

Comparison of photoscreening to chart methodology for vision screening

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Presented as a poster at the Annual Meeting of the Association for Research in Vision and

Ophthalmology, Vancouver, British Columbia, April 28-May 2, 2019.

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Abstract

The goal of this study is to assess the referral rate accuracy of photoscreening versus the chart methodology in identifying preschool children at risk for amblyopia and amblyogenic refractive error. Vision screenings using the plusoptiX S12 and the LEA chart were performed on 127 children, ages three to five-years-old. Comprehensive eye exams were performed after screenings. The sensitivity and specificity of the plusoptiX S12 was 80.3% and 92.1%, and the LEA chart was 43.6% and 94.8%, respectively. The sensitivity of the plusoptiX S12 is significantly higher than the LEA (p-value: < 0.001). After eye exams, 82.9% were correctly passed by the plusoptiX S12 and 64% were correctly passed by the LEA chart (p-value: 0.009). Objective photoscreening is significantly more accurate in identifying preschool children at risk of developing amblyopia and should be considered best practice. The chart methodology provides an inaccurate report on a preschool child's amblyopic risk.

Keywords: vision screening, amblyopia, preschool, School Nurse

Acknowledgments

Thanks to generous donations from the Oregon State Elks Association, all preschool screenings, exams and treatments were provided without charge to the participants.

Introduction

The State of Oregon mandates that all Oregon children entering a public school show proof of a vision screening. Head Starts and public schools are trying to determine how to best comply. In Oregon, Senate Bill 187 of 2017, declares that each education provider shall require vision screening for children under age 7 within 120 days of enrollment and requires vision screenings to be conducted by specific individuals, including school nurses. This bill does not provide guidance on implementation. Many school nurses are asked to oversee the screening process and follow-up on referrals. The chart methodology is the most common recommendation in public schools. Screening young children with the chart methodology is inexpensive and familiar, but it fails to detect 58% of the young children who need to be referred for amblyogenic risk factors.

Head Start is a federal program that serves an ethnically and developmentally diverse population of preschool children who are living 200% below the Oregon poverty line. The federal government mandates a vision screening within the first 45 days of school. However, most Head Starts, as with public schools, are not provided vision screening equipment or training.

To fill this need, the Elks Children's Eye Clinic at Oregon Health & Science University (OHSU) developed the Elks Vision Screening Program. The Oregon State Elks Association provides funding for vision screening tools and staff for screenings throughout the state, and the OHSU Elks Children's Eye Clinic pediatric ophthalmology department provides medical oversight.

The purpose of this vision screening program is to identify children aged 3-to-7-years-old who have risk factors for amblyopia and eye conditions that warrant referral to an ophthalmologist or optometrist. Amblyopia is the number one cause of vision loss in children (McKean-Cowdin et al., 2013; Multi-ethnic Pediatric Eye Disease Study Group, 2008; Pai et al., 2012). Success of

treatment depends to a large degree on how early the problem is identified. Detection prior to 7-years of age is critical, as early treatment can usually reverse amblyopia (Donahue et al., 2013). If it is not reversed, permanent vision loss may occur and result in decreased academic achievement, and the child may experience other developmental problems that can lead to socioeconomic disadvantages and a significantly reduced quality of life (Kelly et al., 2015; Kulp et al., 2016; Membremo et al., 2002; Webber et al., 2008). Healthy People 2010 notes that visual impairment in children is associated with developmental delays and the need for special educational, vocational and social services, often into adulthood.

Approximately 15% of children aged 3 to 7-years-old have amblyopic risk factors (ARFs) including refractive error (such as astigmatism, anisometropia, myopia, and hyperopia) misaligned eyes, or blockage of vision from cataracts or droopy eye lids that can cause amblyopia (Borchert et al., 2010; Donahue et al., 2013; Fozailoff et al., 2011; Multi-ethnic Pediatric Eye Disease Study Group, 2010). Early vision screening is essential to detect these ARFs before loss of acuity becomes irreversible. Despite general agreement that it is important to screen preschool children for ARFs and referral-warranted ocular diseases, only 50% of pre-kindergarten children in the United States were screened as of 2017 (U.S. Department of Health and Human Services, 2020). Amblyopia and other ocular problems go undetected in preschool children, especially in low-income families with reduced access to regular pediatric care. The estimated societal cost of a missing a case of amblyopia is estimated between \$25,000 to 75,000 when considering the lowest possible utility values of diminished quality of life per amblyopic case, even when using a conservatively estimated economic return of detecting a case of amblyopia (Rein et al., 2011).

Since 2004, The Elks Vision Screening Program has been part of an OHSU Institution Review Board (IRB) study with over 60,989 consented participants. In a typical year, the program screens 8,000 Oregon children (average age 4.3 years old) throughout the state of Oregon. If a child's parent provides IRB consent, the program offers follow-up assistance in finding local eye care providers and treatment. Each year, the program typically refers 12% of the participants and conducts follow-up on those who consent. After follow-up, eye exam chart notes are analyzed to determine the accuracy of the referrals. In our screening population from the year 2018-2019, we analyzed 555 chart notes and found 107 children diagnosed with amblyopia.

Originally, the Program performed vision screenings using a methodology promoted by Prevent Blindness America, a distance visual screening to the critical line of 20/40 using the linear Lea symbols visual acuity test (Good-Lite Company, Elgin, Illinois) and Random Dot E depth perception test (Good-Lite Company, Elgin, Illinois). This screening methodology provides an immediate pass or refer result. Although most children can complete the screening, participation is difficult for children younger than 4 years-old, the developmentally delayed and nonverbal/non-English speakers. Chart screening relies on the judgment of the screener to determine if the child is guessing the answers. For this reason, it is considered a subjective screening methodology.

The plusoptiX S12, (Plusoptix GmbH, Nuremberg, Germany) a handheld infrared photorefractor, provides binocular autorefraction in < .08 seconds to screen for refractive error, eye misalignment, unequal pupils, and media opacities. The plusoptiX S12 Vision Screener produces a printed screening certificate with the screening results in portable document format (PDF) that is useful for parents, teachers, and community health providers. It provides immediate objective

data analysis as to why the child was referred, such as hyperopia, anisometropia, myopia, and astigmatism. For this reason, it is considered an objective screening methodology.

The goal of this study is to compare the effectiveness of the plusoptiX S12 Vision Screener in detecting amblyopic risk factors (ARFs) in children aged 3-5 with combined testing using the linear Lea symbols visual acuity (VA) test (Good-Lite Company, Elgin, Illinois) and Random Dot E (RDE) depth perception test (Good-Lite Company, Elgin, Illinois).

Methods

Beginning in January 2019, IRB informed consent was collected from the parent or guardian of 127 three to five year-olds. There were 41.7 % non-English speakers in the cohort. These children were consented to take part in a comparable study between two vision screening methods: the LEA chart system and the plusoptiX S12 photoscreener. All screenings were performed by highly trained Elks Vision Screening staff and ophthalmic technicians. Each child was screened twice, once with each vision screening method. A light box on a stand containing the LEA chart was placed 10 feet from the child. The screener pointed at a symbol and asked the child to identify it while occluding the left and then right eye. To pass the screening, four out of five symbols on the 20/40 critical line needed to be identified correctly. If visual acuity tested below the critical line, with either eye, the child was considered a refer. If the child was unable to complete the LEA screening, their results were not included while calculating the accuracy of the LEA chart.

When screening with the plusoptiX S12 photoscreener, the machine was set to Option 4 referral criteria (Anisometropia, $SE \geq 1.00$ D; Astigmatism, cylinder ≥ 2.25 D; Hyperopia, $SE \geq 2.50$ D; Myopia, $SE \geq 2.25$ D) (Alaska Blind Child Discovery, 2018). The screening was performed at a

distance of three feet from the child in a room with dim lighting. The plusoptiX S12 is a photoscreening device that provides a binocular autorefraction in $< .08$ seconds. Once the screening is complete, it gives an immediate pass or refer recommendation. If the child was unable to complete the plusoptiX S12 screening, the child was not included in the accuracy results for the photoscreener.

Once the screenings were complete, the child then received an onsite dilated eye exam performed on the same day by a pediatric ophthalmologist or optometrist. All preschool screenings, exams, and treatments were provided without charge to the participants thanks to generous donations from the Oregon State Elks Association.

The comprehensive eye exam included visual acuity, cover test, examination of the anterior and posterior ocular segments, and a cycloplegic refraction. Patient chart notes of both passes and refers were reviewed to determine the accuracy of each vision screening methodology.

Based on a patient's normal or abnormal eye exam diagnosis, each method's sensitivity, specificity, and area under the curve (AUC) was calculated. Sensitivity measures the ability of a test to correctly identify people who have a condition. Specificity, on the other hand, measures the ability of a test to correctly identify people who do not have a condition. A reliable screening tool has relatively high sensitivity and specificity values – establishing a good ability to correctly identify people who do and do not have a condition. AUC represents the best measure of the combination of sensitivity and specificity. An AUC of 1.0 would represent a perfectly accurate diagnostic tool.

Results

A total of 127 children underwent the process of a dilated eye examination, screening using the LEA distance chart, and screening using the plusoptiX S12. A total of 126 children were successfully screened using the plusoptiX S12. Of those 126, 124 completed onsite dilated eye exams. The sensitivity and specificity of the plusoptiX S12 was 80.3% and 92.1%, respectively (Table 1). The plusoptiX S12 was able to correctly identify 49 of the 61 children with an eye condition present.

A total of 115 children completed the screening using the LEA chart methodology. Of those 115, 113 completed onsite dilated eye exams. The sensitivity and specificity of the LEA is reported at 43.6% and 94.8% (Table 1). The LEA correctly identified 24 of the 55 children within that cohort who had an eye condition present. The sensitivity of the plusoptiX S12 is significantly higher than the LEA sensitivity (p-value: < 0.001).

Our analysis determined the positive predictive value (PPV) of the plusoptiX S12 and LEA chart to be 90.7% and 88.9%, respectively (Table 1). Of the 70 children passed by the plusoptiX S12 screening, 12 were diagnosed with abnormal eye exam results. The plusoptiX S12 recorded a negative predictive value (NPV) of 82.9%. Of the 86 children passed by the LEA chart screening, 31 were diagnosed with abnormal eye exam results. The LEA chart recorded a NPV of 64.0%. The difference between screening devices was statistically significant (p-value: 0.009).

This means the plusoptiX S12 correctly passed more children with normal eye exams. Of the children who passed the LEA screening, 36% had an abnormal eye exam.

The AUC, a measure of the classification accuracy, was significantly higher in the plusoptiX S12 compared to the LEA distance chart, 0.862 and 0.682, respectively. The plusoptiX S12 is a more reliable screening device when compared to the LEA chart.

Discussion

When the Oregon Elks Preschool Vision screening program was created in 2003, all vision screenings were performed using a LEA chart (critical line of 20/40), a light box, medical tape for eye occlusion, and a Random Dot E stereopsis test. Hundreds of screening kits complete with training videos, measuring tape, pointers, charts and light boxes were placed in the field throughout the state of Oregon.

Nascent photoscreening technologies were becoming available beginning in 2006. The program began research on several promising photoscreeners. Until 2012, most photoscreeners were either too difficult to use (Suresight, Welch Allyn, Skaneateles Falls, NY, USA), did not provide immediate screening results (MTI, Medical Technology and Innovations Inc, Lancaster, PA, USA), and not easily adaptive to the field (plusoptiX S04) (Rogers et al., 2008). In 2009, the plusoptiX S09 was introduced. The program tested the S09 and compared it to the LEA chart methodology. Elks Vision Screening research revealed that the chart methodology missed more than half of the amblyopic suspects, and the S09 was significantly more accurate (Vaughan et al., 2013, IOVS, 54, ARVO Abstract5482).

In 2013, the Program switched to photoscreening exclusively. Since 2013, the Program has performed more than 40,000 photoscreenings using the plusoptiX S12. Although the rate of referrals between the LEA chart and the photoscreening methodologies remain similar (12-15%), the quality of the referrals has improved significantly.

The LEA chart methodology results can be inaccurate for many reasons. Sometimes, the screeners are not measuring the 10-foot screening distance precisely. Often times the child refuses to complete the screening because they do not want their eyes occluded. The child can become fatigued and lose concentration and then be unable to complete the screening. This is especially true for children under four years-old. Even when the methodology was followed precisely by experienced screeners, we found that the chart method only found 8 of the 19 amblyopic children. The plusoptiX photoscreener detected 16 out of 19 (Vaughan et al., 2013, IOVS, 54, ARVO Abstract5482).

Not only is photoscreening significantly more accurate, it is a screening methodology that is fast and easy to use. The most difficult part of screening using a photoscreening device is to make sure the screening area is properly lit. There can be no incandescent light or sunlight entering the screening area. Once the lighting is correct, it takes less than a minute to complete a screening. In contrast, based on our experience, it can take on average five minutes to screen the same child using the LEA chart method.

When screening using the chart methodology, 9.4% were unable to be screened. Their screening results were ambiguous, even after the second attempt at screening six months later. The screening completion rate is much higher for photoscreening. In this study, we found 99.2% of participants, including children with special needs, were able to complete the photoscreening.

The LEA chart methodology was used to perform over 20,000 screenings from 2003-2013. A screening kit was developed and distributed to 200 locations throughout the state. Each kit costs approximately \$500.00. It takes 2 hours to train a lay screener to perform a chart-based screening. Because subjective judgement is involved, it also requires supervision by an experienced trainer throughout the entirety of the screening session. It takes a child

approximately 5 minutes to complete a chart screening. An average screener can screen about 12 kids an hour. Not all young children are able to complete a chart screening. Even with expert screeners, 9.4% refused the screening. Because supervision is required during the entire screening session, it requires a full day salary and travel expenses for remote screenings.

In 2013, the Program purchased our first plusoptiX S12 with an extended warranty for \$6,000. While the initial purchase cost can seem high, this same device is in use seven years later, with little to no maintenance costs. Periodic updates have been performed remotely and without charge. The depreciated cost over the last seven years is \$857.00. A lay screener can be trained to use the plusoptiX S12 in approximately 30 minutes. Screening a child between the ages of 3 to 5-years-old takes less than one minute. Typically, 40 – 60 children can be screened in an hour, especially if they are screened in their classrooms and do not have to transit to a screening station far from their classroom. The machine automatically captures an image when it has proper fixation on the eyes and distance from the child. The refraction is analyzed in less than a second and reports immediate pass/refer results including reason for referral. Because it is an objective screening device, there is little supervision required after the screener is comfortable with the technology. Results can be saved in a PDF and later reviewed. This PDF photo of the child and refraction results recommending a complete eye exam can be sent to the parents and taken to the eye doctor.

School Nursing Implications

It is in the best interest of school children that schools acquire a vision screening tool that provides greater measurement success in a timely manner. The plusoptiX S12 demonstrates faster and more accurate results than the chart methodology. School nurses should work in conjunction with schools, state offices of education, and state health departments, to obtain and

implement policies that mandate the use of the best practice screening tools available. PlusoptiX S12 should be considered as a best practice screening tool for school nurses.

Limitations

There are limitations to this study. There is very little published data relating to U.S. children 3 to 7-years-old to compare our results. Also, our study population is comprised primarily of an ethnically diverse, economically disadvantaged portion of the U. S. population. There is no data to determine if our findings can apply to the general population.

Conclusion

An accurate preschool vision screening should be performed while the visual system is developing. The chart methodology cannot be relied upon to accurately detect amblyopia in young children. Photoscreening by the plusoptiX S12 using Option 4 is a significantly more accurate method to identify young children who are at risk of developing amblyopia.

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