
- Suggest appropriate procedures to effectively examine the eye health, vision status, and ocular manifestations of systemic disease of infants and children
- Reduce the risks and adverse effects of eye and vision problems in infants and children through prevention, education, early diagnosis, treatment, and management
- Inform and educate patients, parents/caregivers, and other health care providers about the importance of eye health and good vision, and the need for and frequency of pediatric eye and vision examinations.

II. BACKGROUND

A. VISUAL DEVELOPMENT

Development of the visual system begins prenatally and continues after birth.[28] Basic visual functions develop rapidly during the first year of life. By 6 months of age, vision has become the dominant sense and forms the basis for perceptual, cognitive, and social development;[29] however, maturation of the visual system continues for several years. From birth to about 6 years of age, the visual system is susceptible to vision conditions that cause either blurred visual input or abnormal binocular interaction such as interference from amblyogenic bilateral refractive error, amblyogenic anisometropia, constant unilateral strabismus, congenital cataracts, hemangioma, corneal scarring, and any other condition that obstructs vision. This interference can lead to amblyopia, which, if left untreated, can cause serious vision loss.

Objective testing (visual evoked response) demonstrates that the visual cortex is capable of achieving 20/20 visual acuity by 6 months of age;[30] however, the ability of a child to respond to subjective visual acuity tests is influenced by verbal and cognitive development. For

some children, it may not be possible to elicit 20/20 visual acuity until after 5 years of age; therefore, it is critical to select age appropriate tests. Stereopsis first appears at 3 to 4 months of age and continues to develop through the first two years of life.[31, 32] Mature accommodative behavior is present at 5 to 24 months of age.[33] Development of accommodative facility, vergence ability, and eye movements continues in the preschool and school-age years.[34-37]

B. EPIDEMIOLOGY OF EYE AND VISION DISORDERS IN CHILDREN

There are many visual conditions and ocular or systemic diseases, which may occur in childhood that can affect visual development. Eye and vision disorders experienced by infants and children may include:

- **Refractive errors**

Refractive errors (hyperopia, myopia, astigmatism, and anisometropia) are the most common causes of correctable reduced vision in children.[38, 39] Estimates of refractive errors in children 6 months to 72 months (6 years) of age are shown in Table 1.

Hyperopia has a high prevalence among young children up to 5 years old, with over 20% estimated to have ≥2.00 diopters (D).[2,3] Hyperopia (≥2.00D) is found to be a significant risk factor for the development of strabismus[40] and amblyopia[41] up to 5 years of age.

Myopia generally develops in children during their early school years and increases in magnitude, as they get older. The age at onset typically ranges from 7 to 16 years. In the Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error Study (CLEERE), one in six children ages 5 to 16 (Asian, Hispanic, African American, Native American and White) developed myopia during their school-age years. More than 75% of the new cases of myopia occurred between the ages of 9 and 13.[42]

Among school-age children, the prevalence of myopia has been increasing in recent years and developing at a younger age.[42,43] The National Health and Nutrition Examination Survey results for 12 to 17 year olds show the prevalence of myopia increased from 24% in 1971-1972 to 33.9% in 1999-2004[44] and it continues to rise.

High levels of myopia can contribute to the development of lattice degeneration, retinal holes, tears, or detachment, cataracts, glaucoma, and myopic macular degeneration.[45,46]

Astigmatism up to 2.00D is common in children under 3 years of age. Studies show that 30 to 50% of infants less than 12 months of age have astigmatism (≥1.00D), which declines over the first few years of life, and becomes stable by approximately 2 1/2 to 3 years of age.[47, 48]

Anisometropia of 1.00D or more is considered clinically significant. There is a low prevalence (4%) of anisometropia before 6 years of age;[49] however, it has been shown to increase to nearly 6% at 12 to 15 years of age. Infantile anisometropia can be transient and may decrease; however, severe anisometropia (≥3.00D) may persist and is likely to lead to the development of amblyopia during the preschool years.[50, 51]

Table 1: Prevalence of Refractive Errors in Children 6 Months to 72 Months (6 Years) of Age

Condition	White Non-Hispanic	Hispanic	African American	Asian
Myopia				
≤1.00D spherical equivalent (SE)	1.2%	3.7%	6.6%	4.0%
≥1.00D SE	0.7%		5.5%	
Hyperopia				
≥2.00D SE	25.7%	26.9%	20.8%	13.5%
≥3.00D SE	8.9%		4.4%	
Astigmatism				
≥1.50D cylindrical refractive error	6.3%	16.8%	12.7%	8.3%
≥3.00D cylindrical refractive error		2.9%	1.0%	
Anisometropia				
≥1.00D SE		4.3%	4.2%	

Source: Multi-Ethnic Pediatric Eye Disease Study[2-4,49] and the Baltimore Pediatric Eye Disease Study[5]

(Note: The ethnicity of children reported in Tables 1, 2, 3 and 4 is based on the categorization used in the studies cited.)

Table 2: Prevalence of Refractive Errors in Children 5 to 17 Years of Age

Condition	White Non-Hispanic	Hispanic	African American	Asian
Myopia				
≥0.75D in each principal meridian	4.4%	13.2%	6.6%	18.5%
Hyperopia				
≥1.25D in each principal meridian	19.3%	12.7%	6.4%	6.3%
Astigmatism				
≥1.00D difference between two principal meridians	26.4%	36.9%	20.8%	33.6%

Source: Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error Study[52]

In the school-based CLEERE study of children 5 to 17 years of age, overall 9.2% of the children were myopic, 12.8% were hyperopic, and 28.4% had astigmatism (Table 2).

Click to view the *(AOA Clinical Practice Guidelines web page)*

- **Amblyopia**

Amblyopia is the leading cause of monocular vision loss in children. It is generally attributable to strabismus, anisometropia, combined strabismus and anisometropia, or form deprivation (e.g., media opacity). Unilateral amblyopia is commonly associated with constant unilateral strabismus and/or amblyogenic anisometropia, while bilateral amblyopia usually results from high bilateral refractive error[53] or bilateral form deprivation.

Although amblyopia is a treatable condition in both children and adults,[54] the end result is better when diagnosed and treated early.[55-60] The prevalence of amblyopia in the general population is believed to be between 2% and 2.5%.[61] Estimates of the prevalence of amblyopia in young children in an urban population are shown in Table 3.

Click to view the *(AOA Clinical Practice Guidelines web page)*

- **Strabismus**

The estimated prevalence of strabismus in the general population varies from 2.5% to 4.6% based on various studies.[62] The prevalence of strabismus in young children in an urban population is shown in Table 3.

Although strabismus can develop at any age, it usually develops during childhood. Infantile esotropia has an onset prior to 6 months of age; accommodative esotropia typically has an onset between 2 to 3 years of age, but can develop before 6 months of age. Young children with constant unilateral strabismus often develop amblyopia and impaired stereopsis. Early identification and treatment of children with strabismus may prevent amblyopia and preserve stereopsis.

Table 3: Prevalence of Amblyopia and Strabismus in Children 6 Months to 72 Months (6 Years) of Age

Condition	White Non-Hispanic	Hispanic	African American	Asian
Amblyopia	1.8%	2.6%	0.8% - 1.5%	1.8%
Strabismus	3.2% - 3.3%	2.4%	2.1% - 2.5%	3.6%

Source: Multi-Ethnic Pediatric Eye Disease Study[6, 8] and the Baltimore Pediatric Eye Disease Study[7]

Click to view the *(AOA Clinical Practice Guidelines web page)*

- **Non-strabismic binocular vision problems and accommodative disorders**

Other than refractive errors, the most prevalent vision conditions in children fall into the category of accommodative and binocular vision anomalies, as

reported in a large-scale prospective study of the prevalence of vision disorders and ocular disease in a clinical population of children between the ages of 6 months and 18 years.[63]

Oculomotor conditions

Oculomotor conditions include a variety of eye movement disorders, which can affect saccadic, fixation, and vergence eye movements.

Convergence insufficiency (CI) is a binocular vision disorder that affects up to 8.3% of school-age children[64] and is associated with symptoms such as eyestrain, headaches, blurred vision, diplopia, sleepiness, difficulty concentrating, movement of print while reading, loss of place, and loss of comprehension after short periods of reading.[65-67] The Convergence Insufficiency and Reading Study Group investigators found that 13% of fifth and sixth grade children (definite and high suspect) had clinically significant CI (insufficient fusional convergence, receded nearpoint of convergence, and/or exophoria at near ≥4 prism diopters at far).[68]

Convergence excess (CE) has been reported to occur in 7.1% of children in one clinical pediatric population.[63] It may be due to a high accommodative convergence/accommodation (AC/A) ratio. Symptoms can include blurred vision, diplopia, headaches, and difficulty concentrating on near tasks.

Accommodative disorders

Children with accommodative dysfunctions may have difficulty focusing on near objects, maintaining focus for long periods, or easily changing focus from near to far and back again. Studies in clinic populations have been conducted to determine the prevalence of accommodative dysfunction. A study of over 2,000 children found that 5% of children between the ages of 6 and 18 years had accommodative disorders.[63]

Click to view the *(AOA Clinical Practice Guidelines web page)*

- **Color vision deficiency**

Children with color vision deficiency, either inherited or acquired, may have difficulty precisely matching colors or discriminating fine color differences. Inherited (X chromosome) color vision deficiency is estimated to occur in nearly 8% of white males and less than 0.4% of white females, with lower prevalence in other ethnicities[69] (Table 4). The severity of color vision deficiency can range from mild to severe. The most common form of color vision deficiency is red-green. Less common is blue-yellow color vision deficiency.

Table 4: Prevalence of Inherited Color Vision Deficiency in Children 61 Months (5 years) to 72 Months (6 Years) of Age

Color Vision Deficiency	White Non-Hispanic	Hispanic	African American	Asian
Boys	7.8%	2.9%	2.1%	3.5%
Girls	<0.4%	<0.4%	<0.4%	<0.4%

Source: Multi-Ethnic Pediatric Eye Disease Study[69]

- **Ocular Diseases**

Ocular inflammatory disease

Ocular inflammation in children involves an array of conditions, including but not limited to conjunctivitis, keratitis, scleritis, and uveitis. It may occur due to infection, trauma, malignancy, or autoimmune response. Inflammations can range from benign and self-limiting to chronic and sight-threatening.[70, 71]

Systemic autoimmune diseases in children can have ocular manifestations that are vision-threatening. Juvenile idiopathic arthritis is associated with the development of chronic anterior uveitis. Other diseases with ocular inflammatory manifestations include sarcoidosis, juvenile rheumatoid arthritis, Behçet's disease, and Sjögren's syndrome.[71, 72]

Ocular conditions of prematurity

Children born prematurely are at risk for the development of severe visual impairment and blindness. Preterm infants have higher rates of

amblyopia, strabismus, optic atrophy, and refractive errors.[73-76]

Sixty percent of infants born at 28 to 31 weeks have been reported to develop retinopathy of prematurity (ROP) and over 80% of infants born before 28 weeks developed ROP.[77] ROP is also common in children with birth weight of less than 1,251 grams (g). Oxygenation of infants in the hours and days after birth may also be a contributing factor.[78] The frequency and severity of ROP is inversely related to gestational age and birth weight of the baby.[79] The incidence of ROP is 47% in infants with birth weights between 1,000 and 1,251 g and 81.6% in infants weighing <1,000 g at birth.[77]

Cataract

Childhood cataracts can be classified as congenital or developmental. They may be idiopathic, due to infection (e.g., rubella), genetics (e.g., Down syndrome), or the result of secondary causes such as trauma or metabolic etiology. The prevalence of visually significant congenital cataracts is estimated to be three to four infants per 10,000 live births.[80] If not treated early, visually significant congenital cataracts may cause vision impairment.

Glaucoma

Childhood glaucoma is an uncommon disease characterized by increased intraocular pressure leading to optic neuropathy and visual field changes, and is often associated with significant vision loss.[81] It may be inherited or associated with other eye disorders.

Glaucoma in children may be classified as congenital (present at birth), infantile (occurring between 1 to 2 years of age), or juvenile (developing after age 3). Most cases develop during the first year of life. A review of records of pediatric patients seen in one county in the United States over a 40-year period found an incidence of glaucoma of 2.29 per 100,000 persons younger than 20 years of age.[81]

Retinitis pigmentosa

Retinitis pigmentosa (RP) is a group of hereditary retinal diseases characterized by progressive loss of peripheral vision and the development of night blindness. RP is caused by the degeneration of photoreceptor cells resulting in severe damage to the retina. While RP is usually limited to the eye, it may also occur as part of a syndrome (e.g., Usher syndrome, Bardet-Biedl syndrome).[82]

Retinitis pigmentosa is the most frequent cause of inherited visual impairment.[82] It is estimated to affect 1 in 3,000 to 1 in 4,000 people in the United States.[83]

Retinoblastoma

Retinoblastoma, a cancer of the retina, usually affects children under age 5. The most common signs of retinoblastoma are leukocoria (white pupillary reflex) and strabismus. Retinoblastoma accounts for approximately 11% of cancers occurring in the first year of life, with 95% diagnosed before 5 years of age.[84] It is the most common intraocular cancer of childhood and affects approximately 300 children in the United States each year. More than 90% of children with retinoblastoma could be treated with early diagnosis;[85] however, significant disparities exist in the care and outcomes of children with retinoblastoma.[86]

Retinoblastoma is associated with a mutation of the RB1 gene. The tumor may be unilateral or bilateral and can be inherited. Prognosis for survival, saving the eye, and preservation of vision are largely dependent on the stage of disease at presentation. Early diagnosis, multidisciplinary treatment, and genetic counseling are all priorities in the management of this tumor.[87]

Diabetic retinopathy

Diabetes is the third most common chronic disease among children and a leading cause of vision impairment among young adults. Type 1 diabetes mellitus has historically been the most common

type in children, affecting approximately 2 per 1,000 school-age children in the United States; however, Type 2 diabetes mellitus now accounts for about 45% of new cases of the disease.[88, 89]

Diabetic retinal disease, primarily manifesting as diabetic retinopathy (DR) and/or diabetic macular edema, is the most common microvascular complication of diabetes. Among pediatric patients, the average duration of diabetes before the development of DR is 5.7 to 9.1 years; however, the risk for developing DR is greater in patients who are diagnosed with diabetes during or after puberty.[88]

Click to view the *(AOA Clinical Practice Guidelines web page)*

Optic nerve hypoplasia

Optic nerve hypoplasia is one of the most prevalent causes of visual impairment among young children. Although the specific prevalence is unknown, the Babies Count Registry reported optic nerve hypoplasia as the third most prevalent cause of vision impairment in children age 3 years or younger in the United States.[90]

The exact cause of optic nerve hypoplasia in not known, but it may be associated with prenatal exposure to alcohol, smoking, recreational drugs, antidepressants and anticonvulsants, and with prenatal complications including gestational diabetes, toxemia, viral infection, and maternal anemia. Seventy percent of the cases identified have no known risk factors. More recent studies have indicated the mother's young age (≤ 20 years) and primiparity (that is, the affected child is the mother's first child, regardless of the mother's age) are the predominant characteristics in the background of children with optic nerve hypoplasia.[91]

Optic nerve hypoplasia was believed to occur either as an isolated anomaly or accompanying the syndrome of septo-optic dysplasia or de Morsier syndrome[92] that includes midline brain malformations and hypopituitarism. Evidence now suggests that optic nerve hypoplasia infrequently occurs in isolation and is more appropriately designated as the syndrome of optic nerve hypoplasia.[93] In the syndrome, most children with optic nerve hypoplasia have hypothalamic dysfunction and/or neurodevelopmental impairment, such as cerebral palsy or growth problems.

Cortical (cerebral) visual impairment

Cortical visual impairment (CVI) is defined as a reduction or complete loss of visual acuity and optokinetic nystagmus due to injury to the visual cortex, with preservation of pupillary response, normal eye motility, and normal retina.[94] In addition to cortical visual impairment, the term cerebral visual impairment is also used to describe not only visual impairment associated with the visual cortex, but also regions outside the cortex that can affect other visual pathway structures.[95]

In children experiencing perinatal or postnatal hypoxia/ischemia, CVI, retinopathy of prematurity, and optic nerve hypoplasia were commonly identified conditions. Of the three, CVI was the most prevalent visual condition identified and was often the last to be diagnosed.[90]

Vision loss associated with brain damage is reported to be a significant cause of visual impairment in young children. Identification of children with suspected CVI requires neuroimaging to ascertain the extent of the injury to specific regions in the brain. Failure to do so will underestimate the level of visual dysfunction and systemic disability.[96]

C. ACCESS TO CARE

Although comprehensive pediatric eye and vision examinations are essential for timely diagnosis and treatment of eye disease and maintenance of good vision, many children do not receive comprehensive eye care. An estimated one in five preschool children and one in four school-age children in the United States has a vision problem; however, the Centers for Disease Control and Prevention report that less than 15% of preschoolers receive an eye examination by an eye care

professional and less than 22% receive some type of vision screening.[97]

A factor that may limit access to comprehensive eye and vision examinations and treatment services is the false sense of security that school screenings mistakenly give to parents (false negative results). Other factors that limit access include the absence of signs, symptoms, or a family history of eye and vision problems,[98] or the inability of parents/caregivers to afford needed services due to lack of insurance coverage or limited family income.[99] Limited access may now be partially resolved because comprehensive eye and vision examinations have received increased attention from the Affordable Care Act and other insurance programs reviewing essential health benefits necessary for children.

D. COST OF EYE AND VISION DISORDERS IN CHILDREN

Eye and vision disorders can impose a significant burden on patients, parents, and the public. The total economic cost of vision loss and eye disorders among children younger than 18 years of age in 2012 was estimated to be $5.9 billion.[100] This includes the direct medical costs for eye examinations, eyeglasses, and low vision aids. Also, the debilitating nature of vision loss results in major indirect and nonmedical costs including special education services, federal assistance programs, and decreased quality of life.

The above estimate does not include the costs of educational services for children with undiagnosed and untreated vision conditions. Learning-related vision problems have been reported to be significant contributors to reading difficulties and ultimately to the need for special education services.[14, 15, 65, 101, 102] Vision problems can increase educational costs in the form of Individualized Education Programs (IEPs) and special education services, which would otherwise not be necessary, if the vision problems were treated. A study of students (ages 6-16) with IEPs found that they have high rates of undiagnosed and untreated vision problems affecting reading speed and comprehension.[103]

In addition to the current costs of care, future costs for undiagnosed and untreated vision problems may include the loss of a child's full potential, and limitations on his or her occupational choices and future earnings. The cost of treating any visual impairment later in life could potentially be more expensive than treatment of the initial problem.

E. EARLY DETECTION AND PREVENTION OF EYE AND VISION DISORDERS

Many vision conditions are asymptomatic or not readily recognized, and will not prompt a patient, caregiver, or parent to seek a comprehensive eye and vision examination.[104] Undiagnosed or uncorrected refractive errors and other visual disorders in children can lead to developmental, academic, and social challenges and in some cases permanent vision loss, which has lifelong complications.[105] In the preschool population, the concern is for early diagnosis and treatment of significant refractive error, amblyopia, strabismus, and ocular disease. For the school-age population, the concern is the negative impact that untreated vision disorders (accommodation, binocular vision, ocular motility, and vision information processing) have on academic performance.

A comprehensive eye examination by a doctor of optometry or ophthalmologist is the reference standard of eye care.[105] Not all children receive professional eye examinations for various reasons including education and language barriers, health literacy, cost, geographic access, immigration status, and transportation challenges.[106]

The role of vision screenings in addressing the current gaps in children's eye care remains unclear. The U.S. Preventive Services Task Force (USPSTF) has concluded that the current evidence is insufficient to assess the balance of benefits and harms of vision screening for children 3 years of age and younger.[107] While the USPSTF concluded with moderate certainty that vision screening for children 3 to 5 years of age has moderate net benefit compared with no screening, they did not compare the benefit of screening to a comprehensive eye examination.[108]

Vision screening procedures lack the evidence needed, with proven high sensitivity and specificity, for identifying

the targeted vision problems present in the population of children being screened.[104,109] The sensitivity of a wide variety of screening techniques was evaluated by the Vision in Preschoolers (VIP) study, which unlike standard screenings used licensed eye doctors who had completed VIP study specific training and certification.[104] In the study, the sensitivity of 11 vision screening techniques used for detecting clinically significant vision problems in children 3 to 5 years of age varied from 16% to 64%, with specificities ranging from 62% to 98%. These tests were compared again with a specificity of 94%, and the sensitivity dropped even further.[109] When these same tests were performed by trained nurses or lay screeners (except for non-cycloplegic retinoscopy, which was deemed too technically challenging), the sensitivity was similar or lower.[110] Even with the use of trained examiners, these vision screening techniques were unable to provide high levels of both sensitivity and specificity for detecting many vision problems in children. Currently, widespread application of vision screenings do not utilize licensed eye care professionals or the techniques found to be most sensitive.

When Snellen visual acuity alone was used as a screening tool, it was 100% specific for identifying reduced acuity, but missed 75.5% of the children found to have binocular and oculomotor vision problems when given a complete visual examination.[111] Additionally, a study of 1,992 school-age children found that 41% of children who failed the State University of New York screening battery would not have been identified if the screening was based on visual acuity alone.[112]

Many children who fail a screening do not receive the necessary treatment of their conditions. A study of public school children reported only 38.7% who failed the vision screening received follow-up care after screenings.[113] Due to a lack of follow-through, screenings alone may not lead to the earlier diagnosis and treatment of eye and vision problems. While screenings may identify some children at risk for vision problems, a comprehensive eye exam is necessary for definitive diagnosis and appropriate treatment.[114]

III. CARE PROCESS

A. COMPREHENSIVE PEDIATRIC EYE AND VISION EXAMINATION

The comprehensive pediatric eye and vision examination provides the means to evaluate the structure, function, and health of the eyes and visual system. It is preferable in most cases for the parent/caregiver to accompany the child into the examination room. The in-person interaction between patient/parent/caregiver and doctor is a dynamic process. It involves collecting subjective data from the patient/parent/caregiver and obtaining objective data by observation, examination, and testing. During the examination, information is obtained to explain symptoms reported by the patient and/or parent/caregiver and diagnose their cause. It also provides the means to identify the presence of other ocular or systemic conditions that may exist with or without symptoms. (See Appendix Figure 1.)

The goals of the comprehensive pediatric eye and vision examination are to:

- Evaluate the refractive, binocular, and accommodative status of the eyes and visual system, taking into account special vision demands and needs
- Assess ocular health and related systemic health conditions
- Establish a diagnosis (or diagnoses)
- Formulate a treatment and management plan
- Counsel and educate the patient/parent/caregiver regarding visual, ocular, and related systemic health care status, including recommendations for prevention, treatment, management, and future care.

1. General Considerations

Since the capabilities and needs of children vary significantly by age, the potential components of the comprehensive pediatric eye and vision examination have been divided into three age groups. This subdivision of the pediatric population is based on the developmental changes that occur from birth through childhood. The following age groups were also chosen

to be compatible with those used by other medical and governmental groups involved with children's health.

Because an individual child's development can vary significantly from expected age norms, it is important not to rely solely upon chronological age when choosing testing procedures. Appropriate test procedures need to be based on the child's developmental age and specific capability.

a. Infants and Toddlers (newborn through 2 years of age)

Children in this age group may perform best if the examination is early in the morning or after an infant's nap. Age-appropriate examination strategies should be used. It is necessary to rely on objective examination procedures and to perform tests more rapidly than with older children.

b. Preschool Children (3 years through 5 years of age)

At about 3 years of age, children have achieved adequate receptive and expressive language skills to begin to cooperate for some of the traditional eye and vision tests; however, testing modifications are often needed to gather useful information. Beginning the examination with procedures that appear less threatening may help to put the child at ease. The use of subjective tests requiring verbal interaction may need to be modified.

c. School-age Children (6 through 18 years of age)

Most of the examination procedures used on adults apply to this age group; however, for some patients, modifications should be made to improve understanding and cooperation. Utilization of tests designed for younger age groups may be appropriate. Tests of accommodation, oculomotor skills, and binocular function should be included as part of the comprehensive examination.

2. Examination Procedures**

The examination procedures described are not intended to be all-inclusive. Professional judgment and individual patient symptoms and findings may significantly influence the nature and course of the examination. It is important to remain alert for new and emerging technologies, instruments, and procedures and incorporate them into the clinical examination, as appropriate.

CONSENSUS-BASED ACTION STATEMENT:
A comprehensive pediatric eye and vision examination should include, but is not limited to:

- Review of the nature and history of the presenting problem, patient and family eye and medical histories, including visual, ocular, general health, leisure and sports activities, and developmental and school performance history of the child
- Measurement of visual acuity
- Determination of refractive status
- Assessment of binocular vision, ocular motility, and accommodation
- Evaluation of color vision (baseline or periodic, if needed, for qualification purposes or if disease related)
- Assessment of ocular and systemic health, including evaluation of pupillary responses, anterior and posterior segment, peripheral retina, evaluation/measurement of intraocular pressure, and visual field testing.

Refer to section III. Care Process, A. 9 for a listing of potential benefits and harms of testing.

Evidence Quality: There is a lack of published research to support or refute the use of all of the tests and/or assessments included in this recommendation.

Benefit and Harm Assessment: Implementation of this recommendation is likely to result in the enhanced ability to diagnose any eye or vision problems in infants and children. The benefits of this recommendation were established by expert consensus opinion.

*** See Appendix Tables 1, 2, and 3 for a listing of specific tests by age group.*

3. Patient History

The patient history is an initial and ongoing component of the examination. The objective is to obtain specific information about the patient and/or parent's/caregiver's perception of the child's eye and vision status and important background information on related medical issues. It helps to identify and assess problems, and it provides an opportunity to become acquainted with the patient and/or his/her parents or caregivers, establishing a relationship of confidence and trust.

The collection of demographic data generally precedes the taking of the patient history. Having the parent or caregiver fill out a questionnaire may facilitate obtaining the patient and family history, if known. Major components of the patient history include, but are not limited to:

- Nature and history of the presenting problem, including chief complaint
- Visual and ocular history
- General health history, including prenatal, perinatal and postnatal history, and review of systems, surgical and/or head or ocular trauma history, and any vision or ocular treatment
- Medication reconciliation, including prescription and nonprescription drugs (e.g., over the counter medications, supplements, herbal remedies) and documentation of medication allergies
- Family ocular and medical history
- Clinical note: It is recommended that the patient history should also include the refractive status of both parents,[115, 116] (Evidence Grade: B) because it is a possible risk factor for the progression of myopia in school-age children.
- Developmental history of the child
- School performance history of school-age children
- Time spent outdoors, on sports activities, and on near work and screen viewing
- Names of, and contact information for, the patient's other health care providers.

4. Testing

4.1 Testing of Infants and Toddlers (newborn through 2 years of age)

a. Visual Acuity

Estimation of visual acuity in an infant or toddler can help to confirm or reject certain hypotheses about the level of visual system development, including binocularity, and provide direction for the remainder of the eye and vision examination. Assessment of visual acuity for infants and toddlers may include these procedures:

- Preferential looking visual acuity

  Preferential looking methods are useful for the assessment of visual acuity in infants and toddlers. Grating acuity targets (e.g., Teller acuity cards) and vanishing optotypes (e.g., Cardiff acuity test) can provide estimates of resolution visual acuity.[117]

- Fixation preference test

  Fixation preference testing results need to be interpreted in the context of all other available information (e.g., degree and type of anisometropia, frequency and type of strabismus). Results of fixation preference testing may be unreliable for diagnosing amblyopia,[118, 119] particularly secondary to anisometropia; therefore, monocular visual acuity measurements should be obtained, if possible.[120]

- Visual evoked potential

  Electrodiagnostic testing, such as visual evoked potentials, is an objective method that can be used to provide an estimate of visual acuity in infants.[121]

b. Refraction

Objective measures of refraction with a lens bar or loose lenses should be used in this age group because of the short attention span and poor fixation of infants. The refractive error measurement should be analyzed with other testing data obtained during the examination. This

information is used to determine if, and in what amount, an optical correction is needed. Procedures may include:

- Cycloplegic retinoscopy

When performing cycloplegic retinoscopy in an infant or toddler, the appropriate cycloplegic agent should be selected carefully.[122] The lowest concentration of drug that yields the desired cycloplegia should be used. A concentration of 0.5% cyclopentolate hydrochloride can be used in most infants under 12 months of age and a 1% concentration for older children.[123] Combination drops (0.2% cyclopentolate hydrochloride and 1% phenylephrine) are also available for use with infants. The potential for systemic absorption may be reduced with nasolacrimal occlusion. The cycloplegic of choice is cyclopentolate hydrochloride; however, when it is not available or is contraindicated, tropicamide 1% has also been shown to be effective for the measurement of refractive error in non-strabismic infants.[124]

Spray administration of cyclopentolate to the open or closed eyes of young children is an acceptable alternative, if necessary, to using eye drops and is often better tolerated and less distressing than other methods of drug administration;[125-128] however, the use of cyclopentolate spray in children with dark irides may not achieve adequate cycloplegia.[129] Spray caps are available for use on bottles of cyclopentolate, eliminating the need to have the spray compounded by a pharmacy.

- Non-cycloplegic retinoscopy

Non-cycloplegic retinoscopy performed at near is an objective means of estimating refractive error in infants and toddlers,[130] but should be used with caution as a substitute for cycloplegic retinoscopy.[131] It may be useful when a child/parent is extremely anxious about instillation of cycloplegic agents, or the child has had, or is at risk for, an adverse reaction to cycloplegic agents.[132]

Video refraction without cycloplegia can also be used to detect infants with significant ametropia, particularly hyperopia or other accommodative problems.[133]

c. Binocular Vision and Ocular Motility

Depending on the patient's age, level of cooperation, and visual signs and symptoms, appropriate tests of binocular vision and ocular motility should be incorporated into the examination. Testing in this age group may include:

- Ocular alignment assessment

The unilateral cover test at distance and near can generally be used with very young children. If cover test results are unreliable because of the child's resistance to testing, use of the Hirschberg test may be successful. Prisms can be used with the Hirschberg test to align the corneal reflex (Krimsky test) and estimate the magnitude of any deviation.

- Brückner test

If cover test results are equivocal, particularly in young or uncooperative patients, the Brückner test may be helpful in detecting strabismus, including small angle strabismus. It may also be useful in the clinical evaluation of anisometropia in infants and young children.[134] Increasing the examination distance from one meter to four meters can improve its sensitivity for detecting anisometropia.[135]

- Stereopsis

Testing of stereopsis, after 6 months of age, can provide a sensitive measure of visual development in infants.[136] In this population, tests like the Preschool Assessment of Stereopsis with a Smile (PASS) 3, which uses a preferential looking paradigm, should be used.

- Near point of convergence (NPC)

Assessment of convergence ability may be determined objectively in infants using a penlight or other interesting targets, which include sounds or blinking lights.

- Ocular motility assessment

  Versions and eye tracking abilities may be assessed using a penlight, small toy, or other object.

4.2 Testing of Preschool Children (3 through 5 years of age)

a. Visual Acuity

The accurate measurement of visual acuity in children allows for the early detection of amblyopia and significant/high refractive errors. While some children in this age group may respond verbally, acuity testing may require the use of a matching or a forced-choice task. An assessment of visual acuity may include the use of:

- Symbol optotype or letter matching visual acuity measurement

  Symbol optotype or letter optotype testing (e.g., Lea symbols) and letter matching testing (e.g., HOTV) can be used to measure the visual acuity of most children aged 3 through 5 years.[137-140]

b. Refraction

A refraction should include objective and, as appropriate, subjective assessment of the child's refractive status; however, the results of a refraction do not provide all the information needed to determine an optical prescription. The refractive error measurement should be analyzed with other testing data and the patient's visual needs obtained during the in-person examination. This information is used to determine if, and in what amount, an optical correction is needed to provide optimal vision and comfort for all viewing distances. Testing in this age group may include:

- Static (distance) retinoscopy

  Use of a lens rack or loose lenses with appropriate control of accommodation, rather than a phoropter, enables the child's eyes to be seen and allows for observation if the child loses fixation. Viewing a video may assist in capturing a child's attention in order to sustain distance fixation.

- Cycloplegic retinoscopy

Spray administration of cyclopentolate to the open or closed eyes of young children is an acceptable alternative, if necessary, to using eye drops and is often better tolerated and less distressing than other methods of drug administration;[125-128] however, the use of cyclopentolate spray in children with dark irides may not achieve adequate cyclopelgia.[129] Spray caps are available for use on bottles of cyclopentolate, eliminating the need to have the spray compounded by a pharmacy.

CONSENSUS-BASED ACTION STATEMENT: Cycloplegic retinoscopy is the preferred procedure for the first evaluation of preschoolers. It is necessary to quantify significant refractive error in the presence of visual conditions such as strabismus, amblyopia, and anisometropia.
Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.
Benefit and Harm Assessment: Implementation of this recommendation is likely to enhance the ability to evaluate and diagnose eye and vision problems in preschool children. The benefits of this recommendation were established by expert consensus opinion.

- Autorefraction

The use of a hand-held autorefractor is preferable in this age group since it may be less intimidating than a table mounted instrument.

Autorefractors can provide an objective measure of refractive error, but may underestimate the level of hyperopia and overestimate the level of myopia under non-cycloplegic conditions,[141, 142] and their usefulness in testing children less than 3 years of age may be limited.[143]

c. Binocular Vision, Ocular Motility, and Accommodation

- Ocular alignment assessment (distance and near)

Testing should include use of the unilateral cover test and alternating cover test. If cover test results are unreliable because of the child's resistance to testing, use of the Hirschberg test may be successful. Prisms can be used with the Hirschberg test to align the corneal reflex (Krimsky test) and estimate the magnitude of any deviation.

- Ocular motility assessment

Examination of eye movements in this age group involves an assessment of comitancy.

- Near point of convergence (NPC)

Assessment of maximum convergence ability may be determined objectively or subjectively.

- Stereopsis

In the preschool population, stereopsis testing can provide useful information about development of binocular vision and eye alignment. Testability in this age group has been reported to be close to 90% using age appropriate techniques.[136, 144, 145] The presence of global stereopsis is an indication that the patient is bifoveally fixating and evidence that a constant strabismus is less likely to be present.[146, 147] This information is valuable when the cover test results are equivocal and the clinician suspects a small angle, constant strabismus may be present. To accomplish this objective, a stereopsis test that assesses global, rather than local stereopsis, should be used. The PASS 3 and the Randot Preschool tests are examples of global stereopsis tests that can be used for this purpose. Stereopsis tests that have monocular cues (local stereopsis e.g., Titmus Test) may lead to false-positive results.[147]

- Positive and negative fusional vergence ranges

Assessment of positive and negative fusional vergence ranges can be done using a step vergence procedure with a hand-held prism bar. [37, 148]

- Accommodative testing

Clinical note: Dynamic retinoscopy has been shown to be a reliable method for assessing accommodation in young children.[149,150] (Evidence Grade: B)

d. Color Vision

Children with color vision deficiency, either congenital or acquired, may have difficulty precisely matching colors or discriminating fine color differences.[151] The severity of color vision deficiency can range from mild to severe depending on the cause. Most children can be reliably evaluated for color vision deficiency after 60 months (5 years) of age.[69]

It is helpful to know whether a color vision deficiency exists, because severe color vision deficiency may cause a child to be misidentified as learning disabled.[152] Identification of abnormal color vision prior to school age is also important, since part of the early educational process generally involves the use of color identification and discrimination. The presence of a color vision deficiency may also indicate an ocular health problem; therefore, color vision testing may need to be repeated, if an acquired color vision deficiency is suspected.

Although effective when used with standard illuminant, some pseudoisochromatic plate tests only detect protan and deutan color vision deficiency,[153] while other color vision tests provide the added advantage of detection of tritan defects and the ability to categorize defects as mild, moderate, or severe.[154]

4.3 Testing of School-age Children (6 through 18 years of age)

a. Visual Acuity

Visual acuity may be measured monocularly and binocularly, at distance and near, with and without the child's most recent spectacle or contact lens correction.

An assessment of visual acuity in children age 6 years or older may include:

- Snellen visual acuity

  For some children, Snellen visual acuity testing may need to be modified by isolating one line, or even one-half line of letters. If amblyopia is suspected, single letters with surround bars should be used.

- Early Treatment of Diabetic Retinopathy Study (ETDRS) visual acuity chart

  The ETDRS chart may be used to measure visual acuity in school-age children[155] and can be especially useful in diagnosing and monitoring children with amblyopia.

b. Refraction

A refraction may include objective and subjective assessment of a child's refractive status; however, the results of a refraction do not provide all the information needed to determine an optical prescription. The refractive error measurement should be analyzed with other testing data and the patient's visual needs obtained during the in-person examination. This information is used to determine if, and in what amount, an optical correction is needed to provide optimal vision and comfort for all viewing distances.

Both objective and subjective testing for refractive error can generally be used in this age group. It may include:

- Static (distance) retinoscopy

  Retinoscopy may be performed with a phoropter, or without a phoropter using a lens rack or loose lenses and fogging glasses.

- Cycloplegic retinoscopy

CONSENSUS-BASED ACTION STATEMENT:
Cycloplegic retinoscopy is the preferred procedure for the first evaluation of school-age children. It is necessary to quantify significant refractive error in the presence of visual conditions such as strabismus, amblyopia, and anisometropia.

Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.

Benefit and Harm Assessment: Implementation of this recommendation is likely to enhance the ability to evaluate and diagnose eye and vision problems in school-age children. The benefits of this recommendation were established by expert consensus opinion.

Clinical note: In school-age children, cycloplegic refraction results in a more positive spherical power measurement than that obtained using optical fogging techniques to relax accommodation.[156] (Evidence Grade: B) The difference in spherical equivalent refractive errors measured in pre- and post-cycloplegic refractions is significant up until age 20.[157] (Evidence Grade: B)

- Subjective refraction

  Typical examination procedures used to measure refractive error in adults can generally be used for school-age children.

- Autorefraction

  Autorefraction may be used as a starting point for subjective refraction, but not as a substitute for it; however, retinoscopy, when performed by an experienced clinician, is more accurate than automated refraction for determining a starting point for non-cycloplegic refraction.[158] (Evidence Grade: C)

c. Binocular Vision, Ocular Motility, and Accommodation

In analyzing the results of these tests, it is important to examine all the data and group findings rather than depend on a single finding to arrive at a diagnosis. Testing in this age group is similar to that for adults and may include:

- Ocular alignment assessment (distance and near)

Testing may use the unilateral cover test and alternating cover test. If cover test results are unreliable because of the child's resistance to testing, use of the Hirschberg test may be successful. Prisms can be used with the Hirschberg test to align the corneal reflex (Krimsky test) and estimate the magnitude of any deviation. Other tests include the Von Graefe phoria, Modified Thorington, and Maddox Rod.

- Ocular motility assessment

Examination of eye movements in this age group involves an assessment of comitancy of fixation, saccadic, and pursuit functions. Versions may also be performed to rule out a noncomitant deviation.

- Near point of convergence (NPC)

Determination of maximum convergence ability may be obtained objectively or subjectively.

- Stereopsis

School-age children should be able to complete any of the available random dot stereopsis tests. If random dot (global) stereopsis is not present, testing should continue to evaluate local stereopsis, potential for flat fusion, and potential for simultaneous perception.

- Positive and negative fusional vergence ranges

Evaluation should be made of both the amplitude and facility of fusional vergence ranges.

- Accommodative testing

Assessment of accommodation may include accommodative amplitude, facility, and response.[149,159] Testing of negative relative accommodation (NRA) and positive relative accommodation (PRA) may provide useful information on both accommodative and binocular status.[149]

d. Color Vision

If not done previously, school-age children should be tested for color vision deficiency. Color vision deficiency can interfere with daily activities involving colors and prohibit some occupational choices.[160] One-third of individuals with abnormal color vision reported their career choice had been affected by color vision deficiency and one-quarter had been precluded from an occupation because of it or had problems in their current job.[161]

CONSENSUS-BASED ACTION STATEMENT: Abnormal color vision can affect daily performance of activities involving color discrimination and may interfere with or prevent some occupational choices later in life. Children should be tested as soon as possible for color vision deficiency and the parents/caregivers of children identified with color vision deficiency should be counseled.
Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.
Benefit and Harm Assessment: Implementation of this recommendation is likely to increase early detection of color vision deficiency and alert parents/caregivers to any potential effects on a child's education or occupational choices. The benefits of this recommendation were established by expert consensus opinion.

5. Ocular and Systemic Health Assessment

Thorough assessment of the health of the eyes and associated structures is an important and integral component of the comprehensive pediatric eye and vision examination. The eyes and associated structures are not only sites for primary ocular diseases, but they are also subject to systemic disease processes that affect the body as a whole (e.g., disorders of neurologic, vascular, endocrine, immune, or neoplastic origin).

Standard procedures used in evaluating adult patients may need to be modified or may not be optimal in very young patients. With some modifications,

the components of the ocular and systemic health assessment may include:

a. Assessment of Pupillary Responses

Evaluation of pupils includes size, shape, symmetry, and direct and consensual response to light and relative afferent pupillary defect.

b. Visual Field Evaluation

Confrontation visual field testing can be used to detect gross peripheral defects and areas of constricted visual fields.

c. Evaluation of the Ocular Anterior Segment and Adnexa

Assessment of the external eye and adnexa, ocular surface, anterior chamber, and crystalline lens.

d. Evaluation of the Ocular Posterior Segment

Pharmacological dilation of the pupil is generally required for thorough stereoscopic evaluation of the ocular media, retinal vasculature, macula, optic nerve, and the peripheral retina.[162] (Evidence Grade: B)

Examination under general anesthesia may be considered under rare circumstances, if the retina cannot be adequately visualized during an examination of at-risk children.[163]

e. Measurement of Intraocular Pressure

Measuring intraocular pressure (IOP) is a part of the comprehensive pediatric eye and vision examination. Although the prevalence of glaucoma is low in children, measurement of IOP should be attempted. Pressure should be assessed when ocular signs and symptoms or risk factors for glaucoma exist. If risk factors are present and reliable assessment of IOP under standard clinical conditions is impossible, testing under anesthesia may be indicated. Recording of tonometry results should include method used and time of day.[164] (Evidence Grade: C)

Clinical note: The Goldmann applanation tonometer (GAT) is considered the reference standard for the measurement of IOP; however, its use may not be practical in very young children. Non-contact and handheld applanation tonometers can provide IOP measurements close to that of the Goldmann.[165] (Evidence Grade: A) Rebound tonometry offers an advantage over GAT in that it is portable, easy to use, and better tolerated.[166] (Evidence Grade: B)

6. Supplemental Testing

During an eye and vision examination, the information obtained from the patient is continually assessed, along with the clinical findings gathered. The interpretation of subjective and objective data may indicate the need for additional testing.

Additional testing may be indicated to:

- Confirm or rule out differential diagnoses
- Enable more in-depth assessment
- Provide alternative means of evaluating patients who may not be fully cooperative or who may not comprehend testing procedures.

Supplemental procedures may be performed immediately or during subsequent examinations. Supplemental testing for infants and children may include:

a. Electrodiagnostic Testing

Electrophysiological techniques may be used to assess children with unexplained reduced vision. Testing may include an electroretinogram (ERG) or measurement of visual evoked potential (VEP).

b. Imaging

The following procedures may be used for imaging of ocular structures:

- Ultrasonography can reveal congenital anatomical abnormalities in the eye and orbit, as well as anatomical changes secondary to disease or injury, and measure axial length
- Optical coherence tomography (OCT) provides cross-sectional, high-resolution imaging of the anterior and posterior segments
- Scanning laser ophthalmoscopy provides 3-D images of the optic nerve head
- Fundus photography, with or without auto fluorescence, is a noninvasive diagnostic technique for examining the fundus
- Corneal topography provides an assessment of corneal thickness, shape, power, and surface details
- Computerized tomography (CT) scan, magnetic resonance imaging (MRI), and other neuroimaging may be indicated for suspicion of neurological disease or trauma/injury
- Scheimpflug camera for anterior segment tomography (Pentacam, Orbscan, and Gallilei) may be used for detection of keratoconus.

c. Testing for Learning-related Vision Problems

Vision problems such as accommodative, binocular vision, eye movement, and visual information processing disorders can interfere with academic performance. When a child's history or initial testing indicates a possible developmental lag or learning disorder, additional testing should be performed to rule out a learning-related vision disorder. This will typically require an additional office visit that includes more extensive testing of accommodation, binocular vision, and eye movements, and an assessment of visual information processing skills. In some instances, this may require a referral to a doctor of optometry with advanced training in this area of practice.

CONSENSUS-BASED ACTION STATEMENT: Children at risk for learning-related vision problems should be evaluated by a doctor of optometry.

Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.

Benefit and Harm Assessment: Implementation of this recommendation is likely to result in more in-depth evaluation and diagnosis of children with learning-related vision problems. The benefits of this recommendation were established by expert consensus opinion.

Click to view the *(AOA Clinical Practice Guidelines web page)*

7. Children with Special Needs

a. At-risk Children

In the United States, the *Individuals with Disabilities Education Act* (IDEA) allows for the development of Individualized Education Programs (IEPs) when indicated.

The following categories of children are considered high-risk (Health and Human Services, Health Resources and Services Administration, Maternal and Child Health Bureau) and recommend direct referral for a comprehensive eye and vision examination:

- Children with obvious evidence of physical anomaly (e.g., strabismus, ptosis, nystagmus)
- Children with central nervous system (CNS) dysfunction (e.g., cerebral palsy, Down syndrome, seizures, developmental delay)
- Children with Autism Spectrum Disorder
- Children enrolled in Early Intervention (EI) Program's
  a). Children with an IEP
  b). Children enrolled in Early Head Start (ages 0-3)
- Children with a family history of amblyopia, strabismus, or other early eye disease

- Children born from high-risk pregnancy (e.g., maternal drug use, infection during pregnancy, preterm delivery).

b. Developmental Disabilities

Many children with special needs have undetected and untreated visual problems[167] (see Appendix Table 4: Partial Listing of Ocular Manifestations of Neurodevelopmental Disorders and Other Syndromes). Children with developmental or intellectual disabilities have a higher rate of vision disorders and should receive a comprehensive pediatric eye and vision examination.[21, 25, 168] Although clinically more challenging, visual assessment is possible in the majority of these children.[167] (Evidence Grade: B),[169] (Evidence Grade: B) Early identification of specific visual deficits could lead to interventions to improve the educational and occupational achievement and quality of life for these high-risk children.

CONSENSUS-BASED ACTION STATEMENT: Many children with developmental or intellectual disabilities have undetected and untreated vision problems and should receive a comprehensive pediatric eye and vision examination.
Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.
Benefit and Harm Assessment: Implementation of this recommendation is likely to result in improved quality of life and educational and occupational achievement for these high-risk children. The benefits of this recommendation were established by expert consensus opinion.

8. Trauma and Ocular Manifestations of Child Abuse/Neglect

a. Trauma (Accidental)

A majority of concussions occur in the pediatric and adolescent population (5 to 17 years of age), with the 11 to 17-year-old group representing the largest proportion of those injured.[170, 171] Children are particularly vulnerable to the consequences of concussion, often having a more prolonged recovery and poorer outcomes, from a cognitive and developmental perspective, than adults with concussion.[172-175] A recent study found a high prevalence of vision problems in adolescents with concussion along with significant symptoms associated with these vision disorders.[176] The most common binocular vision disorder occurring in post-concussion syndrome is convergence insufficiency (CI) with a prevalence of 49% in children. Other common problems are accommodative insufficiency and saccadic dysfunction.

All children with concussion should see their general practitioner in the event they should need more emergent care and should be scheduled for a comprehensive eye examination to confirm visual capabilities are protected.

b. Ocular Manifestations of Child Abuse and Neglect (Non-accidental)

External eye trauma (e.g., conjunctival hemorrhages, lid lacerations, corneal scars and/or opacities) and retinal trauma (e.g., hemorrhages, folds, tears, and/or detachments) are common ocular findings from child abuse and can have an important role in its diagnosis.[177-180] Most often the child is between 2 and 18 months of age at the time of abuse.[179, 181]

The eyes can be direct or indirect targets of child abuse and may provide valuable diagnostic information, particularly when there are limited external signs of abuse. In children, the leading cause of retinal hemorrhages with retinal folds and macular retinoschisis, in the absence of skull fractures or automobile accident history, is typically abusive head trauma.[182, 183] Retinal hemorrhages, poor visual response, and poor pupil response in an infant may indicate abusive head trauma, or Shaken Baby Syndrome,[177] (Evidence Grade: B),[178] (Evidence Grade: C) a form of child abuse in which the child is injured secondary to violent shaking.

A vague history provided by the parent/caregiver that changes on re-questioning or is inconsistent with the age of the child or extent of the injury should be an alert for abuse. In such cases, a detailed history is one of the most important factors to consider when assessing whether a child has been abused.[180]

Table 5: Summary of the Signs of Child Abuse and Neglect

Ocular signs of abuse	General physical signs of abuse or neglect	Emotional and behavioral signs of abuse or neglect
Cortical blindness	Bruises around cheeks, jaw, eyes, ears, or mastoid area	Frozen watchfulness
Ruptured globe	Soft tissue bruises on upper arms, thighs, buttocks or genitals	Fear of strangers
Retinal, preretinal, vitreous hemorrhages particularly if child is less than 2 years old	Hair loss with/without subgaleal menatoma	Indiscriminate attachment to strangers
Detached retina, retinal dialysis	Torn frenum of upper lip	Failure to thrive
Chorioretinal atrophy	Torn floor of mouth	Growth failure
Papilledema	Burns on any posterior part of the body, particularly buttocks, perineum, hands, or feet	Low intellectual performance
Optic atrophy	Full thickness burns	Sad affect
Cataracts	Multiple lesions or fractures in different stages of healing	Low self-esteem
Dislocated, subluxated lens	Poor hygiene	Impaired ability to enjoy life
Glaucoma	Inferior general health	Social withdrawal
Shallow anterior angle	Signs of malnutrition such as sunken cheeks and buttocks, distended abdomen	Learned helplessness
Angle recession	Child not properly immunized	Suicidal ideation or attempts
Iris tears, iris dialysis	Venereal disease in a preadolescent child	Drug or alcohol abuse
Pupillary anomalies		Misconduct in school
Anisocoria	**Case history inconsistencies**	Academic failure
Hyphema	No history offered	Low school attendance
Hypopyon	History vague or inconsistent with injuries	Aggressive behavior
Corneal scars, edema, opacities	History changes during course of examination	Sleeping problems
Conjunctival, subconjunctival hemorrhages	History varies between two parents or between parents and child	Running away
Orbital, periorbital edema	Multiple office visits for accidental injuries	Low level of activity
Lid lacerations	Increase in severity of injuries	Weight fluctuation
Ptosis	Delay in seeking medical attention	Fatigue
Proptosis		Generalized anxiety
Esotropia		Sexual acting out
Strabismus		
Nystagmus		
Disconjugate eye movements		
Eyelash infestation with phthirus pubis (crab louse)		

Source: Smith S. Child abuse and neglect: A diagnostic guide for the optometrist. J Amer Optom Assoc 1988; 59:760-66.

All 50 states and the District of Columbia have laws mandating the reporting of suspected child abuse and provide penalties for failure to do so.

U.S. Department of Health and Human Services, Administration for Children & Families, Children's Bureau *listing of state child abuse and neglect reporting numbers*

Clinical note: Doctors of optometry should be aware of the eye-related findings associated with abusive head trauma and report findings of possible child abuse to the proper authorities, as defined by state law, for the protection of the child.

9. Potential Benefits and Harms of Testing

The potential benefits of a comprehensive pediatric eye and vision examination include:

- Optimizing visual function through diagnosis, treatment, and management of refractive, ocular motor, accommodative, and binocular vision problems
- Preventing and/or minimizing vision loss through early diagnosis, treatment, and management of ocular health conditions
- Detecting systemic disease and referring for appropriate care
- Counseling and educating patients/parents/caregivers on current conditions and preventive care to maintain ocular and systemic health and visual function, and on the relationship between vision problems and early learning.

Potential harms associated with a comprehensive pediatric eye and vision examination may include:

- Patient or parent/caregiver anxiety about testing procedures or resulting diagnosis
- Adverse ocular and/or systemic reactions and/or temporary visual disturbances resulting from testing, or allergic responses to diagnostic pharmaceutical agents or materials used
- Missed or misdiagnosis of eye health or vision problems
- Unnecessary referral or treatment.

B. ASSESSMENT AND DIAGNOSIS

At the completion of the examination, the data collected should be assessed and evaluated to establish a diagnosis (or diagnoses) and formulate a treatment and management plan. The nature and severity of the problem(s) diagnosed determine the need for optical prescription (e.g., eyeglasses and/or contact lenses) or other treatment (e.g., vision rehabilitation, vision therapy, ocular pharmaceuticals).

C. MANAGEMENT

1. Prescription for Correction

A prescription for correction of refractive error, if needed, is provided at the conclusion of the examination.[184] The level of refractive error may be monitored rather than prescribed as a lens correction, or full or partial optical correction may be prescribed, depending on the specific visual needs, refractive measurement, and related visual findings.

2. Additional Treatment Services

Depending on the diagnosed eye and vision condition(s), other treatment services may be needed. For conditions such as accommodative, binocular vision, eye movement, visual information processing disorders, or visual impairment, treatment such as the use of prisms, vision therapy, or vision rehabilitation may be necessary. Ocular pharmaceuticals may also be used for the treatment of various eye diseases.

3. Counseling and Education

It is important for children/parents/caregivers to understand the medical information and recommendations given to them. To enhance understanding, open-ended questions should be used. Children/parents/caregivers should be asked to state their understanding of the information given to them using their own words.[185] Eye models, diagrams, and written materials can also be used to aid in understanding.

Shared decision-making increases patient/parent/caregiver satisfaction with the examination and consultation, and may improve health outcomes. The available options, with their benefits and risks, need to be described and patient/parent/caregiver views and preferences elicited, before agreeing on a course of action.[186]

Language and cultural differences or misunderstandings may prevent some individuals from accepting a doctor's recommendation. When communicating with patients/parents/caregivers, it is important to take their level of

"health literacy" into consideration.[187] Health literacy is "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate decisions regarding their health."[188] Limited health literacy has been associated with a range of adverse health outcomes including decreased use of preventive services and poor disease specific outcomes.[189]

In addition, anxiety reduces the effectiveness of patient-practitioner communications and results in reduced attention, recall of information, and compliance with treatment. The use of "patient-centered" communications and "active listening" can help reduce anxiety and improve patient/parent/caregiver satisfaction and outcomes.[190] Improved doctor-patient communications and higher levels of patient/parent/caregiver involvement in care are linked to better clinical outcomes.[191]

In compliance with the *Americans with Disabilities Act (ADA)*, reasonable accommodations need to be made to ensure that whatever is written or spoken is clear and understandable to individuals with disabilities. Appropriate auxiliary aids and services must be made available, when needed, to enable effective communications when evaluating, treating, or counseling persons with hearing, vision, or speech impairments. According to the ADA, auxiliary aids and services for individuals who are hearing impaired include qualified interpreters, note takers, computer-aided transcription services, written materials, telephone handset amplifiers, assistive listening systems, telephones compatible with hearing aids, closed caption decoders, open and closed captioning, telecommunications devices for the deaf (TDD's), videotext displays and exchange of written notes. For individuals with vision impairments, auxiliary aids and services include qualified readers, taped texts, audio recordings, magnification software, optical readers, Braille materials, and large print materials. Examples for individuals with speech impairments include TDD's, computer terminals, speech synthesizers, and communication boards.[192]

Language interpreters may also be needed to assist patients who have limited English proficiency. Family members of patients may act as interpreters, with the parent/caregiver consent for minors.

CONSENSUS-BASED ACTION STATEMENT: At the conclusion of a comprehensive pediatric eye and vision examination, the diagnosis should be explained to the patient/parent/caregiver and related to the patient's symptoms, and a treatment plan and prognosis discussed.
Evidence Quality: There is a lack of published research to support or refute the use of this recommendation
Benefit and Harm Assessment: Implementing this recommendation is likely to increase patient/parent/caregiver understanding of any diagnosed eye or vision problems and improve compliance with any recommended treatment. The benefits of this recommendation were established by expert consensus opinion

Patient/parent/caregiver counseling and education may include:

- Review of the child's visual and ocular health status in relation to his/her visual symptoms and complaints
- Discussion of any refractive correction that provides improved visual efficiency and/or appropriate eye protection
- Information on learning-related vision problems
- Explanation of available treatment options for diagnosed eye or vision conditions, including risks, benefits, and expected outcomes
- Recommendation of a course of treatment with the reasons for its selection and the prognosis
- Discussion of the importance of patient compliance with the treatment prescribed
- Recommendation for follow-up care, re-examination, or referral.

When appropriate, patients/parents/caregivers should also be counseled about:

a. Eye Safety and Protection

Eye injury is a leading cause of monocular blindness in the United States and a common reason for eye-related emergency department visits. Eye injuries treated in U.S. hospital emergency rooms among children younger than 18 years of age averaged over 70,000 annually in 1990 through 2009.[193] (See Table 6.) The risk for eye injuries in children is highest among 15 to 17 year olds. The most common eye injuries are due to abrasions or foreign bodies.[194]

The majority of eye injuries in children occur at home.[193] Frequent causes are sports and recreation activities, chemicals, or household products.[193,195] Most eye injuries are preventable with appropriate use of protective eyewear;[196, 197] however, in a National Health Interview Survey of children participating in activities that can cause eye injury, only 14.5% were reported to wear protective eyewear all or most of the time. Older children (12 to 17 years of age) were more likely to use protective eyewear than younger children.[198]

Table 6: Most Common Pediatric Eye Injuries Treated in U.S. Emergency Departments

Common Pediatric Eye Injuries
Sports and recreation (e.g., basketball, baseball, football, playground equipment)
Household chemicals (e.g., cleaning agents, bleach, pesticides)
Housewares and furniture (e.g., microwaves, flatware, tables)
Toys
Desk supplies (e.g., pens, pencils, scissors)
Tools and hardware (e.g., hammers, nails)
BB and pellet guns
Tobacco products (e.g., cigarettes, cigars, pipes)
Fireworks

Source: Rankings of common pediatric eye injuries as reported in Pediatric eye injuries treated in U.S. emergency departments, 1990-2009.[193]

It is important to discuss eye safety issues with children/parents/caregivers, including eye hazards at school or home, and during sports and recreational activities, and to promote the use of appropriate protective eyewear to help reduce the incidence of eye injuries among children.[193] (Evidence Grade: B),[199] (Evidence Grade: B) Prevention strategies should focus on the use of protective eyewear, parental supervision, and on childhood education about both the risks of eye injury and the utility of protective eyewear.[194] (Evidence Grade: B) [200]

EVIDENCE-BASED ACTION STATEMENT: Parents/caregivers and children should be educated about potential risks for eye injuries at home, at school, and during sports and recreational activities, and advised about safety precautions to decrease the risk of ocular injury.[193,199] Prevention of eye injuries in children should focus on the use of protective eyewear, parental supervision, and include education about both the risks of eye injury and the benefits of protective eyewear.[194]
Evidence Quality: Grade B: Retrospective cohort studies **Level of Confidence:** Medium **Clinical Recommendation Strength:** Strong Recommendation. This recommendation should be followed unless clear and compelling rationale for an alternative approach is present.
Evidence Statements: It is important to discuss eye safety issues with children/parents/caregivers.[193] (Evidence Grade: B),[199] (Evidence Grade: B) Prevention strategies should focus on the use of protective eyewear, parental supervision, and on childhood education about both the risks of eye injury and the utility of protective eyewear.[194] (Evidence Grade: B)
Potential Benefits: Reduction in eye injuries in children — **Potential Risks/Harms:** None
Benefit and Harm Assessment: Benefits significantly outweigh harms
Potential Costs: Direct cost of counseling as part of a pediatric eye and vision examination

Value Judgments: None
Role of Patient Preferences: Large
Intentional Vagueness: Specific type/form of counseling is not stated, as it is patient specific
Gaps in Evidence: Research is needed to determine the risks and methods of eye protection associated with specific eye injuries in children in order to design appropriate prevention strategies

b. Ultraviolet Radiation and Blue Light Protection

Children/parents/caregivers should be advised about the need to protect children's eyes from excessive exposure to sunlight. Sunlight is comprised of ultraviolet (UVA and UVB) radiation and short wavelength visible energy (blue light), which can cause acute effects in the eye and may also lead to chronic effects over the life of the individual. The eyes of infants and young children are known to have a higher level of UV and short wavelength transmittance than older children and adults, making them more susceptible to energy-related injury.[201, 202]

Exposure to high levels of UV-containing sunlight, especially when reflected from snow, can cause acute photokeratitis and keratoconjunctivitis. Chronic exposure to even low levels of UV radiation is a risk factor for developing cataracts, pterygium, squamous cell carcinoma of the cornea and conjunctiva, and skin cancer.[203] Epidemiological evidence also shows that excess chronic sunlight exposure leads to a significantly increased risk for developing age-related macular degeneration as an older adult.[204]

Exposure to high levels of short wavelength visible energy (blue light) also has the potential to cause photochemical retinal damage, which is known to occur with direct sun viewing.[205, 206] In addition, the increased evening use of laptops and other broad spectrum self-illuminated devices rich in blue light has been suggested to interfere with good sleep hygiene, especially in adolescents.[207]

Children can reduce the potential for eye damage from UV radiation and blue light by not looking directly at the sun, and wearing sunglasses and/or clear prescription lenses and brimmed hats when outdoors.

CONSENSUS-BASED ACTION STATEMENT: All children and their parents/caregivers should be advised about the benefits of the regular use of sunglasses and/or clear prescription glasses that effectively block at least 99% of UVA and UVB radiation, the use of hats with brims when outdoors, and the importance of not looking directly at the sun.
Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.
Benefit and Harm Assessment: Implementing this recommendation is likely to decrease patient risk of eye health problems from acute or chronic exposure to UV radiation and blue light. The benefits of this recommendation were established by expert consensus opinion.

c. Impact of Near Work and Reduced Time Outdoors on Vision

The prevalence of myopia in children has been increasing significantly in the past few decades.[44] Environmental factors such as time spent on reading and other near activities and the limited amount of time spent outdoors have been cited as potential factors contributing to the development and progression of myopia.[208] Most children spend considerable time each day using computers, tablets, or smart phones at school and at home. As a result, they may be spending less time outdoors.

Although there is conflicting evidence, more time spent outdoors and less time indoors doing near work may slow myopia progression and prevent high myopia.[208] (Evidence Grade: A),[209] (Evidence Grade: B),[210] (Evidence Grade: B),[211] (Evidence Grade: D).[212]

EVIDENCE-BASED ACTION STATEMENT: Patients/parents/caregivers should be counseled about the benefits to children's vision of spending more time outdoors.[208-211]

Evidence Quality: Grade B. Randomized clinical trial, Prospective cohort studies, Cross-sectional study **Level of Confidence:** Medium **Clinical Recommendation Strength:** Recommendation. This recommendation should generally be followed, but remain alert for new information.	
Evidence Statements: More time spent outdoors and less time indoors doing near work may slow axial elongation and prevent high myopia thereby reducing the risk of developing sight-threatening conditions such as retinal detachment and myopic retinopathy.[208] (Evidence Grade: A) More time outside may decrease myopia progression. Less outdoor/sports activity before myopia onset may exert a stronger influence on the development of myopia than near work.[209] (Evidence Grade: B) Outdoor time and near work do not have a major effect on myopia progression.[210] (Evidence Grade: B) Higher levels of outdoor activity were associated with lower amounts of myopia in primary school students.[211] (Evidence Grade: D)	
Potential Benefits: Implementation of this recommendation is likely to help reduce the development and progression of myopia in children	**Potential Risks/ Harms:** None
Benefit and Harm Assessment: Benefits significantly outweigh harms	
Potential Costs: Direct cost of counseling as part of a pediatric eye and vision examination and parental/caregiver time off from work	
Value Judgments: None	
Role of Patient Preferences: Moderate	
Intentional Vagueness: Specific type/form of counseling is not stated, as it is patient specific	

Gaps in Evidence: Research is needed on the effects and possible interaction of outdoor activity and near work on myopia in children

d. Myopia Control

Childhood is the preferred time to consider the use of myopia control procedures, as early onset myopia is associated with higher progression rates and increased risk of continuing to high myopia.[213]

The use of progressive addition spectacle lenses, prismatic bifocals, multiple and dual focus contact lenses, orthokeratology, and atropine have been studied to slow myopia progression.[214] The approaches to control of myopia that have been shown in studies to be most successful are the use of low concentrations of atropine eye drops[215] and orthokeratology.[214, 216, 217].

Parents/caregivers of children who are at risk for developing or have developed myopia should be counseled about the potential complications of myopia progression and the treatment options available for its control.

4. Coordination and Frequency of Care

The diagnosis of a wide array of eye and vision anomalies, diseases, disorders, and related systemic conditions may result from a comprehensive pediatric eye and vision examination. The nature and severity of the problem(s) diagnosed determine the need for:

- Optical correction
- Vision therapy
- Vision rehabilitation services
- Prescription or nonprescription medications
- Surgery
- Follow-up for additional evaluation and/or treatment.

a. Coordination of Care

Based on the examination, it may be determined that the patient needs additional services. These may include:

- Intraprofessional consultation with another doctor of optometry for treatment and management of ocular disease, vision rehabilitation, vision therapy, and/or specialty contact lenses.
- Interprofessional consultation with an ophthalmologist may be necessary for ophthalmic surgery or other aspects of secondary or tertiary eye care.
- Some vision problems can interfere with learning. Children at risk for learning-related vision problems should be evaluated by a doctor of optometry.
- Referral for consultation with the child's pediatrician or other primary care physician, developmental pediatrician, pediatric neurologist, the school system, a child psychologist or psychiatrist, or the local or state Department of Special Education should be considered when problems in other developmental areas such as behavior, language, or social development are suspected or when a full psychoeducational evaluation is indicated.
- The comprehensive pediatric eye and vision examination may reveal non-ophthalmic conditions for which coordination of care may be needed. The patient may be referred to his or her pediatrician/primary care physician or another health care provider for further evaluation and treatment of systemic conditions or related health problems. Information shared with other health care providers offers a unique and important perspective resulting in an improved team approach to interdisciplinary care of the patient.
- Ocular telehealth programs may be a component of care for some patients, particularly in areas where access to specialized eye care services is limited. The use of ocular telehealth-based programs has the potential to expand access to eye care services; however, telehealth-based evaluations are not a substitute for an in-person comprehensive eye examination. These programs rely on the digital capture and transmission of standardized ocular images and patient health information at one location for interpretation and evaluation at another location by trained observers who can recommend a treatment and care plan. To date, telehealth programs have been most widely used for the evaluation of patients with diabetic retinopathy.[218]

b. Frequency of Care

Children should receive periodic eye and vision examinations to diagnose and treat any eye disease in its early stages in order to prevent or minimize vision loss and maximize visual abilities. These examinations can also identify problems that may be affecting visual function and achievement at school, at home, and in sports or leisure activities. In addition, the early signs and symptoms of systemic medical conditions, such as diabetes, may be revealed during a comprehensive pediatric eye and vision examination.

The recommended frequency of a comprehensive pediatric eye and vision examination (Table 7) varies with a child's age, ocular and medical history, and other related risk factors.

- Infants and Toddlers (newborn through 2 years of age)

Clinical experience and research have shown that at 6 months the average child has reached a number of critical developmental milestones, making this an appropriate age for the first eye and vision examination. Within the first 6 months of life, rapid changes occur in most components of the visual system including visual acuity,[121, 219] accommodation,[220, 221] and binocular vision.[222-224] Since the developing visual system is considered most susceptible to interference during the first few years of life,[225-227] interference during this critical phase of development may have significant long-term effects; therefore, early diagnosis and treatment are critical to avoid vision loss.

There is a high prevalence of eye and vision problems in preterm children.[228] Preterm infants with a history of retinopathy of prematurity should be closely monitored for the development of high myopia, astigmatism,

anisometropia,[229] (Evidence Grade: B) strabismus,[76] and other ocular diseases.

One of the primary goals of examining young children is to detect amblyopia so that treatment can be initiated as early as possible. Early visual examination of infants for amblyopia and amblyopic risk factors can lower the prevalence and severity of amblyopia in children.[230] (Evidence Grade: B)

Assessment of infant refractive error can identify not only vision problems, but also potential developmental difficulties. Infants with hyperopia may show deficits in many visuocognitive, spatial, visuomotor, and attention tests.[231] (Evidence Grade: B) Significant hyperopia is commonly found in association with the early development of strabismus and amblyopia, with increased risk of development by age 4 years.

The wearing of a partial correction for significant hyperopia and anisometropia throughout infancy can reduce the incidence of poorer than average visual acuity in 3 to 5 1/2 year olds.[232] Spectacle correction in infancy also improves the chances of infants with hyperopia having normal vision at age 4 and beyond.[233]

EVIDENCE-BASED ACTION STATEMENT: Infants should receive an in-person comprehensive eye and vision assessment between 6 and 12 months of age for the prevention and/or early diagnosis and treatment of sight-threatening eye conditions and to evaluate visual development.[229-231]

Evidence Quality: Grade B: Prospective cohort studies, Diagnostic study
Level of Confidence: High
Clinical Recommendation Strength: Strong Recommendation. This recommendation should be followed unless clear and compelling rationale for an alternative approach is present.

Evidence Statements: Preterm infants with a history of retinopathy of prematurity should be closely monitored for the development of high myopia, astigmatism, and anisometropia.[229] (Evidence Grade: B)

Early visual examination in infants for amblyopia and amblyopic risk factors can lower the prevalence and severity of amblyopia in children.[230] (Evidence Grade: B)

Assessment of infant refractive error can identify not only vision problems, but also potential developmental difficulties. Hyperopic infants may show deficits in many visuocognitive, spatial, visuomotor, and attention tests.[231] (Evidence Grade: B)

Potential Benefits: Early identification and treatment of eye and vision problems	**Potential Risks/ Harms:** None
Benefit and Harm Assessment: Benefits significantly outweigh harms	
Potential Costs: Direct cost of testing and parent/caregiver time off from work	
Value Judgments: None	
Role of Patient Preferences: Moderate	
Intentional Vagueness: None	
Gaps in Evidence: None identified	

- Preschool Children (3 through 5 years of age)

Vision care in preschool children is very important because their visual system is still developing. They are at risk for the development of amblyopia, strabismus, and refractive error, which may lead to long term visual impairment.[40, 41, 53, 234-236]

Amblyopia is a treatable condition in children and adolescents[54] (Evidence Grade: A); however, amblyopia is more responsive to treatment among children younger than 7 years of age.[54-60] Significant uncorrected refractive errors are a risk factor for the development of amblyopia. In addition to its impact on vision, amblyopia can affect

an individual's psychosocial functioning, warranting early diagnosis and treatment.[19]

Uncorrected refractive errors have been associated with delays in development of cognitive ability and motor skill.[10, 231, 237] The Vision in Preschoolers-Hyperopia in Preschoolers (VIP-HIP) study found that uncorrected hyperopia ≥4.00D, as well as uncorrected hyperopia ≥3.00D to ≤6.00D in conjunction with reduced binocular visual acuity (20/40 or worse) or reduced near stereoacuity (240 seconds of arc or worse), are associated with significantly worse performance on a test of preschool early literacy (TOPEL) in 4 and 5 year old children.[238] (Evidence Grade: C) Children with astigmatism tend to score lower on measures of academic and developmental skills than children without astigmatism.[239] Spectacle correction of children with astigmatism during the preschool years can also result in significantly improved best-corrected visual acuity by the time they reach kindergarten age.[240] (Evidence Grade: C)

Uncorrected vision problems can have a detrimental effect on vision development, learning, school success, and socialization. Many eye and vision problems are asymptomatic in this age range; therefore, it is important that preschool children receive a comprehensive eye examination. While the U.S. Preventive Services Task Force recommends that children have their vision screened at least once between the ages of 3 and 5 years,[107] (Evidence Grade: B) gaps exist in the delivery of preschool vision screening. Rates of vision screening in preschool children are low, particularly in 3 year old children.[241] (Evidence Grade: C)

EVIDENCE-BASED ACTION STATEMENT:
Preschool age children should receive an in-person comprehensive eye and vision examination at least once between the ages of 3 and 5 to prevent and/or diagnose and treat any eye or vision conditions that may affect visual development.[54,107, 238, 240, 241]

Evidence Quality: Grade B. Systematic Review, Case series, Cross-sectional study
Level of Confidence: Medium
Clinical Recommendation Strength: Strong Recommendation. This recommendation should be followed, unless clear and compelling rationale for an alternative approach is present.

Evidence Statements: Amblyopia is a treatable condition in children and adolescents[54] (Evidence Grade: A); however amblyopia is more responsive to treatment among children younger than 7 years of age.

Uncorrected hyperopia in 4 and 5 year old children has been associated with delays in the development of early literacy.[238] (Evidence Grade: C)

Spectacle correction of astigmatism during the preschool years can result in significantly improved best-corrected visual acuity by kindergarten age.[240] (Evidence Grade: C)

The U.S. Preventive Services Task Force recommends that children have their vision screened at least once between the ages of 3 and 5 years of age;[107] (Evidence Grade: B) however, gaps exist in the delivery of preschool vision screening and rates of screening are low, particularly in 3 year old children.[241] (Evidence Grade: C)

Potential Benefits: Early identification and treatment of eye and vision problems	**Potential Risks/ Harms:** None

Benefit and Harm Assessment: Benefits significantly outweigh harms

Potential Costs: Direct cost of testing and parent/caregiver time off from work

Value Judgments: None

Role of Patient Preferences: Moderate

Intentional Vagueness: None

Gaps in Evidence: None identified

- School-age Children (6 through 11 and 12 through 18 years of age)

Vision may change frequently during the school years. The most common problems are due to the development and progression of refractive errors. Myopia generally occurs in children during their early school years and increases in magnitude as they get older. If myopia is defined as 0.50D or more, the percentage of children becoming myopic is estimated to be 23.4%. The age at onset ranges from 7 to 16 years. Sixteen percent of children enrolled in the CLEERE study developed myopia (0.75D or more) during their school-age years. The highest percentage of new cases occurred at age 11.[42]

Children should receive an eye examination at the beginning of primary school to test for the presence of myopia[115] (Evidence Grade: B) and, if diagnosed, they should have a comprehensive examination at least annually or as frequently as their doctor recommends because of rapid myopia progression.[242] (Evidence Grade: B) Children with myopia, especially those younger than 9 years of age and/or with two parents with myopia, are at higher risk for myopia progression and should be examined more than once per year.[208] (Evidence Grade: A)

In addition to its relationship to the development of strabismus and amblyopia, hyperopia can also affect the development of literacy skills. Children with uncorrected hyperopia show reduced performance in the acquisition of emergent literacy skills.[238] (Evidence Grade: C),[243] (Evidence Grade: C) Correction of hyperopia may, under specific conditions, lead to increased reading speed; therefore, eye examinations to diagnose uncorrected hyperopia are recommended.[244] (Evidence Grade: B)

An accommodative or vergence dysfunction can have a negative effect on a child's school performance, especially after third grade when the child must read smaller print and reading demands increase. Children with convergence insufficiency self-report more problems compared to children with normal binocular vision.[245] These include somatic (e.g., eyes hurt or headaches), visual (e.g., blur and diplopia), and performance (e.g., loss of concentration, frequent need to re-read and difficulty remembering what is read) problems. Due to the discomfort of these symptoms, a child may not be able to complete reading or homework assignments and may be easily distracted or inattentive.

Studies have reported an association between reading and eye movements.[246-248] Efficient reading requires accurate eye movements. Treatment of children with eye movement problems has been shown to improve reading comprehension.[248]

Diagnosis and treatment of an accommodative or vergence problem may reduce the negative impact on academic performance.[65] (Evidence Grade B)[249] Vision therapy has been shown to be effective in improving accommodative amplitude and accommodative facility in school-age children with symptomatic convergence insufficiency and accommodative dysfunction.

Children with Attention Deficit/Hyperactivity Disorder (AD/HD) have been reported to have a much greater incidence of CI than those without AD/HD;[250] therefore, these children may benefit from comprehensive vision evaluation to assess the presence of convergence insufficiency.[251] (Evidence Grade: D) Treatment of convergence insufficiency has been associated with reduction in the frequency of adverse academic behaviors.[65] (Evidence Grade B)[67]

Click to view the *(AOA Clinical Practice Guidelines web page)*

EVIDENCE-BASED ACTION STATEMENT:
School-age children should receive an in-person comprehensive eye and vision examination before beginning school to diagnose, treat, and manage any eye or vision conditions. [65, 115, 238, 243, 244, 251]

Evidence Quality: Grade B. Prospective cohort studies, Case-control study, Cross-sectional study.
Level of Confidence: Medium
Clinical Recommendation Strength: Strong Recommendation. This recommendation should be followed unless clear and compelling rationale for an alternative approach is present.

Evidence Statements: Children should receive an eye examination at the beginning of primary school to diagnose the onset of myopia.[115] (Evidence Grade: B)

Hyperopia can affect the development of literacy skills. Children with uncorrected hyperopia show reduced performance in the acquisition of emergent literacy skills.[238] (Evidence Grade: C),[243] (Evidence Grade: C)

Correction of hyperopia may, under specific conditions, lead to increased reading speed; therefore, eye examinations to diagnose uncorrected hyperopia are recommended.[244] (Evidence Grade: B)

Early diagnosis and treatment of an accommodative or vergence problem may reduce the negative impact on academic performance.[65] (Evidence Grade: B)

Children with AD/HD or related learning problems may benefit from comprehensive vision evaluation to assess the presence of convergence insufficiency.[251] (Evidence Grade: D)

Treatment of convergence insufficiency has been associated with reduction in the frequency of adverse academic behaviors.[65] (Evidence Grade B)

Potential Benefits: Early identification and treatment of eye and vision problems	**Potential Risks/ Harms:** None

Benefit and Harm Assessment: Benefits significantly outweigh harms

Potential Costs: Direct cost of testing and parent/caregiver time off from work

Value Judgments: None

Role of Patient Preferences: Moderate

Intentional Vagueness: None

Gaps in Evidence: None identified

EVIDENCE-BASED ACTION STATEMENT: Children with myopia should have an in-person comprehensive eye and vision examination at least annually, or as frequently as recommended (especially until age 12), because of the potential for rapid myopia progression.[208, 242]

Evidence Quality: Grade B. Randomized clinical trial, Prospective cohort study
Level of Confidence: Medium
Clinical Recommendation Strength: Strong Recommendation. This recommendation should be followed unless clear and compelling rationale for an alternative approach is present.

Evidence Statements: Children with myopia should have an examination at least annually or as frequently as their doctor recommends until the age of 12 because of rapid myopia progression.[242] (Evidence Grade: B)

When both parents have myopia, children are at higher risk for progression and should be examined more than once per year.[208] (Evidence Grade: A)

Potential Benefits: Early identification and treatment of eye and vision problems	**Potential Risks/ Harms:** None

Benefit and Harm Assessment: Benefits significantly outweigh harms

Potential Costs: Direct cost of testing and parent/caregiver time off from work

Value Judgments: None

Role of Patient Preferences: Moderate

Intentional Vagueness: None

Gaps in Evidence: None identified

CONSENSUS-BASED ACTION STATEMENT: School-age children should receive an in-person comprehensive eye and vision examination annually to diagnose, treat, and manage any eye or vision problems.

Evidence Quality: There is a lack of published research to support or refute the use of this recommendation.
Benefit and Harm Assessment: Implementing this recommendation is likely to result in earlier diagnosis and treatment of eye and vision problems and improved visual function. The benefits of this recommendation were established by expert consensus opinion.

c. At-risk Children

The extent to which a child is at risk for the development of eye and vision problems determines the appropriate re-evaluation schedule. Children with ocular signs and symptoms require a prompt comprehensive examination. Furthermore, the presence of certain risk factors may necessitate more frequent examinations based on professional judgment. Factors placing an infant, toddler, or child at significant risk for eye and vision problems include:

- Prematurity, low birth weight, prolonged supplemental oxygen at birth
- Family history of myopia, amblyopia, strabismus, retinoblastoma, congenital cataracts, metabolic, or genetic disease
- Infection of mother during pregnancy (e.g., rubella, toxoplasmosis, venereal disease, herpes, cytomegalovirus, or human immunodeficiency virus)
- Maternal smoking, use of alcohol, or illicit drug use during pregnancy
- Cortical visual impairment
- Difficult or assisted labor, which may be associated with fetal distress
- High or progressive refractive error
- Strabismus
- Anisometropia
- Academic performance problems
- Known or suspected neurodevelopmental disorders
- Systemic health conditions with potential ocular manifestations
- Wearing contact lenses
- Having functional vision in only one eye
- Eye surgery or previous eye injury
- Taking prescription or nonprescription drugs (e.g., over the counter medications, supplements, herbal remedies) with potential ocular side effects

Table 7: Recommended Eye Examination Frequency for the Pediatric Patient**

Examination Interval		
Patient Age	**Asymptomatic/ Low Risk**	**At-risk**
Birth through 2 years	At 6 to12 months of age	At 6 to 12 months of age or as recommended
3 through 5 years	At least once between 3 and 5 years of age	At least once between 3 and 5 years of age or as recommended
6 through 18 years	Before first grade and annually thereafter	Before first grade and annually, or as recommended, thereafter

***The American Optometric Association Clinical Practice Guidelines provide more information on other eye and vision disorders and their risk factors.* Click to view the *(AOA Clinical Practice Guidelines web page)*

D. Conclusion

The prevalence of eye and vision disorders is substantial in children. Research indicates that early detection and intervention are particularly important in children because of the rapid development of the visual system in early childhood and its sensitivity to interference. When visual disorders such as amblyopia, strabismus, non-strabismic binocular vision disorders, and significant refractive error are undetected, the long-term consequences can

lead to significant vision loss, decreased educational and occupational opportunities, and reduced quality of life. In addition, the cost of providing appropriate treatment for longstanding eye and vision disorders may be significantly higher than the cost of diagnosing and treating these problems early in life. A comprehensive pediatric eye and vision examination by a doctor of optometry is imperative for the timely diagnosis and treatment of eye and vision problems.

IV. REFERENCES

1. Institute of Medicine Committee on Standards for Developing Trustworthy Clinical Practice Guidelines. Clinical Practice Guidelines We Can Trust. The National Academies Press. 2011:Washington, D.C.

2. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of myopia and hyperopia in 6- to 72-month-old African American and Hispanic children: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2010; 117:140-47.

3. Wen G, Tarczy-Hornoch K, McKean-Cowdin R, et al. Prevalence of myopia, hyperopia, and astigmatism in non-Hispanic white and Asian children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2013; 120:2109-16.

4. Fozailoff A, Tarczy-Hornoch K, Cotter S, et al. Prevalence of astigmatism in 6- to 72-month-old African American and Hispanic children: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2011; 118:284-93.

5. Giordano L, Friedman DS, Repka MX, et al. Prevalence of refractive error among preschool children in an urban population: the Baltimore Pediatric Eye Disease Study. Ophthalmology 2009; 116:739-46.

6. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of amblyopia and strabismus in African American and Hispanic children ages 6 to 72 months: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2008; 115:1229-36.

7. Friedman DS, Repka MX, Katz J, et al. Prevalence of amblyopia and strabismus in white and African American children aged 6 through 71 months: the Baltimore Pediatric Eye Disease Study. Ophthalmology 2009; 116:2128-34.

8. McKean-Cowdin R, Cotter SA, Tarczy-Hornoch K, et al. Prevalence of amblyopia or strabismus in Asian and non-Hispanic white preschool children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2013; 120:2117-24.

9. Kemper AR, Bruckman D, Freed GL. Prevalence and distribution of corrective lenses among school-age children. Optom Vis Sci 2004; 81:7-10.

10. Roch-Levecq AC, Brody BL, Thomas RG, Brown SI. Ametropia, preschoolers' cognitive abilities, and effects of spectacle correction. Arch Ophthalmol 2008; 126:252-58.

11. Atkinson J, Nardini M, Anker S, et al. Refractive errors in infancy predict reduced performance on the movement assessment battery for children at 3 1/2 and 5 1/2 years. Dev Med Child Neurol 2005; 47:243-51.

12. Kulp MT, Schmidt PP. Visual predictors of reading performance in kindergarten and first grade children. Optom Vis Sci 1996; 73:255-62.

13. Simons HD, Grisham JD. Binocular anomalies and reading problems. J Am Optom Assoc 1987; 58:578-87.

14. Maples WC. Visual factors that significantly impact academic performance. Optometry 2003; 74:35-49.

15. Goldstand S, Koslowe KC, Parush S. Vision, visual-information processing, and academic performance among seventh-grade schoolchildren: a more significant relationship than we thought? Am J Occup Ther 2005; 59:377-89.

16. Basch CE. Vision and the achievement gap among urban minority youth. J Sch Health 2011; 81:599-605.

17. Mojon-Azzi SM, Kunz A, Mojon DS. Strabismus and discrimination in children: are children with strabismus invited to fewer birthday parties? Br J Ophthalmol 2011; 95:473-76.

18. Webber AL, Wood JM, Gole GA, Brown B. Effect of amblyopia on self-esteem in children. Optom Vis Sci 2008; 85:1074-81.

19. Packwood EA, Cruz OA, Rychwalski PJ, Keech RV. The psychosocial effects of amblyopia study. J AAPOS 1999; 3:15-17.

20. Davidson S, Quinn GE. The impact of pediatric vision disorders in adulthood. Pediatrics 2011; 127:334-39.

21. Menacker SJ. Visual function in children with developmental disabilities. Pediatr Clin North Am 1993; 40:659-74.

22. Akinci A, Oner O, Bozkurt OH, et al. Refractive errors and ocular findings in children with intellectual disability: a controlled study. J AAPOS 2008; 12:477-81.

23. Akinci A, Oner O, Bozkurt OH, et al. Refractive errors and strabismus in children with Down syndrome: a controlled study. J Pediatr Ophthalmol Strabismus 2009; 46:83-86.

24. Black K, McCarus C, Collins ML, Jensen A. Ocular manifestations of autism in ophthalmology. Strabismus 2013; 21:98-102.

25. Ikeda J, Davitt BV, Ultmann M, et al. Brief report: incidence of ophthalmologic disorders in children with autism. J Autism Dev Disord 2013; 43:1447-51.

26. Woodhouse JM. Investigating and managing the child with special needs. Ophthalmic Physiol Opt 1998; 18:147-52.

27. Salt A, Sargent J. Common visual problems in children with disability. Arch Dis Child 2014; 99:1163-68.

28. Brémond-Gignac D, Copin H, Lapillonne A, et al. Visual development in infants: physiological and pathological mechanisms. Curr Opin Ophthalmol 2011; 22:S1-S8.

29. Atkinson J. The Developing Visual Brain. Oxford: Oxford University Press; 2002.

30. Sokol, S. Measurement of infant visual acuity from pattern reversal evoked potentials. Vision Res 1978; 18:33-39.

31. Ciner EB, Schanel-Klitsch E, Herzberg C. Stereoacuity development: 6 months to 5 years. A new tool for testing and screening. Optom Vis Sci 1996; 73:43-48.

32. Birch EE, Morale SE, Jeffrey BG, et al. Measurement of stereoacuity outcomes at ages 1 to 24 months: Randot Stereocards. J AAPOS 2005; 9:31-36.

33. Tarczy-Hornoch K. Accommodative lag and refractive error in infants and toddlers. J AAPOS 2012; 16:112-17.

34. Scheiman M, Herzberg H, Frantz K, Margolies M. Normative study of accommodative facility in elementary schoolchildren. Am J Optom Physiol Opt 1988; 65:127-34.

35. Fioravanti F, Inchingolo P, Pensiero S, Spanio M. Saccadic eye movement conjugation in children. Vision Res 1995; 35:3217-28.

36. Yang Q, Kapoula Z. Binocular coordination of saccades at far and at near in children and in adults. J Vis 2003; 3:554-61.

37. Scheiman M, Herzberg H, Frantz K, Margolies M. A normative study of step vergence in elementary schoolchildren. J Am Optom Assoc 1989; 60:276-80.

38. Tarczy-Hornoch K, Cotter SA, Borchert M, et al. Prevalence and causes of visual impairment in Asian and non-Hispanic white preschool children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2013; 120:1220-26.

39. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence and causes of visual impairment in African-American and Hispanic preschool children: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2009; 116:1990-2000.

40. Cotter SA, Varma R, Tarczy-Hornoch K, et. al. Risk factors associated with childhood strabismus: the Multi-Ethnic Pediatric Eye Disease and Baltimore Pediatric Eye Disease Studies. Ophthalmology 2011; 118:2251-61.

41. Pascual M, Huang J, Maguire MG, et al. Risk factors for amblyopia in the Vision in Preschoolers Study. Ophthalmology 2014; 121:622-29.

42. Kleinstein RN, Sinnott LT, Jones-Jordan LA, et al. New cases of myopia in children. Arch Ophthalmol 2012; 130:1274-79.

43. Matsumura H, Hirai H. Prevalence of myopia and refractive changes in students from 3 to 17 years of age. Surv Ophthalmol 1999; 44 Suppl 1:S109-15.

44. Vitale S, Sperduto RD, Ferris FL 3rd. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. Arch Ophthalmol 2009; 127:1632-39.

45. Saw SM, Katz J, Schein OD, et al. Epidemiology of myopia. Epidemiol Rev 1996; 18:175-87.

46. Wong TY, Ferreira A, Hughes R, et al. Epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization: an evidence-based systematic review. Am J Ophthalmol 2014; 157:9-25.

47. Gwiazda J, Mohindra I, Brill S, Held R. Infant astigmatism and meridional amblyopia. Vision Res 1985; 25:1269-76.

48: Mutti DO, Mitchell GL, Jones LA, et al. Refractive astigmatism and the toricity of ocular components in human infants. Optom Vis Sci 2004; 81:753-61.

49. Borchert M, Tarczy-Hornoch K, Cotter SA, et al. Anisometropia in Hispanic and African American infants and young children: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2010; 117:148-53.

50. Abrahamsson M, Sjostrand J. Natural history of infantile anisometropia. Br J Ophthalmol 1996; 80:860-63.

51. Afsari S, Rose KA, Gole GA, et al. Prevalence of anisometropia and its association with refractive error and amblyopia in preschool children. Br J Ophthalmol 2013; 97:1095-99.

52. Kleinstein RN, Jones LA, Hullett S, et al. Refractive error and ethnicity in children. Arch Ophthalmol 2003; 121:1141-47.

53. Tarczy-Hornoch K, Varma R, Cotter SA, et al. Risk factors for decreased visual acuity in preschool children: the Multi-Ethnic Pediatric Eye Disease and Baltimore Pediatric Eye Disease Studies. Ophthalmology 2011; 118:2262-73.

54. Holmes JM, Lazar EL, Melia BM, et al. Effect of age on response to amblyopia treatment in children. Arch Ophthalmol 2011; 129:1451-57.

55. Pediatric Eye Disease Investigator Group. A prospective, pilot study of treatment of amblyopia in children 10 to <18 years old. Am J Ophthalmol 2004; 137:581-83.

56. Scheiman MM, Hertle RW, Beck RW, et al. Randomized trial of treatment of amblyopia in children aged 7 to 17 years. Arch Ophthalmol 2005; 123:437-47.

57. Hertle RW, Scheiman MM, Beck RW, et al. Stability of visual acuity improvement following discontinuation of amblyopia treatment in children aged 7 to 12 years. Arch Ophthalmol 2007; 125:655-59.

58. Scheiman MM, Hertle RW, Kraker RT, et al. Patching vs atropine to treat amblyopia in children aged 7 to 12 years: a randomized trial. Arch Ophthalmol 2008; 126:1634-42.

59. Hess RF, Thompson B. New insights into amblyopia: binocular therapy and noninvasive brain stimulation. J AAPOS 2013; 17:89-93.

60. Hess RF, Mansouri B, Thompson B. A binocular approach to treating amblyopia: antisuppression therapy. Optom Vis Sci 2010; 87:697-704.

61. Powell C, Hatt SR. Vision screening for amblyopia in childhood. Cochrane Database Syst Rev 2009:CD005020.

62. Donnelly UM, Stewart NM, Hollinger M. Prevalence and outcomes of childhood visual disorders. Ophthalmic Epidemiol 2005; 12:243-50.

63. Scheiman M, Gallaway M, Coulter R, et al. Prevalence of vision and ocular disease conditions in a clinical pediatric population. J Am Optom Assoc 1996; 67:193-202.

64. Cooper J, Jamal N. Convergence insufficiency-a major review. Optometry 2012; 83:137-58.

65. Borsting E, Mitchell GL, Kulp MT, et al. Improvement in academic behaviors after successful treatment of convergence insufficiency. Optom Vis Sci 2012; 89:12-18.

66. Letourneau JE, Ducic S. Prevalence of convergence insufficiency among elementary school children. Can J Optom 1988; 50:194-97.

67. Borsting E, Mitchell GL, Arnold LE, et al. Behavioral and emotional problems associated with convergence insufficiency in children: an open trial. J Atten Disord 2016; 20:836-44.

68. Rouse MW, Borsting E, Hyman L, et al. Frequency of convergence insufficiency among fifth and sixth graders. The Convergence Insufficiency and Reading Study (CIRS) group. Optom Vis Sci 1999; 76:643-49.

69. Xie JZ, Tarczy-Hornoch K, Lin J, et al. Color vision deficiency in preschool children: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology 2014; 121:1469-74.

70. Thadani SM, Foster CS. Treatment of ocular inflammation in children. Paediatr Drugs 2004; 6:289-301.

71. Reiff A. Ocular complications of childhood rheumatic diseases: nonuveitic inflammatory eye diseases. Curr Rheumatol Rep 2009; 11:226-32.

72. Towner SR, Michet CJ Jr., O'Fallon WM Nelson AM. The epidemiology of juvenile arthritis in Rochester, Minnesota 1960-1979. Arthritis Rheum 1983; 26:1208-13.

73. VanderVeen DK, Bremer DL, Fellows RR, et al. Prevalence and course of strabismus through age 6 years in participants of the Early Treatment for Retinopathy of Prematurity randomized trial. J AAPOS 2011; 15:536-40.

74. Goktas A, Sener EC, Sanac AS. An assessment of ocular morbidities of children born prematurely in early childhood. J Pediatr Ophthalmol Strabismus 2012; 49:236-41.

75. Saldir M, Sarici SU, Mutlu FM, et al. An analysis of neonatal risk factors associated with the development of ophthalmologic problems at infancy and early childhood: a study of premature infants born at or before 32 weeks of gestation. J Pediatr Ophthalmol Strabismus 2010; 47:331-37.

76. VanderVeen DK, Allred EN, Wallace DK, Leviton A. Strabismus at age 2 years in children born before 28 weeeks gestation: antecedents and correlates. J Child Neurol 2016; 31:451-60.

77. Faia LJ, Trese MT. Retinopathy of prematurity care: screening to vitrectomy. Int Ophthalmol Clin 2011; 51:1-16.

78. Good WV, Hardy RJ, Dobson V, et al. The incidence and course of retinopathy of prematurity: findings from the Early Treatment for Retinopathy of Prematurity Study. Pediatrics 2005; 116:15-23.

79. Gunn DJ, Cartwright DW, Gole GA. Incidence of retinopathy of prematurity in extremely premature infants over an 18-year period. Clin Exp Ophthalmol 2012; 40:93-99.

80. Holmes JM, Leske DA, Burke JP, Hodge DO. Birth prevalence of visually significant infantile cataract in a defined U.S. population. Ophthalmic Epidemiol 2003; 10:67-74.

81. Aponte EP, Diehl N, Mohney BG. Incidence and clinical characteristics of childhood glaucoma: a population-based study. Arch Ophthalmol 2010; 128:478-82.

82. Ferrari S, Di Iorio E, Barbaro V, et al. Retinitis pigmentosa: genes and disease mechanisms. Curr Genomics 2011; 12:238-49.

83. Genetics Home Reference. *http://ghr.nlm.nih.gov/condition/retinitis-pigmentosa*. Accesed 6/25/2015.

84. Wong JR, Tucker MA, Kleinerman RA, Devesa SS. Retinoblastoma incidence patterns in the US Surveillance, Epidemiology, and End Results program. JAMA Ophthalmol 2014; 132:478-83.

85. The Eye Cancer Foundation. Eye Cancer Network. *http://www.eyecancer.com/conditions/42/retinoblastoma*. Accessed 6/25/2015.

86. Truong B, Green AL, Friedrich P, et al. Ethnic, racial, and socioeconomic disparities in retinoblastoma. JAMA Pediatr 2015; 169:1096-104.

87. Delhiwala KS, Vadakkal IP, Mulay K, et al. Retinoblastoma: an update. Semin Diagn Pathol 2016; 33:133-40.

88. Forlenza GP, Stewart MW. Diabetic retinopathy in children. Pediatr Endocrinol Rev 2012; 10:217-26.

89. Lueder GT, Silverstein J. Screening for retinopathy in the pediatric patient with type 1 diabetes mellitus. Pediatrics 2005; 116:270-73.

90. Hatton DD, Schwietz E, Boyer B, Rychwalski P. Babies Count: the national registry for children with visual impairments, birth to 3 years. J AAPOS 2007; 11:351-55.

91. Tornqvist K, Ericsson A, Kallen B. Optic nerve hypoplasia: risk factors and epidemiology. Acta Ophthalmol Scand 2002; 80:300-4.

92. Borchert M. Reappraisal of the optic nerve hypoplasia syndrome. J Neuroophthalmol 2012; 32:58-67.

93. Garcia-Filion P, Borchert M. Optic nerve hypoplasia syndrome: a review of the epidemiology and clinical associations. Curr Treat Options Neurol 2013; 15:78-89.

94. Wong VC. Cortical blindness in children: a study of etiology and prognosis. Pediatr Neurol 1991; 7:178-85.

95. Fazzi E, Bova SM, Uggetti C, et al. Visual-perceptual impairment in children with periventricular leukomalacia. Brain Dev 2004; 26:506-12.

96. Hoyt CS. Brain injury and the eye. Eye (Lond) 2007; 21:1285-89.

97. Centers for Disease Control and Prevention. Vision Health Initiative. http://www.cdc.gov/visionhealth/risk/age.htm. Accessed 2/17/2016.

98. Frazier M, Garces I, Scarinci I, Marsh-Tootle W. Seeking eye care for children: perceptions among Hispanic immigrant parents. J Immigr Minor Health 2009; 11:215-21.

99. Zhang X, Elliott MN, Saaddine JB, et al. Unmet eye care needs among U.S. 5th-grade students. Am J Prev Med 2012; 43:55-58.

100. Wittenborn JS, Zhang X, Feagan CW, et al. The economic burden of vision loss and eye disorders among the United States population younger than 40 years. Ophthalmology 2013; 120:1728-35.

101. Grisham D, Powers M, Riles P. Visual skills of poor readers in high school. Optometry 2007; 78:542-49.

102. Powers M, Grisham D, Riles P. Saccadic tracking skills of poor readers in high school. Optometry 2008; 79:228-34.

103. Quaid P, Simpson T. Association between reading speed, cycloplegic refractive error, and oculomotor function in reading disabled children versus controls. Graefes Arch Clin Exp Ophthalmol 2013; 251:169-87.

104. Schmidt P, Maguire M, Dobson V, et al. Comparison of preschool vision screening tests as administered by licensed eye care professionals in the Vision In Preschoolers Study. Ophthalmology 2004; 111:637-50.

105. National Academies of Sciences, Engineering, and Medicine. Making Eye Health a Population Health Imperative: Vision for Tomorrow. The National Academies Press, 2016: Washington, D.C.

106. Centers for Disease Control and Prevention. Improving the Nation's Vision Health: a Coordinated Public Health Approach. https://stacks.cdc.gov/view/cdc/6846. Accessed 10/20/2016.

107. U.S. Preventive Services Task Force. Vision screening for children 1 to 5 years of age: US Preventive Services Task Force Recommendation statement. Pediatrics 2011; 127:340-46.

108. Chou R, Dana T, Bougatsos C. Screening for visual impairment in children ages 1-5 years: update for the USPSTF. Pediatrics 2011; 127:e442-79.

109. Ying GS, Kulp MT, Maguire M, et al. Sensitivity of screening tests for detecting vision in preschoolers-targeted vision disorders when specificity is 94%. Optom Vis Sci 2005; 82:432-38.

110. Vision in Preschoolers Study Group. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the Vision in Preschoolers Study. Invest Ophthalmol Vis Sci 2005; 46:2639-48.

111. Lieberman S, Cohen AH, Stolzberg M, Ritty JM. Validation study of the New York State Optometric Association (NYSOA) Vision Screening Battery. Am J Optom Physiol Opt 1985; 62:165-68.

112. Bodack MI, Chung I, Krumholtz I. An analysis of vision screening data from New York City public schools. Optometry 2010; 81:476-84.

113. Jacobson J. Why can't Johnny read? Abell Report 2010; 23:1-8.

114. Hartmann EE, Block SS, Wallace DK. Vision and eye health in children 36 to <72 months: proposed data system. Optom Vis Sci 2015; 92:24-30.

115. Jones-Jordan LA, Sinnott LT, Manny RE, et al. Early childhood refractive error and parental history of myopia as predictors of myopia. Invest Ophthalmol Vis Sci 2010; 51:115-21.

116. Kurtz D, Hyman L, Gwiazda JE, et al. Role of parental myopia in the progression of myopia and its interaction with treatment in COMET children. Invest Ophthalmol Vis Sci 2007; 48:562-70.

117. Anstice NS, Thompson B. The measurement of visual acuity in children: an evidence-based update. Clin Exp Optom 2014; 97:3-11.

118. Friedman DS, Katz J, Repka MX, et al. Lack of concordance between fixation preference and HOTV optotype visual acuity in preschool children: the Baltimore Pediatric Eye Disease Study. Ophthalmology 2008; 115:1796-99.

119. Hakim OM. Association between fixation preference testing and strabismic pseudoamblyopia. J Pediatr Ophthalmol Strabismus 2007; 44:174-77.

120. Cotter SA, Tarczy-Hornoch K, Song E, et al. Fixation preference and visual acuity testing in a population-based cohort of preschool children with amblyopia risk factors. Ophthalmology 2009; 116:145-53.

121. Dobson V, Teller DY. Visual acuity in human infants: a review and comparison of behavioral and electrophysiological studies. Vision Res 1978; 18:1469-83.

122. Gray LG. Avoiding adverse effects of cycloplegics in infants and children. J Am Optom Assoc 1979; 50:465-70.

123. Wickim SM, Amos JF. Chapter 21: Cycloplegic refraction. In Bartlett JD, Jaanus SD, eds. Clinical Ocular Pharmacology, 5th edition. St. Louis: Butterworth-Heinemann; 2008; 343-48.

124. Twelker JD, Mutti DO. Retinoscopy in infants using a near noncycloplegic technique, cyclopegia with tropicamide 1%, and cycloplegia with cyclopentolate 1%. Optom Vis Sci 2001; 78:215-22.

125. Bartlett JD, Wesson MD, Swiatocha J, Woolley T. Efficacy of a pediatric cycloplegic administered as a spray. J Am Optom Assoc 1993; 64:617-21.

126. Goodman CR, Hunter DG, Repka MX. A randomized comparison study of drop versus spray topical cycloplegic application. Binocul Vis Strabismus Q 1999; 14:107-10.

127. Ismail EE, Rouse MW, De Land PN. A comparison of drop instillation and spray application of 1% cyclopentolate hydrochloride. Optom Vis Sci 1994; 71:235-41.

128. Wesson MD, Bartlett JD, Swiatocha J, Woolley T. Mydriatic efficacy of a cycloplegic spray in the pediatric population. J Am Optom Assoc 1993; 64:637-40.

129. Syrimi M, Jones SM, Thompson GM. A prospective comparison between cyclopentolate spray and drops in pediatric outpatients. J Pediatr Ophthalmol Strabismus 2013; 50:290-95.

130. Mohindra I. A technique for infant vision examination. Am J Optom Physiol Opt 1975; 52:867-70.

131. Wesson MD, Mann KR, Bray NW. A comparison of cycloplegic refraction to the near retinoscopy technique for refractive error determination. J Am Optom Assoc 1990; 61:680-84.

132. Borghi RA, Rouse MW. Comparison of refraction obtained by “near retinoscopy” and retinoscopy under cycloplegia. Am J Optom Physiol Opt 1985; 62:169-72.

133. Anker S, Atkinson J, Braddick O, et al. Identification of infants with significant refractive error and strabismus in a population screening program using noncycloplegic videorefraction and orthoptic examination. Invest Ophthalmol Vis Sci 2003; 44:497-504.

134. Griffin JR, Cotter SA. The Brückner test: evaluation of clinical usefulness. Am J Optom Physiol Opt 1986; 63:957-61.

135. Gräf M, Jung A. The Brückner test: extended distance improves sensitivity for ametropia. Graefes Arch Clin Exp Ophthalmol 2008; 246:135-41.

136. Ciner EB, Ying GS, Kulp MT, et al. Stereoacuity of preschool children with and without vision disorders. Optom Vis Sci 2014; 91:351-58.

137. Cyert L, Schmidt P, Maguire M, et al. Threshold visual acuity testing of preschool children using the crowded HOTV and Lea Symbols acuity tests. J AAPOS 2003; 7:396-99.

138. Vision in Preschoolers Study Group. Preschool visual acuity screening with HOTV and Lea symbols: testability and between-test agreement. Optom Vis Sci 2004; 81:678-83.

139. Vision in Preschoolers Study Group. Effect of age using Lea Symbols or HOTV for preschool vision screening. Optom Vis Sci 2010; 87:87-95.

140. Hered RW, Murphy S, Clancy M. Comparison of the HOTV and Lea Symbols charts for preschool vision screening. J Pediatr Ophthalmol Strabismus 1997; 34:24-28.

141. Choong YF, Chen AH, Goh PP. A comparison of autorefraction and subjective refraction with and without cycloplegia in primary school children. Am J Ophthalmol 2006; 142:68-74.

142. Vision in Preschoolers Study Group. Comparison of the Retinomax and Palm-AR Auto-Refractors: a pilot study. Optom Vis Sci 2011; 88:830-36.

143. Kemper AR, Keating LM, Jackson JL, Levin EM. Comparison of monocular autorefraction to comprehensive eye examinations in preschool-aged and younger children. Arch Pediatr Adolesc Med 2005; 159:435-39.

144. Schmidt PP, Maguire MG, Moore B, Cyert L. Testability of preschoolers on stereotests used to screen vision disorders. Optom Vis Sci 2003; 80:753-57.

145. Birch E, Williams C, Drover J, et al. Randot Preschool Stereoacuity Test: normative data and validity. J AAPOS 2008; 12:23-26.

146. Pageau M, de Guise D, Saint-Amour D. Random-dot stereopsis in microstrabismic children: stimulus size matters. Optom Vis Sci 2015; 92:208-16.

147. Fawcett SL, Birch EE. Interobserver test-retest reliability of the Randot preschool stereoacuity test. J AAPOS 2000; 4:354-58.

148. Wesson MD. Normalization of prism bar vergences. Am J Optom Physiol Opt 1982; 59:628-34.

149. McClelland JF, Saunders KJ. The repeatability and validity of dynamic retinoscopy in assessing the accommodative response. Ophthalmic Physiol Opt 2003; 23:243-50.

150.Tarczy-Hornoch K. Modified bell retinoscopy: measuring accommodative lag in children. Optom Vis Sci 2009; 86:1337-45.

151. Cole BL. The handicap of abnormal colour vision. Clin Exp Optom 2004; 87:258-75.

152. Gnadt GR, Amos JF. Dichromacy and its effect on a young male. J Am Optom Assoc 1992; 63:475-80.

153. Birch J. Efficiency of the Ishihara test for identifying red-green colour deficiency. Ophthalmic Physiol Opt 1997; 17:403-8.

154. Cole BL, Lian KY, Lakkis C. The new Richmond HRR pseudoisochromatic test for colour vision is better than the Ishihara test. Clin Exp Optom 2006; 89:73-80.

155. Manny RE, Hussein M, Gwiazda J, Marsh-Tootle W. Repeatability of ETDRS visual acuity in children. Invest Ophthalmol Vis Sci 2003; 44:3294-300.

156. Hopkins S, Sampson GP, Hendicott P, et al. Refraction in children: a comparison of two methods of accommodation control. Optom Vis Sci 2012; 89:1734-39.

157. Sanfilippo PG, Chu BS, Bigault O, et al. What is the appropriate age cut-off for cycloplegia in refraction? Acta Ophthalmol 2014; 92:e458-62.

158. Jorge J, Queirós A, Almeida JB, Parafita MA. Retinoscopy/autorefraction: which is the best starting point for a noncycloplegic refraction? Optom Vis Sci 2005; 82:64-68.

159. Wick B, Hall P. Relation among accommodative facility, lag, and amplitude in elementary school children. Am J Optom Physiol Opt 1987; 64:593-98.

160. Cole BL. Assessment of inherited colour vision defects in clinical practice. Clin Exp Optom 2007; 90:157-75.

161. Steward JM, Cole BL. What do color vision defectives say about everyday tasks? Optom Vis Sci 1989; 66:288-95.

162. Parisi ML, Scheiman M, Coulter RS. Comparison of the effectiveness of a nondilated versus dilated fundus examination in the pediatric population. J Am Optom Assoc 1996; 67:266-72.

163. Bansal AS, Hubbard GB 3rd. Peripheral retinal findings in highly myopic children < or =10 years of age. Retina 2010; 30:S15-19.

164. Bradfield YS, Kaminski BM, Repka MX, et al. Comparison of Tono-Pen and Goldmann applanation tonometers for measurement of intraocular pressure in healthy children. J AAPOS 2012; 16:242-48.

165. Cook JA, Botello AP, Elders A, et al. Systematic review of the agreement of tonometers with Goldmann applanation tonometry. Ophthalmology 2012; 119:1552-57.

166. Grigorian F, Grigorian AP, Li A, et al. Comparison of the Icare rebound tonometry with the Goldmann applanation tonometry in a pediatric population. J AAPOS 2015; 19:572-74.

167. Das M, Spowart K, Crossley S, Dutton GN. Evidence that children with special needs all require visual assessment. Arch Dis Child 2010; 95:888-92.

168. Shevell M, Ashwal S, Donley D, et al. Practice parameter: evaluation of the child with global developmental delay: report of the Quality Standards Subcommittee of the American Academy of Neurology and The Practice Committee of the Child Neurology Society. Neurology 2003; 60:367-80.

169. Coulter RA, Bade A, Tea Y, et al. Eye examination testability in children with autism and in typical peers. Optom Vis Sci 2015; 92:31-43.

170. Centers for Disease Control and Prevention. Nonfatal traumatic brain injuries from sports and recreation activities – United States 2001-2005. MMWR Morb Mortal Wkly Rep 2007;56:733-37.

171. Centers for Disease Control and Prevention. Nonfatal traumatic brain injuries related to sports and recreation activities among persons aged ≤19 years – United States, 2001-2009. MMWR Morb Mortal Wkly Rep 2011; 60:1337-42.

172. Zuckerman SL, Lee YM, Odom MJ, et al. Recovery from sports-related concussion: days to return to neurocognitive baseline in adolescents versus young adults. Surg Neurol Int 2012; 3:130.

173. Sim A, Terryberry-Spohr L, Wilson KR. Prolonged recovery of memory functioning after mild traumatic brain injury in adolescent athletes. J Neurosurg 2008; 108:511-16.

174. Moser RS, Schatz P, Jordan BD. Prolonged effects of concussion in high school athletes. Neurosurgery 2005; 57:300-6.

175. Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. J Pediatr 2003; 142:546-53.

176. Master CL, Scheiman M, Gallaway M, et al. Vision diagnoses are common after concussion in adolescents. Clin Pediatr (Phila)2016; 55:260-67.

177. Kivlin JD, Simons KB, Lazoritz S, Ruttum MS. Shaken Baby Syndrome. Ophthalmology 2000; 107:1246-54.

178. Mills M. Funduscopic lesions associated with mortality in Shaken Baby Syndrome. J AAPOS 1998; 2:67-71.

179. Han DP, Wilkinson WS. Late ophthalmic manifestations of the Shaken Baby Syndrome. J Pediatr Ophthalmol Strabismus 1990; 27:299-303.

180. Smith SK. Child abuse and neglect: a diagnostic guide for the optometrist. J Am Optom Assoc 1988; 59:760-66.

181. Budenz DL, Farber MG, Mirchandani HG, et al. Ocular and optic nerve hemorrhages in abused infants with intracranial injuries. Ophthalmology 1994; 101:559-65.

182. Binenbaum G, Forbes BJ. The eye in child abuse: key points on retinal hemorrhages and abusive head trauma. Pediatr Radiol 2014; 44 Suppl 4:S571-77.

183: Bhardwaj G, Chowdhury V, Jacobs MB, et al. A systematic review of the diagnostic accuracy of ocular signs in pediatric abusive head trauma. Ophthalmology 2010; 117:983-92.

184. Classé JG. Release of spectacle prescriptions: an update. J Am Optom Assoc 1996; 67:631-37.

185. Kemp EC, Floyd MR, McCord-Duncan E, Lang F. Patients prefer the method of “tell back-collaborative inquiry” to assess understanding of medical information. J Am Board Fam Med 2008; 21:24-30.

186. Brand PL, Stiggelbout AM. Effective follow-up consultations: the importance of patient-centered communication and shared decision making. Paediatr Respir Rev 2013; 14:224-28.

187. Yin HS, Johnson M, Mendelsohn AL, et al. The health literacy of parents in the United States: a nationally representative study. Pediatrics 2009; 124 Suppl 3:S289-98.

188. Muir KW, Christensen L, Bosworth HB. Health literacy and glaucoma. Curr Opin Ophthalmol 2013; 24:119-24.

189. Hironaka LK, Paasche-Orlow MK. The implications of health literacy on patient-provider communication. Arch Dis Child 2008; 93:428-32.

190. Court H, Greenland K, Margrain TH. Predicting state anxiety in optometric practice. Optom Vis Sci 2009; 86:1295-302.

191. Dawn AG, Santiago-Turla C, Lee PP. Patient expectations regarding eye care: focus group results. Arch Ophthalmol 2003; 121:762-68.

192. Americans with Disabilities Act. ADA Title III Technical Assistance Manual. http://www.ada.gov/taman3.html. Accessed 2/16/2016.

193. Pollard KA, Xiang H, Smith GA. Pediatric eye injuries treated in US emergency departments, 1990-2009. Clin Pediatr (Phila) 2012; 51:374-81.

194. Armstrong GW, Kim JG, Linakis JG, et al. Pediatric eye injuries presenting to United States emergency departments: 2001-2007. Graefes Arch Clin Exp Ophthalmol 2013; 251:629-36.

195. Chen AJ, Linakis JG, Mello MJ, Greenberg PB. Epidemiology of infant ocular and periocular injuries from consumer products in the United States, 2001-2008. J AAPOS 2013; 17:239-42.

196. McGwin G, Jr., Owsley C. Incidence of emergency department-treated eye injury in the United States. Arch Ophthalmol 2005; 123:662-66.

197. Napier SM, Baker RS, Sanford DG, Easterbrook M. Eye injuries in athletics and recreation. Surv Ophthalmol 1996; 41:229-44.

198. Matter KC, Sinclair SA, Xiang H. Use of protective eyewear in U.S. children: results from the National Health Interview Survey. Ophthalmic Epidemiol 2007; 14:37-43.

199. Lesniak SP, Bauza A, Son JH, et al. Twelve-year review of pediatric traumatic open globe injuries in an urban U.S. population. J Pediatr Ophthalmol Strabismus 2012; 49:73-79.

200. Brophy M, Sinclair SA, Hostetler SG, Xiang H. Pediatric eye injury-related hospitalizations in the United States. Pediatrics 2006; 117:e1263-71.

201. Boettner EA, Wolter JR. Transmission of the ocular media. Invest Ophthalmol Vis Sci 1962; 6:776-83.

202. Barker FM, Brainard GC. The direct spectral transmittance of the excised human lens as a function of age. US Food and Drug Administration Report 1991.FDA 785345 0090 Washington, DC.

203. Lucas RM. An epidemiological perspective of ultraviolet exposure–public health concerns. Eye Contact Lens 2011; 37:168-75.

204. Sui GY, Liu GC, Liu GY, et al. Is sunlight exposure a risk factor for age-related macular degeneration? A systematic review and meta-analysis. Br J Ophthalmol 2013; 97:389-94.

205. Okuno T. Hazards of solar blue light. Appl Opt 2008; 47:2988-92.

206. Wu J, Seregard S, Algvere PV. Photochemical damage of the retina. Surv Ophthalmol 2006; 51:461-81.

207. van der Lely S, Frey S, Garbazza C, et al. Blue blocker glasses as a countermeasure for alerting effects of evening light-emitting diode screen exposure in male teenagers. J Adolesc Health 2015; 56:113-19.

208. Gwiazda J, Deng L, Manny R, Norton TT. Seasonal variations in the progression of myopia in children enrolled in the Correction of Myopia Evaluation Trial. Invest Ophthalmol Vis Sci 2014; 55:752-58.

209. Jones-Jordan LA, Mitchell GL, Cotter SA, et al. Visual activity before and after the onset of juvenile myopia. Invest Ophthalmol Vis Sci 2011; 52:1841-50.

210. Jones-Jordan LA, Sinnott LT, Cotter SA, et al. Time outdoors, visual activity, and myopia progression in juvenile-onset myopes. Invest Ophthalmol Vis Sci 2012; 53:7169-75.

211. Lin Z, Vasudevan B, Jhanji V, et al. Near work, outdoor activity, and their association with refractive error. Optom Vis Sci 2014; 91:376-82.

212. Rose KA, Morgan IG, Ip J, et al. Outdoor activity reduces the prevalence of myopia in children. Ophthalmology 2008; 115: 1279-85.

213. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. Lancet 2012; 379:1739-48.

214. Turnbull PR, Munro OJ, Phillips JR. Contact lens methods for clinical myopia control. Optom Vis Sci 2016; 93:1120-26.

215. Chia A, Lu QS, Tan D. Five-year clinical trial on atropine for the treatment of myopia 2: myopia control with atropine 0.01% eyedrops. Ophthalmology 2016; 123:391-99.

216. Liu YM, Xie P. The safety of orthokeratology—a systematic review. Eye Contact Lens 2016; 42:35-42.

217. Lin HJ, Wan L, Tsai FJ, et al. Overnight orthokeratology is comparable with atropine in controlling myopia. BMC Ophthalmol 2014; 14:40.

218. Silva PS, Cavallerano JD, Aiello LM, Aiello LP. Telemedicine and diabetic retinopathy: moving beyond retinal screening. Arch Ophthalmol 2011; 129:236-42.

219. Gwiazda J, Brill S, Mohindra I, Held R. Preferential looking acuity in infants from two to fifty-eight weeks of age. Am J Optom Physiol Opt 1980; 57:428-32.

220. Banks MS. The development of visual accommodation during early infancy. Child Dev 1980; 51:646-66.

221. Brookman KE. Ocular accommodation in human infants. Am J Optom Physiol Opt 1983; 60:91-99.

222. Banks MS, Aslin RN, Letson RD. Sensitive period for the development of human binocular vision. Science 1975; 190:675-77.

223. Hohmann A, Creutzfeldt OD. Squint and the development of binocularity in humans. Nature 1975; 254:613-14.

224. Ciner EB, Scheiman MM, Schanel-Klitsch E, Weil L. Stereopsis testing in 18- to 35-month-old children using operant preferential looking. Optom Vis Sci 1989; 66:782-87.

225. von Noorden GK, Crawford ML. The sensitive period. Trans Ophthalmol Soc U K 1979; 99:442-46.

226. Petrig B, Julesz B, Kropfl W, et al. Development of stereopsis and cortical binocularity in human infants: electrophysiological evidence. Science 1981; 213:1402-5.

227. Mohindra I, Jacobson SG, Held R. Binocular visual form deprivation in human infants. Doc Ophthalmol 1983; 55:237-49.

228. Hård AL, Niklasson A, Svensson E, Hellström A. Visual function in school-aged children born before 29 weeks of gestation: a population-based study. Dev Med Child Neurol 2000; 42:100-5.

229. Wang J, Ren X, Shen L, et al. Development of refractive error in individual children with regressed retinopathy of prematurity. Invest Ophthalmol Vis Sci 2013; 54:6018-24.

230. Eibschitz-Tsimhoni M, Friedman T, Naor J, et al. Early screening for amblyogenic risk factors lowers the prevalence and severity of amblyopia. J AAPOS 2000; 4:194-99.

231. Atkinson J, Braddick O, Nardini M, Anker S. Infant hyperopia: detection, distribution, changes and correlates-outcomes from the Cambridge infant screening programs. Optom Vis Sci 2007; 84:84-96.

232. Anker S, Atkinson J, Braddick O, et al. Non-cycloplegic refractive screening can identify infants whose visual outcome at 4 years is improved by spectacle correction. Strabismus 2004; 12:227-45.

233. Jones-Jordan L, Wang X, Scherer RW, Mutti DO. Spectacle correction versus no spectacles for prevention of strabismus in hyperopic children. Cochrane Database Syst Rev 2014: CD007738.

234. McKean-Cowdin R, Varma R, Cotter SA, et al. Risk factors for astigmatism in preschool children: the Multi-Ethnic Pediatric Eye Disease and Baltimore Pediatric Eye Disease Studies. Ophthalmology 2011; 118:1974-81.

235. Huang J, Maguire MG, Ciner E, et al. Risk factors for astigmatism in the Vision in Preschoolers Study. Optom Vis Sci 2014; 91:514-21.

236. Borchert MS, Varma R, Cotter SA, et al. Risk factors for hyperopia and myopia in preschool children: the Multi-Ethnic Pediatric Eye Disease and Baltimore Pediatric Eye Disease Studies. Ophthalmology 2011; 118:1966-73.

237. Atkinson J, Braddick O, Robier B, et al. Two infant vision screening programmes: prediction and prevention of strabismus and amblyopia from photo- and videorefractive screening. Eye (Lond) 1996; 10:189-98.

238. Kulp MT, Ciner E, Maguire M, et al. Uncorrected hyperopia and preschool early literacy: results of the Vision in Preschoolers-Hyperopia in Preschoolers (VIP-HIP) study. Ophthalmology 2016;123:681-89.

239. Orlansky G, Wilmer J, Taub MB, et al. Astigmatism and early academic readiness in preschool children. Optom Vis Sci 2015; 92:279-85.

240. Dobson V, Clifford-Donaldson CE, Green TK, et al. Optical treatment reduces amblyopia in astigmatic children who receive spectacles before kindergarten. Ophthalmology 2009; 116:1002-8.

241. Kemper AR, Wallace DK, Patel N, Crews JE. Preschool vision testing by health providers in the United States: findings from the 2006-2007 Medical Expenditure Panel Survey. J AAPOS 2011; 15:480-83.

242. Comet Group. Myopia stabilization and associated factors among participants in the Correction of Myopia Evaluation Trial (COMET). Invest Ophthalmol Vis Sci 2013; 54:7871-84.

243. Shankar S, Evans MA, Bobier WR. Hyperopia and emergent literacy of young children: pilot study. Optom Vis Sci 2007; 84:1031-38.

244. van Rijn LJ, Krijnen JS, Nefkens-Molster AE, et al. Spectacles may improve reading speed in children with hyperopia. Optom Vis Sci 2014; 91:397-403.

245. Borsting E, Rouse MW, Deland PN, et al. Association of symptoms and convergence and accommodative insufficiency in school-age children. Optometry 2003; 74:25-34.

246. Kulp MT, Schmidt PP. Effect of oculomotor and other visual skills on reading performance: a literature review. Optom Vis Sci 1996; 73:283-92.

247. Kulp MT, Schmidt PP. The relation of clinical saccadic eye movement testing to reading in kindergarteners and first graders. Optom Vis Sci 1997; 74:37-42.

248. Solan HA, Larson S, Shelley-Tremblay J, et al. Role of visual attention in cognitive control of oculomotor readiness in students with reading disabilities. J Learn Disabil 2001; 34:107-18.

249. Convergence Insufficiency Treatment Trial Study Group. Randomized clinical trial of treatments for symptomatic convergence insufficiency in children. Arch Ophthalmol 2008; 126:1336-49.

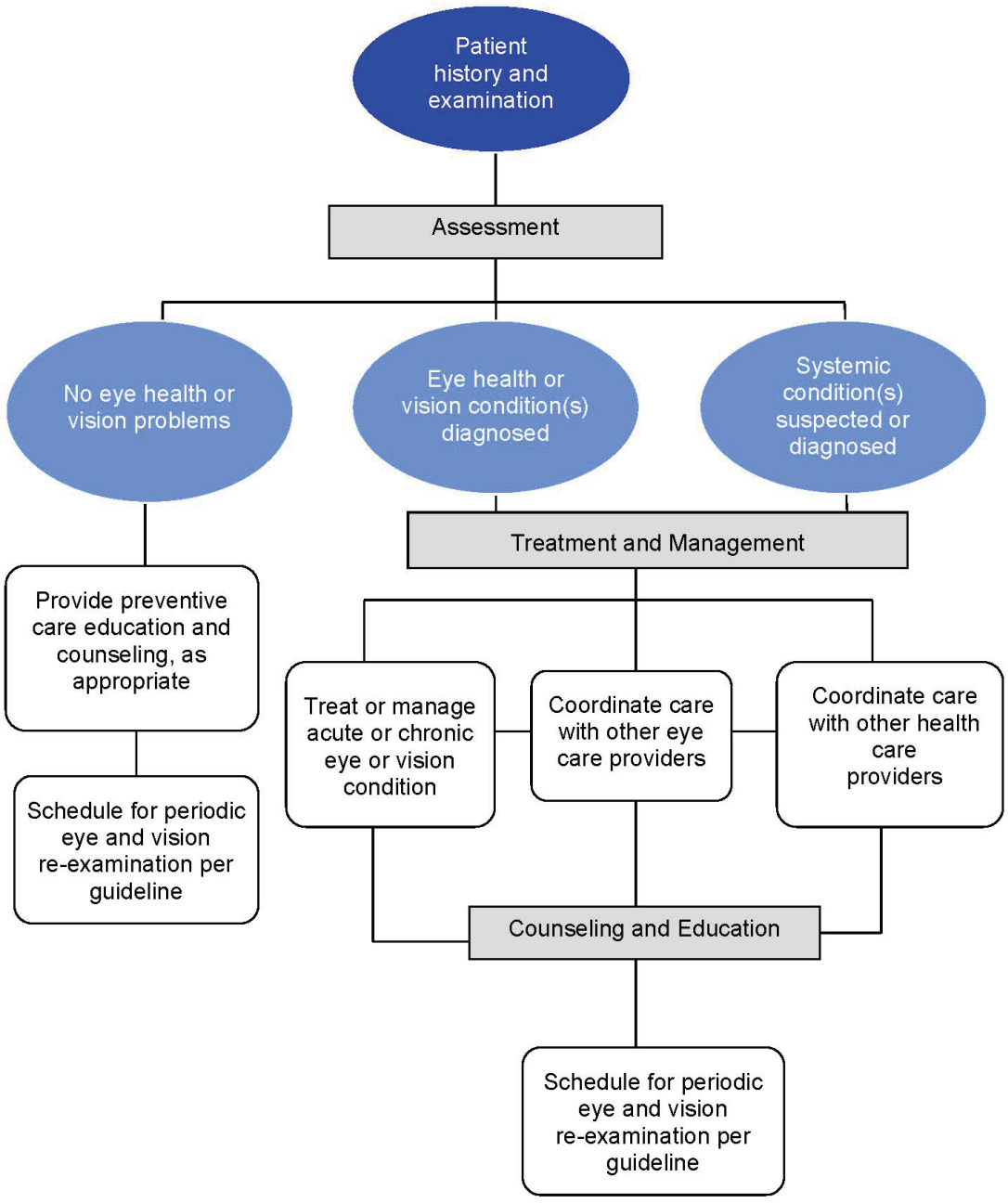
250. Granet DB, Gomi CF, Ventura R, Miller-Scholte A. The relationship between convergence insufficiency and ADHD. Strabismus 2005; 13:163-68.

251. Rouse M, Borsting E, Mitchell GL, et al. Academic behaviors in children with convergence insufficiency with and without parent-reported ADHD. Optom Vis Sci 2009; 86:1169-77.

V. APPENDIX

A. APPENDIX FIGURE 1:

Comprehensive Pediatric Eye and Vision Examination: A Flowchart



B. APPENDIX TABLE 1

Potential Components of the Comprehensive Eye and Vision Examination for Infants and Toddlers

A. Patient History
   1. Nature and history of the presenting problem, including chief complaint
   2. Visual and ocular history
   3. General health history, including prenatal, perinatal, and postnatal history and review of systems, surgical and/or head or ocular trauma history, and any vision or ocular treatment
   4. Medication reconciliation, including prescription and nonprescription drugs (e.g., over the counter medications, supplements, herbal remedies) and documentation of medication allergies
   5. Family ocular and medical histories
   6. Developmental history of the child
   7. Time spent outdoors, on sports activities, and on near work and screen viewing
   8. Names of, and contact information for, the patient's other health care providers

B. Visual Acuity
   1. Preferential looking visual acuity
   2. Fixation preference test
   3. Visual evoked potential

C. Refraction
   1. Cycloplegic retinoscopy
   2. Non-cycloplegic retinoscopy

D. Binocular Vision and Ocular Motility
   1. Ocular alignment assessment (e.g., cover test, Hirschberg test, Krimsky test)
   2. Brückner test
   3. Stereopsis (e.g., Preschool Assessment of Stereopsis with a Smile 3 test)
   4. Near point of convergence
   5. Ocular motility assessment (e.g., versions, eye tracking)

E. Ocular and Systemic Health Assessment
   1. Assessment of pupillary responses
   2. Visual field evaluation (e.g., confrontation)
   3. Evaluation of the ocular anterior segment and adnexa
   4. Evaluation of the ocular posterior segment
   5. Measurement of intraocular pressure

C. APPENDIX TABLE 2

Potential Components of the Comprehensive Eye and Vision Examination for Preschool Children

A. Patient History
   1. Nature and history of the presenting problem, including chief complaint
   2. Visual and ocular history
   3. General health history, including prenatal, perinatal, and postnatal history and review of systems, surgical and/or head or ocular trauma history, and any vision or ocular treatment
   4. Medication reconciliation, including prescription and nonprescription drugs (e.g., over the counter medications, supplements, herbal remedies) and documentation of medication allergies
   5. Family eye and medical histories
   6. Developmental history of the child
   7. Time spent outdoors, on sports activities, and on near work and screen viewing
   8. Names of, and contact information for, the patient's other health care providers

B. Visual Acuity
   1. Symbol optotype or letter matching visual acuity measurement

C. Refraction
   1. Static (distance) retinoscopy
   2. Cycloplegic retinoscopy
   3. Autorefraction

D. Binocular Vision, Ocular Motility, and Accommodation
   1. Ocular alignment assessment - distance and near (e.g., cover test, Hirschberg test, Krimsky test)
   2. Ocular motility assessment
   3. Near point of convergence
   4. Stereopsis (e.g., Preschool Assessment of Stereopsis with a Smile 3 test, Randot Preschool test)
   5. Positive and negative fusional vergence ranges
   6. Accommodative testing (e.g., dynamic retinoscopy)

E. Color vision testing

F. Ocular and Systemic Health Assessment
   1. Assessment of pupillary responses
   2. Visual field evaluation (e.g., confrontation)
   3. Evaluation of the ocular anterior segment and adnexa
   4. Evaluation of the ocular posterior segment
   5. Measurement of intraocular pressure

D. APPENDIX TABLE 3

Potential Components of the Comprehensive Eye and Vision Examination for School-age Children

A. Patient History
   1. Nature and history of the presenting problem, including chief complaint
   2. Visual and ocular history
   3. General health history, including prenatal, perinatal, and postnatal history and review of systems, surgical and/or head or ocular trauma history, and any vision or ocular treatment
   4. Medication reconciliation, including prescription and nonprescription drugs (e.g., over the counter medications, supplements, herbal remedies) and documentation of medication allergies
   5. Family eye and medical histories
   6. Developmental history of the child
   7. School performance history
   8. Time spent outdoors, on sports activities, and on near work and screen viewing
   9. Names of, and contact information for, the patient's other health care providers

B. Visual Acuity
   1. Snellen visual acuity
   2. ETDRS visual acuity

C. Refraction
   1. Static (distance) retinoscopy
   2. Cycloplegic retinoscopy
   3. Subjective refraction
   4. Autorefraction

D. Binocular Vision, Ocular Motility, and Accommodation
   1. Ocular alignment assessment - distance and near (e.g., cover test, Hirschberg test, Krimsky test, Von Graefe phoria, Modified Thorington, Maddox Rod)
   2. Ocular motility assessment (e.g., fixation, saccades, pursuits)
   3. Near point of convergence
   4. Stereopsis (e.g., Random dot stereopsis test)
   5. Positive and negative fusional vergence ranges
   6. Accommodative testing (e.g., amplitude, facility, and response)

E. Color Vision Testing

F. Ocular and Systemic Health Assessment
   1. Assessment of pupillary responses
   2. Visual field evaluation (e.g., confrontation)
   3. Evaluation of the ocular anterior segment and adnexa
   4. Evaluation of the ocular posterior segment
   5. Measurement of intraocular pressure

E. APPENDIX TABLE 4

Partial Listing of Ocular Manifestations of Neurodevelopmental Disorders and Other Syndromes

Neurodevelopmental Disorders	Etiology	Associated Ocular Manifestations
Aicardi Syndrome	Dysgenesis of the corpus callosum	Chorioretinal lacunae, optic nerve colobomas, optic nerve hypoplasia
Alport Syndrome	Irregular synthesis of collagen	Fleck retinal dystrophy, anterior lenticonus, corneal dystrophy, cataracts
Angelman Syndrome	Deletion of maternal genetic material on chromosome 15	Strabismus, hypopigmentation of the choroid
Attention Deficit/Hyperactivity Disorder	Genetic influences on dopaminergic systems, prenatal factors such as maternal use of drugs and alcohol	Convergence insufficiency, accommodative dysfunction, oculomotor disorders
Autism Spectrum Disorders	Unknown; possible link to environmental stressors, genetic mutations and inflammatory processes	Deficits in visual acuity, stereoacuity and ocular alignment; poor saccades and pursuits
Bardet-Biedl Syndrome	Mutation in 14 different genes that lead to problems with the function of cilia in cell structures	Reduced visual acuity, problems with night vision, tunnel vision
Batten-Mayou Syndrome	Autosomal recessive disorder resulting in accumulation of lipids	Lipofuscin accumulation in the retina, optic atrophy, macular pigment
Behçet's Disease	Postulated to be episodic hyperactivity of immune system	Uveitis, cataracts, optic atrophy, macular edema
Behr Syndrome	Autosomal recessive disease resulting in progressive deterioration of the nervous system	Optic atrophy, retrobulbar neuritis, nystagmus
Branchial Arch Syndrome	Disruption of neural crest cell migration	Strabismus, proptosis from poorly formed orbits, coloboma of the eyelid
Cerebral Palsy	Disorder of movement and posture secondary to damage to motor control connections	Strabismus, nystagmus, optic nerve pallor, cataracts, myopia, accommodative dysfunction
Cerebro-oculo-facial Syndrome	Autosomal recessive disorder resulting in defective swallowing mechanism	Microphthalmia, involuntary eye movements, congenital cataracts, blepharophimosis
Charot-Marie-Tooth Syndrome	Genetic anomaly resulting in progressive muscular atrophy	Nystagmus, diminished visual acuity
CHARGE Syndrome	Common mutation of chromosome 8 resulting in association of multiple systemic defects	Bilateral retinal coloboma involving the optic nerve, strabismus, amblyopia
Cri-du-chat Syndrome	Deletion of short arm of chromosome 5	Strabismus, hypertelorism, slanting of the palpebral fissure
Dandy-Walker syndrome	Absence of the cerebellar vermis and dilation of fourth ventricle	Papilledema often seen with hydrocephalus, ptosis and strabismus secondary to cranial nerve palsy
de Lange Syndrome	Mutation in genes responsible for chromosomal adhesions	Long eyelashes, ptosis telecanthus, alternating exotropia

Neurodevelopmental Disorders	Etiology	Associated Ocular Manifestations
Down Syndrome	Triplicate 21st chromosome	Epicanthal folds, upslanting palpebral fissure, high refractive error, strabismus, keratoconus, blepharitis, accommodative dysfunction/ insufficiency
Dubowitz Syndrome	Unknown etiology	Strabismus, ptosis, telecanthus, epicanthal folds
Ehlers-Danlos Syndrome	Genetic or nutritional defects that have altered the biosynthesis of collagen	Lens subluxation, palpebral skin laxity, keratoconus, myopia, blue sclera, angiod streaks
Fabry Disease	Inherited disorder resulting from an abnormal build-up of fat in the blood vessel walls throughout the body	Corneal opacity
Fetal Alcohol Syndrome	CNS damage secondary to alcohol crossing the blood-brain barrier	Telecanthus, strabismus, optic nerve hypoplasia, ptosis, microphthalmia
Fragile X Syndrome	Gene (FMR1) on the X chromosome fails to allow protein synthesis necessary for neural development	Strabismus, astigmatism, amblyopia
Gaucher Disease	Lysomal storage disease	Strabismus, gaze palsies, corneal clouding, pinguecula
Hunter Syndrome	Mucopolysaccharidosis I – Lysomal storage disease	Corneal clouding, pigmentary degeneration of the retina, optic atrophy
Lowe Syndrome	Abnormal protein transport within cellular membranes	Bilateral congenital cataracts, glaucoma, corneal keloids, strabismus
Marfan Syndrome	Genetic disorder affecting the body's connective tissue	Severe nearsightedness, dislocated lens, detached retina, glaucoma, cataracts
Prader-Willi Syndrome	Deletion of paternal genetic material on chromosome 15	Strabismus, almond-shaped palpebral fissures, myopia
Rett Syndrome	Mutation of binding protein (MECP2) that alters the development of gray matter	Difficulty maintaining eye contact
Septo-Optic Dysplasia/DeMorsier Syndrome	Disorder of early brain/optic nerve development associated with a number of environmental and genetic factors	Visual impairment in one or both eyes, nystagmus, strabismus
Spina Bifida	Incomplete closure of embryonic neural tube	Papilledema, nerve palsies, nystagmus, optic atrophy
Stickler Syndrome	Defective biosynthesis of collagen	Myopia, retinal detachments, vitreous anomalies
Usher Syndrome	Inherited autosomal recessive trait	Retinitis pigmentosa
Williams Syndrome	Vast deletion of genes on chromosome 7	Infantile esotropia, anomaly in visual-spatial relationship

Source: Adapted from Table 7.1 Rare Neurodevelopmental Disorders in Taub MB, Bartuccio M, Maino DM. Visual Diagnosis and Care of the Patient with Special Needs. Lippincott Williams & Wilkins, Philadelphia, PA, 2012.

F. ABBREVIATIONS/ACRONYMS

ADA	Americans with Disabilities Act
AD/HD	Attention Deficit/Hyperactivity Disorder
AHRQ	Agency for Healthcare Research and Quality
COI	Conflict of interest
CE	Convergence excess
CI	Convergence insufficiency
CLEERE	Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error
CPG	Clinical Practice Guideline
CT	Computerized tomography
CVI	Cortical (cerebral) visual impairment
D	Diopter
DR	Diabetic retinopathy
EBO	Evidence-Based Optometry
ERG	Electroretinogram
ETDRS	Early Treatment of Diabetic Retinopathy Study
G	Grams
GAT	Goldmann applanation tonometer
GDG	Guideline Development Group
GDRG	Guideline Development Reading Group
IDEA	Individuals with Disabilities Education Act
IEP	Individualized Education Program
IOM	Institute of Medicine
IOP	Intraocular pressure
MRI	Magnetic resonance imaging
NPC	Near point of convergence
NRA	Negative relative accommodation
OCT	Optical coherence tomography
PASS	Preschool Assessment of Stereopsis with a Smile
PRA	Positive relative accommodation
RCT	Randomized clinical trial
OP	Retinopathy of prematurity
RP	Retinitis pigmentosa
SE	Spherical equivalent
SR	Systematic review
TOPEL	Test of Preschool Early Literacy
VEP	Visual evoked potential
UV	Ultraviolet
VIP-HIP	Vision in Preschoolers-Hyperopia in Preschoolers

G. SUMMARY OF ACTION STATEMENTS

A comprehensive pediatric eye and vision examination should include, but is not limited to:

- Review of the nature and history of the presenting problem, patient and family eye and medical histories, including visual, ocular, general health, leisure and sports activities, and developmental and school performance history of the child
- Measurement of visual acuity
- Determination of refractive status
- Assessment of binocular vision, ocular motility, and accommodation
- Evaluation of color vision (baseline or periodic, if needed, for qualification purposes or if disease related)
- Assessment of ocular and systemic health, including evaluation of pupillary responses, anterior and posterior segment, peripheral retina, and evaluation/measurement of intraocular pressure and visual field testing. (Consensus)

Cycloplegic retinoscopy is the preferred procedure for the first evaluation of preschoolers. It is necessary to quantify significant refractive error in the presence of visual conditions such as strabismus, amblyopia, and anisometropia. (Consensus)

Cycloplegic retinoscopy is the preferred procedure for the first evaluation of school-age children. It is necessary to quantify significant refractive error in the presence of visual conditions such as strabismus, amblyopia, and anisometropia. (Consensus)

Abnormal color vision can affect daily performance of activities involving color discrimination and may interfere with or prevent some occupational choices later in life. Children should be tested as soon as possible for color vision deficiency and the parents/caregivers of children identified with color vision deficiency should be counseled. (Consensus)

Children at risk for learning-related vision problems should be evaluated by a doctor of optometry. (Consensus)

Many children with developmental or intellectual disabilities have undetected and untreated vision problems and should receive a comprehensive pediatric eye and vision examination. (Consensus)

At the conclusion of a comprehensive pediatric eye and vision examination, the diagnosis should be explained to the patient/parent/caregiver and related to the patient's symptoms, and a treatment plan and prognosis discussed. (Consensus)

Parents/caregivers and children should be educated about potential risks for eye injuries at home, at school, and during sports and recreational activities, and advised about safety precautions to decrease the risk of ocular injury.[193,199] Prevention of eye injuries in children should focus on the use of protective eyewear, parental supervision, and include education about both the risks of eye injury and the benefits of protective eyewear.[194] (Evidence Grade B/ Strong Recommendation)

All children and their parents/caregivers should be advised about the benefits of the regular use of sunglasses and/ or clear prescription glasses that effectively block at least 99% of UVA and UVB radiation, the use of hats with brims when outdoors, and the importance of not looking directly at the sun. (Consensus)

Patients/parents/caregivers should be counseled about the benefits to children's vision of spending more time outdoors.[208-211] (Evidence Grade B/Recommendation)

Infants should receive an in-person comprehensive eye and vision assessment between 6 and 12 months of age for the prevention and/or early diagnosis and treatment of sight-threatening eye conditions and to evaluate visual development.[229-231] (Evidence Grade B/Strong Recommendation)

Preschool age children should receive an in-person comprehensive eye and vision examination at least once between the ages of 3 and 5 to prevent and/or diagnose and treat any eye or vision conditions that may affect visual development.[54,107,238,240,241] (Evidence Grade B/Strong Recommendation)

School-age children should receive an in-person comprehensive eye and vision examination before beginning school to diagnose, treat and manage any eye or vision conditions.[65,115,238,243,244,251] (Evidence Grade B/Strong Recommendation)

Children with myopia should have an in-person comprehensive eye and vision examination at least annually, or as frequently as recommended (especially until age 12), because of the potential for rapid myopia progression.[208,242] (Evidence Grade B/Strong Recommendation)

School-age children should receive an in-person comprehensive eye and vision examination annually to diagnose, treat, and manage eye or vision problems. (Consensus)

H. GAPS IN RESEARCH EVIDENCE

During the course of the development of this guideline, the Evidence-Based Optometry Guideline Development Group identified the following gaps in evidence as potential areas for future research:

- Research to compare the outcomes of vision screenings versus comprehensive eye and vision examinations
- Research to determine the risks and protective factors associated with eye injuries in children in order to design appropriate prevention strategies
- Research on the effects and possible interaction of outdoor activity with near work and myopia in children.

VI. METHODOLOGY FOR GUIDELINE DEVELOPMENT

This guideline was developed by the AOA Evidence-Based Optometry Guideline Development Group (GDG). Clinical questions to be addressed in the guideline were identified and refined during an initial meeting of the GDG and served as the basis for a search of the clinical and research literature.

An English language search of the medical literature for the eye and vision examination of children birth through 18 years of age, for the time period January 2005 through October 2016 was conducted by trained researchers. If the search did not produce results, the search parameters were extended an additional 5 years.

Search Inclusion Criteria (must meet all):

1. English Studies
2. Study addresses the clinical question(s)
3. Paper meets the age group being addressed (0 to 18 years for pediatrics)
4. Searched by question(s) formulated at the AOA Call to Question Meeting attended by the Guideline Development Group (GDG)
5. Using all similar and relevant terms as defined by the GDG

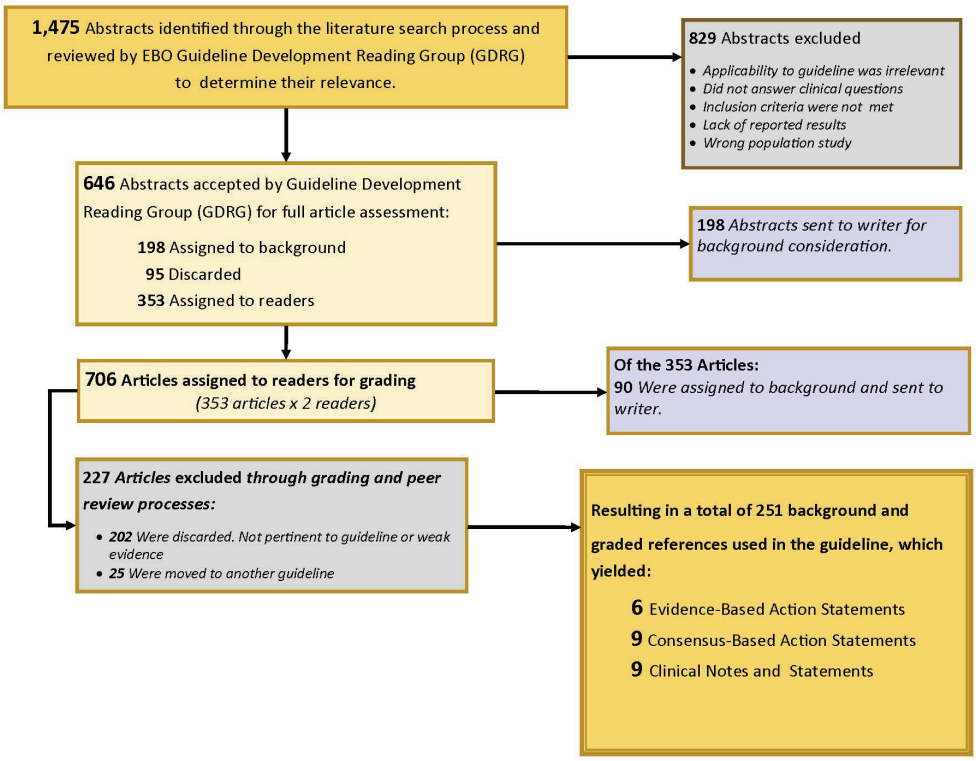
Exclusion Criteria (meeting *any* of the below):

1. Non-English studies
2. Animal studies
3. Studies outside of the patient age range
4. Studies not addressing any topic of the clinical questions searched

In addition, a review of selected earlier research publications was conducted based on previous versions of this guideline. The literature search was conducted using the following electronic databases:

- Agency for Healthcare Research and Quality (AHRQ)
- American Academy of Optometry (AAO)
- American Academy of Neurology
- American Association for Pediatric Ophthalmology and Strabismus (AAPOS)
- American Journal of Optometry and Physiological Optics
- Centers for Disease Control and Prevention, National Center for Health Statistics
- Cochrane Library
- Developmental Medicine & Child Neurology (DMCN)
- Elsevier
- Epidemiology
- Google Scholar
- JAMA Ophthalmology
- Journal of Adolescent Health Care (JAHC)
- Medline Plus
- National Eye Institute
- National Institute of Health Public Access (NIH)
- National Guideline Clearinghouse
- Neurology
- Ophthalmic Epidemiology
- Ophthalmology
- PubMed
- Other medical journals meeting the search criteria will be included in this list when used

The literature search resulted in the retrieval of the number of references shown in the following chart.



All references meeting the criteria were reviewed to determine their relevance to the clinical questions addressed in the guideline. Each article was assigned to two clinicians who independently reviewed and graded the quality of evidence and the clinical recommendations derived from the article, based on a previously defined system for grading quality. If discrepancies were found in the grading results, the article was assigned to an independent third reader for review and grading.

During six articulation meetings (three face-to-face and three using a Webex platform) of the Evidence-Based Optometry Guideline Development Reading Group (GDRG), all evidence was reviewed and clinical recommendations were developed. The strength level of clinical recommendations was based on the quality grade of the research and the potential benefits and harms of the procedure or therapy recommended. Where high quality evidence to support a recommendation was weak or lacking, a group consensus was required to approve any consensus recommendations.

Review and editing of the draft guideline by the Evidence-Based Optometry GDG required one face- to-face meeting and three additional Draft Reading Meetings using a Webex platform. The final Peer Review draft was reviewed and approved by the GDG by conference call, then made available for peer and public review for 30 days for numerous stakeholders (individuals and organizations). Comments were promoted and encouraged. All suggested revisions were reviewed and, if accepted by the GDG, incorporated into the guideline. All peer and public comments and all actions (and inactions) were recorded.

Clinical recommendations in this guideline are evidence-based statements regarding patient care that are supported by the scientific literature or consensus of professional opinion when no quality evidence was discovered. The guideline will be periodically reviewed for new scientific and clinical evidence within 3-5 years.

VII. EVIDENCE-BASED OPTOMETRY GUIDELINE DEVELOPMENT GROUP

AOA Evidence-Based Optometry Committee

Diane T. Adamczyk, O.D., Chair – *State University of New York, College of Optometry, New York, New York*

John F. Amos, O.D., M.S. – *University of Alabama at Birmingham School of Optometry, Birmingham, Alabama, Dean and Professor Emeritus*

Felix M. Barker, II, O.D., M.S. – *W. G. (Bill) Hefner VAMC, Salisbury, North Carolina*

Benjamin P. Casella, OD – *Private Practice – Casella Eye Center, Augusta, Georgia*

Linda M. Chous, O.D. – *United HealthCare Services, Inc., Minneapolis, Minnesota*

Lynn D. Greenspan, O.D. – *Salus University, Pennsylvania College of Optometry, Elkins Park, Pennsylvania*

Lori L. Grover, O.D., Ph.D. – *Health Policy, King-Devick Technologies, Inc., Oakbrook Terrace, Illinois*

Tina R. MacDonald, O.D. – *The Center for the Partially Sighted, Culver City, California*

Harue J. Marsden, O.D., M.S. – *Southern California College of Optometry, Marshall B. Ketchum University, Fullerton, California*

David K. Masihdas, O.D. – *Utah Eye Associates - The Diabetic Eye Center, Salt Lake City, Utah*

Bennett McAllister, O.D. – *Western University of Health Sciences, College of Optometry, Pomona, California*

Trennda L. Rittenbach, O.D. – *Palo Alto Medical Foundation/Sutter Health, Sunnyvale, California*

Carl J. Urbanski, O.D. – *Private Practice, Family Vision Care of Kingston, Kingston, Pennsylvania*

Multidisciplinary and Patient Stakeholders

Ida Chung, O.D. – *Western University of Health Sciences, College of Optometry, Pomona, California*

Beth T. Dessem – *Patient Advocate; Missouri CASA Association, Columbia, Missouri*

David E. Hartenbach, M.D. – *Pediatrician; Creve Coeur Pediatrics, Creve Coeur, Missouri*

Janet Hughes – *Patient (parent); Vision First Foundation, Lemont, Illinois*

Mitchell M. Scheiman, O.D. – *Salus University, The Eye Institute of Pennsylvania College of Optometry, Elkins Park, Pennsylvania*

Non-voting Members

Stephen C. Miller, O.D., Chief Editor - *Innovative Writing Works, St. Louis, Missouri*

Beth A. Kneib, O.D., AOA Director of Clinical Resources, *American Optometric Association, St. Louis, Missouri*

Andrew Morgenstern, O.D., AOA Consultant for Evidence-Based Optometry, *American Optometric Association, Alexandria, VA*

Danette Miller, AOA Manager of Quality Improvement, *American Optometric Association, St. Louis, Missouri*

Alisa G. Krewet, AOA Quality Improvement Coordinator, *American Optometric Association, St. Louis, Missouri*