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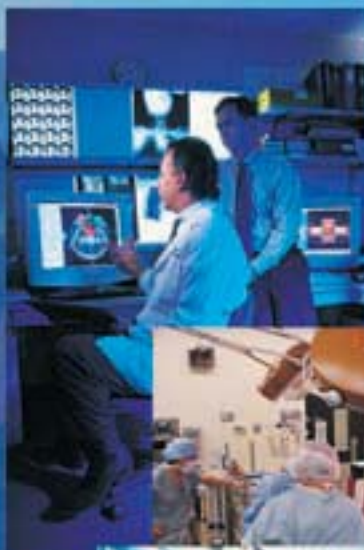
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Preschool Vision Screening



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CADTH
600-865 Carling Avenue
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Tel. (613) 226-2553
Fax. (613) 226-5392
Email: pubs@cadth.ca

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Canadian Agency for Drugs and Technologies in Health

Preschool Vision Screening

Lesley Dunfield, PhD¹
Tamara Keating, MLIS¹

February 2007

¹ Canadian Agency for Drugs and Technologies in Health, Ottawa ON



Health technology assessment (HTA) agencies face the challenge of providing quality assessments of medical technologies in a timely manner to support decision making. Ideally, all important deliberations would be supported by comprehensive health technology assessment reports, but the urgency of some decisions often requires a more immediate response.

The Health Technology Inquiry Service (HTIS) provides Canadian health care decision makers with health technology assessment information, based on the best available evidence, in a quick and efficient manner. Inquiries related to the assessment of health care technologies (drugs, devices, diagnostic tests, and surgical procedures) are accepted by the service. Information provided by the HTIS is tailored to meet the needs of decision makers, taking into account the urgency, importance, and potential impact of the request.

Consultations with the requestor of this HTIS assessment indicated that a review of the literature would be beneficial. The research question and selection criteria were developed in consultation with the requestor. The literature search was carried out by an information specialist using a standardized search strategy. The review of evidence was conducted by one internal HTIS reviewer. The draft report was internally reviewed and externally peer-reviewed by two or more peer reviewers. All comments were reviewed internally to ensure that they were addressed appropriately.

Reviewers

Carey Matsuba, MDCM, MHSc
Clinical Assistant Professor
University of British Columbia
Vancouver BC

Claudette Landry, BN, BEd MN, RN
Project Manager
Department of Health
Dieppe NB

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ABBREVIATIONS

AAO	American Academy of Ophthalmology
AAP	American Academy of Pediatrics
AOA	American Optometric Association
CPS	Canadian Paediatric Society
ICER	incremental cost-effectiveness ratio
NCR	non-cycloplegic retinoscopy
NPV	negative predictive value
NR	not reported
NS	not specified
PPV	positive predictive value
QALY	quality-adjusted life-year
STBS	small target binocular suppression test
STRDS	small target random-dot stereogram
USPSTF	US Preventive Services Task Force
VA	visual acuity
VIP	Vision in Preschoolers

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1 CONTEXT AND POLICY ISSUES

The purpose of preschool vision screening is to detect vision disorders, such as amblyopia, strabismus, and refractive errors, that occur at an early age (younger than six years old) so that they can be corrected. Amblyopia is a loss of vision that cannot be explained by ocular pathology or refractive error. Uncorrected refractive errors, media opacity, and strabismus are the causes of amblyopia.¹ Strabismus, a misalignment of the eyes, is the most common cause of amblyopia.^{1,2} Strabismus includes esotropia (eye turns in), exotropia (eye turns out), and hypertropia (eye turns up).² Refractive errors include myopia (nearsightedness), hyperopia (farsightedness), astigmatism, and anisometropia (unequal refractive power in the eyes).¹ Amblyopia affects approximately 2% to 4% of the population, and strabismus affects approximately 4%.³

Amblyopia and other vision disorders can be corrected if they are detected in infancy or early childhood.¹ Visual pathways develop until about 10 years of age, and treatment of amblyopia should begin before this age if it is to be effective. Visual pathways will not develop properly in children if they do not see clear images. Amblyopia may affect health, academic, occupational, and social functioning.⁴ Left untreated, refractive errors and amblyopia may affect the ability to play sports, development, and school performance.⁵ Children with amblyopia have a risk of vision loss in the non-amblyopic eye, resulting in blindness.^{4,5} The early detection of vision disorders allows proper treatment to be undertaken to improve visual acuity.³

Referral criteria exist for the diagnosis of amblyopia. A visual acuity (VA) of <20/40 is a common criterion.⁶⁻¹² A VA of <20/30^{13,14} and a VA of <20/25¹⁵ have also been used. In addition, a VA of <20/25 or a 0.2 difference between the eyes¹⁶ and a VA of <20/40 or a 2-line difference

between the eyes^{2,17,18} can be used as referral criteria for amblyopia detection.

The detection of vision problems at an early age can lead to effective treatments that may increase visual acuity.¹⁹ There are many methods for detecting vision disorders, with different groups reporting various sensitivities and specificities for specific tests. Tests for visual acuity include Snellen, Tumbling E, HOTV, Allen cards, and Lea Symbols. Ocular alignment is tested using the corneal light reflex, red reflex (Brückner reflex), and cross-cover tests, and random-dot stereotests (Frisby, Randot, Random-dot E, Lang).¹⁷ Different screening tests are recommended for different age groups. Red reflex is checked during the newborn medical examination. At this same time, the eyes are examined for any structural abnormalities. To obtain the most accurate results, the most difficult test that a child can perform should be part of the vision screening.³ The American Academy of Pediatrics (AAP), the American Optometric Association (AOA), the American Academy of Ophthalmology (AAO), and the US Preventive Services Task Force (USPSTF) differ in the tests that they recommend for each age group.^{3,17-20} The Canadian Paediatric Society (CPS) recommends testing of visual acuity, red reflex, and corneal light reflex in children aged three years to five years.²¹

The effectiveness of preschool vision screening has been debated. There is no agreement about the age at which children should be screened, on the tests that should be used, and on the outcomes that should be measured. Some organizations suggest that vision examinations should only be conducted by licensed eye-care professionals.²² Others indicate that ophthalmologists are not the only ones who can effectively detect vision defects through preschool vision screening,^{23,24} and that screening tests can be conducted by nurses, primary-care physicians, or other health professionals.³ Trained lay screeners often administer the tests in public screening programs.³

2 RESEARCH QUESTIONS

What is the published evidence on the clinical and cost effectiveness of preschool vision screening (in children under the age of six years) in comparison to a complete diagnostic vision examination by an optometrist or ophthalmologist?

3 METHODS

3.1 Literature Search

Published literature was obtained by cross-searching EMBASE[®], MEDLINE[®], CINAHL[®], and ERIC databases on the OVID search system. Regular alerts were established on EMBASE, MEDLINE, and CINAHL, and information retrieved via alerts was current to July 21, 2006. Parallel searches were performed on PubMed and the Cochrane Library (Issue 2, 2006) databases. Publications were limited to the English language only, with publication dates of 1996 to the present. Filters were applied to limit the retrieval to health technology assessments, systematic reviews, clinical studies, and economic studies.

The web sites of regulatory agencies, and health technology assessment and related agencies were searched, as were specialized databases, such as those of the University of York's Centre for Reviews and Dissemination. The Google[™] search engine was used to search for information on the Internet. These searches were supplemented by hand-searching the bibliographies of selected papers. The British Columbia Association of Optometrists and the British Columbia Ministry of Health also supplied several documents for review.

3.2 Screening Process

Reports were included that assessed vision screening in children <6 years of age. Studies that included older children were excluded if the results were not separated into age groups that included preschool-aged children only. Three external reviewers provided comments on this report.

4 FINDINGS

4.1 Effectiveness of Preschool Vision Screening

There are criteria to consider when determining whether a screening program will be useful. The screening program should do more good than harm, the tests must be able to identify the defect, there must be an appropriate intervention to treat the defect, there must be an advantage in detecting and treating the defect at an earlier age, and the cost must be justified.²⁵ In addition, the prevalence of the defect must be high enough and must cause substantial disability, to justify screening.²⁵

A UK assessment determined that all these criteria were not met with preschool vision screening.⁵ They found insufficient evidence that treatment of these disorders resulted in visual gains,^{5,26} or that amblyopia, strabismus, and refractive errors caused disability. This assessment recommended that screening programs not be implemented unless they have been evaluated, because there was no evidence found for the benefits of preschool vision screening.⁵

A Cochrane Collaboration review on amblyopia screening concluded that insufficient evidence existed to determine the effectiveness of screening programs on amblyopia prevalence. The authors noted that this did not mean that there was no benefit to screening but rather that there was a lack of

good quality evidence (e.g., randomized controlled trials) in this area.²⁷

Kentucky passed a law in 2000 requiring each child entering public school to have a vision examination by an ophthalmologist or optometrist.²⁸ A survey of Kentucky Optometric Association members found that 5,316 children were examined between July 2000 and April 2001; 13.92% were prescribed eyeglasses, 3.4% were diagnosed with amblyopia, and 2.31% with strabismus.²⁸ The Modified Clinical Technique (which consists of visual acuity tests, a cover test, retinoscopy, and ophthalmoscopy) administered by an ophthalmologist or optometrist was suggested as the only test that can effectively assess preschool vision with an acceptable sensitivity and specificity.⁹ This result was not unexpected, because this technique, which consisted of multiple tests administered by ophthalmologists or optometrists, would be similar to a clinical examination.

A report by C. Green, which was prepared for the BC Ministry of Health Services, suggested that there was a basis for recommending preschool vision screening, even though research evidence was lacking.⁴ Four options were proposed for vision testing in preschoolers: fortify existing vision care, use primary screening by public health nurses with referral to ophthalmology and optometry, use screening by technical or lay examiners, or use comprehensive examinations by optometrists. This report suggested that a combination of these approaches may be the best option.⁴

4.1.1 Specific screening tests

Sensitivity, specificity, PPV, and negative predictive value (NPV) have been assessed for vision screening techniques in preschool children. Appendix 1 summarizes these studies. Screening tests were compared to a complete examination performed by an ophthalmologist, optometrist, or orthoptist (health professionals who assist ophthalmologists), to determine sensitivity

and specificity. The studies that are listed in Appendix 1 are arranged by the type of screening test.

In one comparison, it was found that the positive predictive value (PPV) of photoscreening was 73%, whereas the PPV for traditional screening methods (HOTV, Random-dot E) was 0%.²⁹ A computerized photoscreener was found to have a sensitivity of 94.6% and a specificity of 90.1%, compared to 85.7% sensitivity and 81.0% specificity for retinoscopy in a study comparing these methods among 300 children aged nine months to 50 months.³⁰ This indicates that with the computer photoscreener, 5.4% of patients will have a negative test result and a vision defect (false negative), and 9.9% will test positive without a defect (false positive). As a result, 5.4% of patients will be missed in screening and untreated, and 9.9% of patients will be referred unnecessarily. In this study, retinoscopy had a 14.3% false negative rate and a 19% false positive rate. MTI Photoscreener sensitivity was higher (89%) than in the examination of the Brückner reflex (64%), in a case-control study of 10 patients with amblyogenic risk factors and six patients in the control group.³¹

Numerous comparisons of vision screening tests for preschool children have been published. The Vision in Preschoolers (VIP) study group compared the sensitivities of 11 screening tests among 2,588 children aged three years to five years.³² Visual acuity tests included crowded Linear Lea Symbols and crowded linear HOTV. Tests for stereoacuity were the Random-dot E and Stereo Smile II. Retinoscopy, the Retinomax autorefractor, and the SureSight autorefractor were used to test refractive error. The sensitivity of photoscreeners (iScreen, MTI, Power Refractor II video-photorefraction) and the sensitivity of the cover-uncover test were also examined. Non-cycloplegic retinoscopy (NCR), SureSight, and Retinomax were the most sensitive tests for the detection of amblyopia, at 88%, 80%, and 78% respectively, and 94% specificity. For the detection of strabismus, the MTI

Photoscreener, cover-uncover test, Stereo Smile II test, SureSight, and Retinomax were most sensitive (65%, 60%, 58%, 54%, and 54% respectively). NCR, Retinomax, SureSight, and Lea Symbols were the most sensitive for the detection of significant refractive error (74%, 66%, 63%, and 58% respectively). Lea Symbols, Retinomax, and NCR were most sensitive for detecting reduced visual acuity, at 48%, 39%, and 38% respectively.³²

The VIP study group examined the sensitivities of these tests for the detection of any vision disorder. The most sensitive were NCR (64%), Retinomax (63%), SureSight Vision screener (63%), and Lea Symbols (61%). For discovering conditions that should be detected and treated early, NCR was the most sensitive at 90%, followed by Retinomax (88%), SureSight (81%), and Lea Symbols (77%). The specificities were all $\geq 90\%$.³³ Licensed eye-care professionals administered these tests.

A comparison of Lea Symbols, MTI Photoscreener, keratometry, and Retinomax was carried out in a sample of 379 preschool children for the detection of astigmatism.³⁴ The sensitivity and specificity of the tests were 92% and 56% (Lea symbols), 60% and 86% (MTI photoscreening), 95% and 77% (keratometry), and 93% and 95% (Retinomax).³⁴ Visual acuity screening using Lea Symbols was compared to noncycloplegic refraction for the detection of astigmatism in 245 children aged three years to five years.³⁵ Lea Symbols had a sensitivity of 90% and a specificity of 44%, whereas refraction had a 91% sensitivity and an 86% specificity.³⁵ The sensitivity and specificity of a digital Random-dot test were compared to those of the Randot stereoacuity test, the Titmus test, and the Lang test. Similar results were found in preschool children.³⁶ Randot Stereocards were found to produce reliable valid results in children up to 24 months old.³⁷

Two hand-held autorefractors (Retinomax and SureSight) were compared to cycloplegic retinoscopy (paralysis to minimize accommodation) in 35 children aged three years to five years.³⁸ Moderate agreement was found between the two autorefractors, and between the autorefractors and cycloplegic retinoscopy. The authors concluded that these devices may be useful as screening tools.³⁸ A limitation of this study is that these children were rendered cycloplegic before testing. A screening program would likely not use cycloplegia, hence these results may not be generalizable to a screening program.³⁸ In another study, 43 children were tested before and after the induction of cycloplegia with autorefractors.³⁹ The results of the testing with autorefractors when cycloplegia was not induced were inconsistent. The best device would give a more accurate reading and would not allow accommodation by the child being tested.³⁹ Another study found that the Retinomax was a useful screening device for children 46 weeks to 81 weeks old. The accuracy of the results was affected by patients' cooperation.⁴⁰ Furthermore, these children were rendered cycloplegic.⁴⁰ The results obtained by an ophthalmic nurse using a handheld autorefractor (Retinomax) were compared to those of traditional retinoscopy performed by an ophthalmologist in children under the age of six years.⁴¹ Results were similar using the methods with cycloplegia, indicating that Retinomax is useful for measuring refractive error. The results obtained without cycloplegia were inaccurate.⁴¹

4.1.2 Screening effectiveness

A randomized controlled trial examining the effects of preschool vision screening was conducted in the UK.⁴² The methods of randomization and allocation concealment were inadequate, because the date of birth was used to determine which children were assigned to the intervention group. The control group was assessed with visual surveillance (eight- and 18-month examinations by health

visitors and family doctors using the cover test and observing visual behaviour), while those in the intervention group were examined by an orthoptist who tested visual acuity, ocular alignment, stereopsis, and non-cycloplegic refraction.⁴² The specificity was 92% for the control group and 95% for the intervention group ($p < 0.01$). More children were found to have amblyopia in the intervention group (1.6%) compared with the control group (0.5%, $p < 0.01$). In a comparison of the tests that were administered as part of the intervention, it was found that photorefraction was the most sensitive component.⁴²

An observational study designed to test the validity of a preschool vision screening program was conducted in Canada.⁴³ Public health nurses administered tests for visual acuity, stereoacuity, and ocular alignment to >1,100 children per year, over three years. The results were compared to those from practitioners' reports. The sensitivity ranged from 60.4% to 70.9%, and the specificity ranged from 69.6% to 79.9%. The PPV was 21.6% to 32.3%, and the NPV was 92.6% to 95.3%. This study concluded that based on the numbers of children detected with vision defects, the screening program is valid and should be continued.⁴³

A comparison of 808 eight-year-old children who had received screening for vision defects in infancy and 782 children who had not received screening found that the prevalence of amblyopia was higher in the children who were not screened (2.6%) compared with those who had received screening (1%) ($p = 0.0098$).⁴⁴ Ophthalmologists conducted the screening, which included a corneal reflex test, fixation-and-following test, ductions and versions examination, cover-uncover test, alternate cover test, and retinoscopy. The screening program had a sensitivity of 85.7%, a specificity of 98.6%, a PPV of 62.1%, and an NPV of 99.6%, indicating that it was effective.⁴⁴

A retrospective cohort study of 6,081 children assessed the visual outcomes of children aged

7.5 years who had received preschool vision screening or who had not received screening in the UK.⁴⁵ More children were offered preschool vision screening (24.9%) than actually attended the screening (16.7%). Children who received vision screening had a 45% lower prevalence of amblyopia compared to those who did not receive screening. When all children who were offered the screening were included in the analysis, the effects of early detection on amblyopia outcome diminished. The authors concluded that the effectiveness of preschool vision screening had to be improved.⁴⁵ This study indicated that although a vision screening program can be efficacious, its effectiveness is limited by the number of children who receive screening. The effectiveness of the screening program will be increased if a greater proportion of children who are offered vision screening receive it.

Screening of 3.5-year-old children by an orthoptist and the results of referrals to the hospital eye service were examined in a retrospective study of 6,794 children conducted in the UK.⁴⁶ The screening test resulted in 5.1% of children referred to the hospital eye service, and detection of straight-eyed amblyopia and strabismic amblyopia. Upon treatment, 87.2% of children with straight-eyed amblyopia and 64.3% of children with strabismic amblyopia achieved an improvement in visual acuity.⁴⁶ Another retrospective study that followed 3,126 children from birth to age 10 years found that vision screening is effective in detecting defects.¹⁵ Visual acuity was assessed at ages four years, 5.5 years, seven years, and 10 years by nurses at child health care centres or in the schools. Ametropia (any refractive error) was mainly detected at age four years. Most cases of strabismus were detected before the age of four years, while microtropia (small angle heterotropia⁴⁷) was detected at four years. The prevalence of amblyopia was reduced to 0.2% from 2% by screening, and most patients with amblyopia increased their visual acuity with treatment, indicating that

screening and treatment can reduce the prevalence of amblyopia.¹⁵

An assessment of the vision screening program in Sweden found that tests (HOTV) for children four years and 5.5 years of age had a sensitivity of 92% and a specificity of 97%.¹⁶ This study found that screening and subsequent treatment decreased the prevalence of amblyopia.¹⁶

4.1.3 Re-screening effectiveness

A retrospective study of 1,545 children in the UK examined the effects of a secondary screening program that was led by optometrists and orthoptists. Children were referred to the program by physicians, community medical officers, health visitors, school nurses, and primary orthoptic screeners who had conducted a screening protocol. This method of secondary screening that combines the skills of an optometrist and an orthoptist was found to be effective in detecting most children with vision problems, while avoiding unnecessary referrals to the hospital service.⁴⁸ Upon secondary testing, 43% of patients were found to be normal and did not require examination by the hospital eye service.⁴⁸

A preschool vision screening program that was developed by nursing students and faculty in the US assessed vision using Lea Symbols and the Random-dot E stereopsis test.⁴⁹ This study screened 181 children aged three years to five years and found 5.5% had abnormal results (28/181). Upon re-screening 20 of these children, it was found that nine had an abnormal result and were referred. This approach decreased the number of referrals to primary-care providers.⁴⁹

4.1.4 Personnel administering vision screening

A study of personnel using the MTI Photoscreener for children <3 years of age found that the sensitivity and specificity of the screening method were unaffected by the screeners' ophthalmic knowledge. Screening

was conducted by ophthalmologists, pediatricians, ophthalmic technicians, health department employees, Prevention of Blindness Society employees, and Lions Club volunteers.⁵⁰ The AAP suggests that photoscreening may result in higher screening rates. Photoscreening will be useful for difficult-to-screen children, and the evaluator should be properly trained.⁵¹ The AAO recognizes that photoscreening and autorefractive devices may be useful for screening, but state that they should not replace current screening protocols.³

An evaluation of screening programs in Sweden and Canada found that properly trained non-ophthalmologists can reliably screen four-year-old children. It was noted that children who fail screening tests should be referred to an ophthalmologist.²³ HOTV is the most common test used in Canada.²³ The VIP study compared the administration of vision screening tests among three- to five-year-olds by nurses and lay screeners. The tests administered were Retinomax, SureSight, crowded linear Lea Symbols, single Lea Symbols (administered by lay screeners only), and Stereo Smile II.²⁴ A gold standard examination by an ophthalmologist or an optometrist was used for comparison. The single Lea Symbols test administered by lay screeners resulted in higher sensitivity compared to the crowded linear Lea Symbols administered by lay screeners or nurses. All other screening tests resulted in higher sensitivity when administered by the nurses compared to the lay screeners. Except in the case of the linear Lea Symbols, these differences were small and not statistically significant. This indicates that similar results can be achieved with nurses and lay screeners.²⁴

A UK study comparing vision screening conducted by orthoptists (1,582 children), health visitors (2,081 children), and clinical medical officers (1,701 children) found insufficient evidence to support an orthoptic-conducted preschool vision screening program.¹⁴ The

prevalence of amblyopia was similar in children who were screened by the examiners.¹⁴

A Canadian review of literature from 1983 to 1995 was conducted to assess screening for strabismus.⁵² This review found that low-risk children should be screened by a primary-care physician, whereas high-risk children (with low birth weight, a family history of strabismus, congenital ocular abnormality, or systemic conditions with vision-threatening ocular manifestations) should be examined by an ophthalmologist.⁵² A UK study of 2,041 children examined the effectiveness of preschool vision screening.⁵³ This study found that screening by health visitors was as effective as screening by orthoptists.⁵³ Lay screeners were used in a study using the MTI photoscreener for preschool vision screening.⁵⁴ The PPV was 41.4% for astigmatism, 60.5% for anisometropia, and 84.2% for strabismus. In a study based in Taiwan, trained and certified kindergarten teachers effectively tested preschool children for amblyopia and strabismus.⁵⁵

4.1.5 Testability

A more direct comparison in the VIP study found that HOTV scores were lower than Lea Symbols scores, likely because of the difficulty in testing younger children (three years) with HOTV numbers.⁵⁶ Another study found similar results, with testability rates (i.e., children being able to complete the tests) that were higher for Lea Symbols than HOTV for vision screening of three-year-olds.¹¹ Testability rates in yet another study were found to be similar for Lea Symbols and the HOTV chart in the testing of three-year-old children.⁵⁷ Lea symbols have been shown to be effective in detecting amblyopia in children as young as 23 months.⁵⁸ The VIP study also examined the testability of three Random-dot stereotests and found a significant difference.⁵⁹ The testability of the Stereo Smile test was 91%, 81% for the Random-dot E test, and 71% for the Randot Preschool test, when assessed in children aged three years to 3.5 years. The authors suggest that tests offering two choices for the children

to pick from, such as the Stereo Smile test and the Random-dot E test, offer higher testability.⁵⁹ Another study found that successful screening in four-year-olds was higher (88% to 98%) compared to three-year-olds (70% to 90%). It suggested that there is insufficient evidence showing that the detection of amblyopia at three years of age results in better treatment outcomes than detection at four years of age.⁷ Overall, testability is higher in older children, because screening in younger children is more difficult.

4.1.6 Limitation of Studies

There is a lack of rigorous controlled studies examining the effectiveness of preschool vision screening. One randomized controlled study that was identified was not of high quality, so its findings should be viewed accordingly.⁴² The other types of studies reviewed are observational studies or non-randomized controlled studies.

Another limitation relates to the population screened. Some studies are screening children from a head-start program (which serves children from low-income families^{24,32-34}) who would not reflect the general population. One study includes children from a clinical practice who may have had underlying conditions.⁶⁰ Another limitation is the small size of the sample undergoing screening that was used in some studies.^{29,31} The screening age can also be a limitation in some studies. The screening of children <4 years of age can be difficult, and the screening results for this age group will be difficult to apply to an older population.^{54,60}

Agreement in the literature regarding the type of test to use for preschool vision screening is lacking. Most studies measure the reduction in amblyopia as the outcome, but measures such as school performance may be a more relevant outcome to consider. In addition, no long-term studies exist, making it difficult to determine how these screening programs may affect future outcomes for these children.

One limitation of this review is the fact that it was conducted by one reviewer, because of the need to provide this report in a short timeframe. This may introduce bias in terms of selection of studies and interpretation of results. This report, however, was reviewed by several external clinical experts. In addition, the literature search was limited to the English language and excluded studies published before 1996. In some of the studies that are cited, orthoptists administered the vision-screening tests to preschool children. Orthoptists are common in areas such as the UK, but there is a lack of orthoptists in Canada. The generalizability of these findings to a Canadian setting is therefore questionable.

4.2 Current Practice

Throughout Canada, there exist a variety of programs for vision screening in children. Table 1 describes the current preschool vision screening programs in some provinces.

4.3 Professional Organizations

The CPS recommends an examination of external eye structures, red reflex, signs of posterior eye disease, and corneal light reflex for newborn children to age three months.²¹ At ages six months to 12 months, ocular alignment, ocular fixation, and following should be tested. Visual acuity testing should be completed for children aged three years to five years.²¹ These recommendations are based on those of the AAO. The Canadian Task Force on Preventive Health Care also recommends the visual acuity testing of preschoolers.⁶¹

The American Public Health Association recommends a comprehensive eye examination for preschool children at ages six months, two years, and four years.²² The USPSTF assessed vision screening for

children under the age of five years and found fair evidence to suggest that screening tests could detect amblyopia, strabismus, and refractive error with “reasonable accuracy.”¹⁹

The cover test and the Hirschberg corneal light reflex test can be used to screen for strabismus from birth to one year.

Amblyogenic risk factors can be detected by photoscreening in children up to the age of three years. Stereopsis (with Random-dot E, Titmus Fly Stereotest), visual acuity (HOTV, Lea Symbols, Tumbling E) can be used in children >3 years of age.^{6,19} No direct evidence was found to suggest that screening improves visual acuity in preschool children.¹⁹ Furthermore, the USPSTF did not find enough evidence to suggest an optimal screening test. The task force found fair evidence that visual acuity can be improved by the early detection of amblyogenic risk factors. These recommendations are “B level,” which indicates that fair evidence was found that the outcomes of preschool vision screening can outweigh the harms, and that this service should be provided.¹⁹

The AOA’s recommendations for the screening of infants and toddlers include visual acuity (fixation preference tests, preferential looking visual acuity test), refraction (cycloplegic retinoscopy, near retinoscopy), binocular vision, and ocular motility (cover test, Hirschberg test, Krimsky test, Brückner test, versions, near point of convergence).²⁰ Tests for preschool children should include visual acuity (Lea symbols, Broken Wheel Acuity cards, HOTV), refraction (static retinoscopy, cycloplegic retinoscopy), binocular vision, accommodation, and ocular motility (cover test, positive and negative fusional vergences, near point of convergence, stereopsis, monocular estimate method retinoscopy, versions).²⁰

Table 1*: Preschool vision screening programs in Canada

Province	Current Practice	Tests
New Brunswick (Claudette Landry, NB Department of Health, Fredericton: personal communication, 2006 July 11)	public health nurses conduct vision screening for children at age 3.5 years	visual inspection of eyes, Randot, HOTV
Prince Edward Island (Aaron Campbell, Medical Programs Coordinator, Dept. of Health, Charlottetown: personal communication, 2006 September 12)	public health nurses conduct vision screening for children at birth, 2 months, 4 months, 6 months, 12 months, 15 months, 18 months, 4 years to 4.5 years	Frisby stereotest and Lea Symbols
Newfoundland ⁴	public health nurses, children aged 3 years	Sheridan-Gardner, cover-uncover, corneal light reflexes
Nova Scotia ⁶²	public health nurses, children ages 4.5 years to 5.5 years	
Quebec	no information provided	
Ontario ⁶³	screening done by primary care providers as part of 18-month “Well Baby” visit, testing repeated at ages 2 years to 3 years, 4 years to 5 years	red reflex, corneal light reflex, cover-uncover test
Manitoba	no information provided	
Saskatchewan ⁴	no province-wide preschool vision screening program	
Alberta ⁴	“Eye see...Eye learn” program provides examinations conducted by optometrist for children before they start school	
British Columbia ⁴	no province-wide preschool vision screening program	
Nunavut (Terry Creagh, Department of Health and Social Services, Government of Nunavut, Iqaluit: personal communication, 2006 Aug 21)	screening done primarily by public health nurses, community health nurses, community health representatives for children aged 4 years to 6 years	light reflex and visual acuity
Yukon	no information provided	
Northwest Territories ⁴	conducted by public health nurses	illiterate E test or symbol chart, stereoscopic fly, corneal light reflex, cover-uncover

*Preschool vision screening programs may not be universally conducted across the province. Additional vision screening programs may be available in some regions through the work of charitable organizations.

Recommendations from the AAO for newborn to age three months include red reflex and inspection.³ Infants aged three months to six months should be tested for their ability to fix and follow, for red reflex, and for inspection. Children aged six months to 12 months should undergo the same tests; testing should also be done for alternate occlusion and corneal light reflex. Visual acuity, corneal light reflex,

cover-uncover, red reflex, and inspection should be performed on children aged three years. These tests should be repeated at five years of age. If abnormalities are detected by screening, a comprehensive medical eye examination should be performed.³ These recommendations are based on the interpretations of an expert panel based on the best available scientific data.³

The AAP recommends ocular history, vision assessment, external inspection of the eyes and lids, ocular motility assessment (corneal reflex test, cross cover test, Random-dot E test), pupil examination, and red reflex examination for children up to the age of three years. In addition, age-appropriate visual acuity tests (Lea Symbols, Allen cards, Snellen letters and numbers, Tumbling E, and HOTV) and ophthalmoscopy are recommended for children aged three years to five years.^{17,18}

4.4 Cost Effectiveness of Preschool Vision Screening

A US study was developed to design and test a cost-efficient community-based preschool vision screening program for a population of native American children among whom there was a high prevalence of astigmatism. Autorefractometry was found to be the most expensive test, but it had the greatest specificity.⁶⁴ An economic evaluation, based on a field study of 121 German kindergartens, found that vision screening in kindergartens by orthoptists costs approximately €924 for each case of amblyopia detected.⁶⁵ Another study, conducted by the same group, but using a decision analytic model, calculated the cost-effectiveness ratio to be €727 for each case of amblyopia detected.⁶⁶ The cost-effectiveness ratio was found to be influenced by the prevalence rate of the target condition and by test specificity. In the decision analytic model, one orthoptic examination costs €7.87 compared to €36.40 for an examination by an ophthalmologist.⁶⁶ In Canada, there is a lack of orthoptists, so orthoptic screening is unlikely to be an option. Thus, the costs of screening described in these studies are unlikely to be generalizable to the Canadian setting.

The same group of German investigators constructed another decision analytic model to calculate the cost per detected case of amblyopia for five methods of screening

among three-year-olds.⁶⁷ In this German scenario, the least expensive option was visual acuity testing with re-screening for children who had inconclusive results, at an average cost of €878 per detected case. The most expensive option was the combination test of visual acuity, cover test, examination of eye motility, and direct referral to an ophthalmologist or to re-screening for inconclusive results.⁶⁷ In yet another German study, a different group of investigators used a decision analytic model and found that the most cost-effective screening strategy for the detection of amblyopia or its risk factors is screening by an ophthalmologist for all children before the age of one year.⁶⁸ This analysis, however, suggested that all four screening scenarios left a significant proportion of undetected children.

A cost-benefit analysis of vision screening methods for preschool and school-aged children found the benefit-to-cost ratio for screening programs was >1.0, indicating that the benefits of screening outweighed the costs.⁶⁹ Another study found that, in 2005, comprehensive eye examinations conducted by an ophthalmologist or optometrist compared to usual care would cost US\$12,985 per quality-adjusted life-year (QALY); the authors concluded that it was cost effective.⁷⁰ This may be optimistic because the authors used the cost of monocular blindness to define costs, and not all children with amblyopia will develop monocular blindness. This same study found that when compared to vision screenings, universal eye examinations were cost-effective at US\$18,390 per QALY. The cost-effectiveness of the treatment of amblyopia in 2005 was US\$1,800 per QALY.⁷⁰ In a separate study, the authors suggest that decision makers should consider orthoptic screening based on the ICER.⁷¹ Again, in Canada, this strategy would be unfeasible because of the lack of orthoptists to conduct screening.

5 CONCLUSIONS AND IMPLICATIONS

Preschool vision screening aims to detect vision disorders at an early age, with the assumption that early detection leads to earlier treatment and an improvement in outcomes. According to the literature examined in this review, the specific test that is used, the age and underlying health of the children, and the personnel administering the test all influence the effectiveness of preschool vision screening. Some studies suggest that screening should only be conducted by a trained eye-care professional, whereas others state that physicians, nurses, and lay screeners can effectively conduct preschool vision screening. There does not seem to be a consensus as to who should be administering the preschool vision screening test.

The effectiveness of the tests for preschool vision screening varies. For example, with photoscreening, sensitivities ranged from 27.8% to 88%, and specificities ranged from 40% to 98.5% in different studies (Appendix 1). Other preschool vision screening tests have variable sensitivities and specificities. In addition, professional organizations recommend different tests to assess vision in different age groups of preschool children. Although many studies have been published examining different tests to detect vision defects in preschool children, no single test or group of tests has been shown to be superior for preschool vision screening. While no Canadian studies have assessed the cost effectiveness of preschool vision screening, the studies suggest that universal eye examinations for preschool children have a low cost per QALY.

A preschool vision screening program meets most of the general criteria to consider when assessing a screening program. Although the prevalence of vision defects is low, they do cause disability. An earlier age of detection is a

benefit in the treatment of amblyopia. No studies showed harms associated with screening. The tests can detect the defects that they are meant to detect, and there are effective treatments for these defects. Additional research is needed to ascertain the utility of preschool vision screening in the Canadian context. Such research should aim to determine who can conduct such tests, what tests should be used for what ages of children, and whether one- or two-stage screening is most effective from a clinical and a cost viewpoint.

6 REFERENCES

1. Ciner EB, Schmidt PP, Orel-Bixler D, Dobson V, Maguire M, Cyert L, et al. Vision screening of preschool children: evaluating the past, looking toward the future. *Optom Vis Sci* 1998;75(8):571-84.
2. Broderick P. Pediatric vision screening for the family physician. *Am Fam Physician* 1998;58(3):691-4. Available: <http://www.aafp.org/afp/980901ap/broderic.html> (accessed 2006 Jun 28).
3. American Academy of Ophthalmology Pediatric Ophthalmology Panel. *Pediatric eye evaluations: preferred practice pattern*. San Francisco: American Academy of Ophthalmology; 2002. Available: http://www.aao.org/education/library/PPP/pediatric_new.cfm (accessed 2007 Feb 15).
4. Green C. *A review of the science underlying preschool vision screening with implications for BC: report prepared for Healthy Children, Women & Seniors, BC Ministry of Health Services*. C Green Health Info; 2005.
5. Snowdon SK, Stewart-Brown SL. Preschool vision screening: results of a systematic review. *Health Technol Assess* 1997;1(8):i-iv, 1-83. Available: <http://www.hta.ac.uk/fullmono/mon108.pdf> (accessed 2007 Feb 14).
6. Hartmann EE, Dobson V, Hainline L, Marsh-Tootle W, Quinn GE, Ruttum MS, et al. Preschool vision screening: summary of a task force report. *Ophthalmology* 2001;108(3):479-86.

7. Hartmann EE, Bradford GE, Chaplin PK, Johnson T, Kemper AR, Kim S, et al. Project Universal Preschool Vision Screening: a demonstration project. *Pediatrics* 2006;117(2):e226-e237. Available: <http://pediatrics.aappublications.org/cgi/reprint/117/2/e226> (accessed 2006 Jun 29).
8. Hartmann EE. Preschool vision screening. Maternal and Child Health Bureau and National Eye Institute Task Force on Vision Screening in the Preschool Child. *Optom Vis Sci* 2001;78(2):122-6.
9. Bradley LJ, Riederer ML. The Vision First Check Program in British Columbia: a preschool vision screening program for children age two and age three. *Can J Public Health* 2000;91(4):252-5.
10. Kemper AR, Margolis PA, Downs SM, Bordley WC. A systematic review of vision screening tests for the detection of amblyopia. *Pediatrics* 1999;104(5 Pt 2):1220-2. Available: <http://pediatrics.aappublications.org/cgi/reprint/104/5/S1/1220> (accessed 2006 Jun 29).
11. Hered RW, Murphy S, Clancy M. Comparison of the HOTV and Lea Symbols charts for preschool vision screening. *J Pediatr Ophthalmol Strabismus* 1997;34(1):24-8.
12. Lim HT, Yu YS, Park SH, Ahn H, Kim S, Lee M, et al. The Seoul Metropolitan Preschool Vision Screening Programme: results from South Korea. *Br J Ophthalmol* 2004;88(7):929-33. Available: <http://bjo.bmjournals.com/cgi/reprint/88/7/929> (accessed 2006 Jun 28).
13. Newman DK, East MM. Preschool vision screening: negative predictive value for amblyopia. *Br J Ophthalmol* 1999;83(6):676-9. Available: <http://bjo.bmjournals.com/cgi/reprint/83/6/676>
14. Bray LC, Clarke MP, Jarvis SN, Francis PM, Colver A. Preschool vision screening: a prospective comparative evaluation. *Eye* 1996;10(Pt 6):714-8.
15. Kvarnström G, Jakobsson P, Lennerstrand G. Visual screening of Swedish children: an ophthalmological evaluation. *Acta Ophthalmol Scand* 2001;79(3):240-4.
16. Kvarnström G, Jakobsson P, Lennerstrand G. Screening for visual and ocular disorders in children, evaluation of the system in Sweden. *Acta Paediatr* 1998;87(11):1173-9.
17. Eye examination in infants, children, and young adults by pediatricians: organizational principles to guide and define the child health care system and/or improve the health of all children. *Ophthalmology* 2003;110(4):860-5.
18. American Academy of Pediatrics Committee on Practice and Ambulatory Medicine, Section on Ophthalmology. Eye examination and vision screening in infants, children, and young adults. *Pediatrics* 1996;98(1):153-7. Available: <http://pediatrics.aappublications.org/cgi/reprint/98/1/153> (accessed 2006 Jun 29).
19. Screening for visual impairment in children younger than age 5 years: recommendation statement. *Ann Fam Med* 2004;2(3):263-6. Available: http://www.ithacalions.com/PhotoScreen/Annals_Family_Medicine.pdf (accessed 2006 Jun 28).
20. American Optometric Association Consensus Panel on Pediatric Eye and Vision Examination, Scheiman MM, Amos C, Ciner EB, Marsh-Tootle W, Moore B, et al. *Pediatric eye and vision examination [Optometric clinical practice guideline]*. St. Louis (MO): American Optometric Association; 2002. Available: <http://www.aoa.org/documents/CPG-2.pdf> (accessed 2006 Jul 11).
21. Community Paediatrics Committee, Canadian Paediatric Society. *Vision screening in infants, children and youth: reaffirmed February 2006* [Position statement CP98-01]. Ottawa: Canadian Paediatric Society; 2006. Available: <http://www.cps.ca/english/statements/CP/cp98-01.htm> (accessed 2006 Jul 11).
22. American Public Health Association. Improving early childhood eyecare [Policy statement 2001-1]. *Am J Public Health* 2002;92(3):451-2.
23. Lennerstrand G, Jakobsson P, Kvarnström G. Screening for ocular dysfunction in children: approaching a common program. *Acta Ophthalmol Scand Suppl* 1995;(214):26-38.

24. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the vision in preschoolers study. *Invest Ophthalmol Vis Sci* 2005;46(8):2639-48. Available: <http://www.iovs.org/cgi/reprint/46/8/2639> (accessed 2006 Jun 28).
25. Bamford J, Davis A, Boyle J, Law J, Chapman S, Brown SS, et al. Preschool hearing, speech, language, and vision screening. *Qual Health Care* 1998;7(4):240-7. Available: <http://qshc.bmj.com/cgi/reprint/7/4/240> (accessed 2007 Feb 15).
26. Snowdon S, Stewart-Brown S. The value of preschool vision screening. *Nurs Times* 1998;94(4):53-5.
27. Powell C, Porooshani H, Bohorquez MC, Richardson S. Screening for amblyopia in childhood [Cochrane review]. In: *Cochrane Database of Systematic Reviews 2005 Issue 3*. Chichester (UK): John Wiley & Sons; 2005. CD005020.
28. Zaba JN, Johnson RA, Reynolds WT. Vision examinations for all children entering public school: the new Kentucky law. *Optometry* 2003;74(3):149-58.
29. Salcido AA, Bradley J, Donahue SP. Predictive value of photoscreening and traditional screening of preschool children. *J AAPOS* 2005;9(2):114-20.
30. Guo X, Jia X, Guo L, Xiao X, Shen H, Li S, et al. Comparison of computer-photoscreening with non-cycloplegic retinoscopy for amblyopiogenic risk factors in children. *Chin Med J (Engl)* 2000;113(11):1007-10.
31. Paysse EA, Williams GC, Coats DK, Williams EA. Detection of red reflex asymmetry by pediatric residents using the Brückner reflex versus the MTI photoscreener. *Pediatrics* 2001;108(4):E74. Available: <http://pediatrics.aappublications.org/cgi/reprint/108/4/e74> (accessed 2006 Jun 29).
32. Ying GS, Kulp MT, Maguire M, Ciner E, Cyert L, Schmidt P. Sensitivity of screening tests for detecting vision in preschoolers-targeted vision disorders when specificity is 94%. *Optom Vis Sci* 2005;82(5):432-8.
33. Schmidt P, Maguire M, Dobson V, Quinn G, Ciner E, Cyert L, et al. Comparison of preschool vision screening tests as administered by licensed eye care professionals in the Vision In Preschoolers Study. *Ophthalmology* 2004;111(4):637-50.
34. Miller JM, Dobson V, Harvey EM, Sherrill DL. Comparison of preschool vision screening methods in a population with a high prevalence of astigmatism. *Invest Ophthalmol Vis Sci* 2001;42(5):917-24. Available: <http://www.iovs.org/cgi/reprint/42/5/917> (accessed 2006 Jun 28).
35. Miller JM, Harvey EM, Dobson V. Visual acuity screening versus noncycloplegic autorefraction screening for astigmatism in Native American preschool children. *J AAPOS* 1999;3(3):160-5.
36. Yang JW, Son MH, Yun IH. A study on the clinical usefulness of digitalized random-dot stereoacuity test. *Korean J Ophthalmol* 2004;18(2):154-60.
37. Birch EE, Morale SE, Jeffrey BG, O'Connor AR, Fawcett SL. Measurement of stereoacuity outcomes at ages 1 to 24 months: Randot® Stereocards. *J AAPOS* 2005;9(1):31-6.
38. Steele G, Ireland D, Block S. Cycloplegic autorefraction results in pre-school children using the Nikon Retinomax Plus and the Welch Allyn SureSight. *Optom Vis Sci* 2003;80(8):573-7.
39. Suryakumar R, Bobier WR. The manifestation of noncycloplegic refractive state in pre-school children is dependent on autorefractor design. *Optom Vis Sci* 2003;80(8):578-86. Available: <http://www.optvissci.com/pt/re/ovs/pdfhandler.00006324-200308000-00012.pdf> (accessed 2006 Sep 5).
40. Gole GA, Schluter PJ, Hall J, Colville D. Comparison of the Retinomax autorefractor with hand-held retinoscopy in 1-year-old infants. *Clin Experiment Ophthalmol* 2003;31(4):341-7.
41. el-Defrawy S, Clarke WN, Belec F, Pham B. Evaluation of a hand-held autorefractor in children younger than 6. *J Pediatr Ophthalmol Strabismus* 1998;35(2):107-9.

42. Williams C, Harrad RA, Harvey I, Sparrow JM, ALSPAC Study Team. Screening for amblyopia in preschool children: results of a population-based, randomised controlled trial. *Ophthalmic Epidemiol* 2001;8(5):279-95.
43. Robinson B, Bobier WR, Martin E, Bryant L. Measurement of the validity of a preschool vision screening program. *Am J Public Health* 1999;89(2):193-8. Available: <http://www.pubmedcentral.nih.gov/picrender.fcgi?artinid=1508544&blobtype=pdf> (accessed 2006 Sep 7).
44. Eibschitz-Tsimhoni M, Friedman T, Naor J, Eibschitz N, Friedman Z. Early screening for amblyogenic risk factors lowers the prevalence and severity of amblyopia. *J AAPOS* 2000;4(4):194-9.
45. Williams C, Northstone K, Harrad RA, Sparrow JM, Harvey I. Amblyopia treatment outcomes after preschool screening v school entry screening: observational data from a prospective cohort study. *Br J Ophthalmol* 2003;87(8):988-93. Available: <http://bjo.bmjournals.com/cgi/reprint/87/8/988> (accessed 2006 Jun 28).
46. Newman DK, Hitchcock A, McCarthy H, Keast-Butler J, Moore AT. Preschool vision screening: outcome of children referred to the hospital eye service. *Br J Ophthalmol* 1996;80(12):1077-82.
47. Sjöstrand J, Abrahamsson M. Prevention of amblyopia and the concept of cure. *Eur J Ophthalmol* 1997;7(2):121-9.
48. Donaldson LA, Karas MP, Charles AE, Adams GG. Paediatric community vision screening with combined optometric and orthoptic care: a 64-month review. *Ophthalmic Physiol Opt* 2002;22(1):26-31.
49. Crowley AA, Bains RM, Pellico LH. A model preschool vision and hearing screening program: students and faculty serve a community. *Am J Nurs* 2005;105(6):52-5.
50. Tong PY, Enke-Miyazaki E, Bassin RE, Tielsch JM, Stager DR, Beauchamp GR, et al. Screening for amblyopia in preverbal children with photoscreening photographs. *Ophthalmology* 1998;105(5):856-63.
51. Committee on Practice and Ambulatory Medicine and Section on Ophthalmology, American Academy of Pediatrics. Use of photoscreening for children's vision screening. *Pediatrics* 2002;109(3):524-5. Available: <http://pediatrics.aappublications.org/cgi/reprint/109/3/524> (accessed 2006 Jun 29).
52. Weinstock VM, Weinstock DJ, Kraft SP. Screening for childhood strabismus by primary care physicians. *Can Fam Physician* 1998;44:337-43.
53. Thorburn R, Roland M. The effectiveness of preschool vision screening by health visitors. *Br J Community Nurs* 2000;5(1):41-4.
54. Donahue SP, Johnson TM, Leonard-Martin TC. Screening for amblyogenic factors using a volunteer lay network and the MTI photoscreener: initial results from 15,000 preschool children in a statewide effort. *Ophthalmology* 2000;107(9):1637-44.
55. Tung IC, Tsai RK, Chang CH, Sheu MM. Comparison of trained kindergarten teachers and public health nurses in the administration of preschool amblyopia and strabismus screening tests. *Tzu Chi Med J* 2006;18(1):29-33, 77.
56. Preschool visual acuity screening with HOTV and Lea symbols: testability and between-test agreement. *Optom Vis Sci* 2004;81(9):678-83.
57. Kvarnstrom G, Jakobsson P. Is vision screening in 3-year-old children feasible? Comparison between the Lea Symbol chart and the HVOT (LM) chart. *Acta Ophthalmol Scand* 2005;83(1):76-80.
58. Becker RH, Hübsch SH, Gräf MH, Kaufmann H. Preliminary report: examination of young children with Lea symbols. *Strabismus* 2000;8(3):209-13.
59. Schmidt PP, Maguire MG, Moore B, Cyert L. Testability of preschoolers on stereotests used to screen vision disorders. *Optom Vis Sci* 2003;80(11):753-7.
60. Tong PY, Bassin RE, Enke-Miyazaki E, Macke JP, Tielsch JM, Stager DR, et al. Screening for amblyopia in preverbal children with photoscreening photographs: II. Sensitivity and specificity of the MTI photoscreener. *Ophthalmology* 2000;107(9):1623-9.

61. Feightner JW. Routine preschool screening for visual and hearing problems. In: Canadian Task Force on the Periodic Health Examination, editor. *Canadian guide to clinical preventive health care*. Ottawa: Health Canada; 1994. p.298-304. Available: http://www.ctfphc.org/Full_Text/Ch27full.htm (accessed 2006 Jul 11).
62. Chui L, Fraser T, Hoar K, LaRoche GR. Negative predictive value of a vision screening program aimed at children aged 3 to 4 years old. *J AAPOS* 2004;8(6):566-70.
63. *Report of the Expert Panel on the 18 Month Well Baby Visit*. Toronto: Ontario Children's Health Network; 2005. Available: http://www.children.gov.on.ca/NR/CS/publications/18_expert_en.pdf (accessed 2006 Aug 17).
64. Miller JM, Dobson V, Harvey EM, Sherrill DL. Cost-efficient vision screening for astigmatism in native american preschool children. *Invest Ophthalmol Vis Sci* 2003;44(9):3756-63. Available: <http://www.iovs.org/cgi/reprint/44/9/3756> (accessed 2006 Jun 28).
65. König HH, Barry JC, Leidl R, Zrenner E. Economic evaluation of orthoptic screening: results of a field study in 121 German kindergartens. *Invest Ophthalmol Vis Sci* 2002;43(10):3209-15. Available: <http://www.iovs.org/cgi/reprint/43/10/3209> (accessed 2006 Jun 28).
66. König HH, Barry JC, Leidl R, Zrenner E. Cost-effectiveness of orthoptic screening in kindergarten: a decision-analytic model. *Strabismus* 2000;8(2):79-90.
67. König HH, Barry JC. Economic evaluation of different methods of screening for amblyopia in kindergarten. *Pediatrics* 2002;109(4):e59. Available: <http://pediatrics.aappublications.org/cgi/reprint/109/4/e59> (accessed 2006 Jun 29).
68. Gandjour A, Schlichtherle S, Neugebauer A, Rüssmann W, Lauterbach KW. A cost-effectiveness model of screening strategies for amblyopia and risk factors and its application in a German setting. *Optom Vis Sci* 2003;80(3):259-69.
69. Joish VN, Malone DC, Miller JM. A cost-benefit analysis of vision screening methods for preschoolers and school-age children. *J AAPOS* 2003;7(4):283-90.
70. White AJ, Abt Associates. *Eye exams for children: their impact and cost effectiveness*. Alexandria (VA): Vision Council of America; 2005.
71. König H, Barry J. Cost-utility analysis of orthoptic screening in kindergarten: a Markov model based on data from Germany. *Pediatrics* 2004;113(2):e95-e108. Available: <http://pediatrics.aappublications.org/cgi/reprint/113/2/e95> (accessed 2006 Jun 29).
72. Donahue SP, Baker JD, Scott WE, Rychwalski P, Neely DE, Tong P, et al. Lions Clubs International Foundation Core Four Photoscreening: results from 17 programs and 400,000 preschool children. *J AAPOS* 2006;10(1):44-8.
73. Donahue SP, Johnson TM, Ottar W, Scott WE. Sensitivity of photoscreening to detect high-magnitude amblyogenic factors. *J AAPOS* 2002;6(2):86-91.
74. Berry BE, Simons BD, Siatkowski RM, Schiffman JC, Flynn JT, Duthie MJ. Preschool vision screening using the MTI-Photoscreener. *Pediatr Nurs* 2001;27(1):27-34, 42.
75. Weinand F, Graf M, Demming K. Sensitivity of the MTI photoscreener for amblyogenic factors in infancy and early childhood. *Graefes Arch Clin Exp Ophthalmol* 1998;236(11):801-5.
76. Cooper CD, Gole GA, Hall JE, Colville DJ, Carden SM, Bowling FG. Evaluating photoscreeners II: MTI and fortune videorefractor. *Aust N Z J Ophthalmol* 1999;27(6):387-98.
77. Cooper CD, Bowling FG, Hall JE, Colville DJ, Dortmans RJ, Munch J, et al. Evaluation of photoscreener instruments in a childhood population. 1. Otago photoscreener and Dortmans videophotorefractor. *Aust N Z J Ophthalmol* 1996;24(4):347-55.
78. Fern KD, Manny RE, Garza R. Screening for anisometropia in preschool children. *Optom Vis Sci* 1998;75(6):407-23.
79. Pott JW, Oosterveen DK, Van Hof-van Duin J. Screening for suppression in young children: the Polaroid Suppression Test. *J Pediatr Ophthalmol Strabismus* 1998;35(4):216-22.

80. Birch E, Williams C, Hunter J, Lapa MC. Random dot stereoacuity of preschool children. *J Pediatr Ophthalmol Strabismus* 1997;34(4):217-22.
81. Rasmussen F, Thorén K, Caines E, Andersson J, Tynelius P. Suitability of the Lang II Random Dot Stereotest for detecting manifest strabismus in 3-year-old children at child health centres in Sweden. *Acta Paediatr* 2000;89(7):824-9.
82. Simons K, Avery KE, Novak A. Small-target random dot stereogram and binocular suppression testing for preschool vision screening. *J Pediatr Ophthalmol Strabismus* 1996;33(2):104-13.
83. Barry JC, König HH. Test characteristics of orthoptic screening examination in 3 year old kindergarten children. *Br J Ophthalmol* 2003;87(7):909-16. Available: <http://bjo.bmjournals.com/cgi/reprint/87/7/909> (accessed 2006 Jun 28).
84. Cordonnier M, Kallay O. Non-cycloplegic screening for refractive errors in children with the hand-held autorefractor Retinomax: final results and comparison with non-cycloplegic photoscreening. *Strabismus* 2001;9(2):59-70.
85. Barry JC, König HH. Non-cycloplegic screening for amblyopia via refractive findings with the Nikon Retinomax hand held autorefractor in 3 year old kindergarten children. *Br J Ophthalmol* 2001;85(10):1179-82. Available: <http://bjo.bmjournals.com/cgi/reprint/85/10/1179> (accessed 2006 Jun 28).
86. Cordonnier M, Dramaix M. Screening for refractive errors in children: accuracy of the hand held refractor Retinomax to screen for astigmatism. *Br J Ophthalmol* 1999;83(2):157-61. Available: <http://bjo.bmjournals.com/cgi/reprint/83/2/157> (accessed 2006 Jun 28).
87. Cordonnier M, Dramaix M. Screening for abnormal levels of hyperopia in children: a non-cycloplegic method with a hand held refractor. *Br J Ophthalmol* 1998;82(11):1260-4. Available: <http://bjo.bmjournals.com/cgi/reprint/82/11/1260> (accessed 2006 Jun 28).
88. Briscoe D, Lifshitz T, Grotman M, Kushelevsky A, Vardi H, Weizman S, et al. A new computer program for mass screening of visual defects in preschool children. *Br J Ophthalmol* 1998;82(4):415-8. Available: <http://bjo.bmjournals.com/cgi/reprint/82/4/415> (accessed 2006 Jun 28).
89. Simon JW, Siegfried JB, Mills MD, Calhoun JH, Gurland JE. A new visual evoked potential system for vision screening in infants and young children. *J AAPOS* 2004;8(6):549-54.
90. Atilla H, Oral D, Coskun S, Erkam N. Poor correlation between "fix-follow-maintain" monocular/binocular fixation pattern evaluation and presence of functional amblyopia. *Binocul Vis Strabismus Q* 2001;16(2):85-90.
91. Kemper AR, Keating LM, Jackson JL, Levin EM. Comparison of monocular autorefractor to comprehensive eye examinations in preschool-aged and younger children. *Arch Pediatr Adolesc Med* 2005;159(5):435-9.
92. Büchner TF, Schnorbus U, Grenzbach UH, Busse H. Examination of preschool children for ametropia: first experiences using a new hand-held autorefractor. *Strabismus* 2004;12(2):111-7.

Appendix 1:* Sensitivity, specificity, PPV, and NPV for pre-school vision screening tests

Study	Number of Children Tested	Age of Children	Screening Test	Sensitivity	Specificity	PPV	NPV	Administered By
Donahue <i>et al.</i> ⁷²	>400,000	preschool age	MTI Photoscreener	NR	NR	80%	NR	technicians, orthoptists, ophthalmologists, optometrists, medical students, program coordinators
Donahue <i>et al.</i> ⁷³	949	6 months to 59 months	MTI Photoscreener	50.0%	98.5%	57.5%	94.4%	NS
Berry <i>et al.</i> ⁷⁴	51	3 years to 5 years	MTI Photoscreener	83%	68%	68%	83%	NS
Tong <i>et al.</i> ⁶⁰	392	<4 years	MTI Photoscreener	65%	87%	NR	NR	ophthalmologist, ophthalmic medical technologist
Weinand <i>et al.</i> ⁷⁵	112	6 months to 48 months	MTI Photoscreener	82.8%	61.8%	68.2%	48.1%	pediatrician, orthoptist, ophthalmologist
Tong <i>et al.</i> ⁵⁰	100	≤3 years	MTI Photoscreener	37% to 88%	40% to 88%	NR	NR	ophthalmologist, pediatrician, ophthalmic technician, health department employee, Prevention of Blindness Society employee, Lions Club volunteer
Cooper <i>et al.</i> ⁷⁶	105	12 months to 44 months	Fortune Photoscreener, MTI Photoscreener	Fortune 60% to 68%; MTI 56% to 61%	Fortune 75% to 86%; MTI 79% to 86%	NR	NR	NS
Cooper <i>et al.</i> ⁷⁷	113	11 months to 44 months	Otago and Dortmans Photoscreeners	70%, 70%	82%, 90%	NR	NR	ophthalmologist
Fern <i>et al.</i> ⁷⁸	220	<6 years	Photoscreener	27.8% to 47.0%	NR	66.7% to 94.4%	NR	optometry students
Pott <i>et al.</i> ⁷⁹	196	5 years	Polaroid suppression test	60%	91%	NR	NR	NS
Birch <i>et al.</i> ⁸⁰	1,260	2 years to 5 years	Random-dot stereoacuity	91%	91%	NR	NR	NS
Rasmussen <i>et al.</i> ⁸¹	400	3 years	Lang II Random-dot stereotest	33%	85%	9.5%	96%	nurses
Simons <i>et al.</i> ⁸²	112	3 years to 5 years	STRDS and STBS test	NR	STRDS 80%; STBS 96%	NR	NR	NS
Lim <i>et al.</i> ¹²	894	3 years to 5 years	home vision screening (visual acuity testing with picture cards)	NR	NR	77%	NR	NS
Barry <i>et al.</i> ⁸³	1,180	3 years	cover test, Lea single optotype	90.9%	93.8%	NR	NR	orthoptist

Appendix 1:* Sensitivity, specificity, PPV, and NPV for pre-school vision screening tests

Study	Number of Children Tested	Age of Children	Screening Test	Sensitivity	Specificity	PPV	NPV	Administered By
Cordonnier <i>et al.</i> ⁸³	1,218	9 months to 36 months	Retinomax	37% to 87%	93% to 99%	19% to 69%	96% to 100%	orthoptist
Barry <i>et al.</i> ⁸⁵	404	3 years	Retinomax–non-cycloplegic retinoscopy	80%	58%	NR	NR	orthoptist
Cordonnier <i>et al.</i> ⁸⁶	1,205	9 months to 36 months	Retinomax	51% to 84%	90% to 98%	58% to 84%	90% to 96%	orthoptist
Cordonnier <i>et al.</i> ⁸⁷	897	9 months to 36 months	Retinomax	70.2% to 78.7%	79.2% to 94.6%	51.4% to 78.6%	91.7% to 93.0%	orthoptist
Newman <i>et al.</i> ¹³	936	3.5 years	Sheridan-Gardiner single optotype test, cover test, ocular movement, 20 ^A prism test, TNO stereotest	NR	NR	NR	100% (99.6% Sheridan Gardiner test alone)	orthoptist
Chui <i>et al.</i> ⁶²	178	3 years to 4 years	Lea Symbols, Frisby plates	50% to 75%	68% to 95%	NR	90% to 96%	public health nurses
Briscoe <i>et al.</i> ⁸⁸	292	4 years to 6 years	vision screening computer program	50%	98.9%	63%	NR	non-trained personnel
Simon <i>et al.</i> ⁸⁹	122	6 months to 5 years	visual evoked potential system	97.3%	80.8%	70.6%	98.4%	NS
Atilla <i>et al.</i> ⁹⁰	89	<4 years	fix-follow-maintain	53.1%	38.5%	32.6%	NR	NS
Kemper <i>et al.</i> ⁹¹	170	<5 years	SureSight autorefractor	80% to 88%	41% to 58%	NR	NR	study investigator or ophthalmologist
Büchner <i>et al.</i> ⁹²	336	3.5 years to 4.5 years	SureSight autorefractor	41% to 95%	73% to 92%	NR	NR	NS

NR=not reported; NS=not specified; NPV=negative predictive value; PPV=positive predictive value; STRDS=small target Random-dot Stereogram; STBS=small target binocular suppression.

*Likelihood ratio of positive test=sensitivity/(1-specificity); likelihood ratio of negative test=(1-sensitivity)/specificity.