Practical Community Photoscreening in Very Young Children

WHAT’S KNOWN ON THIS SUBJECT: Amblyopia affects 2% to 4% of the US population and is preventable. In January 2011, the US Preventive Services Task Force concluded there is insufficient evidence to support vision screening in children younger than age 3 years.

WHAT THIS STUDY ADDS: Results of the Iowa photoscreening program in 210,695 children older than 11 years suggest photoscreening reliably detects amblyogenic risk factors in children 1 to 3 years of age, and we recommend photoscreening children starting at 1 year of age.

abstract

OBJECTIVE: Recent US Preventive Services Task Force recommendations on vision screening reported insufficient data to recommend vision screening in children <3 years of age. The Iowa photoscreening program, KidSight, has screened children from 6 months of age and older since 2000. We report our experience with vision screening in these children and compare the results of the photoscreens in children younger than 3 years with those of children of preschool age and older.

METHODS: A retrospective review of results from the Iowa KidSight database using the MTI PhotoScreener containing results of children screened between May 1, 2000, and April 30, 2011.

RESULTS: During the 11 years of the study, 210,695 photoscreens on children were performed at 13,750 sites. In the <3-year age group, the unreadable rate was 13.0%, the referral rate was 3.3%, and the overall positive-predictive value was 86.6%. In the 3- to 6-year-old children, the unreadable rate was 4.1%, the referral rate was 4.7%, and the overall positive-predictive value was 89.4%.

CONCLUSIONS: No statistically significant difference was found in screening children from 1 to 3 years old compared with screening children >3 years old. These results confirm that early screening, before amblyopia is more pronounced, can reliably detect amblyogenic risk factors in children younger than 3 years of age, and we recommend initiation of photoscreening in children aged 1 year and older. Pediatrics 2013;131:e764–e769

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KEY WORDS vision screening, amblyopia, photoscreening

ABBREVIATIONS CI—confidence interval
PPV—positive-predictive value
USPSTF—US Preventive Services Task Force

Dr Longmuir designed the study with Dr Scott, critically revised the manuscript, approved the final manuscript as submitted, and contributed to statistical analysis; Mrs Boese drafted the initial manuscript, was involved in statistical analysis, and approved the final manuscript as submitted; Ms Pfeifer collected data for the analysis and supervised the initial manuscript development, critically revised the manuscript, and approved the final manuscript as submitted; Dr Zimmerman critically analyzed the data, revised the manuscript, and approved the final manuscript as submitted; Ms Short collected data for analysis, organized the data, critically revised the manuscript, and approved the final manuscript as submitted; Dr Scott designed the study with Dr Longmuir, critically revised the manuscript, and approved the final manuscript as submitted. www.pediatrics.org/cgi/doi/10.1542/peds.2012-1638
doi:10.1542/peds.2012-1638

Accepted for publication Nov 9, 2012

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

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Amblyopia is a significant health problem, affecting 2% to 4% of the US population.\(^1\)\(^-\)\(^4\) Although it is considered primarily in the realm of pediatric issues, the visual impairment is lifelong and continues to be the leading cause of monocular visual impairment in young and middle-aged adults in the United States.\(^4\)\(^-\)\(^6\)

There is a high prevalence of amblyopia that could be readily treatable, if recognized.\(^7\)\(^-\)\(^8\) There is overwhelming evidence that amblyopia treatment effectively restores vision; however, success rates decrease with increasing age.\(^7\)\(^-\)\(^10\) Amblyopia is also known to be easily treatable. A prospective, randomized study by the Pediatric Eye Disease Investigator Group known as the Amblyopia Treatment Study revealed that, with proper treatment, >75% of amblyopic children <7 years old were able to recover vision to better than 20/30 in the affected eye.\(^8\)

Because early recognition is the key to effective treatment, vision screenings have gained widespread attention.\(^11\)\(^-\)\(^12\) Vision screenings have been successful in recognizing amblyogenic factors,\(^13\)\(^-\)\(^16\) and the early institution of treatment has been shown to be cost-effective.\(^17\) There are many techniques of vision screening being used today. In literate children and adults, visual acuity can easily be measured directly with Snellen charts. However, vision screening in young children is often limited by attention spans, cooperation, symbol recognition, and communication. Photoscreeners and handheld refractive devices offer noninvasive and objective screening methods that require minimal cooperation by the child. These factors make them ideal for screening preliterate children, and even infants.

Photoscreeners, such as the MTI PhotoScreener (no longer in production; formerly Medical Technology Inc, Riviera Beach, FL), use the principle of photorefraction, the same technique used in retinoscopy.\(^18\) The fundal light reflex pattern from an off-axis light source is captured in photographs that can later be interpreted by qualified readers (orthoptists and pediatric ophthalmologists) and by computers.\(^19\)

Such photoscreeners have been shown to be effective and reliable in detecting amblyogenic factors, such as anisometropia, astigmatism, high refractive errors, strabismus, and media opacities.\(^19\)\(^-\)\(^22\) Photoscreening technology can facilitate vision screening in children, and the American Academy of Pediatrics recommends more studies be performed on this technique of vision screening for use in preschool vision screenings.\(^11\)\(^,\)\(^12\) In January 2011, the US Preventive Services Task Force (USPSTF) released new recommendations that vision screenings be performed at least once between the ages of 3 and 5 years and show “moderate net benefit.” They also identify the MTI PhotoScreener as having the one of the best testability rates in this age group. However, the USPSTF concluded that there is insufficient evidence to support vision screening in children younger than 3 years.\(^11\)

The Iowa photoscreening program, Iowa KidSight, is a joint project between the University of Iowa Department of Ophthalmology and Visual Sciences and the Lions Clubs of Iowa and has been in existence since 2000. Since its inception, >11 years of data have been collected by using the same criteria, screening mechanism, and photo interpreter, making it the largest cohort of children from a single statewide vision photoscreening program.\(^23\) The program has been collecting vision screening results from children as young as 6 months of age, thus providing data on this group of children <3 years of age, in whom the USPSTF concluded that there was insufficient evidence to recommend vision screening. The purpose of this study is to report our experience in younger-than-preschool-aged children and compare it with that in preschool-aged children.

METHODS

Photoscreening Database Analysis
To be able to reach the desired target population, Iowa KidSight trains Lions Club volunteers across the state to conduct free vision screening events with the MTI PhotoScreener. Although the program’s target population is children 6 to 48 months old, no preschool-aged child is turned down, and the results include screenings of children >48 months of age. The Iowa KidSight program has been previously described in detail.\(^23\)

Since its inception in May 2000, Iowa KidSight has maintained a database of all results from the photoscreener program. All data from the screenings are entered into a specially formatted Microsoft Access database (Microsoft Corporation, Redmond, WA). After approval by the institutional review board, the photoscreener database results were retrospectively reviewed and queried for number of screens performed, age of child screened, referral rate, re-take rate, follow-up rate, diagnosis, and positive-predictive values (PPVs).

Criteria for Referral

Iowa KidSight is able to screen across the state by using trained volunteers to photograph children in the field after receiving written consent. The photos are then sent to Iowa KidSight in Iowa City to be analyzed by the staff photo-reader. First, the readability of the photos is determined by using the same criteria used by volunteers in the field; a photograph is considered “unreadable” if the pupil diameter is <4 mm (termed “pupil”), the photo is out of focus (“focus”), the corneal light reflexes are not central (“fixation”), or...
both eyes are not fully viewed in the top and bottom photograph (“4 eyes”). Unreadable photographs are sent back to the Lions Club to have the child repeat the photoscreening.

Photos determined to be readable by the above criteria are subsequently analyzed by using the photographic referral criteria (Table 1). Because the referral criteria are based on amblyogenic risk factors detected by the MTI Photoscreener, children are considered to be at high risk for amblyopia if they meet these criteria. When a photoscreen meets any of the referral criteria, the child’s parent or guardian is sent a packet containing a list of local ophthalmologists and optometrists, a copy of the failed photoscreening, and an evaluation form and a referral letter explaining the importance of follow-up. The parents are instructed to see an eye care professional to complete a full vision evaluation and return the evaluation form to Iowa KidSight.

The examination referral criteria (Table 2) are used to identify the children who have amblyogenic risk factors found on the examination by the eye care professional. The criteria differ from the current American Association of Pediatric Ophthalmology and Strabismus (AAPOS) standards. The results of the eye examination from the evaluation form are then logged into the Iowa KidSight database, which allows the PPV of the screenings to be determined.

In addition, 95% confidence intervals (CIs) for proportions were computed, and Pearson’s $\chi^2$ test was used to compare the age groups.

**RESULTS**

In the 11 years between May 1, 2000, and April 30, 2011, 210,695 children were screened at 13,750 sites. The mean age of the children screened was 3.4 years. The total number of children referred was 9360 (4.4%). The reasons for referral on photoscreening are listed in Table 3. The majority (84.6%) of children of all ages who failed the photoscreening were referred because of a refractive error (32.6% astigmatism, 26.5% high hyperopia, 22.8% anisometropia, and 2.7% high myopia). Other reasons for referral included strabismus (11.0%), media opacity (0.4%), and other (4.0%). The “other” category included iris abnormalities and anisocoria $>1$ mm. Overall, there were 12420 (5.9%) unreadable photoscreens obtained. The overall PPV for all ages of children undergoing photoscreening was 88.8%.

Of the children screened, 42,149 (20.0%) children were aged 0.5 to 3 years. In this age group, 1379 (3.3%) were referred to an eye care professional for amblyogenic risk factors detected on photoscreening. The number of unreadable photoscreens in this age group was 5483 (13.0%). The majority of unreadable photographs was due to fixation and small pupil size. Overall, the PPV for children 0.5 to 3 years of age for the detection of any amblyogenic risk factor was 86.4% (95% CI: 83.8%, 88.8%). After exclusion of children $<1$ year old, the PPV for children slightly increased to 87.4% (84.5%, 89.9%).

In the 3- to 5-year age group, 165,935 (78.8%) children underwent photoscreening. From these photoscreenings, 7819 (4.7%) were referred to an eye care professional due to a failed

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**Table 1**

Photographic Referral Criteria

<table>
<thead>
<tr>
<th>Reason for Referral</th>
<th>Occurrences</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refractive error</td>
<td>7917</td>
<td>84.6</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>3053</td>
<td>32.6</td>
</tr>
<tr>
<td>High hyperopia</td>
<td>2479</td>
<td>26.5</td>
</tr>
<tr>
<td>Anisometropia</td>
<td>2135</td>
<td>22.8</td>
</tr>
<tr>
<td>High myopia</td>
<td>251</td>
<td>2.7</td>
</tr>
<tr>
<td>Strabismus</td>
<td>1030</td>
<td>11.0</td>
</tr>
<tr>
<td>Media opacity (cataract)</td>
<td>39</td>
<td>0.4</td>
</tr>
<tr>
<td>Other</td>
<td>373</td>
<td>4.0</td>
</tr>
</tbody>
</table>

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**Table 2**

Criteria to Fail Eye Examination for Iowa KidSight Program

<table>
<thead>
<tr>
<th>Reason for Referral</th>
<th>Number of Occurrences</th>
<th>PPV, % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperopia $&gt;3.50$ diopters</td>
<td>225</td>
<td>80.9 (75.1, 85.8)</td>
</tr>
<tr>
<td>Myopia $&lt;-3.00$ diopters</td>
<td>860</td>
<td>89.0 (86.7, 91.0)</td>
</tr>
<tr>
<td>Astigmatism $&gt;1.00$ diopter</td>
<td>889</td>
<td>83.3 (82.3, 84.3)</td>
</tr>
<tr>
<td>Anisometropia $&gt;1.00$ diopter</td>
<td>889</td>
<td>83.3 (82.3, 84.3)</td>
</tr>
<tr>
<td>Refractive error</td>
<td>2135</td>
<td>91.1 (89.4, 92.8)</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>1030</td>
<td>92.5 (91.5, 93.5)</td>
</tr>
<tr>
<td>High hyperopia</td>
<td>1030</td>
<td>93.6 (92.5, 94.7)</td>
</tr>
<tr>
<td>Anisometropia</td>
<td>1030</td>
<td>93.6 (92.5, 94.7)</td>
</tr>
<tr>
<td>High myopia</td>
<td>1030</td>
<td>93.6 (92.5, 94.7)</td>
</tr>
<tr>
<td>Strabismus</td>
<td>1030</td>
<td>93.6 (92.5, 94.7)</td>
</tr>
<tr>
<td>Media opacity (cataract)</td>
<td>375</td>
<td>91.1 (89.1, 93.1)</td>
</tr>
<tr>
<td>Other</td>
<td>3379</td>
<td>92.5 (91.5, 93.5)</td>
</tr>
</tbody>
</table>

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**Table 3**

Reasons for Referral on Photoscreening in All Age Groups

<table>
<thead>
<tr>
<th>Reason for Referral</th>
<th>Number of Occurrences</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refractive error</td>
<td>7917</td>
<td>84.6</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>3053</td>
<td>32.6</td>
</tr>
<tr>
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<td>2479</td>
<td>26.5</td>
</tr>
<tr>
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<td>2135</td>
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</tr>
<tr>
<td>High myopia</td>
<td>251</td>
<td>2.7</td>
</tr>
<tr>
<td>Strabismus</td>
<td>1030</td>
<td>11.0</td>
</tr>
<tr>
<td>Media opacity (cataract)</td>
<td>39</td>
<td>0.4</td>
</tr>
<tr>
<td>Other</td>
<td>373</td>
<td>4.0</td>
</tr>
</tbody>
</table>
TABLE 5

<table>
<thead>
<tr>
<th>Reason for Referral</th>
<th>Number of Referrals by Age Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anisometropia</td>
<td>7</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>44</td>
</tr>
<tr>
<td>High hyperopia</td>
<td>70</td>
</tr>
<tr>
<td>Media opacity</td>
<td>0</td>
</tr>
<tr>
<td>Strabismus</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
</tr>
</tbody>
</table>

PPV for Amblyogenic Risk Factors by Age and Diagnosis

<table>
<thead>
<tr>
<th>Age</th>
<th>PPV, % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1 y</td>
<td>82.5 (75.3, 88.4)</td>
</tr>
<tr>
<td>1–2 y</td>
<td>81.5 (76.3, 86.4)</td>
</tr>
<tr>
<td>2–3 y</td>
<td>80.7 (75.9, 85.3)</td>
</tr>
<tr>
<td>3–4 y</td>
<td>79.6 (74.7, 84.3)</td>
</tr>
<tr>
<td>4–5 y</td>
<td>78.3 (73.1, 83.3)</td>
</tr>
<tr>
<td>5–6 y</td>
<td>76.1 (70.7, 81.2)</td>
</tr>
<tr>
<td>6–7 y</td>
<td>74.0 (68.0, 80.0)</td>
</tr>
<tr>
<td>7 y</td>
<td>72.3 (66.0, 78.4)</td>
</tr>
<tr>
<td>Total</td>
<td>76.4 (71.2, 81.4)</td>
</tr>
</tbody>
</table>

The PPV increased with increasing age, but not significantly; the 1-year-old age group had a PPV of 82.5% (95% CI: 75.3%, 88.4%). The PPV increased with increasing age, but not significantly; the 1-year-old age group had a PPV of 84.0% (95% CI: 78.2%, 88.7%), the 2-year-old age group had a PPV of 89.2% (95% CI: 85.7%, 92.1%), and the 3-year-old age group revealed a PPV of 89.4% (95% CI: 87.5%, 91.0%). The PPV among the 4-year-old children was 90.1% (95% CI: 88.4%, 91.6%) and was 88.8% (95% CI: 85.3%, 90.4%) among the 5-year-old children. The PPV and CI can be further stratified by age and diagnosis (Table 5).

Consistent with previous studies, the rate of unreadable photoscreens decreased with increasing age. For children ≤1 year old, 25.5% (1790) of the photoscreens were unreadable. The unreadable rate decreased markedly for the 1-year-old age group with a rate of 13.7% (2044), and again for the 2-year-old age group with a rate of 8.15% (1649). The unreadable rate continued to drop with increasing age, with an overall unreadable rate of 5.9% (Table 6).

DISCUSSION

We believe that this study reports on the largest number of participants in a photoscreening program from 1 site using the same screening device over an 11-year period, with 210,695 screenings conducted in children in a statewide program. Twenty percent of the children screened were <3 years of age (42,149 photoscreens). Our study focused on comparing the screening of young children with that of preschool-aged children because of the recent USPSTF recommendation that did not support vision screening in children younger than age 3 years due to lack of data. Our data reveal that the accuracy and reliability of vision photoscreening can be extended to children as young as 1 year old because there was no significant difference between the PPV of vision screening in the preschool-aged group (3–5 years) that is currently recommended by the USPSTF and younger children aged between 1 and 2 years (P = .15).

Our vision screening program photo-screened children as young as 6 months. If children <1 year of age are included, the PPV is slightly less in this younger age group but still significant (P = .02). Without the inclusion of these very young children, the PPV for the very young children, the PPV for the

<table>
<thead>
<tr>
<th>Age</th>
<th>Children Screened, n</th>
<th>Unreadable Rate, %</th>
<th>Referral Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1 y</td>
<td>7012</td>
<td>25.5</td>
<td>3.7</td>
</tr>
<tr>
<td>1–2 y</td>
<td>41,916</td>
<td>13.7</td>
<td>2.7</td>
</tr>
<tr>
<td>2–3 y</td>
<td>20,221</td>
<td>8.1</td>
<td>3.6</td>
</tr>
<tr>
<td>3–4 y</td>
<td>52,910</td>
<td>5.4</td>
<td>4.4</td>
</tr>
<tr>
<td>4–5 y</td>
<td>81,002</td>
<td>3.7</td>
<td>4.9</td>
</tr>
<tr>
<td>5–6 y</td>
<td>32,023</td>
<td>3.2</td>
<td>4.8</td>
</tr>
<tr>
<td>6–7 y</td>
<td>18,686</td>
<td>2.6</td>
<td>5.6</td>
</tr>
<tr>
<td>&gt;7 y</td>
<td>945</td>
<td>2.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Total</td>
<td>210,695</td>
<td>5.9</td>
<td>4.4</td>
</tr>
</tbody>
</table>

The unreadable rate refers to the rate of photoscreens that were unable to be interpreted, and the referral rate represents the percentage of children referred for abnormal photoscreens.
younger age group increased from 86.4% (95% CI: 83.8%, 88.8%) to 87.4% (84.5%, 89.9%), which is enough to account for the significance calculated. Children <1 year of age have been notoriously difficult to screen. Because the 6-month to 1-year age group was included in our screenings, we included the data for completeness. However, for further analysis, we excluded this group aged <1 year for several reasons, including increased false positives and a high unreadable rate.

High false-positive results within this young age group are thought to be due to accommodation and refocusing between photos taken. One of the benefits of the MTI PhotoScreener is that no invasive techniques, including eye drops, are used. Because the screenings are conducted without the use of cycloplegics, children are still able to accommodate between the 2 flashes of the photoscreen, which is detected on film. This behavior is most noticeable in children unable to keep fixation for the short duration of the screen, thus increasing the false-positive rate. Another reason for excluding the 6-month age group is due to the high unreadable rate. Of all 210,695 children screened, 12,420 (5.9%) of the children were determined to have an unreadable photoscreen from the first attempt. Some cooperation is necessary for successful screens, and the unreadable rate increased with decreasing ages. The highest unreadable rate was in those children aged 6 months to 1 year, although the PPV for this group was 82.5%. Once the unreadable rate goes below 10%, the PPV becomes more consistent. We feel that even though it was more difficult to obtain a photoscreen in this age group, once obtained, the photoscreen remained reliable in the detection of amblyogenic risk factors.

The benefits of early diagnosis are widely accepted; the response to amblyopia treatment is more rapid and results in better visual outcomes in younger children. Whether vision screening is the most effective way of identifying risk factors in children ages 1 to 5 years is not known. What is known, however, is that photoscreening programs can identify children who are at risk of amblyopia because of risk factors and subsequently can be treated successfully. Waiting to screen for amblyogenic risk factors until after the age of 3 years may result in identifying children after they have already developed amblyopia. The study by Leon et al revealed that children <3 years of age were less likely to have amblyopia from anisometropia. After 3 to 4 years of age, the prevalence of amblyopia reached a plateau but the severity of the visual impairment steadily worsened. Whereas the children <3 years of age either had no or mild amblyopia, more than half of children >3 years with the same risk factors developed moderate to severe amblyopia.

The MTI PhotoScreener is no longer commercially available. Newer digital photoscreening devices such as the iScreen (iScreen Vision Inc, Cordova, TN), PlusOptix S09 (PlusOptix, Nürnberg, Germany), and Spot by PediaVision (Lake Mary, FL) are commercially available now.

CONCLUSIONS

The most recent guidelines for vision screenings released by the USPSTF recommend vision screenings be performed at least once between the ages of 3 and 5 years but concluded that there is insufficient evidence to support vision screening in children <3 years old. The purpose of this article is to share our vision screening results in this younger population in comparison with the preschool population supported by the recommendations. The data gathered over 11 years and from 210,695 children presented in this article reveal that there was no statistically significant difference in the reliability of the vision photoscreens in the 1- to 2-year-old age group compared with that in 3- to 5-year-old children. Interestingly, when we included the children aged from 0.5 to 1 year who were photoscreened by the KidSight program, we observed a slight statistical significance ($P = .02$). Photoscreens require some cooperation, and children <1 year of age have been previously shown to be difficult to screen and their photoscreens show a high unreadable rate. On the basis of 11 years of results from our statewide volunteer-led vision screening program, we recommend photoscreening children as early as 1 year of age.

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