NATIONAL CHILDREN'S VISION SCREENING PROJECT

Literature Review

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Healthier Kids. Healthier Future.

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1 Main messages

- Cataracts, refractive errors, amblyopia and associated conditions, such as strabismus, are vision conditions that can affect children and can, if left untreated, lead to poor outcomes in childhood including impaired learning and reading, and the risk of permanent loss of vision later in life.
- The prevalence of amblyopia in Australian children is reported to be between 1.4% and 3.6%; the prevalence of strabismus between 0.3% and 7.3%; and the prevalence of refractive error between 1% and 14.7%.
- Most Australian and international guidelines recommend vision screening for children in some form and many recommend a newborn screen.
- The effectiveness of children's vision screening has been reported on widely in the literature. However, only one randomised controlled trial evaluating the effectiveness of screening has been identified by this review.
- Vision screening in the newborn has not been well documented and is therefore lacking a solid evidentiary base. However, while disorders in the newborn are rare, the degree of impairment that can result from such conditions is high. Further research in this area is necessary. If they are to be performed, newborn screening programs need to be of high quality.
- The available evidence suggests that vision screening programs aimed at children aged 18 months to five years of age lead to improved visual outcomes. However, visual acuity is more difficult to measure prior to approximately three years of age.
- There are few studies examining screening following school entry. Those identified suggest that school screening is necessary only if preschool screening has not been conducted previously.
- There was no evidence to support multiple screening events.
- Children at high risk of vision disorders (such as children from remote indigenous populations, children with multiple disabilities and children born prematurely) require separate assessment and diagnosis. Screening programs are not appropriate for these populations.
- Barriers to follow-up care include financial, logistical (lack of a car or phone, family issues) and perceptual (results not believed, not seen as a priority).
- The evidence suggests that vision professionals such as orthoptists perform more accurate screens (in comparison to health visitors, nurses and general practitioners). However, with appropriate training and follow-up, nurses are capable of performing effectively as screeners and may be a more cost-effective option.
- Links have been made between vision impairment and poor educational outcomes. It is suggested that vision impairment is correlated with lower visuocognitive and visuomotor skills, poorer reading ability and lower scores on achievement tests. However, visual deficits related to educational outcomes are often not identified during screening.
- Referral criterion for diminished visual acuity of 6/9 for four up to six year olds is generally recommended to reduce over-referrals and false positive rates.

- Treatment for amblyopia from the age of three is recommended by the available literature, but it may not be detrimental to defer treatment from the age of four to the age of five years. Older children (seven years and above) can achieve improvements in visual acuity but may require lengthier treatment.
- Vision screening may be cost-effective, in terms of dollars per quality adjusted life year (QALY). However, this may depend on the value placed on loss of vision in one eye.
- In order to rigorously evaluate vision screening programs, future research is required. Future research needs to encompass high quality randomised controlled trials, particularly in relation to screening during the newborn period, screening at the preschool versus the school entry period, and the effects of treatment of amblyopia in school-aged children on quality of life. The effects of loss of vision in one eye also require study.

2 Executive Summary

Purpose

The National Children's Vision Screening Project has been funded by the Commonwealth Department of Health and Ageing to inform future policy by determining the effectiveness of vision screening for children aged from birth to 16 years in Australia. The literature review was commissioned to evaluate screening programs designed to detect vision conditions such as diminished visual acuity, amblyopia, strabismus or squint, refractive error, cataracts and glaucoma.

The review examines the effectiveness of vision screening programs for populations with a low to moderate risk of developing a vision condition. Populations who are at high risk of developing a vision disorder, including children born prematurely, children in remote indigenous communities and children with multiple disabilities, require separate assessment, diagnosis and follow-up treatment and care. Vision screening programs alone are not considered appropriate to meet the particular needs of these populations.

Vision screening is different to assessment and diagnosis, and this review focuses solely on the former. Screening consists of a test or tests, generally quick and easy to administer and score, that determine whether a child meets certain criteria considered normal or 'healthy' for his or her age group. A screen does not provide a definitive diagnosis, but determines who should and should not be referred on for a more comprehensive eye examination.

The decision to commence, terminate or modify a health screening program can be contentious. There are certain criteria that screening programs ought to meet in order to effectively identify health conditions, and in order to effectively refer on for reduction, treatment or amelioration of these conditions. The screening of vision in children has been widely debated in the literature, with researchers, eye experts, economists and other professionals divided over whether vision screening should occur at all. For those who believe an Australian vision screening program should be in place, there is a lack of consensus about how and when it should occur. There is a lack of evidence, or lack of consistent evidence, regarding when vision disorders can be detected, whether disorders detected can improve over time without treatment, at what age treatment is most effective, what tools or tests are the most accurate and effective measures of vision disorders and who is best placed (in terms of accuracy, availability and cost-efficiency) to conduct vision screens.

All Australian states and territories have systems in place to offer testing of children's vision to some degree. While some states/territories offer universal screening of all children prior to or following school entry, others offer only targeted screening for at-risk children or those with an obvious vision concern. Most of the screening or assessment that currently occurs prior to a child entering school relies on parents or caregivers being vigilant in taking their child along to regular checks, usually with child health nurses.

Given the inconsistency of vision screening approaches across Australia, and the general lack of or inconsistent evidence regarding these approaches to vision screening in Australia and internationally, the three key objectives of this literature review were to determine:

- *Is a screening program the most appropriate method to use to detect vision conditions in children?*
- *What types of vision screening programs appear to be effective and therefore what properties or processes do programs require in order to be effective?*
- *At what age/s and how often should children attend a vision screen, if screening is deemed an effective method by which to detect vision conditions?*

Methodology

The literature search focused on detecting studies that examined the effectiveness of vision screening programs for children aged from birth to 16 years. Trials were identified through a variety of sources including standard clinical databases, published systematic reviews, hand searches of key articles and via consultation with expert reviewers.

It is important to note that the level of evidence from studies identified for this review was generally low, with the majority falling into category III-3, and to a lesser extent, III-2 (see Appendix A for level definitions). This was largely due to the study designs used to test vision screening effectiveness (i.e., the use of non-randomised controlled trials, observational studies and retrospective reports as opposed to systematic reviews or randomised controlled trials). Consequently, the overall quality of the findings was low, implying that caution must be taken in the interpretation of results and formulation of directions from the evidence.

Findings

As the literature search was focused on screening programs, the studies identified generally evaluated a screening program, or particular component of a screening program, as opposed to comparing a screening program with an alternative method of vision health assessment.

The studies identified incorporated a large number of screening parameters that could be altered to increase or reduce a screening program's effectiveness, such as the age of children at screening (which varied from seven months to 15 years), the characteristics and qualifications of screening personnel and available referral pathways following screening, to name a few. Given the large variation in screening parameters, any directions taken from the evidence can only apply to programs designed with the same parameters. A screening program with changes to any one of these parameters could produce different effectiveness outcomes to that reported in the literature.

Whether or not screening for a non-terminal health condition is required in part depends on its prevalence in the community, and the outcomes associated with having the condition. In Australia, the reported prevalence of common eye conditions in children is 1.4% to 3.6% for amblyopia, 0.3% to 7.3% for strabismus and 1% to 14.7% for refractive error. These statistics show large variations and further research may be required to consolidate these figures. However, they suggest that vision conditions are relatively prevalent among Australian children.

Screening is one of numerous solutions that could be considered to detect and identify vision conditions in children; ranging somewhere along a spectrum that includes no formal detection process at one end (e.g., relying on parental or teacher identification as the basis of concern) and comprehensive detection and diagnoses processes at the other (e.g., using vision professionals such as optometrists, orthoptists or ophthalmologists to carry out detailed assessments of every child).

Some studies did examine the process of relying on parent and teacher identification. These studies generally found that the parent and teacher questionnaire method may be a useful tool for older school-aged children (i.e., those who have been missed by a previous screen), but may be of little assistance in identifying vision conditions in children younger than the critical age of eight years.

The review identified one study that considered the use of universal comprehensive eye examinations for children. The study concluded that this method would detect, treat and cure significantly more cases of amblyopia in children than a universal screening program, and would be more cost-effective. However, the cost-effectiveness component of the study was flawed in its use of monocular blindness as a cost comparator; a condition that does not always result from amblyopia. It is therefore difficult to recommend that Australian states and territories take this approach without further evidence and cost-analysis.

Most studies suggested that screening for visual acuity was feasible from approximately three years of age onwards, and that this was also the age at which treatment for amblyopia was both well received and effective. Other studies noted that foregoing treatment for amblyopia until age four or five was not detrimental, and that treatment after the age of seven or even 10 was still effective and was advisable if necessary.

Based on the limited evidence available, this would suggest that the recommended screening range for children is between three and five years of age. Though many guidelines recommend, and some current Australian practice adopts, screening at multiple points in time, there was no evidence identified to support multiple screenings (e.g., during the preschool years *and* at school entry).

While no studies focused solely on the neonatal period, the literature that did touch on this area suggested that screening for strabismus, cataracts and other eye conditions, such as retinoblastoma, be carried out as early as possible following birth, and at no later than three months of age. While uncommon, these neonatal vision conditions could have severe ramifications for the infant.

Conversely, screening children at eight and 10 years was shown to pick up very few new cases of visual abnormalities requiring treatment, provided that an earlier preschool screen or child health check had taken place. Likewise, screening in secondary school was not recommended given the small likelihood of detecting any further functionally significant eye pathology.

Undetected or untreated vision impairment was shown to have links with educational outcomes. The evidence suggested that infant children diagnosed with hyperopia had poorer visuocognitive and visuomotor skills up to around five years of age and that children diagnosed with ametropia at 4.6 years had poorer visuomotor skills, even though some of the children's vision had been corrected with glasses.

The academic performance at school age of some children diagnosed with visual deficits was reported to be compromised. Children with refractive errors obtained lower scores on achievement tests, and those with ocular motility deficits and hyperopia obtained poorer achievement scores. Further, children with deficits in visual motor, ocular motor, binocular, accommodative, and visual perception skills scored poorly on educational tests, and the majority of children who were academically and behaviourally at-risk had failed one or more visual tests. Visual deficits in school age children were also shown to be associated with reading problems.

Evidence regarding the characteristics and qualifications of the administrators of screening was largely derived from international studies, which often did not incorporate consideration of all eye health practitioners available in the Australian context (such as optometrists). The evidence available suggested that orthoptists were the 'screener of choice' in comparison to nurses, health visitors and general practitioners. Nurses were also deemed to be accurate and efficient screeners when provided with appropriate training and supervision.

Some studies reported that a secondary screen (following a positive or questionable result for a vision condition) prior to ophthalmological referral decreased the false positive rate and was a more cost-effective screening method. The secondary screen was also effective in reducing the age of presentation of amblyopia, and facilitated the early detection, referral and treatment of eye problems. The available evidence indicated that orthoptists may be best employed in this role of secondary screener.

As noted, an important component of a screening program is its inclusion of appropriate referral pathways following detection of relevant conditions. Studies that focused exclusively on the follow-up component of screening programs found that there were a number of barriers preventing children and their families from complying with referral or treatment recommendations. This is concerning, given the potential long-term consequences of vision impairment or loss, and given the resources that screening programs consume.

Finally, the literature suggested that visual acuity in Aboriginal children was not necessarily poorer than in non-Aboriginal children. However, rates of endemic trachoma were reported to be high in Aboriginal communities. It was suggested that child health surveillance (where health issues are considered at multiple points in time with information from different sources) and community education may be more appropriate in remote Aboriginal communities than screening. Other high risk populations, such as children born prematurely or children with multiple disabilities, are not considered suitable candidates for screening programs as more in-depth diagnosis and assessment measures are required for these groups.

Conclusions

Overall, the available evidence suggested that vision screening between 18 months and five years of age was optimal. However, this evidence was derived largely from low quality trials not utilising randomised controlled procedures. There were few studies evaluating screening at school entry, particularly under conditions where preschool screening had not already taken place. The increased accuracy of screening as children get older and the accessibility that would be optimised by screening children at school would need to be balanced against the potential diminished effectiveness of treatment at a later age. There was no evidence supporting screening on multiple occasions (e.g. during the preschool years *and* at school entry).

Some studies also suggested that secondary screening (further screening prior to referral for assessment) by a vision professional following a primary screen by either a layperson or a nurse, was effective in the early detection, referral, and treatment of eye problems. Studies reported that while secondary screening could incur additional preliminary costs, it could potentially save costs in the long-term by reducing the number of false positive referrals made to hospitals or specialist clinics. Educating parents to be more aware of and attentive to their child's vision, or creating awareness campaigns to ensure that treatment is adhered to and cultural barriers to compliance are addressed and removed, could enhance the overall effectiveness of vision screening programs, according to some of the evidence identified.

Whilst vision pathology in the newborn is not common, conditions such as congenital cataracts and retinoblastoma can have a severe impact on vision, and delay of detection until conditions are clinically evident or identified via a later screening program could have detrimental consequences. Though evidence to support newborn screening was not identified, the literature supported neonatal screening, including provision of formal training and with clear referral guidelines. Regardless of age, the literature recommended that high-risk children be referred to an ophthalmologist, rather than rely on population screening.

Most studies concluded that orthoptists were the more accurate screening personnel, in comparison to nurses, health visitors and general practitioners; although the majority of studies from which these conclusions were drawn were not high quality randomised controlled trials and did not consider all screening personnel available in the Australian context The studies examining nurses as screeners concluded that, while the sensitivity and specificity of screening by nurses may be lower than that of orthoptists or ophthalmologists, this did not preclude them from being considered valid primary screeners for a vision screening program, with appropriate training and referral protocols. This may be a more cost-effective process for administration of screening in the Australian context.

There were a number of reported barriers to follow-up care and treatment that reduced the effectiveness of documented screening programs, such as financial pressures and accessibility concerns. Future screening programs should address these barriers in the design of the program.

Further research consisting of high quality, randomised controlled trials is required in order to effectively evaluate screening programs in general, and to determine whether screening would lead to an increase in the treatment of correctable visual acuity deficits and subsequently a decrease in the prevalence of correctable visual acuity deficits for older children and adults. Future research should also focus on an evaluation of screening at school entry (in comparison to preschool screening), and provide a rigorous evaluation of newborn screening. Further research is required to explicate any relationship between vision impairment and educational outcomes. Further, research which aims to determine the 'value' of vision, or the impact on quality of life for vision loss in one eye, is vitally important. Likewise, the impact of treatment for vision impairment on quality of life must be explored. Without a sound evidence base incoporating all of these facets of screening for vision conditions, it is difficult to clearly state the effectiveness or otherwise of vision screening programs.

Again, it must be emphasised that the literature contained few robust trials for appropriate evaluation of vision screening programs. However, the available evidence suggested that vision screening be carried out between the ages of three and five years, which could incorporate the preschool years and/or first year of primary school. The screening pathway recommended by many studies was that screening be conducted by orthoptists or by appropriately trained nurses with orthoptists as secondary screeners, followed by referral to medical eye specialists if required.

3 Background

This literature review was conducted to support the aims of the National Children's Vision Screening Project, which seeks to inform future policy by determining the effectiveness of vision screening for Australian children aged from birth to 16 years. The literature review was commissioned to identify studies on the effectiveness of screening programs designed to detect vision disorders including diminished visual acuity, amblyopia, strabismus or squint, refractive error, cataracts and glaucoma. The directions drawn from the evidence summarised in this literature review may assist in the development of the key components of a national vision screening program for children in Australia, if vision screening can be recommended by the evidence.

Therefore, this review seeks to answer the following questions:

- *Is a screening program the most appropriate method to use to detect vision conditions in children?*
- *What types of vision screening programs appear to be effective and therefore what properties or processes do programs require in order to be effective?*
- *At what age/s and how often should children attend a vision screen, if it is deemed an effective method by which to detect vision conditions?*

To answer these questions, it is first important to note what screening is and what it is not. Over 30 years ago, Wilson and Jungner[1] developed a framework for evaluating screening tests or programs for the World Health Organisation (see Figure 1). This framework is still frequently adopted as the base benchmark against which a screening program should be assessed prior to roll-out. It is important to note that a screening program consists of and requires more than just a suitable screening test.

Figure 1. Criteria for a Screening Program, Wilson, J.M. and Jungner, Y.G. (1968)[1]

Criteria for a Screening Program	
Knowledge of disease	The condition must be an important health problem
	The condition must have a recognisable latent or early symptomatic stage
	The natural course of the condition, including development from latent to declared disease, should be adequately understood
Knowledge of test	There must be a suitable test or examination
	The test or tests must be acceptable to the population
	Case finding should be a continuing process and not a "once and for all" project
Treatment for disease	There must be an accepted treatment for patients with recognised disease
	Facilities for diagnosis and treatment must be available
	There must be an agreed on policy concerning whom to treat as patients
Cost considerations	The costs of case finding (including diagnosis and treatment of patients diagnosed) must be economically balanced in relation to possible expenditures on medical care as a whole

> "A screening program is not a means of diagnosing vision problems, but uses collected data to refer students with possible problems for further evaluation and treatment. The distinguishing characteristic, then, is intervention, which is an essential component of a screening program" *(Colorado Department of Education).[2]*

If screening programs do not meet the Wilson and Jungner criteria, not only can there be unnecessary costs to the economy supporting the program, there can also be unnecessary costs to participants involved in the screening. For example, false positive results can cause intrapersonal angst and personal expense, while false negative results can lead to a mistrust of the system. Inadequate follow-up or treatment facilities can deem the initial screening program irrelevant. Hence, all components of the screening criteria outlined by Wilson and Jungner are important and should be taken into consideration.

Screening, however, is not the only method by which vision disorders in children can be identified. While this review focuses on the effectiveness of screening, the literature also identified some alternatives to screening that are also worth noting. For example, the use of parent or teacher identification of vision conditions has been explored. However, the results of a survey study by Thyer[3] found that primary school teachers in New South Wales lacked confidence and felt ill-prepared to take on a role of identifying children's health problems.

At the other end of the spectrum, there is the option of foregoing screening for more comprehensive and diagnostic procedures conducted by eye specialists. As this review only identified one study that had reported on this alternative, and the discussion related to cost-effectiveness only, little interpretive comment can be made. The feasibility of this model in the Australian context would need to be evaluated in accordance with workforce availability and economic modelling.

Thus, while acknowledging that there are alternatives to vision screening programs, the purpose of this literature review is to evaluate vision screening in terms of the three questions outlined earlier. More specifically, by drawing on a critical evaluation of peer-reviewed published literature, electronic publications, websites and expert consultation, this literature review aims to:

- identify vision screening guidelines, protocols, and/or recommendations that are published in Australia and overseas
- outline the characteristics of vision screening programs currently in practice in Australia
- identify whether vision screening programs are effective, in terms of the criteria used to evaluate screening programs
- examine whether vision screening programs prevent/minimise vision conditions and their consequences
- identify whether vision screening program effectiveness is modified by the characteristics of the screener (i.e., different screening personnel)
- identify the optimal age for a vision screening program
- identify the ideal visual acuity level at which to refer children from screening for further examination and/or diagnosis
- identify information on the cost effectiveness of vision screening programs
- identify variations in a screening program that may be required for application in Indigenous and/or remote populations

4 Methodology

Trials were identified from a variety of sources including standard clinical databases, published systematic reviews, through hand searching of key articles, and via consultation with expert reviewers. We asked expert reviewers (members of the Project Advisory group) to identify any studies over and above those found by the search detailed below that (a) fitted the review trial criteria, (b) were new and promising in the field or (c) offered a specifically Australian perspective.

Below is a detailed summary of the inclusion criteria, search strategies used to identify the trials, and how the quality of each study was rated.

4.1 Inclusion criteria

The search focused on detecting studies that examined the effectiveness of vision screening programs for children aged from birth to 16 years. This included studies incorporating the use of age appropriate screening tests administered by various personnel, including laypeople. The focus of the search was on identifying screening 'programs'; that is, studies evaluating not only screening, but also screening personnel, referral pathways, treatment and consideration of outcomes. The search for guidelines or policies on vision screening, the cost effectiveness or economic evaluations of vision screening and prevalence of vision disorders were also included in the search criteria. Criteria were limited to studies in English and studies published from 1990 onwards.

Studies initially considered for inclusion were:

- Systematic reviews
- Randomised controlled trials (RCTs)
- Pseudorandomised controlled trials

Few studies meeting these criteria were identified. In order to be able to draw some directions from the evidence, the inclusion criteria were expanded to include the following types of non-randomised controlled trials (non-RCTs):

- Comparative studies with concurrent controls
    - Non-randomised experimental studies
    - Cohort studies
    - Case-control studies
    - Interrupted time series with a control group
- Comparative studies without concurrent controls
    - Historical control studies
    - Two or more single-arm studies
    - Interrupted time series without a parallel control group

The following studies were excluded:

- Case series

See Appendix A for the 'Designation of levels of evidence' table (NHMRC 2000).

4.2 Identification of trials

Studies were identified using the following strategy:

1. A search was conducted of published literature in the databases of Medline, CINAHL and Embase from 1990-2008. See Appendix B for the MeSH terms used in the search.

This yielded 461 abstracts of which 36 were selected for potential inclusion. The search was restricted to RCTs only.

2. A second search of the above databases was conducted using the same MeSH terms, but adding the criteria for non-RCTs. This yielded 1346 additional abstracts, of which 33 were selected for potential inclusion.

3. A hand search was conducted for any RCTs or non-RCTs meeting the inclusion criteria. Nine relevant studies were extracted from the following reviews: Child Health Screening & Surveillance: A critical review of the evidence. Prepared by CCCH, RCH for the NHMRC; Screening for Visual Impairment in Children Younger than Age 5 Years: A Systematic Evidence Review for the US Prevention Services Task Force; Snowdon, S. K. and S. L. Stewart-Brown (1997). "Preschool vision screening." Health Technology Assessment 1(8): i-iv.).

4. A search of the Cochrane Database of Systematic Reviews was conducted. Two relevant reviews were found.

5. A search of published guidelines from 1990 – 2008 in the Clin-eguide (also incorporating National Guidelines), MDConsult and TRIP databases using the search terms "vision screening guidelines children" in various combinations produced 71 papers, which were reduced to 11 potential inclusions.

6. A request for further literature was sent out to eye health and other relevant professionals via members of the Project Advisory group and via members of the National Community Child Health Council. This yielded the following:

   - Two literature reviews that lead to the implementation of the Statewide Eyesight Preschooler (StEPS) program in NSW: Models of Service for Preschool Vision Screening, and Vision Screening Tools, courtesy of Robyn Davies, Senior Policy Officer for StEPS (28 studies in total)
   - Qualitative data collected by Dr Merri Paech, Lecturer, University of South Australia, on a vision screening study of high school students in South Australia (1 study)
   - A summary of published research papers to 2005 relevant to community child health, on vision screening and outcomes from treatment of amblyopia, compiled by Dr Jann Marshall, Department of Health, Government of Western Australia (86 studies in total)
   - Information on Western Australian vision and eye health screening tests and standards of practice, courtesy of Mark Drake, Assistant Director, Child & Adolescent Health Service, WA Department of Health (1 study)
   - Information on the Western Australian universal vision assessment schedule, courtesy of Mark Drake (1 study)
   - UK guidelines developed by National Institute for Health and Clinical Excellence (NICE)
   - Literature review completed by the Optometrists Association Australia (vision problems in children and vision screening success, both in Australia and overseas), courtesy of Patricia Kiely PhD, Research Officer (total of 102 studies)
   - Referral to the Optometric Clinical Practice Guideline: Paediatric Eye and Vision Examination (American Optometric Association 2002) available at: http://www.aoa.org/documents/CPG-2.pdf, which reviews the general literature on paediatric vision and addresses preschool and school age child assessment and conditions, courtesy of Patricia M Kiely PhD, Research Officer, Optometrists Association Australia (1 study)

- Information on the Literacy Pathways Program study (Southern Tasmania), supplied by Kylie Smith PhD Candidate, Menzies Research Institute (total of 3 studies)
- Literature update on vision screening compiled and forwarded by Tim Fricke Researcher, International Centre for Eyecare Education Limited (total of 16 studies)

7. A request was sent out to various State and Territory contacts in Australia regarding current vision screening practice in each state and territory. The following information was received (see also Appendix C for further details):

    - Referral to the child health record for NSW data on current vision screening practices by child health nurses
    - Referral to the child health record for Victoria for current vision screening practices by child health nurses
    - Queensland Health Guidelines for using screening and surveillance in the early detection of childhood health conditions, including guidelines taken from the Child and Youth Health Practice Manual
    - Information from the Tasmanian Child Health Record on current vision screening practices by child health nurses
    - Information from the Northern Territory on their proposed 'Under 5' schedule and their 'Healthy School-Aged Kids' program for remote areas, including the proposed vision screening practices of nurses, allied health workers and doctors
    - Information on current vision screening practices by community nurses, paediatricians and general practitioners in South Australia
    - Information on current vision screening practice in the Australian Capital Territory

4.3 Quality ratings for each study

If a study met the initial inclusion criteria and was directly related to an assessment of screening program effectiveness, including the longer-term outcomes of screening (e.g. educational success) and the personnel required to administer a successful program, it was assigned a quality rating using the National Medical Health & Research Council (NHMRC) recommendations from the 2000 report "How to review the evidence: systematic identification and review of the scientific literature" (See Appendix D, Box 1).

Using the NHMRC recommendations, there were four areas of quality rating for an intervention study: 1) method of treatment assignment, 2) control of selection bias after treatment assignment, 3) blinding of outcome assessment and 4) the quality of outcome assessment.

Bias can occur in any of these four areas and affect the interpretation of the study's results. For example, random allocation of children to the intervention or control arm of a trial is essential, as parents of children perceived to be at greater health risk may seek out the intervention if given a choice. When considering selection bias after treatment assignment, losing >15% of the study sample at follow-up or failing to report the effectiveness of the intervention according to how the intervention was received is important. Finally, in terms of outcome assessment, an 'intention to treat' analysis means that the outcomes have been analysed according to the way children were initially randomised (i.e., the way they were intended to be treated). Serious bias can occur if this is not done. For example, if some children from the intervention group did not receive the intervention (and this often occurs in 'real life') but the study reported only on those who did receive the intervention, then the effectiveness of the intervention could be artificially inflated.

Virtually all studies are open to bias. Many of the studies in this review made non-blinded assessments of the outcomes: that is, most outcomes were reported back to children and parents and most children and parents were aware if they or their child had received an intervention or not. However, as some studies did use blinding (either of the participant, the assessor, or both), criterion three was used to determine quality ratings. Criterion four was included in the determination of quality ratings, but was not given a high weighting as all studies included a standardised assessment of the child.

A study was designated as 'high' quality if criteria 1 and 2 were fully met, 'moderate' quality if one or more of the criteria were partly met (e.g. received a 'B' or 'C' rating), and 'low' quality if neither criteria 1 nor 2 was met (see Appendix D, Box 2 for a full list of criteria and associated quality ratings).

Systematic reviews were assessed using criteria created by the Centre for Community Child Health in their review of child health surveillance and screening (see Appendix D, Box 3). Criteria 2 and 3 were deemed more important than Criteria 1 and 4 in assessing the quality of a systematic review, thus were weighted more heavily in the evaluation. A rating of 'A' was high quality, 'B' medium quality, and 'C' low quality. If the score was the same for both criteria 2 and 3, this was the overall quality rating i.e., C and C would equal a low quality study. If the score was either A and B, or B and C, then Criteria 1 and 4 were consulted. Unless both Criteria 1 and 4 were rated A, the lower rating out of Criteria 2 and 3 applied. The median score was chosen if the rating was A and C, or C and A (see Appendix D, Box 4).

4.4 Data analysis

Two members of the project team initially evaluated each paper to determine its eligibility for inclusion. Disagreements occurred on 49 of the studies, and were subsequently resolved through discussion and consensus.

Two researchers independently extracted data from the included studies and rated their quality. Prior to extracting data from the papers, both reviewers evaluated a selection of papers to determine consistency in evaluation and quality ratings. Any discrepancies apparent were discussed and rectified. A total of two RCTs, 38 Non-RCTs and 11 systematic reviews were included in the literature summary on the effectiveness of vision screening.

5 Literature

The majority of the literature identified by the search centred on three of the key themes identified as crucial to the study; the effectiveness of screening programs, the effectiveness of different screening personnel and the influence on educational outcomes should vision conditions fail to be detected. Literature on these three themes were categorised according to age group: neonate, toddler, preschool and school-age plus. Appendix E contains a full summary in table format of all RCTs and non-RCTs covering these themes.

Summaries of the other key themes, such as prevalence of vision conditions and optimal age of treatment, have been included in the body of this review, with more detailed material included in tables in Appendix E for ease of reference.

5.1 Prevalence of vision conditions in Australian and overseas children

Amblyopia

A study in south-eastern Australia conducted between 1980 and 2000 estimated that the incidence of infantile glaucoma was rare, at 1 in 30,000 births.[4] The prevalence of amblyopia in Australia for six year old children involved in the Sydney Myopia Study was reported in one study to be 1.4% (for those without eyestrain symptoms) and 3.6% (for those with eyestrain symptoms),[5] In another study, these figures were 1.8% (taking into account all children previously diagnosed and treated) and 0.5% (non-correctable visual impairment).[6]

Two United Kingdom studies found comparably low prevalence of amblyopia, reporting rates of 0.5% (in Weston-super-Mare) and 1.1% (in Southmead)[7] for children screened at six weeks to 3.5 years, and 2.5% for children screened at 3.5 – 5.5 years.[8] A Singaporean study of children screened at 4 – 4.5 years reported the incidence of amblyopia to be 1.8%.[9]

A Canadian study, which screened four year old children over a three year period, found the prevalence to average around 1.0% over the three years.[10] Another Canadian study reported a higher incidence for four year olds at 4.7%,[11] while the Vision in Preschoolers Study Group (VIP) in the United States reported prevalence of 5.3% for children aged three to five years.[12] For children slightly older in the United States (four to eight years of age), the incidence of amblyopia was 3.9%.[13]

The prevalence of amblyopia for children 12 years of age in the Sydney Myopia Study was 1.9% (including all children previously diagnosed and treated) and 0.9% (non-correctable visual impairment).[14] The results from the United Kingdom for eight and 10 year olds were also low in relation to both mild amblyopia 0.8% and marked amblyopia 0.6%.[15]

Strabismus

The prevalence of strabismus in six year olds in the Sydney Myopia Study was 1.8% (for children without eyestrain symptoms) and 7.3% (for children with eyestrain symptoms),[5] but was as low as 0.3% in another study of children three to 12 years in Victoria and New South Wales.[16] A study in the United Kingdom of children screened at 8.1 months found a low incidence of strabismus at 0.6%,[17] as did a study in Holland of children aged nine months to two years (0.8%),[18] and a study in the United States of children aged six months to 3.9 years (0.2%).[19]

Another study in the United Kingdom of children aged 3.5 – 5.5 years also reported a low incidence of strabismus (at 1.0%),[8] However, prevalence rates in the United States were higher, with strabismus being detected in 7.1% of one to five year old children, 15.4% of one to six year old children,[20] 2.1%[12] and 3.9%[21] of three to five year old children, and 3.1% of four to eight year old children[13]. Rates reported in Canada for four year olds were 1.0% - 1.4%[10] and 4.3%.[11] In children aged eight to nine years of age in Northern Ireland the prevalence of strabismus was 4.0%.[22]

Refractive error

The prevalence of refractive error (including myopia, hyperopia, anisometropia, and astigmatism) for four year old children in New South Wales was reported to be 1.0%[23] (myopia) for children screened from 1990 to 1994 and 2.3%[24] (myopia) for those screened from 1998 to 2004. The Sydney Myopia Study found that 2.5% of children screened at six years had significant hyperopia, 7.3% had mild hyperopia, and 1.4% had myopia.[25] In an investigation of six year olds without eyestrain symptoms, 2.8% had hyperopia, 1.4% had myopia, and 6.8% had astigmatism, whereas in children with eyestrain problems, 7.3% had hyperopia, 2.3% had myopia, and 8.2% had astigmatism.[5] Another paper reporting results of the Sydney Myopia Study found that 13.2% of six year olds screened had moderate hyperopia.[26] Junghans et al.[16] found that out of 2490 children aged three to 12 years who completed at least one of four vision tests, 3.3% had hyperopia >1.50D, 4.1% had myopia >-0.75D and 2% had astigmatism >1D.

In children aged 8.1 months in the United Kingdom, anisometropia was detected in 2.1% of the population,[17] while refractive error in three to 5.5 year olds was reported to be 1.7%[8] and 1.2%.[27] In Holland, refractive error in children aged nine months to two years was reported to be only 0.5%.[18]

Higher rates of refractive error were generally found in the United States in children one to five years (high hyperopia 32.8%, myopia 5.5%, astigmatism 18.3%, anisometropia 28.6%), one to six years (high hyperopia 16.3%, myopia 2.0%, astigmatism 29.8%, anisometropia 34.2%),[20] three to five years (refractive error 5.1%),[12] five to seven years (refractive error

6.1%),[28] and six years (myopia 4%).[29] Two United States studies obtained lower rates with children six months to 3.9 years (high hyperopia 0.3%, high myopia 0.03%, astigmatism 0.3%, and anisometropia 0.5%),[19] and children four to eight years (myopia 3.1%, astigmatism 2.5%, and anisometropia 2.6%).[13]

The prevalence of refractive error was high (at 14.0%) in a Singapore study of children 4 – 4.5 years,[9] a Canadian study of four year olds (refractive error 10.6% - 11.9%),[10] and studies from China and Hong Kong of children five to seven years (myopia: rural China 5%, Chinese Malays 24%, urban Hong Kong 30%).[30-34] Another Canadian study found lower rates of refractive error in children aged four years (hyperopia 4.8%, myopia 1.1%, astigmatism 3.1%, anisometropia 1.4%).[11]

For 12 year old children in the Sydney Myopia Study, the prevalence of refractive error was quite high with 5.0% relating to hyperopia, 12.8% to myopia, and 9.4% to astigmatism.[26, 35] A New South Wales study found that 8.3% of 12 year olds had myopia when screened between 1990 to 1994[23] and 14.7% when screened between 1998 to 2004.[24]

For children aged eight to 10 years in Ireland, the prevalence of refractive error was fairly low with hyperopia at 3.4%, myopia at 1.4%, and astigmatism at 3.4%.[22] A study in the United Kingdom reported a high rate of myopia in eight and 10 year olds at 8.2%.[15] A United States study obtained a rate of 5.4% for refractive error in children screened eight to 10 years of age, and 7.4% for children screened at 11 – 13 years,[28] whilst another United States study for 12 year olds reported the rate of myopia to be 20%.[29] Studies from China and Hong Kong of children 11 - 12 years found high rates of myopia (rural China 23%, urban China 40%, Chinese Malays 47%, urban Hong Kong 57%).[30-34]

Summary

The significant variations in prevalence reflect in part the use of different tests, different definitions of pathology, and the natural history of vision disorders in children whereby there is often a change with increasing age. This is independent of the increasing accuracy of testing with increasing developmental ability.

Therefore, while the aforementioned studies provide an indication of the prevalence of vision disorders in Australia and overseas, it would be remiss to justify a screening program or otherwise on the basis of prevalence rates alone. Prevalence is certainly one of the key factors to take into consideration, but should be considered in conjunction with the quality of life and various other aspects of life that may be impacted by a vision disorder. The effectiveness of screening programs should be evaluated in the context of both prevalence and outcomes (e.g., educational) associated with having a vision disorder. Such outcomes will be outlined further on in this review.

5.2 Australian and international guidelines on vision screening practice

Fourteen guidelines or position statements were identified on the topic of vision screening. Guidelines were evaluated for quality using the Appraisal of Guidelines for Research and Evaluation (AGREE) instrument, developed by The AGREE Collaboration in 2001 (see Appendix F). Guidelines were rated and given a score out of 100 for each of the following categories: scope and purpose; stakeholder involvement; rigour of development; clarity and presentation; applicability and editorial independence. For this review, particular weight was placed on the ratings given to rigour of development and stakeholder involvement.

Overall, all of the guidelines recommended screening for children. The majority of the higher quality guidelines recommended a screen sometime during the newborn to three months of age period (generally, an inspection and a red reflex) and a major screen during the 'preschool' years (ranging from ages 2.5 to five years). Some guidelines recommended further screening during the school years (either every year or every two years after the age of five). Other recommendations were as follows:

- that testing for visual acuity should commence at three years
- that vision screening should occur at the age of three years only if an appropriate test is developed to reduce the high number of false positives
- that any vision difficulties suspected between one and six weeks of age should be referred directly to an ophthalmologist
- that any abnormal screens be referred on for a secondary screen or full diagnosis
- that community health nurses conducting screening programs should refer for orthoptic review where possible, before referring to a general practitioner or ophthalmologist

See Appendix G for a summary table of all guidelines and policy statements.

5.3 Current vision screening practice in Australia

All Australian states and territories have systems in place to offer assessment of children's vision to some degree, from birth through to the adolescent years and beyond. However, the methods used to conduct these assessments or screenings and the personnel used to conduct them varies across Australia. While some states/territories offer universal screening of all children prior to or following school entry, others offer only targeted screening for at-risk children or those with an obvious vision concern. Most of the screening or assessment that currently occurs prior to a child entering school relies on parents or caregivers being vigilant in taking their child along to regular checks with child health nurses. For a detailed description of current vision screening practices in Australia, see Appendix C.

5.4 Screening effectiveness

5.4.1 Overall summary – screening effectiveness

In this review, studies were identified that looked not only at the effectiveness of screening programs per se, but also at the effectiveness of the screening process; a process that includes the lead-up to screening (marketing and engagement) and the follow-up after screening (referral pathways and treatment compliance). Ideally, studies included information about testing, treatment and outcomes.

Eight systematic reviews on screening effectiveness were identified; one of high quality, four of medium quality, and three of low quality. One randomised controlled trial of medium quality, and seventeen non-randomised controlled trials met our inclusion criteria. Three of the non-randomised controlled trials were of medium quality, and 14 were of low quality.

The evidence available reported that early vision screening, and subsequent early treatment, led to improved visual outcomes[36-38] and lower prevalence of amblyopia.[39-44] The ages of children screened in the studies ranged from seven months to 10 years. Screening children at eight and 10 years was shown to identify very few new cases of visual abnormalities requiring treatment, with most having been detected at the five year school vision screen.[15] School nurse screening in secondary school (13 – 15 years) failed to detect any new cases of eye pathology in one study.[45]

Two systematic reviews of the literature on the effectiveness of vision screening programs reported that no randomised controlled trials fitted their criteria. The reviews concluded that screening may still be valuable, but that this value had yet to be properly identified.[46, 47] Other systematic reviews recommended that: screening for strabismus should be performed in the neonatal period, at six months, at three years, and at five to six years;[48] that inspection of eyes should occur during the neonatal period;[48] that high-risk children should be referred to an ophthalmologist;[48] that parents should be taught to be more attentive to their child's vision;[48] that screening of visual acuity should be performed as early as possible;[48] and that screening of children for refractive errors should be conducted at a community level and integrated into school health programs, accompanied by awareness campaigns to ensure that the corrections are used and compliance barriers are addressed and removed.[49]

One systematic review and four non-randomised controlled trials outlined the social, economic, and political barriers that contributed to the underutilisation of vision screening among preschool and school-aged children.[49-53] One study suggested that strategies were required to achieve earlier diagnosis and increase the proportion of cases of congenital and infantile cataract detected through screening in the first three months of life.[54]

Two studies demonstrated that the introduction of a secondary screen was effective in reducing the age of presentation of amblyopia associated with microtropia or no strabismus,[55] and the early detection, referral, and treatment of eye problems.[56]

Four studies examined the use of questionnaires administered to teachers, parents and/or students as screening tools.[45, 57-59] Finally, two studies reported that appropriate marketing strategies could increase the number of preschoolers who received vision care[60] and decrease the age at which amblyopia and strabismus were detected.[61]

Many of the recommendations made in the literature were based on medium to low quality studies with no control group. In considering these recommendations for future research or policy decisions, the quality of the study and the nature of the data obtained (primary, or secondary in the case of reviews) need to be taken into account.

5.4.2 Neonates (0-1 month)

No relevant studies were identified.

5.4.3 Toddler age (1 month-3 years)

One randomised controlled trial and four non-randomised controlled trials evaluated the effectiveness of screening programs in detecting refractive errors, the effects of early correction on visual outcomes, the mode and detection of congenital and infantile cataracts, and the impact of introducing a secondary orthoptic screen. Two further non-randomised controlled trials examined the impact of marketing strategies on increasing participation rates and decreasing the age at which vision conditions were detected.

A study in the United Kingdom examined two different screening programs on infants aged seven to nine months (Cambridge Infant Vision Screening program).[36] The first program used an isotropic photorefractor with cycloplegia and a standard orthoptic examination (n=3166). The second program used the VRP-1 isotropic videorefractor, which was followed-up by refraction under cycloplegia (n=5091). Both programs demonstrated consistency between infants identified at screening and retinoscopic refractions at follow-up. The first program found that children who were hyperopic in infancy were 13 times more likely to become strabismic, and six times more likely to show acuity deficits by four years of age, compared to a control group. Wearing a partial spectacle correction reduced these risk ratios to 4:1 and 2.5:1 respectively. Thus, cycloplegic refraction in infancy had a high predictive value for identifying children at risk of strabismus and amblyopia.

A follow-up study of this cohort at seven years of age showed that, for the first program, infants with +3.5D or more of hyperopia who did not wear a spectacle correction had, by four years, a high prevalence of strabismus (21%) compared with emetropic controls (1.6%).[37] In infant hyperopes who wore a partial spectacle correction, the prevalence of strabismus was reduced to 6.3% from 21%, while amblyopia was reduced to 28.6% from 68%.

In the second program, infant hyperopes greater than +4D, who were not corrected, showed much higher prevalence of strabismus (17%) and amblyopia (68%) than emetropic controls

(0.5% and 0.5%). Those who wore a spectacle correction had a significantly reduced rate of amblyopia (17.1%), however the prevalence of strabismus was not significantly reduced in the treated group. In both programs, 'intention to treat' analysis showed significantly improved acuity results for the group assigned spectacle correction, irrespective of compliance. The authors concluded that photo/videorefraction can successfully screen infants for refractive errors, with visual outcomes improved through early refractive correction. The authors also added that this depended on adequate skills and organisation for delivering the program and in follow-up (confirming refractions, prescribing corrections, and encouraging and monitoring compliance). Both the original and the follow-up study were of low quality.

A randomised controlled trial was conducted in 2001 to assess the effectiveness of preschool vision screening in the United Kingdom.[39] Participants were part of the Avon Longitudinal Study of Parents and Children (ALSPAC). The control group received visual surveillance at eight and 18 months by health visitors and family doctors, which included observing visual behaviour and administering a cover test (n=1461). The intervention group was assessed at eight, 12, 18, 25 and 31 months by an orthoptist testing for visual acuity, ocular alignment, stereopsis, and non-cycloplegic photorefraction (n=2029). Mothers' dates of birth were used to determine assignment of children to the intervention group, a method of randomisation that could be improved upon. Further, due to the intensive nature of the testing involved, the authors acknowledged that the intervention program was not designed to be practicable. However, it was found that the intervention program detected more children with amblyopia than the control program (1.6% versus 0.5%), and the intervention program was more specific (95% versus 92% for the control group program). Photorefraction was the most sensitive component of the program (>95%).

A 2002 follow-up study was conducted with the same cohort to assess the outcome of treatment for amblyopia.[40] It was found that the intensive screening protocol (screening at eight, 12, 18, 25, 31 and 37 months), was associated with better acuity in the amblyopic eye and a lower prevalence of amblyopia at 7.5 years of age, in comparison to screening at 37 months only (0.6% versus 1.8%). The authors concluded that earlier treatment for amblyopia led to a better outcome than later treatment, supporting the principle of preschool vision screening. It should be noted however, that only half of the sample was followed-up, which may have biased the results.

A comparison of eight year old children in Israel who either had received screening for vision defects at 1 - 2.5 years (808 children) or had not (782 children), found that the prevalence of amblyopia was much higher in the children who had not been screened (2.6%) compared to those who had received screening (1%) (p=0.0098).[41] The screening was detailed and performed by an ophthalmologist or an orthoptist and consisted of a corneal reflex test, fixation-and-following test, ductions and versions examination, cover-uncover test, alternate cover test and retinoscopy without cycloplegia. The screening program sensitivity was 85.7% and specificity 98.6%, with a positive predictive value 62.1% and negative predictive value 99.6%, indicating an effective screening program.

Rahi and Dezatuex[54] conducted a cross-sectional study to determine the mode of detection and timing of ophthalmic assessment of a nationally representative group of children with congenital and infantile cataract in the United Kingdom. It was found that 47% of the children newly diagnosed with congenital or infantile cataract were detected through examinations from birth to eight weeks. Fifty-seven per cent had been examined by an ophthalmologist, but 33% were not assessed until after their first birthday. The authors concluded that strategies were required to achieve earlier diagnosis and increase the proportion of cases detected through screening in the first three months of life.

Smith et al.[55] investigated the impact of changes to vision screening in Leicester, United Kingdom. Before 1988, health visitors referred children suspected of having a vision problem to their GP who would refer them on to an ophthalmologist. This system allowed delay, drop out and error. The new system involved children being referred directly from primary screening to a secondary orthoptic screen, in order to reduce drop out and to offer a trained assessment of the child's problems. The introduction of the secondary screen resulted in the mean age of presentation of amblyopia associated with microtropia or no strabismus being reduced from 6.6 years to five years. No change in age of presentation for amblyopia was associated with large angle of strabismus. Prior to the introduction of the program, children from more deprived areas presented later, whereas this association was not found after the secondary screen was introduced. Thus, following changes to the system, children were referred earlier, and those from deprived areas were not overlooked. However, the design of the study was limited in that children started treatment in different years, thus there were no pure birth cohorts. Further, the screening experience may have varied within the two groups, as data was collected from children attending an orthoptic clinic in 1983 and 1992.

Filipovic et al.[61] attached an ophthalmologic screening card to children's vaccination cards to examine whether this reduced the age at which children were first admitted to the Department of Paediatric Ophthalmology. After the screening card was introduced, the mean age at which amblyopia and strabismus were detected decreased significantly, from a mean of 4.4 years to a mean of 2.5 years.

Bradley and Riederer[60] conducted a pilot of the Vision First Check Program to determine whether appropriate marketing strategies could result in a substantially higher number of two and three year old children receiving a thorough vision assessment. Screening was provided voluntarily by optometrists, and follow-up by public health personnel. Marketing materials were displayed in optometrists and family physicians' offices, in health units and in libraries. The study concluded that the Vision First Check Program was successful in increasing the number of two and three year old children receiving vision care.

5.4.4 Preschool age (3-6 years)

Four systematic reviews were identified that evaluated the effectiveness of vision screening in reducing rates of amblyopia, the effectiveness of screening for strabismus and subsequent treatment, the effectiveness of primary orthoptic screening, and barriers that contributed to the underutilisation of vision screening. Five non-randomised controlled trials were identified that looked at visual outcomes after screening and subsequent treatment, the effectiveness of secondary screening, the effectiveness of using a teacher questionnaire and some barriers to follow-up care post-screening.

A systematic review was conducted to evaluate the effectiveness of vision screening in reducing the prevalence of amblyopia in screened versus unscreened children before or as they entered school.[47] No randomised controlled trials were identified that fitted the criteria. The authors concluded that the absence of such evidence could not be taken to imply that vision screening is not necessary - simply that screening has yet to be tested in rigorous trials. They concluded that the optimum protocol for conducting screening remained unclear, and that there appeared to be no detrimental effect in terms of visual outcome on leaving screening until school entry. This in fact appeared to improve the participation rate achieved.

A low quality review by Weinstock et al.[48] examined the clinical classification of strabismus, described the timing and method of strabismus screening examinations, and discussed principles of treatment. The main recommendations from the review were that (a) primary care physicians should screen all low-risk children, (b) high-risk children (low birth weight, family history of strabismus, congenital ocular abnormality, or systemic conditions with vision threatening ocular manifestations) should be referred to an ophthalmologist for screening, (c) screening should be performed in the neonatal period, at six months, and at three years (Grade A recommendation), as well as at five to six years (Grade B recommendation), and (d) these screening examinations should include inspection, examining visual acuity, determining pupillary reactions, checking ocular alignment, testing eye movements, and ophthalmoscopy.

Weinstock et al.[48] reported that strabismus is a common problem affecting four per cent of school-aged children and that, untreated, up to 50% of patients with heterotropias would develop permanent vision loss in the deviated eye. The authors also reported that improperly aligned eyes would impede normal binocular vision and stereoscopic depth perception, which could interfere with a child's ability to read, play sport and relate to others. This social dysfunction could continue into adulthood and affect self-image, employment, and relationships. The study recommended that all cases of manifest strabismus and all symptomatic cases of latent strabismus should be referred to an ophthalmologist promptly. The report stated that amblyopia could be successfully treated, that binocular vision and depth perception could develop normally if strabismus and amblyopia were detected early and that lives could be saved if serious cases of ocular disease were identified promptly. However, no evidence was provided to substantiate these claims.

A systematic analysis of screening programs used to detect visual dysfunction in Sweden and Canada was performed in 1995, and the performance of these programs was found to be favourable.[62] Based on analysis and evaluation, the review made seven main recommendations: (1) that inspection of eyes and preferably examination of the red reflex with an ophthalmoscope should occur in the neonatal period; (2) that children at high-risk for ocular and visual disorder should be examined by an ophthalmologist; (3) that teaching parents to examine the eyes and vision of their children may make them more attentive to the visual development of their children, and that staff at paediatric departments and child health care centres should be alert to symptoms and signs of visual defects; (4) that paediatric exams should include detection of squint and that fundoscopy should be undertaken when there is a clinical indication; (5) that screening of visual acuity should be performed as early as possible, that a screening test of monocular visual acuity in four year old children can be reliably performed by non-ophthalmic personnel, allowing for re-testing if children are uncooperative, and that this screening test should be repeated by school nurses during first grade of school and at regular intervals during the school years; (6) that children who screen positively should be seen by orthoptists, and in some cases ophthalmologists, without delay; and (7) that there is a need for a better preschool acuity test that can be used at age 2.5 - 3 years.

A systematic review[63] and a survey study[50] addressed the barriers which contributed to the underutilisation of vision screening among preschool age children. It was found that a variety of social, economic and political barriers prevented children from receiving proper vision screening. Social barriers included ignorance, inconvenience, language, and lack of providers, while political barriers arose from the disproportionately small amount of funding allocated to preventative medicine. Financial barriers primarily affected low income families to the extent that low income, minority, and uninsured families were at high risk of not utilising vision screening. Both studies concluded that in order to address barriers to follow-up care, parents needed to be fully aware of the objectives and benefits of vision screening. Paediatricians or primary care providers should also be re-introduced to the importance of vision screening among preschoolers. Once children receive comprehensive vision screening, appropriate networking needed to be established to help with follow-up of children with referrals to specialists.

A retrospective cohort study, using the same birth cohort as Williams et al.[39] (ALSPAC), assessed the visual outcomes of children in the United Kingdom aged 7.5 years who either did or did not receive preschool vision screening at three years of age (n=6081).[42] Children were screened by an orthoptist using a monocular vision test, a cover test, and an assessment of binocularity or a test of strabismus, or both. More children were offered preschool screening (24.9%) than those who actually attended (16.7%). Children who received preschool screening had a 45% lower prevalence of amblyopia compared to those who did not receive preschool screening (1.1% of 1,019 screened versus 2.0% of 5,062 not screened). Once all children who were offered the screening (whether or not it took place) were included in the analysis, amblyopia was still less common in the children offered preschool screening, but was not statistically significant.

The study indicated that, while a vision screening program can be effective, the effectiveness can be affected by the number of children who actually receive screening. It was also reported that children screened at preschool (3.1 years) had slightly better outcomes following treatment than children screened at school entry (preschool group mean visual acuity 0.14 LogMAR, school-entry group 0.2 LogMAR). This beneficial effect was significant for straight-eyed amblyopia, but not amblyopia associated with squint. The authors also noted that the cohort under-represented children from very deprived families, families of Asian extraction, and families where the mother was a teenager at time of birth. Thus, findings may not be generalisable to these populations.

A retrospective review conducted in the United Kingdom in 1991 examined vision screening by orthoptists during 1987-88 with 5,162 children aged three to four years.[38] The review examined for gross abnormalities, corneal reflections, abnormalities of ocular movements and binocular convergence. Orthoptists also used the cover test for strabismus, prism reflex test for abnormality of binocular function and Sheridan Gardiner 7 letter test for visual acuity. Of those screened, 309 were referred and 233 received treatment (218 were prescribed spectacles, 87 were prescribed occlusion treatment, and 10 were listed for surgery). The number of children who improved in terms of lines on a standard Snellen chart after treatment was: 18 (4+ lines); 34 (3 lines); 67 (2 lines); 49 (1 line); 30 (no improvement); 30 (no results). As the review was undertaken in a disadvantaged health district, results may be less generalisable.

A retrospective study was undertaken in the United Kingdom to evaluate a community orthoptic service, which served as a secondary assessment prior to hospital follow-up.[56] A total of 2,600 children were evaluated. Primary vision screening at 3.1 years by orthoptists working in local clinics led to the referral of 140 children (6.3%). One hundred and fifteen (85.8%) of those seen at hospital were identified as having an eye problem, and of these, 82 (61.2%) required immediate treatment. The community orthoptist request service referred 70 (17.8%) children. Sixty (95.2%) children were identified as having an eye problem, and of these, 42 (66.7%) required immediate treatment. The authors concluded that primary screening was an efficient and effective way for early referral of specific targeted eye problems, the majority of which had been undetected. Had there only been a request service available, the eye problems would not have been identified until school age. Providing the request service allowed children with suspected eye conditions to be confirmed and referred immediately to hospital. Filtering referrals via a community orthoptic service allowed hospital resources to be utilised more efficiently by reducing the number of false referrals; and enabled effective early treatment of vision problems.

Finally, Concannon and Robinson[57] evaluated the effectiveness of a questionnaire designed to enable teachers to assess children's vision. Twenty-two primary schools in northern Sydney were selected for the study (n=1345, children aged four to six years). Visual assessments conducted by nurses were compared to reports from teachers. It was found that only five out of 42 children (4%) identified by the teachers' reports were considered by the nurse to have a vision problem. A further 31 children identified by the nurses' screen as having a vision problem were missed by teachers. It was concluded that teachers' reports were an unreliable and unsatisfactory alternative to screening by school health nurses.

5.4.5 School age (6+ years)

Two systematic reviews examined the effectiveness of vision screening in schools, and the global magnitude of visual impairment caused by uncorrected refractive error. Ten non-randomised controlled trials examined various topics including the effectiveness of screening and treatment in reducing amblyopia, the detection of new defects at 8 – 10 years following screening at five years, the efficacy of screening in secondary schools, the effectiveness of parent and student questionnaires in detecting vision conditions and the barriers to receiving adequate follow-up care.

A systematic review was conducted to evaluate the effectiveness of school vision screening programs in reducing the prevalence of undetected, correctable visual acuity deficits due to refractive error.[46] The authors did not find any randomised controlled trials that met their inclusion criteria, thus no formal analysis was performed. In order to report on current practice, the authors identified observational, cross-sectional, and cohort studies. The authors concluded that there were no robust trials available to measure the effectiveness of vision screening, therefore the value of vision screening had yet to be properly identified.

The authors noted that the potential for screening to be harmful should also be acknowledged. They reported that the consequences of administering programs with poorly defined parameters for intervention included undue cost and inconvenience in regards to false referrals, and unnecessary treatment. However, the authors acknowledged that where primary eye care services were very scarce, screening in schools allowed the opportunity to identify problems that would otherwise be missed. Again, it was concluded that there was a clear need for well-planned randomised control trials to be implemented to measure the effectiveness of vision screening.

A review of the literature was conducted on the global magnitude of visual impairment caused by uncorrected refractive errors for people aged five years and over.[49] The study concluded that: (a) screening of children for refractive errors should be conducted at a community level and integrated into school health programs, accompanied by awareness campaigns and the removal of barriers to compliance; (b) refractive corrections needed to be made more accessible and affordable for all ages; (c) eye-care personnel should be trained in refraction techniques and teachers and school health-care workers should also receive training and information programs; (d) reliable and affordable equipment for refractive assessments should be developed; and (e) impairment and outcomes should be monitored at a national level to identify communities in need and to evaluate the most cost-effective interventions..

A retrospective study conducted in Sweden in 2001 followed 3,126 children from birth to 10 years of age.[43] Children were screened at age four, 5.5, seven and 10 years by nurses at Child Health Care Centres or at schools. At four and 5.5 years, monocular vision was tested using the HOTV-chart, while at seven years children were tested with a Line E-chart or HOTV-chart, and at 10 years Monoyer's linear letters were used. It was found that the screening and subsequent treatment of amblyopia decreased the prevalence of the condition. The difference in the number of amblyopes between screening and non-screening was most pronounced for the lower visual acuities. The screening tests at four and 5.5 years (HOTV-chart) had a sensitivity of 92% and specificity of 97%.

Another retrospective study using the same birth to 10 years cohort as Kvarnstrom et al.[43] examined the various ophthalmological conditions detected in a Swedish vision screening program for children.[44] Ametropia (any refractive error) was mainly detected at four years, when visual acuity tests were first performed. Manifest strabismus was in many cases detected before age four, while microtropia (small angle heterotropia) was detected at four years. The prevalence of amblyopia was reduced to 0.2% from 2% by screening and treatment, and the majority of patients with amblyopia increased their visual acuity with treatment, indicating that screening and treatment can reduce the prevalence of amblyopia.

A prospective study of school vision screening tests was undertaken on 1,809 children aged eight and 10 years in Cambridge, United Kingdom.[15] The authors examined whether a significant number of new defects of vision were detected. It was found that only 15 (0.83%) of the children tested had a newly diagnosed problem requiring treatment. Almost all children with marked visual abnormalities had already been detected before school entry, either at the five year school vision test or on another occasion.

A United Kingdom study examined the effectiveness of vision screening on 1,069 secondary school students aged 13 – 15 years.[45] The screening was carried out by school nurses using the Snellen chart. It was found that 3.8% of children failed the vision screening test. There was no evidence to suggest that failing vision screening increased across the age range. Less than 1% of children were prescribed glasses, and no new cases of eye pathology were found. However, this study obtained a lower sample size than expected, which decreased the power of the study.

Scherrer and Stevens[58] conducted a comparison of nurse screenings and screenings using a parental and student questionnaire, with students aged 10 – 11 years (n = 191). The study was undertaken in six schools from two large rural cities in New South Wales. It was found that the questionnaire method exhibited a relatively low error rate when data from both parent and student were combined. Only two of 191 students would have been overlooked if the questionnaire was the only method used to screen. However, the study was limited in that the sample was small, the socioeconomic group contained well-educated students and parents, and the children were older and therefore better able to provide information on their own health. The prevalence rate of vision disorders may also have been lower in this sample to begin with, due to possible prior screenings and treatment.

Edgecombe et al.[59] found that the inclusion of simple questions directed at parents about their child's visual history on the School Entrant Health Questionnaire (SEHQ) could provide useful vision screening information to school nursing personnel. In a similar study, Jewell et al.[45] asked parents to complete a questionnaire concerning their children's past eye history. This was a large (n=1069) United Kingdom study of children aged 13 - 15 years and their parents. It was reported that 38% of secondary school children with abnormalities identified by screening had already been self-detected or detected by a family member. Caution should be taken in generalising these findings due to the age of the children in this study and therefore the greater time period allowed for the child or family to detect problems.

Three studies looked at the reasons why children identified as having a vision condition during a screen did not always attend appointments for follow-up care or treatment.[51-53] The studies concluded that the major barriers to follow-up care or treatment compliance fell into three major categories: (1) financial – cost and money concerns; (2) logistical – lack of a car or phone, an inability to plan ahead and/or family issues; and (3) perceptual – results not believed or not seen as a priority. Other reasons for non-compliance included a lack of general community awareness about vision impairment and some adolescents' reluctance to wear glasses.[51]

5.4.6 Screening effectiveness – directions from the evidence

Overall, there is a lack of evidence to conclusively evaluate the effectiveness of screening. However, the evidence available suggests that if screening is to be conducted, then doing so at an earlier age (from 18 months to five years), is more likely to lead to improved visual outcomes. Screening at an older age, such as eight to ten years or 13 – 15 years, was shown to detect very few or no new cases of eye pathology, which would suggest this is not recommended practice. There was an absence, however, of studies evaluating screening at school entry, which may be the ideal time to improve coverage via increased accessibility to a larger number of participants.

The evidence also suggested a secondary screen (a referral screen after a primary screen and prior to a follow-up screen), was an effective component of early detection, referral, and treatment of eye problems. While this would incur additional initial costs, it is possible that it would save costs in the long-term by reducing the number of false positive referrals made to hospitals or specialist clinics. Secondary screening appeared to be most important when the initial screening was carried out by non-vision health professionals. The effectiveness of vision screening programs could also be enhanced by the use of strategies such as teaching parents to be more attentive to their child's vision, or creating awareness campaigns to ensure that the corrections are used and cultural barriers to compliance are addressed and removed.

The evidence evaluating teacher, parent and student questionnaires as an alternative or an adjunct to other vision screening tools suggested that while parent and student questionnaires were useful tools to use with older school-aged children, teacher questionnaires were not accurate tools for collecting information. Little has been revealed about the usefulness of questionnaires in general on children younger than the critical age of eight years. Further research is required in this area before a proper comparison and analysis against other methods of screening could be conducted.

While none of the literature identified focused solely on screening in the neonatal period, the studies that touched on this area suggested that screening for strabismus and cataracts (as well as other vision disorders of the newborn) be carried out as early as possible following birth, and no later than three months of age. At any age, the literature recommended that high-risk children should be referred to an ophthalmologist.

The effectiveness of screening programs in any age group depends in part upon adequate participation from children and their families. The literature suggested that low income families in particular were often not aware of: (a) screening programs available to them, (b) the conditions detected by screening programs and the possible benefits of detecting these conditions early and/or, (c) the financial assistance that may be available to them for screening, follow-up care and treatment. A screening program is also only as effective as its follow-up care with regards to participants who obtain a positive result for a vision condition. However, it appeared that there were a number of barriers to follow-up care and treatment that reduced the effectiveness of screening programs overall. Future screening programs should seek to address these barriers in their program design.

Once again, it is noted that the evidence outlined was based on trials of medium to low quality, in accordance with this review's rating system, and thus caution should be taken in deriving any directions from the studies. However, it is also noted that the current lack of evidence does not imply that vision screening is not effective, simply that programs have yet to be rigorously tested.

5.5 Screener characteristics

5.5.1 Overall summary – screener characteristics

Two systematic reviews were identified that compared the results achieved by different personnel in screening children for vision conditions. The first review, of medium quality, supported screening of children aged six years and over by school nurses with appropriate professional support and training by orthoptists.[64] The second review, of high quality, concluded that orthoptic screening programs performed better than health visitor or general practitioner screening programs in terms of yield and positive predictive value when screening children aged three to six years.[65]

One randomised controlled trial of medium quality evaluated the screening of three to six year old children. The study reported that nurses and lay screeners achieved similar results regarding sensitivity and specificity in the screening of preschool children.[12]

There were 11 non-randomised controlled trials that met the inclusion criteria; 10 of low quality and one of medium quality. In the age group of one month to three years, three studies concluded that screening by orthoptists was superior to screening by other medical personnel,[7] health visitors[66] and health visitors and general practitioners together.[67]

The seven studies examining screening in the three to six years age group compared different screening personnel, as well as different screening tests, making it difficult to amalgamate results. The studies reported that orthoptists were effective screeners;[68] that health visitors were just as effective as orthoptists;[27] that nurses achieved better results than teacher questionnaires,[57] similar results to optometrists,[69] and results of sufficient specificity and sensitivity to be considered primary screeners[10]; that parents were effective administrators of vision tests in the home,[70] and that referral and treatment rates differed substantially between lay screeners and primary care practitioners, although little information was provided as to why this was the case.[71]

The final non-randomised controlled trial, examining screening in children aged six years and over, concluded that nurses could perform the role of primary screener with appropriate training from other eye health professionals. It was reported that training was particularly required for the detection of strabismus[72] and it was hoped that this training would address the high false positive rate obtained by the nurses in the study.

The evidence summarised in this section was largely drawn from international studies where the workforce available to conduct vision screenings often differed from the Australian context. While theoretical directions can be drawn from the evidence available, the application of this evidence in the Australian context must be done with due consideration to the Australian eye health practitioner workforce and related economic systems (see Appendix H for a summary of the Australian eye health practitioner workforce).

5.5.2 Neonates (0-1 month)

No relevant studies were identified.

5.5.3 Toddler age (1 month-3 years)

In this age group, two non-randomised controlled trials and one controlled clinical trial evaluated how different screening personnel performed in the detection of amblyopia and/or refractive error. All studies were conducted in the United Kingdom.

The first study reported that the use of orthoptists as primary screeners improved detection rates of visual abnormalities (positive predictive value of 47.5% and false predictive value of 46.4%) and lowered the rate of false-positive referrals to secondary clinics as compared to 'other medical personnel' (positive predictive value of 14.4% and false predictive value of 82%).[7] The authors concluded that amblyopia screening should be conducted by orthoptists. However, there were potential limitations to the study which may have had bearing on the results. For example, the prevalence of amblyopia and squint may have differed between the orthoptist and the 'other' cohort; the arbiters of the screens were orthoptists themselves, so may have had more of a tendency to agree with other orthoptists; the vision screen by orthoptists did not take place in the context of a more detailed, broader health assessment, therefore the orthoptists may have received greater cooperation from children; and the tests used by orthoptists and the 'other medical personnel' differed slightly.

The second study, a controlled clinical trial, compared visual outcomes at seven years of age for children screened at three years of age by either orthoptists, health visitors or general practitioners.[66] Orthoptists tested visual acuity and ocular movements, and used a cover test, alternate cover test and prism test, whereas the health visitor screen only included an assessment of ability to pick up a thread and observation of any manifest squint. Screening by general practitioners involved the observation of manifest squint only.

It was found that the prevalence of amblyopia was similar in children screened by the different examiners (1.0% to 1.2%). Orthoptic screening did not significantly lower the age at which squint (excluding microtropia) presented (orthoptic 3.8 years, health visitor 3.9 years, general practitioners 4.1 years). However, orthoptic screening did have an effect on the age at which straight-eyed amblyopia and refractive errors presented (straight-eyed amblyopia: orthoptic 3.4 years, health visitor 5.6 years, general practitioners 4.5 years; refractive errors: orthoptic 3.8 years, health visitor 5.4 years, general practitioners 5.1 years).[66]

The authors concluded that more children with amblyopia were identified in the orthoptic screening cohort. However, limitations (such as the possibility of a difference in family history of squint across the cohorts) were noted. It was also reported that insufficient evidence was obtained to support the introduction of a nationwide primary orthoptic preschool vision screening program.[66]

The third study compared results obtained by three groups of personnel - orthoptists, health visitors, and health visitors and general practitioners combined - following screening of children aged five to nine months, and three years.[67] All three personnel groups produced equally poor results when screening children less than nine months of age. Orthoptists who screened children aged three years achieved a sensitivity of 100% and specificity of 97%, while health visitors achieved better specificity at 100%, but sensitivity of only 50%. Data was not available from the health visitors and general practitioners for their screening of three year olds for comparison.

While the results suggested that orthoptists were the superior screener, it should be noted that, again, screening methods differed between personnel. Orthoptists used cover tests, ocular movements, 20 dioptre base out prism tests, convergence, and Sheridan Gardiner letter matching or Kay Picture tests, while health visitors used squint checks and/or ‘pick up a thread’ tests only. The authors also referred to several other limitations that may affect the results of the follow-up to the study that was still occurring at the time of publication. It was thought that the limitations could have an impact on screening sensitivity, prevalence of amblyopia between cohorts and referral uptake.

5.5.4 Preschool age (3-6 years)

Within this age group, one systematic review and two randomised controlled trials were identified that compared the results of different personnel screening for refractive error and/or amblyopia.

A systematic review, consisting of one prospective controlled trial and 16 retrospective studies (observational studies and audits) of different screening programs, reported that orthoptic screening programs performed better than health visitor or general practitioner screening programs.[65] The mean referral rate was 6.7% for primary orthoptic programs and 3.9% for screening by health visitor or general practitioner. The positive predictive value ranged from 47.5% to 95.9% for orthoptic screening and from 14.4% to 61.5% for screening by health visitor or general practitioner. Despite these results, the authors concluded that no new preschool vision screening programs should be implemented unless they have been vigorously evaluated.

An observational study was conducted in Canada to assess the validity of preschool vision screening.[10] Public health nurses conducted tests of visual acuity, ocular alignment and stereoacuity to approximately 1,110 children each year over a three year period, and results were compared to those obtained from practitioner reports. The sensitivity of the nurse screen ranged from 60.4% to 70.9%, while specificity ranged from 69.6% to 79.9%. The positive predictive value was 21.6% to 32.3% and the negative predictive value was 92.6% to 95.3%. The percentage of children who failed vision screening ranged from 25.5% to 34.7% over the three year period. This study concluded that, based on the number of children detected with vision defects, the screening of children by public health nurses was valid and should be continued.

The Vision in Preschoolers (VIP) study compared the performance of nurse screeners with that of lay screeners in administering preschool vision screening tests to three to five year old children.[12] Results from both cohorts were then compared to results of a gold standard eye examination by an ophthalmologist or optometrist. It was found that the lay screeners achieved higher sensitivity with the single Lea Symbols test than did the nurses or lay screeners using the linear Lea Symbols. All other screening tests resulted in higher sensitivity when administered by the nurses compared to the lay screeners, although the differences were small and not statistically significant. The study concluded that similar results could be obtained by using either nurses or laypeople as screeners, but noted that these results should be replicated before being applied to the general population.

Six non-randomised controlled trials were found comparing the characteristics of different personnel who screened children in the three to six years age group. As outlined in the background of this literature review, one study tested the feasibility of using a questionnaire for teachers in place of the traditional screen conducted by school nurses for students in their first year of school.[57] Using the orthoptic screen as 'gold standard', the nursing screen showed excellent specificity and sensitivity, whereas the teacher questionnaire only yielded a 13.9% sensitivity rate. Given that the teacher questionnaire was unable to detect 86% of the visually impaired, the authors concluded that they would not recommend the questionnaire as a screening tool.

In another study, monocular visual acuity and stereopsis testing was implemented at four sites; two community-based sites with testing performed by lay volunteers and two primary care practice sites with testing performed by nursing staff or other office staff.[71] The results showed that significantly more children were referred and treated following a community-based screen than a primary care practice screen. Unfortunately, the authors could only speculate as to why this occurred, suggesting that perhaps lay screeners were more conservative, or that nurses and doctors lacked an understanding of the systematic screening of young children.

In a retrospective study in Cornwall, United Kingdom, orthoptists were reported to achieve a screening sensitivity of approximately 90% and specificity 99%, using comprehensive testing methods and referring at 6/9.[68] The study did not use a comparison group, and suggested that a future study should compare the orthoptists' performance with that of health visitors as primary screeners.

A United Kingdom study examined the effectiveness of preschool vision screening of 3 – 3.5 year olds by health visitors.[27] The study reported that screening by health visitors was as effective as screening by orthoptists. A retrospective review of the records of children identified with amblyopia following a school entry medical at five years was undertaken to detect possible failure of the earlier health visitor examination. Of the 33 children with amblyopia (out of 2,423 who were screened), it was possible to trace the health visitor record of 10 of these. There were only two children where an abnormality might have been missed by the health visitor at the three year check.

Parents of 21,906 children in Tokyo, Japan were sent a home vision test with a health examination notification.[70] The vision test comprised picture cards of familiar figures. The results showed that over 96% of children could complete the test and that 41 new cases of amblyopia were found, suggesting that parents could be successful early screeners. However, the program required that the home vision test be followed up with a professional eye examination or screen, particularly as it could not detect strabismus alone.

In the final study for this age group, 28 children aged five to six years were screened by a registered nurse and a week later, by an optometrist.[69] The five test items assessed visual acuity, hyperopia, convergence, binocular eye movement (tracking) and binocularity of vision. At least 86% agreement was achieved between the nurses and optometrists for each test. However, this result was based on a low number of participants, so may need to be replicated with a larger sample.

5.5.5 School age (6+ years)

One systematic review and one non-randomised controlled trial were found comparing nurses with orthoptists in detecting refractive error in children aged six years and over. The systematic review supported screening by school nurses with appropriate professional support and training by orthoptists[64]. It was found that nurses were highly accurate in screening for visual acuity, but may benefit from more assistance and training in detecting strabismus. The literature revealed positive outcomes associated with using parent and teacher referral methods for older children, but highlighted the lack of evidence supporting this method as an alternative to professional screening at school entry. It was also noted that this was an inadequate method for younger children.

The non-randomised controlled trial compared the ability of nurses and orthoptists to conduct accurate screens of visual impairment in children attending Primary One in the United Kingdom.[72] The nurses achieved a positive predictive value of 40%, negative predictive value of 99%, sensitivity of 83% and specificity of 95%. The authors concluded that orthoptists conducted more accurate screens, but that all children with significant visual defects were detected by nurses (without specifying what constituted a 'significant visual defect'). The authors also recommended that the high false positive rate obtained by the nurses needed to be reduced and that the study should be replicated with a larger sample size.

5.5.6 Screener characteristics – directions from the evidence

While the papers identified across the three age groups (toddler, preschool and school age) were quite different in scope, a theme emerged that demonstrated some consistency in findings. Most studies concluded that orthoptists were the most accurate screening personnel, in comparison to nurses, health visitors and general practitioners. However, the majority of studies from which these conclusions were drawn were not of high quality and were not randomised controlled trials. Further, the testing tools and equipment used by the screeners may have confounded the results of the study, as orthoptists generally performed comprehensive tests with multiple instruments while nurses, health visitors, general practitioners and lay screeners were often limited to more basic tools or tests. As the evidence was largely drawn from international studies, not all personnel available in the Australian context were incorporated into the comparisons. Optometrists, for example, were a key professional body largely absent from the literature.

The majority of studies examining nurses as screeners concluded that, while the sensitivity and specificity of screening by nurses may be lower than that of orthoptists or ophthalmologists, this did not preclude them from being positioned as primary screeners for a vision screening program, with appropriate training and referral protocols. This may be a more cost-effective process to administer screening in the Australian context.

The use of a vision test administered by parents in the home was shown to have successful completion rates. However, this could not be used in isolation as children required a follow up vision screen or professional eye examination. The evidence suggested that questionnaires administered to teachers regarding their students' vision would not produce accurate results and therefore should not replace screening by nurses or eye health professionals.

5.6 Educational outcomes of vision screening

5.6.1 Overall summary – educational outcomes

Three non-randomised controlled trials of medium quality and seven non-randomised controlled trials of low quality met the inclusion criteria. The evidence showed that infants identified at screening with hyperopia had poorer visuocognitive and visuomotor skills up to around five years of age,[73, 74] and that children diagnosed with ametropia at 4.6 years had poorer visuomotor skills.[75] After wearing spectacles for six weeks, children with ametropia improved their visuomotor abilities.[75]

The academic performance of children diagnosed with visual deficits at school age was compromised. Children with refractive errors, ocular motility deficits and hyperopia obtained lower scores on achievement tests,[76, 77] Further, children with deficits in visual motor, ocular motor, binocular, accommodative, and visual perception skills scored poorly on educational tests,[78] and the majority of children who were academically and behaviourally at risk had failed one or more visual tests.[79] However, improvements were noted once children with vision problems had been identified and treated.

Visual deficits in school age children were also shown to be associated with reading problems, in that children with amblyopia had a significantly slower reading speed in comparison to normal sighted children.[11] Nonproficient readers were found to have significantly poorer visual efficiency abilities than proficient readers, however no differences were found between the groups for visual health.[80] Another study found that poorer accommodative facility was significantly associated with reading difficulty for preschool children aged five years of age.[81] It is noted, however, that many of the visual deficits identified and related to educational outcomes require detailed assessment and would not usually be identified as part of preschool or school-aged vision screening.

5.6.2 Neonates (0-1 month)

No relevant studies were identified.

5.6.3 Toddler age (1 month-3 years)

Two non-randomised controlled trials examined the relationship between visual dysfunction and developmental delay and motor skills.

Using the same cohort as Atkinson et al.,[36] Atkinson et al.[73] assessed the visual outcomes from the Cambridge Infant Vision Screening program and looked at the relationship between early vision and possible developmental delay. The program comprised non-cycloplegic videorefraction and orthoptic examination. Of the 5,142 children screened from 8.1 months of age up to 5.5 years of age, 71 were diagnosed as hyperopes. It was found that children identified at screening with significant hyperopic refractive errors showed consistently poorer performance on a range of visuocognitive and visuomotor tests up to age five years, compared to control children without significant refractive errors, although these differences were relatively small. The authors concluded that early hyperopia is associated with a range of developmental deficits that persist at least to age 5.5 years. The effects were concentrated in visuocognitive and visuomotor domains, rather than in the linguistic domain. The results of this longitudinal group were confirmed in a cross-sectional analysis, but this analysis did not represent the same set of individuals at each stage thus may be subject to some selection biases.

In 2005, Atkinson et al.[74] compared the motor skills of children tested at 3.5 years and 5.5 years using the same cohort as Atkinson et al.[36, 73] It was found that at 3.5 and 5.5 years of age, children who had been hyperopic in infancy performed significantly worse than controls on at least one test from each category of motor skill (manual dexterity, balance, and ball skills). The hyperopic group's mean total impairment score for motor competence was significantly higher than the control group's score (5.1% versus 0.9%). Distributions of scores showed that these differences were not due to poor performance by a minority but to a widespread mild deficit in the hyperopic group.

5.6.4 Preschool age (3-6 years)

One non-randomised controlled trial examined the cognitive abilities of children with ametropia following spectacle correction.

Roch-Levecq et al.[75] examined the cognitive abilities of low-income preschoolers in the United States with uncorrected ametropia (4.6 years, n=70) and the effects of spectacle correction after six weeks. Optometrists administered retinoscopy under cycloplegia and most children received autorefraction. Visual acuity was assessed before correction prior to cycloplegia and after correction under cycloplegia using the Allen Preschool Vision Test (near test) and the B-VAT PC version 2.3 (distance test). Compared to emmetropic controls, it was found that uncorrected ametropes scored significantly lower on the Visual-Motor Integration test (VMI), which assessed visual perception and hand-eye co-ordination, and most of the

Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R) performance subsets, which required eye-hand coordination. After six weeks of wearing glasses, the ametropic group significantly improved on the VMI compared to the control group. The ametropic group also improved on the WPPSI-R, although results were not significant. The authors concluded that early identification and correction should optimise cognitive development and learning, at least in the studied sample. Caution should be taken in generalising results as the sample was small and restricted to low-income preschool children.

5.6.5 School age (6+ years)

Eight non-randomised controlled trials examined the relationship between visual deficits and educational attainment, academic performance, reading ability, and visual perception.

One study examined the relationship between hyperopia and educational attainment in a sample of 1,298 eight year old children in the United Kingdom.[76] School nurses administered the Snellen chart as well as the fogging test for hyperopia. A total of 166 children (12.8%) were referred to an ophthalmologist for failing the fogging test and 105 ophthalmic records of fogging test failures were obtained. It was found that National Foundation for Educational Research (NFER) scores of children with untreated refractive errors were lower than the respective scores of children with a less positive refractive state, the non-referred group, and the total sample. The Standardised Assessment Test results (SATs) followed a similar trend.

A retrospective study in the United States assessed the results of vision screens of five to 12 year old children in accordance with their ability to predict academic performance.[77] Second year optometric students, in conjunction with a faculty member of the State University of New York College of Optometry, screened 1,365 children in 1996-97 and 1,463 children in 1998-99. The screening battery was primarily based on the Modified Clinical Technique (MCT) which included distance and near visual acuity, hyperopia assessment, cover test, stereopsis, fusion, accommodation, and ocular motility as measured by the New York State Optometric Association's (NYSOA) King Devick test, and near point convergence. It was found that the King Devick test and the hyperopia assessment screening showed significant correlation with citywide achievement scores. Both of these tests were significant for predicting students in the lower 25% of the class for all grades in both years of screening.

Another United States study examined the relationship between performance on various vision tests and reading ability with children five to seven years of age (n=181).[81] The screening was performed by a school nurse, an optometrist, and an optometry student. The screening comprised the MCT, ±2.00 D flipper lenses, Randot, Test of Visual Analysis Skills short form, Gardner Reversals Frequency test, noncycloplegic retinoscopy, Reduced Snellen or Allen figures, and cover testing. It was found that accommodative facility was significantly associated with successful reading performance for the children and that the relationship between accommodative facility and reading performance became more significant as age and grade increased. Failure on the MCT was significantly related to reading difficulty in five year olds. Stereoacuity worse than 100 sec arc, MCT failure plus stereoacuity worse than 50 sec arc or 100 sec arc, and decreased accommodative facility were predictive of reduced reading skill in children of average intelligence. The authors concluded that good visual and visual perceptive skills were significantly associated with whether a child would show successful or reduced reading performance.

A study in Israel compared visual and visual-information processing skills between a convenience sample of children aged 12 years and 7 months, with and without reading and academic problems and with and without visual defects.[80] Therapists experienced in paediatric assessment used MCT items, which were divided into two functional categories: (1) Visual Efficiency (i.e., saccades, visual tracking, cover test far and near, near point of convergence, suppression [Worth 4-Dot] and stereopsis) and (2) Visual Health (i.e., visual acuity far and near, retinoscopy, ophthalmoscopy, and colour vision). It was found that nonproficient readers had significantly poorer visual efficiency abilities than proficient readers. In contrast, there were no significant differences between these groups with respect to MCT items reflective of visual health.

Significantly more nonproficient readers were referred as opposed to proficient readers (28% versus 4%). Further, participants who passed the MCT (no visual deficits) had significantly better academic scores than those who failed the MCT (had visual deficits). Children with visual deficits were compared to those without in relation to their visual-processing scores. It was found that children who passed the MCT performed significantly better on the Motor-Free Visual-Perception Test (MVPT-R) than children who failed the MCT. No significant differences were found between the two groups in relation to the Developmental Test of Visual Motor (VMI) Integration. The authors concluded that visual function significantly distinguished between children with and without mild academic problems, as well as between low and high visual-perception scores. Caution should be taken in generalising these results as the children represented a convenient sample of students, and factors other than those accounted for in the study may have impacted upon children's academic achievement, such as IQ, emotional status, the value of education bestowed upon children by their parents, and motivation.

A study was conducted in the United States to examine visual factors that significantly impacted upon academic performance.[78] Examinations were performed on 540 children aged six to seven years and 10 – 11 years by optometrists, consisting of a battery of tests. It was found that visual motor, ocular motor, binocular, accommodative, and visual perception skills were significant factors in children who scored poorly on the Iowa Test of Basic Skills educational test (ITBS). Race and social economic status were less significant predictors of some scores on the ITBS.

In another study, the NYSOA Vision Screening Battery was administered to 81 at-risk eight to 18 year old students to assess whether vision deficits contributed to academic difficulties.[79] A researcher administered the following tests: tracking, fusion, acuity-distance, stereopsis, acuity-near, convergence, hyperopia, colour vision, and visual motor integration. It was found that 85% (69) of all students failed one or more of the visual tests, with more participants failing the tracking subset than any other subtest 37% (30). A significant number of students failed visual acuity far and near, stereopsis, and visual motor integration. Students who were academically and behaviourally at-risk were more likely to fail the tracking test than students who were academically but not behaviourally at-risk (52% versus 27%). These same students were also more likely to fail visual acuity far and near, hyperopia, stereopsis, colour vision and visual motor integration. Ninety seven per cent of these students failed at least one subset.

A study in Austria compared the monocular and binocular reading performance of children with amblyopia to children with normal sight.[82] Children were aged 10 – 12 years (n=40). The examination comprised cover–uncover test and alternate cover tests, dynamic retinoscopy, convergence, motility, ophthalmoscopy, the Worth Four dot Test, and the Titmus Stereo test. In regards to the binocular maximum reading speed (MRS), there were significant differences between children with amblyopia and the normal sighted children. The controls achieved a binocular MRS of 200.4, or 11 words per minute (wpm), while the children with amblyopia achieved a binocular MRS of only 172.9, or 43.9 wpm. No significant differences were found between the two groups with respect to binocular logMAR visual acuity and reading acuity.

5.6.6 Educational outcomes – directions from the evidence

The studies detailed above, spanning an age group of 3.5 – 18 years, provided some evidence for a relationship between visual impairment and poor educational outcomes. The visual deficit outcomes outlined in the literature included visuocognitive and visuomotor deficits, poorer educational attainment and academic performance, and impaired reading ability. Most of the differences between control and intervention groups were significant.

The majority of the studies described were of low quality, and all were non-randomised controlled trials, thus caution must be taken in interpreting results. Potentially confounding variables, such as IQ and motivation, could have had some effect on the results. In addition, many of the conditions diagnosed were done so after in-depth assessment and would not be identified by most vision screening programs. However, the available evidence suggests that there may be a link between vision impairment and educational outcomes. Consequently, earlier detection and treatment may decrease the likelihood that educational outcomes will be compromised. Further research is needed into the relationship between vision impairment and educational outcomes before the utility of vision screening can be recommended based on educational gains.

5.7 Treatment of vision conditions

One of the factors influencing the age at which vision screening should take place, if vision screening is pursued, is the age at which treatment of vision conditions is effective. To this extent, the literature review incorporated a search for treatment effectiveness of the specified vision conditions.

Amblyopia

Seven randomised controlled trials were identified that evaluated different regimes in the treatment of amblyopia. In one study, 507 participants were randomised into either a treatment group (two to six hours of patching per day, plus near visual activities and atropine sulphate for children aged seven to 12 years) or an optical correction group (optical correction alone). Participants whose amblyopic eye acuity improved by two or more lines on a Snellen chart by 24 weeks were considered "responders".[83]

In the 7 - 12 year olds, 53% of the treatment groups were responders, compared with 25% of the optical correction group. In the 13 - 17 year olds, responder rates were 25% and 23% respectively.[83] While this suggests that treatment for some children can still be effective after the age of seven, it appears that the likelihood of successful treatment reduces dramatically from the age of seven years (if not earlier).

Another study in Newcastle, United Kingdom, randomised 177 children aged three to five years into three groups; no treatment, glasses, and glasses with patching.[84] Children in the full and glasses treatment groups had incrementally better uncorrected (without glasses) and corrected (with glasses) visual acuity at follow-up (4.3 to 6.5 years) compared with those in the no treatment group, but the effect was small. Full treatment had an effect on children with moderate acuity loss at baseline (6/18 to 6/36) but had no significant effect in the group of children with mild acuity loss (6/9 or 6/12). When all children received treatment six months after the end of the trial, there was no significant difference in acuity between the groups. The study concluded that children whose treatment is deferred from age four years until age five have the same acuity after treatment, but that fewer required any patching treatment.

A study carried out in Glasgow screened 712 children aged between 3.5 and 4.5 years, assigned treatment to those who required it, discharged them from the program at 7.5 years of age, and then followed up 255 of these children at age 12.3 years.[85] It was found that 79% of the amblyopes improved or maintained their visual acuity after discharge but this was reduced to 42% after an age induced increase was compensated for. The authors concluded that the majority of amblyopes maintained or improved their visual acuity after discharge. Children who demonstrated deterioration of their amblyopia had usually improved well during the program and were commonly fixating eccentrically at follow-up.

Two studies compared patching regimens with atropine administration and found that an effect of both was similarly present throughout the age range of three years to seven years (noting that children over the age of seven years were not included in the study).[83, 86]

Two further studies evaluated occlusion rates (measured in hours per day) with associated improvements in visual acuity. Stewart et al.[87] found that children less than four years of age required significantly less occlusion than older children. Children aged over six years of age required occlusion for more than three hours per day. This concords with the results obtained by Awan et al.[88] who found that the visual acuity of eyes effectively patched for more than three hours per day improved significantly. However, Awan et al. found that age at treatment did not influence the visual outcome (noting that all participants in the study were less than eight years of age).

One quasi-randomised controlled trial investigated the effectiveness of full-time occlusion therapy in treating amblyopia in 11 – 15 year old children and found that the mean improvement was 4.6 Snellen lines (0.46 logMAR unit).[89]

A study by Newman et al.[90] found that treatment of amblyopia at an average age of 7.7 years resulted in 87.2% of straight-eyed amblyopic children and 64.3% of strabismic amblyopic children achieving improvement in visual acuity. The study concluded that most amblyopic children detected by a vision screening program achieved a good visual outcome with treatment.

A study of 12 year old Australian schoolchildren found that 84% who had been previously diagnosed with amblyopia had received treatment consisting of spectacle prescription, occlusion, atropine penalisation, or a combination of the three.[14] In this treated population, the presence of myopia (28%), hyperopia (51%) and astigmatism (44%) was significantly higher than in non-amblyopic children (12%, 4% and 9% respectively). However, only 27% of the amblyopic children were visually impaired in their amblyopic eye, while 50% of previously untreated children were visually impaired in their amblyopic eye.

Recurrence of amblyopia following cessation of treatment was found in two non-randomised controlled trials, but this effect could be reduced by weaning patching down to two hours per day prior to treatment cessation.[91] Recurrence was also associated with better visual acuity at time of cessation, improvement of amblyopic eye visual acuity during treatment, and previous recurrence.[92]

Refractive error

Two randomised controlled trials evaluated whether spectacle correction of infants' refractive errors, which has been shown to have beneficial effects in reducing strabismus and amblyopia, impeded normal visual development, or emmetropisation. The earlier study found that the process of emmetropisation appeared to have been impeded by the consistent wearing of spectacle correction from the age of six months.[93] The later study found that a small, temporary effect of refractive correction occurred between nine and 18 months of age, but had disappeared by 36 months.[94]

The US Preventive Services Task Force systematic evidence review found that it was unclear whether treating young children with refractive errors associated with amblyopia would prevent the development of amblyopia. The report concluded that treatment for the majority of eye conditions generally seemed most effective when initiated before the grade-school years, but that treatment of refractive errors not associated with amblyopia was nearly always successful and did not depend on the age of the child.[95]

Cataracts

One study evaluated the outcome of very early treatment of dense congenital unilateral cataract on newborns aged one to six weeks, and two to eight months. The results suggested that treatment initiated at one to six weeks of age maximised the opportunity for normal or near-normal visual development of a congenitally cataractous eye with little or no risk to the phakic fellow eye[96].

The US Preventive Services Task Force systematic evidence review found that treating children younger than age three years who had cataracts or strabismus may have prevented the development of amblyopia.[95]

Compliance with treatment

The Baltimore Vision Screening Project looked at whether the barriers to follow-up care could be reduced by providing on-site evaluation and minimal-cost treatment, thus increasing treatment compliance and hypothetically reducing vision disorder prevalence rates. However, the results showed that fewer than 33% of children had followed through on the recommendations (wearing spectacles) and fewer than 20% passed the follow-up screening test.[97]

Summary

Given the limited number of studies reporting on each condition, care needs to be taken in evaluating the results. However, in summary, the literature suggested that treatment at one to six weeks of age for cataract was better than treatment at two to eight months, and that any effects of refractive correction on emmetropisation may have disappeared by the age of 36 months. It also appeared that some older children (aged seven years and above) responded to treatment for amblyopia and could achieve improvements in visual acuity. However, older children may require longer occlusion rates per day and may also require longer total periods of occlusion or atropine treatment, which could, in turn, impact on their social well-being.

Generally, children appeared to respond well to treatment for amblyopia from the age of three, but it may be possible to defer treatment from the age of four to the age of five years without any major detrimental effects. Deterioration in visual acuity could occur following cessation of treatment, which may call for longer-term follow-up processes to be considered. Further study is required to determine why compliance with treatment rates was so low, even when treatment was provided at no, or very low, cost.

5.8 Evaluation of referral criteria

The sensitivity and specificity of screening programs can be influenced by the criteria that is set for the 'pass or fail' of a particular test. Many of the programs evaluated in the literature used different levels as the 'cut-off' for onward referral.

Hard et al.[98] examined the introduction of new referral criteria for preschool vision screening in Sweden. Prior to 1992, children with a visual acuity of less than 6/7.5 at four years of age were referred. Post 1992, children with a greater reduction in visual acuity (less than 6/9 in both eyes or less than 6/9 in one eye and 6/7.5 in the other) were retested at 5.5 years and referred if their visual acuity was worse than 6/7.5. Visual acuity was tested by paediatric nurses using the HOTV chart. It was found that only a small number of the children with slightly reduced visual acuity who were retested at 5.5 years had visual defects that required treatment. In those who were treated, the results of the treatment were good. The authors concluded that children with visual acuity of less than 6/9 in each eye or less than 6/9 in one eye and 6/7.5 in the other at the age of four years rarely had visual problems that required treatment. The visual problems needing treatment were generally mild and could be treated, with good results, at the age of 5.5 years. Thus, the study concluded that the new screening criterion was appropriate.

A study by the same authors in Sweden, using a different cohort of six year old children (n=3885), compared the outcome of using either a referral criteria of 6/7.5 or 6/9.[99] It was found that children with visual acuity of 6/9 in the worse eye constituted 74.5% of those who had failed the screening. More than half of these were found to have visual acuity ≥6/7.5 in the clinic. Many were not refractive in cycloplegia and only 6.7% were found to have significant ametropia. Of those 6.7%, 13.4% were prescribed glasses. The authors reported that six year olds with a visual acuity of 6/9 rarely had defects that required treatment, therefore the screening criterion of less than 6/7.5 was probably too demanding for effective utilisation of resources. The study concluded that changing the screening criteria from less than 6/7.5 to less than 6/9 could substantially reduce over-referrals, but could also fail to identify some children who would benefit from glasses.

Lim et al.[9] assessed the appropriate referral criteria for a vision screening program in Singapore. Four year old preschool children were tested with Snellen or Sloan visual acuity charts and the Frisby stereotest. When the referral rate was changed to less than 6/12 instead of less than 6/9, referrals dropped from 39.6% to 26.7% and the positive predictive value improved from 35.4% to 48.3%.

A United Kingdom study of four year old children (n=8142) assessed the effectiveness of preschool screening using different referral criteria.[100] Children were screened by orthoptists using the Sheridan Gardiner singles chart, cover test, ocular movements, fusion and stereo testing. It was found that there was a high false positive rate when all children with worse than 6/6 visual acuity were considered (74.8%). The false positive rate reduced when children with worse than 6/9 were considered (38.5%) but this also incorporated a reduction of the true positive rate (worse than 6/6: 97.2%, worse than 6/9: 70.6%).

The majority of studies recommended a referral criterion of less than 6/9 for four to six year olds. This criterion was shown to reduce over-referrals and false positive rates compared to criterions of less than 6/6 or less than 6/7.5. A less stringent referral criterion (less than 6/12 instead of less than 6/9) could fail to identify some children who would benefit from glasses, and could reduce the true negative rate. When one study re-set their referral criteria to less than 6/12 instead of less than 6/9 the positive predictive value improved from 35.4% to 48.3%. However, this was still an unacceptably low rate, perhaps indicative of an ineffective program overall.

5.9 Vision screening of Indigenous Australian children

Stocks et al.[101] conducted an eye health survey of the Anangu Pitjantjatjara of South Australia, and subsequently reported that young rural Aboriginal Australians had good visual acuity. The results from the 1990 survey showed that in the birth to 19 years age group almost every individual had 6/6 vision (n=348).

Blair et al.[102] reported on the Western Australia Aboriginal Child Health Survey. Out of 1,480 Aboriginal children aged 12 - 17 years, 11.3% had abnormal vision and 7.8% wore contact lenses or glasses, compared with 20.7% and 16% in non-Aboriginal 12 - 16 year olds. The prevalence of abnormal vision decreased as the level of relative isolation increased.

Paterson and Ruben[103] evaluated the effectiveness of a school screening program in meeting the needs of Aboriginal children in a rural district in the Northern Territory Top End. Seven hundred and seventy-four school age children were screened. It was found that 3% (23/694) failed visual acuity, and 61% of these were not followed-up (14/23). Furthermore, 1% (10/703) were found to have strabismus, although no new cases were identified by the program. Rates of trachoma reached 26%. The authors concluded that the school screening had a limited role in identifying and meeting the health needs of Aboriginal children in remote areas. They suggested that ongoing child health surveillance would be more appropriate.

The National Trachoma Surveillance and Reporting Unit in 2006 collected active trachoma data from the Northern Territory, South Australia and Western Australia.[104] Aboriginal children aged five to nine years were screened for signs of active trachoma. Reported prevalences ranged from 2.5% to 30% in the Northern Territory, 0% to 25% in South Australia and 18% to 53% in Western Australia. Currie and Brewster[105] reported that in the tropical north of Australia there were high rates of gonococcal conjunctivitis and endemic trachoma in Aboriginal children in remote communities.

Thus, while it appears that visual acuity in Aboriginal children is not necessarily poorer than in non-Aboriginal children, rates of trachoma are excessively high in this population. Educational and awareness campaigns and appropriate diagnosis and assessment are more appropriate for this population than general screening.

5.10 Utilisation of eye care services and the cost of vision lost

A report prepared by Access Economics Pty Ltd for the Centre for Eye Research Australia and the Eye Research Australia Foundation examined the economic impact and cost of vision loss in Australia from 1993-94 and 2004, and also projected costs out to 2020.[106]

The report found that the indirect costs of visual impairment outweighed the health costs by nearly 1.8:1. These indirect costs included: lost earnings for visually impaired and blind people ($A1.8 billion in 2004); the cost of carers, including their lost productivity ($A845 million); aids, equipment, home modifications and other indirect costs ($A371 million); and losses associated with transfer payments such as taxation revenue foregone and welfare payments ($A208 million). They also found that visual impairment led to a higher use of social services and admission to nursing homes, lower employment rates and social functioning, and increased mental illness and social isolation.

This correlates with findings from a previous study which showed that patients with glaucoma had significantly poorer adjusted mean scores on seven National Eye Institute Visual Functioning Questionnaire scales, including general vision, discomfort or pain in and around the eyes, difficulty with driving, decreased well-being due to vision, role limitations attributable to vision, difficulty with near vision and difficulty with distance vision activities.[107]

Access Economics also found that visual impairment increased the risk of death and decreased the quality and length of life. This morbidity and premature mortality in the visually impaired and blind population is estimated to cost the economy an additional $A4.8 billion. Added to that was an additional $A1.8 billion for treatment of eye diseases, which brought the total cost of vision impairment and blindness in Australia to $A9.85 billion.[106] Neither evaluation, directly reported on the impact of vision disorders in children. The conditions leading to negative impacts on health and well-being in adults were in general age-related, and not those likely to be identified during vision screening in childhood.

The report noted that half of all visual impairment was correctable and that one quarter was preventable. According to the World Bank in Australia, interventions are considered cost-effective if they are under $A112,000 per quality adjusted life year (QALY). [106] In the United States, this figure is $50,000 per QALY.[108] The costs and cost-effectiveness of various international screening programs are outlined below (see ‘Economic evaluations’). An evaluation of the costs associated with vision screening in Australia will commence shortly, with results expected by January 2009.

Ganz et al.[109] described the use and expenditure patterns of eye-care services for 48,304 children under 18 years of age in the United States from 1996-2001. It was found that children with diagnosed eye conditions had higher levels of health care use and expenditure than children without diagnosed conditions. It was also found that children with diagnosed eye conditions had higher use and expenditure levels for non-eye-related services.

5.11 Economic evaluations

An economic evaluation assessment form was used to determine the criteria for inclusion of cost-benefit and cost-effectiveness studies of vision screening in this review (see Appendix I). Ten studies were subsequently selected for inclusion.

A recent report by Carlton et al.[110] estimated the cost effectiveness of screening for amblyopia and strabismus in children aged three, four and five years by conducting a systematic review and economic evaluation. The data from the review informed the structure and implementation of an amblyopia screening model, which was analysed to estimate the cost and effects of six alternative screening options at the three different ages using alternative sets of tests. The reference case results showed that screening programs that included autorefraction dominated screening programs without autorefraction. Thus, analyses concentrated on screening programs that included autorefraction.

Carlton et al.[110] reported that screening at three or four years of age prevented cases of amblyopia and strabismus at a low absolute cost (of approximately £4,000 - 6,000). However, at the currently accepted values of a QALY (incremental gains cost less than £20,000 - 30,000), the authors reported that no form of screening for amblyopia was likely to be cost-effective.

The one parameter that did radically counter this conclusion was the impact of loss of vision in one eye on quality of life, and the fact that amblyopes were at increased risk of bilateral vision loss. However, in the absence of evidence on the long-term effects of unilateral vision loss, the authors reported that the prevention of the utility loss derived from the increased risk of bilateral vision loss in amblyopes was not sufficient to justify the use of resources on screening programs. The authors also reported that there was an increased probability of treated children being bullied at school. Sensitivity analyses indicated that small utility effects of bullying would improve the cost-effectiveness of early screening significantly. A prospective study of the utility effects of bullying would be useful to determine whether bullying decreases with reduced school-age treatment.

Konig et al.[111] conducted a study analysing the cost-effectiveness of orthoptic screening for amblyopia in German kindergartens. In this program, all children aged three years were examined by an orthoptist. Children with positive screening results were referred to an ophthalmologist for diagnosis.

According to the base analysis, the cost of one orthoptic screening test was 7.87 Euro compared to 36.40 Euro for an examination by an ophthalmologist. The total cost of the screening program in all kindergartens was 3.1 million Euro. The cost-effectiveness ratio was 727 Euro per case detected, but was found to be greatly influenced by the prevalence rate of the target condition along with the test specificity. The authors concluded that it was more cost-effective to re-screen non-cooperative children in kindergarten in the following year than to refer them to an ophthalmologist immediately (assuming that it was still effective to commence treatment at the time of the second screen).

In a similar but later study, Konig and Barry[112] concluded that testing for uncorrected monocular visual acuity with a pass threshold of 6/12 and <1 line difference between eyes produced the best average cost-effectiveness ratio of 876 Euro per detected case. This was in comparison to four other options: (2) same as 1, but pass threshold 6/9; (3) same as 1, plus cover tests and examination of eye motility and head posture; (4) same as 3, but pass threshold 6/9; and (5) refractive screening without cycloplegia using the Nikon Retinomax autorefractor. The most expensive option was visual acuity, cover test, examination of eye motility, and either direct referral to an ophthalmologist or re-screening for inconclusive results. Again, for all screening methods, it was more cost-efficient to rescreen children with inconclusive results than to refer them to an ophthalmologist directly.

In a further study on three year old children in German kindergartens, Konig et al.[113] found that the cost-effectiveness ratio was 924 Euro per detected case of amblyopia. Konig and Barry[114] estimated the long-term cost-effectiveness of a hypothetical screening program for untreated amblyopia in three year old children conducted by orthoptists in all German kindergartens in 2000. It was found that the incremental cost-effectiveness ratio (ICER) of orthoptic screening was 7397 Euro per quality-adjusted life year (QALY). The authors suggested that decision makers should consider orthoptic screening based on the ICER.

Miller et al.[115] examined the comparative costs of conducting a 1,000-child screening program in a Native American indigenous population, with a target sensitivity of 90% using photoscreening, noncycloplegic autorefraction, autokeratometry, and Lea symbols distance visual acuity testing. It was found that screening with an autokeratometer (KERS) produced fewer unnecessary eye examinations than the number associated with LSVAS, and this smaller number was sufficient to offset the higher capital acquisition cost of the autokeratometer. For a large screening program of at least 2,052 children, the autorefractor screening method (NCARS) was financially more advantageous than the KERS in the number of unnecessary referrals generated compared with the higher acquisition cost. This program selected the KERS as the primary screening method.[115]

Joish et al.[116] conducted a study to determine the costs and benefits of visual acuity screening (VAS) or photoscreening in children aged six to 18 months, three to four years and seven to eight years of age in the United States. All of the benefit-to-cost ratios exceeded 1.0, meaning that all screening programs studied had benefits that exceeded the cost of screening. The total net benefit was highest for photoscreening in children of three to four years of age, and the least for VAS in children seven to eight years of age. The benefit-to-cost ratio was highest for the VAS in children three to four years of age, and least for photoscreening in infants six to 18 months of age. Sensitivity of the photoscreening instrument and VAS charts were the most influential variables in determining the most cost-beneficial program. The authors concluded that based on the best available data, the net benefit of photoscreening in three to four year old preschool children was greater than VAS in children seven to eight years, photoscreening in toddlers, and VAS in children three to four years of age. The net benefit to society was greatest when vision screening was performed in preschool children compared with school-aged children.

Magnusson and Persson[117] conducted a study to estimate, on a national basis in Sweden, the costs versus consequences of combined maternity ward and well-baby clinic eye screening compared to well-baby clinic screening alone. Two scenarios were created and compared regarding healthcare costs: visual acuity development and quality-adjusted life years (QALYs).

The total cost of the maternity ward and well-baby clinic screening scenario was 7.9 million SEK (in 2001) and that of the well-baby clinic screening scenario was 6.9 million SEK. The incremental cost-effectiveness ratio was estimated at 234,000 SEK/QALY, provided three more children per year were detected by mandatory maternity ward and well-baby clinic screening. The authors suggested that the incremental expense was cost effective and within acceptable levels of cost/QALY when compared with other widely accepted therapies across diverse medical specialities.[117]

Gandjour et al.[118] examined four different scenarios for their cost-effectiveness: (1) screening of high-risk children up to the age of one year (by ophthalmologists); (2) screening of all children up to the age of one year (by ophthalmologists); (3) screening of all children aged three to four years (by paediatricians or general practitioners); and (4) screening of children aged three to four years visiting kindergarten (by orthoptists).

The results suggested that screening of high-risk children by ophthalmologists had the lowest average cost per case detected but became dominated (less effective and more costly than an alternative) if a low (5.3%) probability of familial clustering of strabismus was assumed.

Screening of all children up to the age of one year by ophthalmologists was the only strategy not dominated by others. Detection rates, including cases detected before screening, were between 72% and 78% for the strategies that screened all children.[118]

The model suggests that in Germany, both from a cost-effectiveness and a pure effectiveness point of view, screening all children up to the age of one year by ophthalmologists was the preferred strategy to detect amblyopia or amblyogenic factors. Screening all children between three and four years of age was economically less attractive both from the perspective of the health insurance and society. The inefficiency was due to the high number of cases already identified prior to screening, leading to the high number that needed to be screened to detect one additional case. The most effective screening, in terms of detection rates, was screening all children up to one year and all children between three and four years of age (78% detection rate). However, all strategies left a significant portion of children undetected.[118]

An analysis and report prepared for the Vision Council of America examined the impact and cost effectiveness of providing comprehensive eye examinations to all preschool-age children and comparing this to two options: (1) a system in which all preschool-age children received a vision screen and (2) the eye care that would be provided to children without the presence of a formal vision screening or eye examination program.[108] The study examined these options for the detection of amblyopia alone.

The analysis resulted in two main conclusions; (1) that eye examinations would detect, treat and cure significantly more cases of amblyopia in children than a universal screening program or the “usual patterns of care” that would exist without a formal vision screening program in place, and (2) that a universal comprehensive eye exam program would be highly cost effective and produce a greater return on investment than many other health care interventions.[108] The measure of cost effectiveness used was based on a comparison of the costs of interventions against the improvement in outcomes (QALYs) generated, and resulted in a cost of US$18,390 per QALY. The authors acknowledged that gaps in the literature contributed to study limitations, but still maintained that the conclusions were robust across most model parameters. However, the use of monocular blindness to define costs is a limitation, given that not all children with amblyopia will develop this condition.

It is difficult to provide a cohesive summary of these studies, given that the papers examined various options (e.g., screening versus eye examinations, newborn screening versus preschool screening versus school screening, and so on) and were based on different economic systems.

While most studies deemed vision screening to be cost-effective in terms of dollars per QALY, the recent study by Carlton et al.[110] found evidence to the contrary. Two studies reported that comprehensive eye examinations by ophthalmologists were more cost-effective than screenings, while seven other studies reported that screenings were cost-effective. None of the studies provided different costing options by comparing two or more screening personnel, which certainly requires some thought in the Australian context. Without access to further research using Australian prevalence data and workforce parameters, it is not possible to take directions from the evidence on the economic costs and benefits of vision screening children in Australia.

6 Limitations of studies

Overall, there was a lack of rigorous controlled trials examining the effectiveness of preschool vision screening. Only two randomised controlled trials were identified and they were both of medium quality. The other types of studies reviewed were non-randomised controlled trials, observational studies, and retrospective reports (38 in total). The majority of those were classified as low quality (according to the criteria used to rate randomised controlled trials).

The populations screened often limited generalisation of results. For example, the Vision in Preschoolers Study Group (VIP), one of the two randomised controlled trials, screened children from the Head Start Program which consisted of selected children from low-income families.[12, 21] Unfortunately, results from this population cannot be generalised to the normal population.

Some studies used very small samples (e.g., n=28,[69] n=40,[82] n=70;[75]), while others evaluated programs that screened thousands of children in a community. The variation in power makes it difficult to compare the results of studies.

Other major variations in studies included the type of test that was employed to conduct the vision screen, personnel used to conduct the screens and the training and qualifications of the screening personnel. These differences made it even more difficult to compare the results and recommendations of studies.

Most studies had a limited duration of follow-up, making it difficult to determine how the screening programs influenced outcomes in childhood, let alone adult outcomes, such as increased occupational opportunities, or potential for improved adult vision. The majority of the studies reviewed measured the reduction of amblyopia as the primary outcome.

7 Directions from the evidence

Largely due to the study designs used to test vision screening effectiveness (i.e., non-randomised controlled trials, observational studies, and retrospective reports), most of the level of evidence obtained in this review was categorised as level III-3, with a lesser amount of evidence pertaining to level III-2 (see Appendix A for level definitions).

While there were few studies that focused exclusively on screening during the neonatal period, and no direct evidence could be taken from those studies, the literature identified suggested that a screen should occur within the first three months from birth, and ideally as close to birth as practicable. Given the lack of evidence, but the importance of detection, newborn screening would ideally occur alongside other standard health checks following birth.

The available evidence suggested that screening was a viable method of detecting vision conditions in children, and positioned the ideal age for vision screening at no earlier than 18 months and no later than five years (level of evidence – 1; quality – low). As visual acuity was more difficult to assess in children younger than three, vision screening guidelines recommended that screening occur after three years of age. In transferring these evidential recommendations into practice, the increase in accuracy and the optimised accessibility that would come with school-entry screening would need to be balanced against the potential for diminished treatment effectiveness by commencing treatment at a later age.

The evidence also pointed to the adoption of other methods to increase general awareness of vision conditions and propensity for parents and teachers to assess children outside of the screening period (level of evidence – 1; quality – low). For example, education and marketing campaigns have reportedly been successful in increasing general awareness of vision and the number of children attending vision screenings.[60]

Overall, the evidence was in favour of orthoptists or nurses conducting primary vision screens (level of evidence – 1; quality – high). However, whether this is appropriate in the Australian context requires further assessment of the relevant Australian workforce's capability. If employing nurses as primary screeners, the literature recommended that adequate training in screening techniques be made available so as to increase sensitivity and specificity (level of evidence – 1; quality – medium). The literature also recommended that a program of secondary screening be considered, whereby any questionable or positive results were referred for a second screen (perhaps by an orthoptist or optometrist) prior to referral to an ophthalmologist (level of evidence – 111-3; quality – low). Again, whether this is appropriate in the Australian context requires further analysis.

The referral criteria recommended for use in determining pass or fail of a vision screen was dependent upon the age selected for universal screening. The direction from the evidence was that at age three, visual acuity of less than 6/9 in either eye should be considered a fail. At age four to six, visual acuity of 6/9 or less in either eye should be considered a fail and referred on for a secondary screen or further diagnosis.

As the evidence has shown, any screening program must take into consideration follow-up procedures that will be involved to facilitate compliance with secondary screens or treatment (level of evidence 1; quality – medium). This is particularly vital in vulnerable or disadvantaged communities where families may not understand the results of screens, may have limited resources to attend screenings or treatment facilities, and/or may not understand the importance of treatment to future vision potential.

As noted in the introduction to this literature review, groups such as children born prematurely, the remote Aboriginal population, and children with multiple disabilities are considered at high risk for certain vision conditions and therefore are not considered suitable candidates for a general vision screening program. Building an eye health program that would meet the needs of high-risk groups would require further detailed consultation with appropriate professionals in these communities and is beyond the scope of this literature review.

The cost of a screening program is obviously an important component involved in considering screening viability. The majority of studies reported that vision screening had a positive cost/benefit ratio; that early screening saved future healthcare costs. This review did not identify any Australian evaluations of vision screening costs in relation to screening in childhood. However, Deakin University have formed an agreement with the Murdoch Childrens Research Institute's Centre for Community Child Health to undertake an economic evaluation of vision screening in Australia in the near future. It is anticipated that results will be available by January 2009.

8 Further research

Currently, very few randomised controlled trials exist in the literature in regards to evaluating vision screening programs. Future research should encompass high quality randomised controlled trials in order to rigorously assess vision screening programs, and to determine whether vision screening leads to a substantial decrease in the prevalence of correctable visual acuity deficits. Once these studies have been completed, the effectiveness of vision screening programs in offering health gains can be better evaluated. Further evaluation of the impact of different screening methods administered by various personnel in a variety of settings is also required.

There is specifically a need for more trials examining the effectiveness of vision screening at school entry. Screening at school entry (as the first screen following newborn screening) has not been adequately compared with preschool screening. Screening at school entry affords convenience, equity and accuracy as children are easier to access, less likely to be missed and more able to cooperate. Future research should focus on comparing vision screening at either preschool or school entry to determine the best age period to detect and treat vision impairments. Research would also need to take into consideration the economic and practical implications of these time periods.

Research into newborn screening has been limited. Thus, the directions that have been provided by the evidence - to screen within the first three months from birth, and ideally as close to birth as practicable - are based on a small number of studies. Rigorous trials are required in the future to determine whether screening in the neonatal period is indeed a necessity. These trials should also aim to determine specific information about conditions to be screened for, age at screening and appropriate screening tools to use in the neonatal period.

There is also a need for further research into educational outcomes and vision screening. The majority of the studies were low quality, had confounding variables, and all were non-randomised controlled trials. Sound research is needed into the relationship between vision impairment and educational outcomes before vision screening can be recommended based on improved educational achievement.

The value of vision screening is derived, in part, from the importance placed on normal vision in two eyes versus one eye, and also the impact of treatment for amblyopia on the family life and psychological well-being of the child, and on quality of life. Vision screening carries with it an implicit assumption that the child will benefit. Thus, there is a real need for research into the extent of disability attributable to vision impairment in one eye, and the possible impact of amblyopia treatment on well-being and quality of life. Without a sound evidence base that vision screening affords health gains, the ethical basis for implementation is poor.

Summary and concluding comments

In Australia, the prevalence of amblyopia in children ranged from 1.4% to 3.6%, while strabismus ranged from 0.3% to 7.3%, and refractive error ranged from 1% to 14.7%. These rates show large variations and further research may be required to consolidate these figures. However, they suggest that vision conditions are relatively prevalent among Australian children.

A review of the literature suggested that screening and subsequent treatment of visual impairment at an early age (from 18 months to five years), led to improved visual outcomes. However, the majority of evidence available was derived from low quality, non-randomised controlled trials.

Screening children of an older age, such as eight to ten years or 13 - 15 years, identified very few or no new cases of eye pathology, which would suggest this is not recommended practice. There was a lack of studies evaluating screening at school entry, which would be an ideal and convenient time to ‘capture’ a larger number of participants. The few studies identified that touched on neonatal screening recommended screening of the newborn between birth and three months of age, particularly for the detection of congenital cataracts. The literature recommended that high-risk children of any age should be referred to an ophthalmologist.

While most studies concluded that orthoptists were the most accurate screening personnel, the majority of studies examining nurses as screeners concluded that, with appropriate training and referral protocols, they could be effective and capable screeners. There was a lack of studies examining the role of optometrists as screeners.

Some studies reported that secondary screening (following a primary screen by non vision health professionals, and prior to referral and assessment), was shown to be effective in the early detection, referral, and treatment of eye problems. Studies also suggested that teaching parents to be more attentive to their child’s vision, or creating awareness campaigns to ensure that corrections were used and cultural barriers to compliance were addressed and removed, could increase the effectiveness of vision screening programs.

There were a number of social, economic and political barriers to children seeking follow-up care and treatment post-screening. These undermined the effectiveness of vision screening campaigns. Any future screening programs should address these barriers in the design of the program.

Links were established in the literature between vision impairment and poor educational outcomes. It was suggested that vision impairment was correlated with lower visuocognitive and visuomotor skills, poorer reading ability and lower scores on achievement tests. However, many of the types of vision impairment considered would not usually be detected by community vision screening programs.

Overall, the best evidence from the available literature recommended that vision screening be implemented either in the preschool years, or by school entry at the latest. Best available evidence also directed that screening could be carried out by appropriately trained nurses, followed by secondary screening by an orthoptist prior to referral to an ophthalmologist. These directions incorporated consideration of screening sensitivity and specificity and cost-effectiveness. From the few studies available, it was recommended that neonatal screening should continue to be performed with efforts to optimise training of screeners, and referral practices. However, without the availability of research utilising higher levels of evidence (preferably levels I or II) and without available data on the cost-effectiveness of vision screening in the Australian context, it is difficult to state unequivocally that vision screening is the best method for detecting vision conditions in children.

Appendix A Levels of Evidence

NHMRC 2000 designations of levels of evidence

Level I: Evidence obtained from a systematic review of all relevant randomised controlled trials.
Level II: Evidence obtained from at least one properly designed randomised controlled trial.
Level III-1: Evidence obtained from well-designed pseudorandomised controlled trials (alternate allocation or some other method).
Level III-2: Evidence obtained from comparative studies (including systematic reviews of such studies) with concurrent controls and allocation not randomised, cohort studies, case-control studies, or interrupted time series with a control group.
Level III-3: Evidence obtained from comparative studies with historical control, two or more single-arm studies, or interrupted time series without a parallel control group.
Level IV: Evidence obtained from case series, either post-test or pretest/post-test.

Source: National Health and Medical Research Council. *How to use the evidence: assessment and application of scientific evidence. Handbook series on preparing clinical practice guidelines. Table 1.3: Designation of levels of evidence*. Canberra: NHMRC, February 2000: 8. Available at: www.health.gov.au/nhmrc/publications/pdf/cp69.pdf

Appendix B MeSH search terms

Vision Screening/

exp Vision Disorders/

exp Refractive Errors/

"Retinopathy of Prematurity"/

Cataract/

exp Glaucoma/

Retinoblastoma/

Vision, Binocular/

exp Strabismus/

exp Visual Acuity/

2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10

"sensitivity and specificity"/ or "predictive value of tests"/

"reproducibility of results"/

observer variation/

12 or 13 or 14

sheridan gardiner.mp.

snellen$.mp.

LogMAR.mp.

glasgow acuity card$.mp.

lea symbol$.mp.

hotv.mp.

(photorefraction$ or photo refraction$ or photoscreening$ or photo screening$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]

red reflex.mp. [mp=title, original title, abstract, name of substance word, subject heading word]

exp Diagnostic Techniques, Ophthalmological/

exp Vision Tests/is [Instrumentation]

16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25

*Vision Screening/ and (exp *Vision Disorders/ or exp *Refractive Errors/ or *"Retinopathy of Prematurity"/ or *Cataract/ or exp *Glaucoma/ or *Retinoblastoma/ or *Vision, Binocular/ or exp *Strabismus/ or exp *Visual Acuity/)

*Vision Screening/ and 15

(*Vision Screening/ or (exp *Vision Disorders/ or exp *Refractive Errors/ or *"Retinopathy of Prematurity"/ or *Cataract/ or exp *Glaucoma/ or *Retinoblastoma/ or *Vision, Binocular/ or exp *Strabismus/ or exp *Visual Acuity/)) and (exp *Diagnostic Techniques, Ophthalmological/ or exp *Vision Tests/is)

(*Vision Screening/ or (exp *Vision Disorders/ or exp *Refractive Errors/ or *"Retinopathy of Prematurity"/ or *Cataract/ or exp *Glaucoma/ or *Retinoblastoma/ or *Vision, Binocular/ or exp *Strabismus/ or exp *Visual Acuity/)) and (16 or 17 or 18 or 19 or 20 or 21 or 22 or 23)

*mass screening/ and (exp *Vision Disorders/ or exp *Refractive Errors/ or *"Retinopathy of Prematurity"/ or *Cataract/ or exp *Glaucoma/ or *Retinoblastoma/ or *Vision, Binocular/ or exp *Strabismus/ or exp *Visual Acuity/)

27 or 28 or 29 or 30 or 31

1 or 32

limit 33 to (humans and english language and "review articles" and "all child (0 to 18 years)")

clinical trial.pt,sh.

randomi#e$.ab.

placebo$.ab.

exp clinical trials as topic/ or drug evaluation/

randomly.ab.

(trial or trials).ti.

35 or 36 or 37 or 38 or 39 or 40

exp animals/

humans/

42 not 43

41 not 44

33 and 45

limit 46 to (english language and "all child (0 to 18 years)")

34 or 47

Appendix C Australian states and territories – current vision screening practice

State/Territory	Age:	Condition/s screened for:	Tool/s used:	Referral criteria	Screened by:
Australian Capital Territory	1-4 weeks	Cataracts, observation	Family and nurse observation		Child health nurse
	6-8 weeks	Cataracts, ocular movements	Family and nurse observation, cover-uncover test		Child health nurse
	6 months	Cataracts, ocular movements	Family and nurse observation, cover-uncover test		Child health nurse
	12 months		Family and nurse observation, cover-uncover test		Child health nurse
	18 months		Family and nurse observation, cover-uncover test		Child health nurse
	3 years	Visual acuity at distance of three metres	Striker cards	Children need to see down to the smallest letter in the 3 x 3, otherwise referred to orthoptist.	Child health nurse
	5+ years (Kindergarten)	Visual acuity at distance of six metres	Vision box	If child is less than 6 years of age, refer at less than 6/9 in either eye. If child is 6 years of age or more, refer at less than 6/6 in either eye.	
New South Wales	Neonatal	Eye check	Examination, parental questionnaire about family history		
	1-4 weeks	Observation, corneal reflection, white pupil	Parental questionnaire on vision risk		Child & Family Health Nurse, GP or Paediatrician
	6-8 weeks	Observation, fixation, corneal reflections, response to occlusion	Parental questionnaire		Child & Family Health Nurse, GP or Paediatrician
	6 months	Observation, fixation, corneal reflections,	Parental questionnaire		Child & Family Health Nurse, GP or Paediatrician

		response to occlusion, ocular movements			
	12 months	Observation, fixation, corneal reflections, response to occlusion, ocular movements	Parental questionnaire		Child & Family Health Nurse, GP or Paediatrician
	18 months	Observation, fixation, corneal reflections, response to occlusion, ocular movements	Parental questionnaire		Child & Family Health Nurse, GP or Paediatrician
	2 years	Observation, fixation, corneal reflections, response to occlusion, ocular movements	Parental questionnaire		Child & Family Health Nurse, GP or Paediatrician
	3 years	Observation, fixation, corneal reflections, response to occlusion, ocular movements	Parental questionnaire		Child & Family Health Nurse, GP or Paediatrician
	4 years	Visual acuity tested monocularly	Sheridan Gardiner Matching Test, Brief parental questionnaire	Unavailable at present	Child & Family Health Nurse, GP or Paediatrician
Northern Territory (proposed schedule)	Neonatal	As per NHMRC			
	8 weeks	Following	Parental questionnaire		Nurse, Allied Health Worker
	6 months	Squint	Observation or otherwise suspected or identified		Nurse, Allied Health Worker to refer to GP
	18 months	Vision, eye contact			Nurse, Allied Health Worker
	4 or 5	Visual acuity	Lea chart	Refer if unable to read 3 symbols on the 6/12 line,	Nurses, Allied Health Workers as

	years			or, if 2 or more line difference between eyes, or, skips symbols within any line, or, obvious squint or other concern	part of the Healthy School-Age Kids program
	Remote areas	Trachoma			Nurses, Allied Health Workers as part of the Healthy School-Age Kids program
Queensland	Neonatal		Eye check, red reflex		Medical practitioners
	0-4 weeks	Vision	Assessing visual behaviour		
	2 months	Vision profile	Assessing visual behaviour		During ‘well-child’ visit (child health nurse)
	6 months	Vision profile	Assessing visual behaviour, Hirschberg test		During ‘well-child’ visit (child health nurse)
	12 months	Vision profile	Assessing visual behaviour		During ‘well-child’ visit (child health nurse)
	18 months	Vision profile	Assessing visual behaviour, Hirschberg test		During ‘well-child’ visit (child health nurse)
	2.5-3.5 years	Vision profile, corneal light reflex	Hirschberg test, vision – near cover test		During ‘well-child’ visit (child health nurse)
	4-5 years	Vision acuity (right and left)	Hirschberg test, cover near/far, Lea Symbols or HOTV letters with confusion bar (for 3.5 years plus), Linear STYCAR 5 letter chart with key-card for Prep students, 7 letter chart with/without key-card for Year 1 students	Unavailable at present	
	6-12 years (referred by parent)	Visual acuity	Snellen chart (or other appropriate chart)	Unavailable at present	
South Australia	1-4 weeks	Appearance, fixation, red reflex			Paediatrician or GP and visiting community nurse
	6-8 weeks	Appearance, fixation and following			Paediatrician or GP and health centre community nurse or community youth health orthoptist

	6-9 months	Appearance, fixation and following, corneal light reflex			Health centre community nurse with orthoptist review as required
	18 months	Appearance, fixation and following			Health centre community nurse with orthoptist review as required
	2-3.5 years	Appearance, fixation and following		Unless there is head turning, squinting, peering or eye turn, refer at 6/12. It is also important to observe near vision and print size required and refer if this out of the normal range.	Health centre community nurse with orthoptist review as required
	4-5 years	Distance visual acuity	Snellen test or HOTV test		Kindergarten or Health centre community nurse
Tasmania	1-2 weeks	Eye check	Parental questionnaire		Family and Child Health Nurse, GP or Paediatrician
	6-8 weeks	Corneal light reflections, fixation, following	Parental questionnaire		Family and Child Health Nurse
	6 months	Corneal light reflections, red reflex, corneal light reflexes	Parental questionnaire, cover test, ophthalmoscopy		Family and Child Health Nurse (corneal light reflections, cover test) and GP (red reflex, corneal light reflexes, cover test)
	18 months	Corneal light reflections, red reflex, corneal light reflexes	Parental questionnaire, cover test, ophthalmoscopy		Family and Child Health Nurse (corneal light reflections, cover test) and GP (red reflex, corneal light reflexes, cover test)
	3.5 years	Visual acuity R6/ L6/, corneal light reflections, eye movements, red reflex, corneal light reflexes, visual acuity	Parental questionnaire, cover test, ophthalmoscopy		Family and Child Health Nurse (visual acuity R6/ L6/, cover test, corneal light reflections), GP (ophthalmoscopy, eye movements, corneal light reflexes, visual acuity)
	5-12 years	Routine screening of vision in Prep, and routine screening of vision in Year 6	Distance vision test		Family and Child Health Nurses
Victoria	Neonatal	Eye examination			
	2 weeks	Eye examination			Maternal and Child Health Nurse, GP or Paediatrician
	4 weeks	Observation,			Maternal and Child Health Nurse,

		following			GP or Paediatrician
	8 weeks	Fixation, following			Maternal and Child Health Nurse, GP or Paediatrician
	4 months	Fixation, following	Tasks in Child Health Record		Maternal and Child Health Nurse, GP or Paediatrician
	6-8 months	Fixation, following	Tasks in Child Health Record		Maternal and Child Health Nurse, GP or Paediatrician
	12 months	Squint, head tilt, fixation, following	Tasks in Child Health Record		Maternal and Child Health Nurse, GP or Paediatrician
	18-21 months	Fixation, following	Tasks in Child Health Record		Maternal and Child Health Nurse, GP or Paediatrician
	2 years	Squint, fixation, following	Tasks in Child Health Record		Maternal and Child Health Nurse, GP or Paediatrician
	3.5 years	Squint, vision screen	MIST, tasks in Child Health Record	MIST 3 out of 5 for both eyes = pass Less than 3 out of 5 on either eye = fail and refer	Maternal and Child Health Nurse, GP or Paediatrician
	4-5 years	Vision screen	MIST, tasks in Child Health Record	MIST 3 out of 5 for both eyes = pass Less than 3 out of 5 on either eye = fail and refer	Maternal and Child Health Nurse, GP or Paediatrician
	School age (Prep) 4.5 - 6 years	Visual acuity, distance vision screen, parental questionnaire	Lea LogMAR symbols, Primary School Nursing Program School Entrant Health Questionnaire	Accepted limits are 3/4.8 or better in each eye separately, and less than 2 lines difference between eyes	School nurse
Western Australia	Neonatal	Visual appraisal	Red reflex (or Pupil Light reflex, Bruckner test)	Abnormalities (asymmetries) of the red reflex require urgent referral to a specialist ophthalmologist	Not stated
	6-8 weeks	Visual appraisal	Parental questionnaire, Red reflex (or Pupil Light reflex, Bruckner test)	Abnormalities (asymmetries) of the red reflex require urgent referral to a specialist ophthalmologist	Community Health Nurse (universal screening for red reflex)
	3-4 months	Visual appraisal	Parental questionnaire, Red reflex (or Pupil Light reflex, Bruckner test)	Abnormalities (asymmetries) of the red reflex require urgent referral to a specialist ophthalmologist	Community Health Nurse (universal screening for red reflex)
	8 months	Visual appraisal, eye movements, examination for strabismus, vision behaviours	Corneal light reflex test, Hirschberg test	Convergent or divergent squints to be referred to GP for onward referral	Community Health Nurse (universal screening for strabismus)
	18	Visual appraisal	Parental questionnaire	Convergent or divergent squints to be referred to	Community Health Nurse (will

	months			GP for onward referral	screen for strabismus, otherwise targeted screening only if there is a concern or family history)
	3 years	Visual appraisal	Parental questionnaire	Convergent or divergent squints to be referred to GP for onward referral	Community Health Nurse (will screen for strabismus, otherwise targeted screening only if there is a concern or family history)
	3.5-5 years	Visual appraisal, examination for strabismus, distance visual acuity, amblyopia	Cover test, corneal light reflex, Hirschberg test, Lea Symbols chart or 4 metre letter matching test	3.5 years = test to 6/9.5 VA = at least 6/12 for each eye Re-test in 3 months and refer if VA worse than 6/12 Re-test in 12 months if VA not 6/9.5 for each eye Re-test in 2 months and refer if child is not attentive or not concentrating	Community Health Nurse (universal screening)
				4 years = test to 6/7.5 VA = at least 6/12 for each eye, plus less than a 2 line difference between the eyes Re-test in 2 months and refer if VA worse than 6/12 Re-test in 12 months if child passes the VA but was skipping symbols and has a 1-line difference Re-test in 12 months for a child with 2-line difference Re-test in 2 months if child not attentive or not concentrating	Community Health Nurse
				5 years = test to 6/6 VA – at least 6/9.5 for each eye, plus less than a 2-line difference between the eyes Re-test in 2 months and refer if VA worse than 6/12 Re-test in 12 months if child passes VA but was skipping symbols and has a less than 1-line difference Re-test in 12 months for child with 2-line difference Re-test in 2 months and refer is child not attentive or concentrating	Community Health Nurse
				6 years = test to 6/6 VA = at least 6/9.5 for each eye Re-test in 2 weeks and refer if VA worse than 6/9.5 Re-test in 2 weeks and refer if child passes VA but was skipping symbols and has a 1-line difference Make referral without delay if child is not attentive or not concentrating	Community Health Nurse

Appendix D Criteria for inclusion of studies

Box 1: NHMRC 2000 checklist for appraising the quality of studies of interventions

Quality Criteria 1. Method of treatment assignment
A. Correct, blinded randomisation method described OR randomised, double-blind method stated AND group similarity documented.

B. Blinding and randomisation stated but method not described OR suspect technique (e.g., allocation by drawing from envelope).

C. Randomisation claimed but not described and investigator not blinded.

D. Randomisation not mentioned.

2. Control of selection bias after treatment assignment
A. Intention to treat analysis AND full follow-up

B. Intention to treat analysis AND <15% loss to follow-up

C. Analysis by treatment received only OR no mention of withdrawals

D. Analysis by treatment received AND no mention of withdrawals OR more than 15% withdrawals/loss to follow-up/post-randomisation exclusions

3. Blinding
A. Blinding of outcome assessor AND patient and care giver

B. Blinding of outcome assessor OR patient and care giver

C. Blinding not done

4. Outcome assessment (if blinding not possible)
A. All patients had standardised assessment

B. No standardised assessment OR not mentioned

Source: modified from I Chalmers, Cochrane Handbook; available on the Cochrane Library CDROM *How to review the evidence* (cited in NHMRC additional levels of evidence and grades for recommendations for developers of guidelines. Pilot Program 2005-2007).

Box 2. Criteria allocated to studies and their associated quality ratings

High quality				**Low quality**			
1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
A	A	A	A	C	C	C	B
B	B	B	A	D	D	A	A
				D	D	B	A
Medium quality				D	D	C	A
C	C	B	A	D	D	C	B
C	C	C	A	C	C	C	B
B	D	B	A	C	D	D	A
C	D	B	A	C	D	C	A
C	D	A	B	D	C	C	A
C	A	C	A				
D	C	B	A				

Box 3: Checklist for evaluating the quality of systematic reviews

Quality Criteria 1. Clearly defined question and inclusion criteria
A. (high quality) A clear aim or research question AND a list of clear inclusion criteria was reported.

B. (some limitations) A clear aim or research question OR a list of clear inclusion criteria was reported.

C. (unsatisfactory quality) No aims or clear research questions were reported. It was unclear what had been done.

2. Comprehensive search
A. (high quality) Electronic databases and one or more of the following were used: the ‘grey’ literature, internet sources, conference proceedings, hand searches, reference lists, technical reports, experts, theses, etc AND the search was not restricted to the English language literature only.

B. (some limitations) More than 1 electronic database was used OR the search was restricted to the English language literature only.

C. (unsatisfactory quality) Only 1 major electronic database was used (e.g., Medline).

3. Critical appraisal of the validity of studies reviewed
A. (high quality) Explicit criteria for critical appraisal were stated and the findings of that appraisal were considered in the conclusions and recommendations.

B. (some limitations) Critical appraisal was undertaken but explicit criteria were not stated.

C. (unsatisfactory quality) No critical appraisal of the studies reviewed was reported.

4. Consistency of results
A. (high quality) Homogeneity of results (i.e., all studies indicate positive/negative effects of similar magnitudes).

B. (some limitations) Heterogeneity of size of effect but trend obvious (i.e., all studies indicate positive/negative effects, but of differing magnitudes).

C. (unsatisfactory quality) Heterogeneity of direction of effect (i.e., some studies indicate positive effect, others negative).

Source: Review by the Centre for Community Child Health for NHMRC (*Child Health Surveillance and Screening: A Critical Review of the Evidence*).

Box 4. Criteria allocated to systematic reviews and their associated quality ratings

High quality		**Low quality**	
2	**3**	**2**	**3**
A	A	C	C
Medium quality		B	C
2	**3**	C	B
A	B		
B	A		
B	B		
A	C		
C	A		

Appendix E Literature tables

Table 1: Randomised Controlled Trials

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
1 MONTH - 3 YEARS - screening effectiveness								
M	Williams et al. 2001[39] & Williams et al. 2002[40]*	Avon, West England, UK	8 months	3490 *2740	Control: Received surveillance for visual problems by health visitors and family doctors. Exam involved: • Family history • Cover test, with ad hoc referrals if there was suspicion of strabismus or reduced visual acuity. Intervention: Received surveillance plus a program of visual testing by orthoptists. • Visual acuity was tested by: behaviour when either eye was occluded (all ages), Cardiff Cards (8, 12, 18, 25, 31 months) and Kay Picture test (25 and 31 months). • Ocular alignment was tested by: cover test (all ages), stereopsis with Lang tests 1 and 2 (18, 25, 31 months) and Frisby test (12, 18, 25, and 31 months), and motor fusion with the 20 Dioptre base-out test (all	1. Intervention n=2,029 2. Control) n=1,461 (* Intervention n=1,914, control group orthoptic screening at 37 months only n=826)	Health visitor, family doctor (control); orthoptist (intervention)	Intervention program yielded more children with amblyopia (1.6% vs 0.5%) and was more specific (95% vs 92%) than the control program. Cover test and visual acuity tests were poorly sensitive until children were 37 months, but were always 99% specific. Photorefraction was more sensitive than acuity at all ages below 37 months (95% at 31 and 37 months). Intervention program was more sensitive than control program for detecting strabismus and straight eyed amblyopia. There were fewer false positive referrals from the intervention group than the control group (however, the intervention program was not designed to be practicable). Most cases of strabismus were not apparent until after age 25 months, and most cases of straight-eyed amblyopia could not be identified until at least 37 months. (*The intervention program was associated with better acuity in the amblyopic eye and lower prevalence of amblyopia at 7.5 years compared to the control group. Children treated for amblyopia were four times more likely

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					ages). • Stereopsis • Non-cycloplegic photorefraction Referral criteria for Kay Picture test result below 6/12 at 25 months and 6/9 at 31 months.			to remain amblyopic if they were screened at 37 months only than if they were screened repeatedly between 8 and 37 months. Children screened early could see an average of one line more with their amblyopic eye after treatment than children screened at 37 months).
3 - 6 YEARS - screener characteristics								
M	Vision in Preschoolers Study Group (VIP), 2005[12]	US	3-5 years	1452	• Retinomax Autorefractor • SureSight Vision Screener • Linear Lea Symbols VA at 10 ft • Single Lea Symbols VA at 5 ft • Stereo Smile II	1. Failed Head Start vision screening n=785 2. Passed Head Start vision screening n=844	Nurse or lay screener	Nurse screeners achieved slightly higher sensitivities with the Retinomax, SureSight, and Stereo Smile II than the lay screeners; however, most differences were small and not significant. Nurse screeners achieved significantly higher sensitivity with the Linear Lea Symbols vs lay screeners. Lay screeners achieved higher sensitivity with Single Lea Symbols vs nurse or lay screeners using Linear Lea Symbols. Combining Stereo Smile II with each of the other tests did not result in improved sensitivities. Nurse and lay screeners could achieve similar sensitivity when specificity was set at 90%.

Table 2: Non-Randomised Controlled Trials

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
1 MONTH - 3 YEARS - screening effectiveness								
L	Atkinson et al. 1996[36] & Atkinson et al. 2007[37]*	Cambridge, UK	1st program: 6-8 months 2nd program: 8.1 ± 0.8 months, 7-9 months	1st 3166 2nd 5091	1st program: Basic orthoptic exam (Hirschberg test, cover test, ability to overcome 20 Δ prisms) and isotropic photorefraction with cycloplegia. 2nd program: Full orthoptic exam and four sets of videorefractive images without cycloplegia.	1st program 1. Met criteria for follow-up n=DK 2. Control group met no criteria for follow-up n=DK 2nd program as above.	Orthoptist	Both programs showed good agreement between infants identified at screening and retinoscopic refractions at follow-up, showing that photo- and video-refraction (with or without cycloplegia) can be effective methods for screening ametropia in infants/young children. For the 1st program, children who were hyperopic in infancy were 13 times more likely to become strabismic, and six times more likely to show acuity deficits by 4 years compared to controls. Wearing a partial spectacle correction reduced these risk ratios 4:1 and 2.5:1 respectively (*at 7 years improvement in strabismus was found for the 1st program only. Infant hyperopia was found to be associated with mild delays across many aspects of visuocognitive and visuomotor development.)
L	Bradley and Riederer 2000[60]	British Columbia, Canada	2-3 years	383	The purpose of the pilot was to determine whether the Vision First Check Program (using the MCT) would result in a substantially higher number of 2 and 3 year olds receiving a thorough	Screening group n=383	Optometrist s	The Vision First Check program was successful in increasing the number of preschoolers receiving vision care. The program screened 2 year olds at 4.7 times the previous rate and 3 year olds 2.8 times.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					vision assessment than currently indicated by provincial government data.			
M	Eibschitz-Tsimhoni et al. 2000[41]	Haifa and Hadera, Israel	1-2.5 years	1590	Exam involved: • History • External inspection • Hirschberg corneal reflex test • Monocular fixation-and-following test • Ductions and versions exam • Cover-uncover test • Alternate cover tests	1. Screened n=808 2. Not screened n=782	Ophthalmologist or an orthoptist	The prevalence of amblyopia in 8 year olds screened in infancy was 1.0% vs 2.6% for non-screened children. Prevalence of amblyopia with visual acuity of 6/12 or worse in the amblyopic eye was 0.1% for screened children vs 1.7% for non-screened children. Screening sensitivity was 85.7%, specificity 98.6%, positive predictive value 62.1%, and negative predictive value 99.6%.
M	Filipovic et al. 2003[61]	Rijeka, Croatia	5 years or less	200	An ophthalmologic screening card was attached to children's vaccination cards to examine whether this reduced the age at which children were first admitted to the Dept. of Paediatric Ophthalmology.	1. Screening card, 1990 group n=100 2. No screening card, 1980 group n=100	Neonatologists, and paediatricians or trained nurses	After the screening card was introduced, the mean age at which amblyopia and strabismus were detected decreased significantly from 4.4 to 2.5 years.
L	Rahi and Dezatuex 1999[54]	UK	0-12 months	248	Program to determine the mode of detection and timing of ophthalmic assessment of a nationally representative group of children with	Newly diagnosed cataract n=248	Paediatrician an/or ophthalmologist	Congenital and infantile cataracts were not detected by a health professional before the child's 1st birthday in 29% of cases, despite recommendations to examine all newborn and young infants routinely.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					congenital and infantile cataract. Postal questionnaires were sent to paediatricians and ophthalmologists to determine who first suspected the child had an ocular defect, at what age, date and reason for contact with a health professional during which cataract was detected and age at first referral to, and first examination by, an ophthalmologist.			
L	Smith et al. 1995[55]	Leicester, UK	6 weeks to 3.5 years	412	The current program made improvements from 1988-1991. Before 1988, health visitors referred children suspected of having a vision problem to their GP who would refer them on to an ophthalmologist. The new system involved children being referred directly from primary screening to a secondary orthoptic screen.	1. 1983 cohort screened n=209 2. 1992 cohort screened n=203	Health visitors	After introduction of changes to the screening program, the mean age at presentation of amblyopia associated with microtropia or no strabismus reduced from 6.6 to 5.5 years. In 1983 there was a significant relationship between deprivation and age at presentation, with those form more deprived areas presenting later. No similar associations were found in children referred in 1992. There was no change in the mean age of presentation of amblyopia associated with large angle strabismus (3.3years) and no relationship between deprivation and age of presentation in 1983 or 1992.
3 - 6 YEARS - screening effectiveness								

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
L	Fathy and Elton 1993[38]	North Manchester, UK	3-4 years	5,162	Children were examined for: • Gross abnormalities • Corneal reflections • Abnormalities of ocular movements and binocular convergence • Cover test for strabismus • Prism reflex test for abnormality of binocular function • Sheridan Gardiner 7 letter test for visual acuity	Screening group n=5,162	Orthoptists	As a result of screening, 4.4% of children received treatment for a defect not previously detected as a result of developmental surveillance or parents reporting their concerns. Treatment resulted in a considerable improvement in vision. 309 children were referred to an ophthalmologist, 284 (92%) attended. 233 were treated, 49 had a defect but were not treated, 2 no abnormality was confirmed, and 25 did not attend. 99 had a refractive error with no amblyopia, 119 had amblyopia with refractive error, 8 amblyopia with no refractive error. Detection rate of amblyopia was 25/1000, refractive without amblyopia 19/1000, and strabismus 44/1000.
L	Kemper et al. 2006[50]	US	3-5 years	62	A survey was administered to a randomly selected national cohort of primary care paediatricians and family physicians. They were asked to recruit parents whose preschool aged children had an abnormal vision	Parents n=62	Paediatricians and family physicians	Most, but not all parents knew that their child had an abnormal vision screening result (91.1%), and among these, most received follow-up eye care (75.6%). Most preschoolers received follow-up eye care within 2 months of screening. Barriers included lack of insurance coverage, inconvenience of follow-up, and lack of knowledge about benefits of early

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					screening result.			intervention. Minority children and those with low family incomes were less likely to receive follow-up care.
L	Milne 1994[56]	Newcastle-Upon-Tyne, UK	3.1 years	2,600	Primary vision screening: Vision screening: • Sheridan Gardiner single optotype or Kay Picture test • Cover test • Ocular motility • Convergence • 20-dioptre base-out reflex test Community orthoptist request service (Secondary): the Newcastle community orthoptic service also provided assessments for any child aged other than 3.1 years on request basis by GPs, health visitors, school nurses, and other professionals.	1. Routinely screened n=1,858 2. Recalled from previous visit n=349 3. Seen as request referrals n=393	Orthoptists	Primary vision screening at 3.1 years by orthoptists working in local clinics: 140 (6.3%) referred. 115 (85.8%) of those seen at hospital were identified as having an eye problem, of these, 82 (61.2%) required immediate treatment. Community orthoptist request service (Secondary): 70 (17.8%) referred. 60 (95.2%) were identified as having an eye problem, of these, 42 (66.7%) required immediate treatment. Raising the screening age from 35 to 37 months helped reduce the number of children being recalled, as more children in the lower age group were too immature to respond satisfactorily to the tasks required. Secondary orthoptic assessment can be very effective with 27 (100%) of the children who were referred under 34 months had a target eye condition; yet the service is cost effective with 323 (82.2%) not needing referral to hospital, therefore, reducing false referrals to hospital. High hospital attendance rate 98.4%.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
M	Williams et al. 2003[42]	Avon, West England, UK	1. 3 years	1,019	The orthoptist preschool screening exam included: • Monocular vision test (Kay Picture test or Sheridan Gardiner singles) • Cover test • Assessment of binocularity 20 dioptre prism or test of stereopsis, or both	1. Children who received vision screening at 3 years n=DK 2. Children who did not receive vision screening at 3 years n=DK	Orthoptist	Preschool screening at 3 years was associated with an improved treatment outcome for individuals with amblyopia, however the improvement was clinically small and disappeared when considering all children offered screening rather than those who just received it. Of 6,081 children, 24.9% had been offered screening, 16.7% attended. The prevalence of amblyopia was approx 45% lower in children who received preschool screening than those who did not. Mean acuity in the worse seeing eye after patching treatment was better for amblyopia children who received preschool screening than those who did not. Effects did not persist in an intention to treat analysis. Treatment for amblyopia does improve visual acuity and on average, the results of treatment after screening are better for screening before 3 years than after 3 years and slightly better again after screening at 3 years than at school entry, especially for children with straight eyed amblyopia.
6+ YEARS - screening effectiveness								
L	Cummings 1996[15]	Cambridge, UK	8 and 10 years	1,809	Examined the outcome of vision screening in children and established whether such tests are necessary at a time when there are increasing	1. 8 year olds n=822 2. 10 year olds n=927		Of the 1,809 children in the study, 1,249 had perfect visual acuity recorded as 6/6 for both distant and near vision. For the other 560, defects (6/6 part or worse) of visual acuity were found in 34.6% of the

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					demands on limited resources.			1429 children in rural schools and 30% of the 380 children found in urban schools. Of the 560 classified as abnormal, most (68%) had been found on a previous occasion. Of the 181 new findings, 83% were in the less significant categories. Routine vision screening after 5 years identifies only a very small number of children with significant new abnormalities.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
L	Edgecombe et al. 1998[59]	Victoria, Australia	5-7 years	998 parents	The study described the analysis of data from the first testing of the School Entrant Health Questionnaire (SEHQ). The SEHQ is distributed each year to the parent(s)/guardian(s) of preparatory children enrolled in participating primary schools in Victoria, Australia. The SEHQ assists school nurses in developing a health profile of children.	Parents surveyed n=998	School nurses	The SEHQ was found to be reliable and valid to provide an excellent means of distinguishing those who had problems and needed intervention from those who did not. It was found that the majority of children were healthy, however there were a significant number of children with problems that would require intervention by a school nurse and/or referral to specialist services e.g., 49 parents did not understand that a 'turned eye' or strabismus could affect their child's vision. The SEHQ proved to be a useful adjunct for the school nursing assessment of children in prep.
L	Jewell et al. 1994[45]	Oxfordshire, UK	13-15 years	1,069	A school nurse used Snellen at 6 m for visual acuity.	1. 13 year olds n=371 2. 14 year olds n=377, 3. 15 year olds n=321	School nurse	It was found that 3.8% of children 13 - 15 years had visual acuity worse than 6/12 in one or both eyes (fail). There was no evidence that this percentage increased across the age range. Less than 1% were prescribed and wore glasses as a consequence of failing

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
								vision screening and no new cases of eye pathology were detected. Questionnaire responses from parents suggested that approx 50% of children who did not wear glasses had had an eye exam in the previous 2 years. The proportion of secondary school children failing screening increased by less than 2% per year, implying that the majority who are likely to benefit from screening find their own way to an optometrist.
L	Kimel 2006[52]	Rockford, US	5-6 to 10-11 years	78	School nurses in the Rockford Public Schools gathered names of 175 English speaking students K-5th grade that had failed school vision screening and had not reported receiving follow-up eye exams. The parents of these children were interviewed.	Parents n=78	School nurses	Family issues, parental perceptions of vision problems and difficulty planning ahead were found to be significant barriers. Financial barriers - cost and money concerns 31%, no insurance coverage 11%, waiting for insurance 9%. Logistical barriers - appointment problems 22%, can't plan ahead 16%, no phone 11%, no car 9% 3. Social/family barriers - all adults work 45%, family issues 34%, large family 29%, parent disabled 13%, change in residence 11%. Perceptual barriers - do not believe results 38%, not a priority 38%, no need for an exam 29%, no interest in follow-up 18%. Factors that increase compliance: parent wears glasses, parent has at least a high school diploma/general equivalency diploma, at least one nonworking adult in the home, family income above 200% of federal poverty level, family has both a car

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
								and phone, and trust in the school nurse.
L	Kvarnstrom et al. 1998[43]	Huddinge, Lund, and Linkoping, Sweden	0-10 years	3,126	• At four and 5.5 years, monocular vision was tested using the HOTV-chart. • At seven years children were tested with a Line E-chart or HOTV-chart. • At 10 years the children's vision was tested using Monoyer's linear letters.	Screening group n=3,126	School nurses	Attendance rate at 4 years was better than 99%. Sensitivity of 4 and 5.5 year screening was on average 92%, and specificity 97%. The average number of false negatives at 4 years was 5.6 in 1000 (0.56%). With this screening and subsequent diagnosis and treatment, the prevalence of amblyopia at different levels of visual acuity at age 10 years was 0.06% with visual acuity ≤0.1, 0.9% with visual acuity ≤0.5 and 1.7% visual acuity ≤0.7. The prevalence of deep and moderate amblyopia had been markedly reduced by screening and early treatment.
L	Kvarnstrom et al. 2001[44]	Huddinge, Lund, and Linkoping, Sweden	0-10 years	3,126	• At four and 5.5 years, monocular vision was tested using the HOTV-chart. • At seven years children were tested with a Line E-chart or HOTV-chart. • At 10 years the children's vision was tested using Monoyer's linear letters.	Screening group n=3,126	School nurses	Ametropia (any refractive error) was mainly detected at 4 years, when the first visual acuity test was performed. Manifest strabismus was in many cases detected before age 4, while microtropia (small angle heterotropia) was detected at 4 years. Prevalence of amblyopia was reduced to 0.2% from 2% by screening and treatment, and the majority of patients with amblyopia increased their visual acuity with treatment, indicating that screening and treatment can reduce the prevalence of amblyopia.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
L	Mark & Mark 1999[53]	Durham (North Carolina), US	Grade 1, 4 & 7 (US)	232 parents	Each year in Durham Public Schools, vision screening is performed on students in grade 1, 4, & 7. If child has an abnormal screening test, they are re-tested and a second abnormal screen results in a referral letter being sent to parents recommending evaluation by an eye professional.	Parents surveyed n=232	School nurse	Most parents (90%) recalled receiving a referral letter from the school nurse. 65% of parents who recalled receiving a referral had taken their child to eye professional. 80% of these needed glasses. Reasons for no appointment: 25% lack of time, 24% lack of financial resources, 51% something else (43% children had glasses but refused to wear them, 18% had taken their child to eye doctor in the past year and didn't want to take them again that year, 14% forgot, 25% illness & waiting for insurance.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
L	Scherrer & Stevens 1997[58]	New South Wales, Australia	10-11 years	191	The study applied the experimental questionnaire method of school screening (the parent and children questionnaires that inquire about various aspects of their own and their child's health) to school students and their parents and then re-tested this group with the traditional one on one screening method.	Students returned questionnaires n=191	School nurses	It was found that the questionnaire method exhibited a relatively low error rate when data from both parent and student were combined. Only two of 191 students would have been overlooked if the questionnaire was the only method used to screen. The authors concluded that, while identifying the problems that do exist with the questionnaire (literacy levels of the students and parents need to be high, students need to be compliant in caring for the parent questionnaire, students need to be truthful and not bias their responses), it was shown to be a relatively accurate model and that it can be employed efficiently to allow the school nurse to expand her role into other areas.
L	Yawn et al. 1998[51]	Rochester, Minnesota, US	Over 6 years	94	Community focus groups to identify barriers that may delay seeking professional care following school vision screening.	Focus group=94	Not stated	Major barriers to delay of seeking follow-up eye care include lack of community awareness about the frequency and potential effect of refractive errors in children, a parental perception of inadequate communication between the schools and parents and community, high cost of corrective lenses, limited availability of convenient eye care appointments, and adolescents' reluctance to wear glasses. Lack of emphasis on school-age children's

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
								vision by primary care physicians, the medical community, and the media appear to compound these barriers.
1 MONTH - 3 YEARS - screener characteristics								
L	Bolger et al. 1991[7]	Southmead and Weston-super-Mare, UK	6 weeks to 3.5 years.	10,082	Vision checked as part of developmental screening. Screening test: visual acuity in both eyes, ocular movements.	1. Orthoptist screening n=5,176 2. Other medical personnel n=2,530	Orthoptist or other medical personnel	Screened by orthoptist: yield 2.4%, positive predictive value 47.5%, false positive value 46.4%. Screened by other medical personnel: yield 0.6%, positive predictive value 14.4%, false positive value 82%. False-positive 17 cases per 1,000 for orthoptists, 31 cases per 1,000 for other medical personnel. The use of orthoptists as primary screeners improved detection rates of visual abnormalities and lowered the rate of false-positive referrals to secondary clinics.
L	Bray et al. 1996[66]	Newcastle and Northumberland, UK	3 years	5,364	Screening carried out at 35 months by orthoptist in local clinic. History Visual acuity Kay Picture test or Sheridan Gardiner Cover test and alternate cover test, A 20 dioptre prism test (for binocular function) Ocular movements Home visit by health visitor at 30-36 months. History Ability of child to pick up	1. Orthoptic screening n=1,582 2. Health visitor screening n=2,081 3. GP screening n=1,701	Orthoptist, health visitor, or GP	Orthoptic screening detected many more cases of amblyopia assoc. with microtropia and anisometropia, but the overall amblyopia prevalence at 7 years was similar in *each* cohort. Orthoptic screening has no influence on the age of detection of squints or strabismic amblyopia, but achieves a sig reduction in age at which straight-eyed amblyopes and refractive errors present. Despite this, the study was unable to demonstrate differences in amblyopia rates between cohorts, but sample sizes and low rates of ascertainment of amblyopia in comparison groups, do not allow

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					thread. Screening carried out at 30 months by GPs, CMOs, or HVs in local clinics. History Any manifest squint noted			definitive conclusions.
L	Jarvis et al. 1990[67]	Newcastle and Northumberland, UK	Younger cohort 5-9 months, Older cohort 30-36 months	6,526	Northumberland: Younger cohort at 7-9 months squint check. Older cohort at 30-36 months squint check (also 18 month check) (by health visitor or GP). Orthoptist: Younger cohort at 5 months: • History • Observation • Cover test • Ocular movements • 20 dioptre base out prism test • Convergence Older cohort at 35 months as at 5 months plus acuity test (Sheridan Gardiner letter matching or Kay Picture test). (community orthoptist). Comparison (Newcastle):	1. Orthoptist screen younger (9 months) n=1,050 2. Orthoptist screen older (35 months) n=1,026 3. Health visitor younger (9 and 30 months) n=1,321 4. Health visitor older (30 months) n=1259 5. N'land squint younger (7-9 months) n=903 6. N'land squint older (30-36 months) n=967	Orthoptist, health visitor or GP and health visitor	Screening at 35 months by an orthoptist was superior to health visitor surveillance at 30 months and to the program of screening squint at 30-36 months (sensitivity 100% vs 50% vs 50%, incidence of treated target conditions 17 vs 3 vs 5 per 1,000 person years). In the orthoptist group, 13 children received treatment for straight eyed visual acuity loss from among 1,000 children whereas there were no such cases among 2,500 in the comparison areas. In the younger cohorts (5-9 month screening) all 3 programs showed equally poor results, only one of the eight treated target conditions arising from all 3,500 younger children being screen detected. Specificity was high for all groups and cohorts.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					Younger cohort at 9 months standard check, 'doubt about infant or personal/family history of squint'. Older cohort at 30 months standard check, pick up a thread (health visitor).			
3 - 6 YEARS - screener characteristics								
M	Concannon and Robinson 1997[57]	Sydney, Australia	4-6 years	1,345	Tested the feasibility of using a questionnaire for teachers in place of the traditional screen conducted by school nurses on students in their first year of school.	1. Screened group n=1,087 2. Control group n=258	Nurse	Using the orthoptist as the standard, the nursing screen showed excellent specificity and sensitivity (100%). Using the nurses' results as the standard, the questionnaire sensitivity was 13.9% and specificity 96.5%, indicating a high false negative rate, with 86% of the visually impaired being missed by the teacher's questionnaire.
L	Hartmann et al. 2006[71]	US	3-4 years	3 years 1,258 4 years 1,613	Two programs: 2 sites worked with primary care practices (testing performed by nursing staff) and 2 sites worked with community based programs (lay volunteers). Community based: • HOTV • LEA chart • HOTV cards with bars	1. Community based (lay volunteers) 3 year olds n=DK 2. Community based (lay volunteers) 4 year olds n=DK 3. Primary care (staff) 3 year olds n=DK 4. Primary care (staff) 4 year olds	Nursing staff or lay volunteers	The rate of successful screening for 3 year olds was 80%, and 4 year olds 94%. Referral rates for the community based program were 31% for 3 year olds, and 28% for 4 year olds. Referral rates for the primary care program were 4% for 3 year olds, and 5% for 4 year olds. The overall follow-up rates were relatively low. 56% who were referred did not receive a follow-up exam, or the follow-up results were not communicated to the referral source. Initially, volunteers and staff

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					• Random Dot E (3 year olds were required to pass a critical line 6/12 and 4 year olds 6/9). Primary care: same as above plus • Vision history • External inspection of eye • Ophthalmoscopic exam (Red reflex check) • Tests for ocular muscle motility and eye muscle imbalances (Corneal light reflex, Fixation/tracking, Unilateral cover test)	n=DK		embraced the program and training. However, sustaining a high level commitment to consistent implementation of the protocol was difficult.
L	Paech and Calabretto 1999[69]	SA, Australia	5-6 years	28	Children were screened individually by a RN (registered nurse) using OVSK (Oyarzum Vision Screening Kit), and re-screened a week later by the optometrist. OVSK contains a battery of 5 tests. • Visual acuity was assessed by the Lea Symbols Chart • Hyperopia by the Wand	Screening group n=28	Nurse	13 (46%) of the children failed one or more tests. The largest numbers of failures occurred in the tracking test. The RNs had good screening skills when compared with the optometrists with at least 86% agreement achieved for each test. The optometrist was faster than the RN.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					• Converge by the Prism • Tracking by the pencil topper • Binocularity with the Red Bear test.			
L	Robinson et al. 1999[10]	Oxford County, Canada	4.4 years	1866	Screening by public health nurse versus screening by eye care practitioner of parent's choice. • Visual acuity • Ocular alignment • Stereoacuity	1. Screened as a 'fail' n=1,017 2. Control group n=849	Public health nurses	Vision screening of preschool children can be delivered effectively by public health nurses as part of the overall screening programs conducted in a health fair design. Sensitivity ranged from 60.4% to 70.9%, while specificity ranged from 69.6% to 79.9%. The positive predictive value was 21.6% to 32.3% and the negative predictive value was 92.6% to 95.3%
L	Spowart et al. 1998[72]	Glasgow, UK	Primary one students (no age specified)	766	Comparison of screening results between school nurses and orthoptists	Tested by nurses and orthoptists n=766	Nurses and orthoptists	Prevalence of decreased visual acuity for nurse screening was 8.6%, but only 4.2% for orthoptist testing. For nurses, positive predictive value was 40%, negative predictive value was 99%, sensitivity was 83%, and specificity was 95%. Orthoptists were more accurate visual screeners than others, but all children with significant visual defects were detected by the current screening system (by nurses). The authors concluded that nurses should continue to be the primary screener, despite the high false positive rate.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
L	Thorburn and Roland 2000[27]	Warrington, North West England, UK	3-3.5 years	2,041	Health visitors carried out a test of visual acuity in all children aged 3-3.5 years as part of a routine child health surveillance review. Vision screening was undertaken using a Stycar single letter matching test at 3 m, testing each eye separately. Children were referred to the community orthoptic service. Vision screening was repeated as part of the school entry assessment at age 5. Visual acuity was tested using Keener mark 2 OAT at 6 m, each eye tested separately. Children were referred to the orthoptic service.	1. 3-3.5 year old referrals n=227 2. 5 year old referrals n=181	Health visitors	Of the 2041 children screened, 12% were referred. Amblyopia was found in 11 children, five children had squints without amblyopia, and 25 had significant refractive errors. Possible failure of early screening was found in only 2 children. A high proportion of children referred required ongoing orthoptic follow-up or treatment (63% true positive at orthoptist level, 28% at gold standard level).
L	Wormald 1991[68]	Cornwall, UK	1st cohort 4.3 years, 2nd cohort 4.4 years	598	• History • Distance vision Measured with Snellen at 6 m with card (Sheridan Gardiner at 6 m or Kay Picture test used if co-op was poor) • Head posture • Convergence to nose • Cover test, near and distance • Prism cover test	1. 1980 cohort n=298 2. 1982 cohort n=300	Community orthoptists	Community orthoptists achieved a sensitivity of about 90% and specificity of 99%. Sensitivity: 87.2% (1980), 92.64% (1982). Specificity: 99.58% to 99.64%(1980), 99.64% to 99.69% (1982). Predictive positive value 93.46% (1980), 94.96% (1982), negative value 99.12% to 99.25% (1980), 99.46% to 99.54% (1982).

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					• 20 dioptre base out (occasionally 10) • Ocular movements • 9 positions of gaze • Stereoscopic vision: Wirt fly test and pictures of animals			
L	Yazawa et al. 1992[70]	Tokyo, Japan	3 years 1 month	21,906	Home vision test. The test kit contained a picture card, instructions and an answer sheet. Tissue paper and plastic tape were used to patch alternately the eye not being tested.	Screening group n=21,906	visual acuity (amblyopia)	96.4% of the children were able to complete the home test. Results disclosed below-normal acuity in 407 children (1.9%). 0.19% of amblyopia and 0.22% of strabismus were reported after referrals to hospitals or private practitioners. Over 96% of children could complete the test and 41 cases of previously undetected amblyopia were found.
1 MONTH - 3 YEARS - screening outcomes								
L	Atkinson et al. 2002[73]	Cambridge, UK	8.1 months	137	Vision screening: non-cycloplegic videorefraction and orthoptic examination. Measures of cognitive, motor and language skills: • Atkinson Battery of Child Development for Examining Functional Vision • Henderson Movement Assessment Battery for	1. Hyperopes n=71 2. Control n=66	Orthoptist	Children identified at infant screening with significant hyperopic refractive errors showed consistently poorer performance on a range of visuocognitive and visuomotor tests up to age 5 years, compared to control children without significant refractive errors.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					Children, • The Griffiths Child Development Scales, • MacArthur Communicative Development Inventory • British Picture Vocabulary Studies			
L	Atkinson et al. 2005[74]	Cambridge, UK	8.1 months	453	Vision screening: non-cycloplegic videorefraction and orthoptic examination. Those meeting criteria for focussing error (misaccommodation on the target in one or both eyes), and/or failure on orthoptic exam were invited for a follow-up appointment one month later.	1. Hyperopic group 3.5 years n=110, 5.5 years n=99 2. Control group (visually normal) 3.5 years n=131, 5.5 years n=113	Orthoptist	Hyperopic group performed significantly worse than the control group at both ages. Overall and on at least one test from each category of motor skill (manual dexterity, balance and ball skills). Differences were due to widespread mild deficit in hyperopic group.
3 – 6 YEARS – screening outcomes								
L	Roch-Levecq et al. 2008[75]	San Diego, US	4.6 years	70	Cycloplegia was induced. After 30 minutes, children received retinoscopy and most had autorefraction and manifest refraction. Visual acuity was assessed before correction prior to cycloplegia and after correction under cycloplegia at near using the Allen Preschool	1. Uncorrected ametropia n=35 2. Emmetropia controls n=35	Optometrists	At baseline, uncorrected ametropes scored significantly lower on the Visual-Motor Integration test (VMI), which assesses visual perception and hand-eye co-ordination, and most of the WPPSI-R performance subsets requiring eye-hand coordination, compared to emmetropic controls. However, after six weeks of wearing glasses, the ametropic group significantly improved on the VMI compared to the control group. The

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					Vision Test and at far using B-VAT PC version 2.3.			ametropic group also improved on the WPPSI-R, but was not significant.
6+ YEARS - screening outcomes								
M	Goldstand et al. 2005[80]	Jerusalem, Israel	12 years, 7 months	71	Comparing visual and visual-information processing skills between children with and without mild reading and academic problems and examining the incidence of visual deficits among them. Screening tests used: • Altaleft Reading Screening Test (quick screen for reading ability) • Tivka Reading Test (analyses basic phonological skills as well as comprehension and proficiency in silent reading and recitation in Hebrew language) • The Modified Clinical Technique • The Developmental Test of Visual-Motor Integration	1. Proficient readers n=46 2.Nonproficient readers n=24	Occupational therapists	Nonproficient readers had significantly poorer Visual Efficiency abilities than proficient readers did. However, there were no significant differences between these groups with respect to Visual Health.

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					• The Motor-Free Visual Perception Test • The Revised Conners • Parent and Teacher Rating Scale • Academic Performance Questionnaire			
L	Johnson et al. 1996[79]	New York, US	8-18 years	81	New York State Optometric Association Vision Screening Battery (NYOSA) • Tracking • Fusion • Acuity-Distance • Stereopsis • Acuity-Near • Convergence • Hyperopia • Colour Vision • Visual Motor Integration	1. Academically and behaviourally at risk n=33 2. Academically at risk only n=48		85% (69) of all students failed one or more of the visual tests, with more children failing the tracking subset than any other subtest 37% (30). A significant number of students failed visual acuity far and near, stereopsis, and visual motor integration. Students who were academically and behaviourally at risk were more likely to fail the tracking test than students who were academically but not behaviourally at risk (52% vs 27%). They were also more likely to fail visual acuity far and near, hyperopia, stereopsis, colour vision and visual motor integration. 97% of these students failed at least one subset.
M	Kulp and Schmidt 1996[81]	Cleveland, Ohio, US	Kindergarten 5.7 years, First grade 6.8 years	181	• Modified Clinical Technique (MCT) • ±2.00 D flipper lenses with red/green suppression check for accommodative facility • Randot for stereoacuity • Test of Visual Analysis	Kindergartners n=90, 1st graders n=91	School nurse, optometrist, and an optometry student	Accommodative facility was predictive of successful reading performance in 7 year olds, first graders, and in the entire group when age or grade was controlled. The relationship between accommodative facility and reading performance became more significant as age and grade increased. Failure on the MCT was significantly

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					Skills (TVAS) Short Form • Gardner Reversals • Frequency Test for visual perceptual skills • Retinoscopy (noncycloplegic) assessed refractive error • Near visual acuities assessed with Reduced Snellen or Allen figures • Distance visual acuities were assessed independently by school nurse. • Cover testing to assess phoria • Randot testing to measure stereoacuity			associated with decreased reading skill in 5 year olds. Stereoacuity worse than 100 sec arc, MCT failure plus stereoacuity worse than 50 sec arc, and accommodative facility were predictive of reduced reading skill in children of average intelligence. The addition of stereoacuity to the MCT screening would make the results more useful to educators.
L	Krumholtz 2000[77]	New York (US)	5-12 years	1996-97: 1,365 1998-99: 1,463	Based on Modified Clinical Technique (MCT) and some tests used from New York State Optometric Association's (NYSOA) vision screening battery: • Distance and near visual acuity • Hyperopia assessment	1. Screened 1996-97 n=1,365 2. Screened 1998-99 n=1,463	Second year optometric students, in conjunction with a faculty member of the State University of New York	Twenty nine percent of children screened in 1996-97 were referred. This matched the referral rate in 1998-99. Screening in 1998-99 yielded a higher referral rate (35%) in functional vision tests vs visual acuity screening procedures than the screening in 1996-97 (30%). King Devick test and hyperopia assessment showed significant correlation with citywide achievement test scores. Both tests were

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					• Cover test • Stereopsis • Fusion, accommodation and ocular motility measured with the NYOSA King Devick test, and near point of convergence (NPC) • (ophthalmoscopy and colour vision also performed, but not included in article)		College of Optometry	significant for predicting those students in the lower 25% of the class for all grades in both years of screening. More than 70% of kids who were seen in 96-97 and received glasses, were still using their glasses.
M	Maples et al. 2003[78]	Oklahoma, US	6-7 years and 10-11 years	540	• Visual acuity far and near • Disease screening with binocular loupe, transilluminator, and direct ophthalmoscope • Cover test both far and near • Phoria both far and near with Howell card and binocular ± D AC/A at near with near Howell Card • Near stereo with Wirt circles and autorefractor • Near point of accommodation blur out and recovery with the	Vision tested n=540		VMI and Wold were the most robust predictors of academic success. Other tests were also significant predictors of academic performance: visual acuity, visual-auditory processing, ocular motor, binocular skills, accommodative skills, and refractive status. Visual motor, ocular motor, binocular, accommodative, and visual perception skills were significant factors in children who scored poorly on the Iowa Test of Basic Skills educational test (ITBS).

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					dominant eye • Accommodative rock ± D Flippers, monocularly and binocularity with polaroid suppression check for binocular testing • Nearpoint of convergence break and recover • Nott retinoscopy • Prism bar ranges base in/base out at near • Prism flippers 8 base out/8 base in at near • Maples Ocular Motor Test • Developmental Eye Movement Test (DEM) • Motor Free Visual Perception Test (MVPT) • Wold Sentence Copy Test • Visual Motor Integration Test (Beery)			
L	Stifter et al. 2005[82]	Austria	11.6 years	40	• Cover–uncover test and alternate cover tests • Dynamic retinoscopy • Convergence • Motility • Ophthalmoscopy • Worth Four dot Test	1. Unilateral amblyopia n=20 2. Normal sighted controls n=20	Not stated	In regards to the binocular maximum reading speed (MRS), there were significant differences between children with amblyopia and the normal sighted children. The controls achieved a binocular MRS of 200.4 (11) wpm (words per minute), while

Quality L, M, H	Study Author/date	Study location	Age/Age range	Sample size	Description of study	Intervention groups (n=)	Screener	Results
					• Titmus Stereo test			the children with amblyopia achieved only a binocular MRS of 172.9 (43.9) wpm. No significant differences were found between the two groups with respect to binocular logMAR visual acuity and reading acuity.
L	Williams et al. 2005[76]	Rhondda Cynon Taff, UK	8 years	1,298	Community paediatric service in Rhondda Cynon Taff provides a conventional vision screening program: • Distance acuity at 7-8 years (Snellen 6 m), referral: vision 6/9 or worse in either eye to orthoptist (under 8 years) or optometrist (over 8 years). • Colour vision screening on boys at 11-12 years offered on a demand basis. • Preschool program: selective vision screening of high risk population (squint, defective visual acuity, relevant family history) by orthoptist. • For this study, fogging test for hyperopia was used.	Fail Fogging test n=166	School nurses	166 fogging test failures were referred for ophthalmic assessment. Ophthalmic tests on 105 children provided accurate diagnosis of vision defects, for reference to their education scores. 50% of children examined by optometrists required an intervention (prescription change, glasses, referral). Mean NFER score (education score) for children with refractive errors were lower than the respective scores of children with a less positive refractive state, the non-referred group, and the total sample. SATs followed a similar trend. A high proportion of fogging test failures (16%) and confirmed hyperopes (29%) had been referred to an educational psychologist, and the latter group contributed substantially to the poor education scores.

Table 3: Systematic Reviews

Quality L, M, H	Study Author/date	Findings/ Recommendations	Clearly defined research question and inclusion criteria (A,B,C)	Comprehensive search (A,B,C)	Critical appraisal of the validity of studies reviewed (A,B,C)	Consistency of results (A,B,C)
M	Castanes (2003) [63]	The objective of the review was to determine the social, economic, and political barriers which contributed to the underutilisation of vision screening among preschool age children. It was found that a variety of barriers existed which prevented children from receiving proper vision screening. Social barriers included ignorance, inconvenience, language, and lack of providers. Financial barriers affected low income families. Political barriers resided in the disproportionately small funding of preventative medicine. Low income, minority, and uninsured families were at high risk of not utilising vision screening.	B	A	B	B
L	Lennerstr and et al. (1995) [62]	The aim of the review was to perform a systematic analysis of the screening programs for detection of visual dysfunction. The performance characteristics of the screening programs used in Sweden and Canada were evaluated and found to be very favourable. Based on analysis and the evaluation, the following recommendations were made: 1) Inspection of eyes in the neonatal period and examination of the red reflex with the ophthalmoscope should occur. 2) Children at high risk for ocular and visual disorder (i.e., born before 32 weeks of age, or with genetic disease, hearing deficit and/or neurological and mental disorder), should be examined by an ophthalmologist. 3) Staff at paediatric departments and child health care centres should be familiar with the visual development of the normal baby and should be alerted to symptoms and signs of visual defects. 4) Paediatric exams should include detection of squint. 5) A screening test of monocular visual acuity in 4 year old children could be reliably performed by non-ophthalmic personnel after proper training. The screening test should be repeated by school nurses during first grade of school, and at regular intervals during the school years. 6) Children who screen positively should be seen by ophthalmologists, and in some cases orthoptists, without delay. 7) There was a need for a better preschool acuity test that could be used at age 2.5-3 years. 8) Colour vision screening was recommended and should be carried out between 9 and 13 years of age.	B	C	C	B
M	Pattison and Plymat (2001) [64]	The purpose of the literature review was to summarise the literature on vision screening in preschools and schools. It was found that parent and teacher referral methods of screening were less than satisfactory, and professional screening of all children at school age should be continued. This should be carried out by nurses if they are adequately trained by orthoptists.	B	A	C	B

Quality L, M, H	Study Author/date	Findings/ Recommendations	Clearly defined research question and inclusion criteria (A,B,C)	Comprehensive search (A,B,C)	Critical appraisal of the validity of studies reviewed (A,B,C)	Consistency of results (A,B,C)
M	Powell et al. (2004) [46]	The objective of the review was to evaluate the effectiveness of vision screening programs in schools in reducing the prevalence of undetected, correctable visual acuity deficits due to refractive error in school-age children. The authors did not find any randomised controlled trials that met their inclusion criteria. It was concluded that there were no robust trials available that allowed the effects of vision screening to be measured. The absence of evidence of effectiveness did not imply that screening was not valuable, simply that any value had yet to be properly identified. The possibility of doing harm should also be considered. The authors stated that there was a real need for robust randomised control trials to be implemented to measure the effectiveness of vision screening.	A	B	N/A	N/A
M	Powell et al. (2005)[47]	The aim of the review was to evaluate the effectiveness of vision screening in reducing the prevalence of amblyopia in screened versus unscreened children before or as they entered school. No randomised controlled trials were located that fitted the criteria. The authors concluded that the absence of such evidence could not be taken to imply that vision screening was not necessary; simply that screening had yet to be tested in rigorous trials. The optimum protocol for carrying out screening remained unclear. There appeared to be no detrimental effect in terms of visual outcome on leaving screening until school entry and this appeared to improve the coverage achieved.	A	B	N/A	N/A
L	Resnikoff et al. (2008)[49]	A review of the literature was conducted on the global magnitude of visual impairment caused by uncorrected refractive errors in 2004 for people aged 5 years and over. The authors concluded that: 1) Screening of children for refractive errors should be conducted at a community level and integrated into school health programs, accompanied by education and awareness campaigns to ensure that the corrections were used and cultural barriers to compliance were addressed and removed. 2) Cost of refractive corrections was still high compared to personal and family resources in many regions, thus corrections should be made accessible and affordable for all ages. 3) Eye-care personnel should be trained in refraction techniques. Teachers and school health-care workers should also receive training and information programs. 4) Reliable and affordable equipment for refractive assessments should be developed. 5) Refraction services should be integrated with eye-care systems and included as part of cataract surgery services. 6) Impairment and outcomes should be monitored at national levels to identify communities in need and to evaluate the most cost-effective interventions. 7) The unmet need of correction of presbyopia should also be addressed.	A	A	C	B

Quality L, M, H	Study Author/date	Findings/ Recommendations	Clearly defined research question and inclusion criteria (A,B,C)	Comprehensive search (A,B,C)	Critical appraisal of the validity of studies reviewed (A,B,C)	Consistency of results (A,B,C)
H	Snowdon and Stewart-Brown (1997)[65]	The objective of the review was to evaluate the effectiveness of preschool vision screening. One prospective controlled trial and 16 retrospective studies (observational studies and audits) of different screening programs were found. It was reported that orthoptic screening programs performed better than health visitor or GP screening in terms of program yield and positive predictive value. The mean uptake rate was 64.8%. The mean referral rate was 6.7% for primary orthoptic screening programs and 3.9% for screening by health visitor or GP. The positive predictive value ranged from 47.5% to 95.9% for orthoptic screening and from 14.4% to 61.5% for screening by health visitor or GP.	A	A	A	A
L	Weinstock et al. (1998)[48]	The aim of the review was to examine the clinical classification of strabismus, to describe the timing and method of strabismus screening examinations, and to discuss principles of treatment. The main findings were that primary care physicians should screen all low-risk children. High risk children (low birth weight, family history of strabismus, congenital ocular abnormality, or systemic conditions with vision threatening ocular manifestations) should be referred to an ophthalmologist for screening. Screening should be performed in the neonatal period, at 6 months, and at 3 years (Grade A recommendation), as well as at 5 to 6 years (Grade B recommendation). Screening exams should include inspection, examining visual acuity, determining pupillary reactions, checking ocular alignment, testing eye movements, and ophthalmoscopy.	B	C	C	B

Table 4: Prevalence studies (Australia)

Study Author/date	Age	Sample size	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism
Robaei et al. (2005)[25] Sydney Myopia Study	6 years Uncorrected visual acuity	1,738	-	Uncorrected: 71 (4.1%) Presenting: 54 (2.8%), worse eye	-	Significant: 43 (2.5%) Mild: 125 (7.3%)	24 1.4%	-
Robaei et al. (2006a)[6] Sydney Myopia Study	6 years	1,739	13 (0.7%) 32 (1.8%), including those successfully treated	-	-	-	-	-
Ip et al. (2006)[5] Sydney Myopia Study	6 years With eyestrain symptoms	220	8 (3.6%)	-	16 (7.3%)	16 (7.3%)	5 (2.3%)	18 (8.2%)
	Without eyestrain symptoms	1,242	17 (1.4%)		22 (1.8%)	34 (2.8%)	17 (1.4%)	84 (6.8%)
Robaei et al. (2006b)[35] Sydney Myopia Study	12 years	2,353	-	10.4% Uncorrected (at least 1 eye)	-	116 (5.0%) (overall)	300 (12.8%) (overall)	220 (9.4%) (overall)
Robaei et al. (2006c)[119] Sydney Myopia Study	12 years	2,353	-	Uncorrected: 268 (11.4%) Presenting: 117 (5.0%), worse eye		Uncorrected: 19 0.8% Presenting: 11 0.5%	Uncorrecte d: 208 8.8% Presenting: 67 2.8%	Uncorrected : 81 3.4% Presenting: 32 1.4%

Study Author/date	Age	Sample size	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism
Robaei at al. (2008)[14] Sydney Myopia Study	12 years	2,353	44 (1.9%)	-	-	-	-	-
Ip et al. (2007)[26] Sydney Myopia Study	6 years	1,724	-	Unilateral uncorrected: 71 (4.1%)		Moderate: 227 13.2%	-	-
	12 years	2,340	-	Unilateral uncorrected: 268 (11.4%)	-	Moderate: 116 (5.0%)	-	-
Junghans et al. 2002[16] NSW & VIC	3 - 12 years	2,697	-	-	8 (0.3%)	-	-	2%
Junghans and Crewther (2003)[23] visiting the Vision Education Centre at the University of NSW 1990-94	4 years	2,535 4 -12 yrs	-	-	-	-	1%	-
	12 years	-	-	-	-	-	8.3%	-
	4-12 years	-	-	-	-	-	6.5%	-

Study Author/date	Age	Sample size	Amblyopia	Visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism
Junghans and Crewther (2005)[24] visiting the Vision Education Centre at the University of NSW 1998-2004	4 years	-	-	-	-	-	2.3%	-
	12 years	-	-	-	-	-	14.7%	-
	4-12 years	-	-	-	-	-	8.4%	-
MacKinnon et al. (2004)[4] South-eastern Australia between 1980-2000 The incidence of infantile glaucoma was estimated to be 1 in 30,000 births.								

Table 5: Prevalence studies (international)

Study Author/date	Age	Sample size	Abnormal find	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism	Cataract	Refractive error	Anisometropia	Squint
Anker et al. (2003)[17] Cambridge, UK	8.1 months	5,142	-	-	-	29 0.6%	-	-	-	-	-	108 2.1%	-
Juttman (2001)[18] Rotterdam, Holland	9 months - 2 years	4,072	160 4.0%	-	-	33 0.8%	-	-	-	-	20 0.5%	-	-
Bolger et al. (1991)[7] UK	6 weeks - 3.5 years	Southmead 7,105	-	81 1.1%	-	-	-	-	-	-	-	-	75 1.1%
		Weston-super-Mare 2,977	-	14 0.5%	-	-	-	-	-	-	-	-	8 0.3%
Arnold and Donahue (2006)[20] US	Alaska, US 1-5 years	14,000	-	-	-	58 7.1%	High: 266 32.8%	45 5.5%	148 18.3%	6 0.7%	-	232 28.6%	-
	Tennessee, US 1-6 years	100,827	-	-	-	524 15.4%	High: 554 16.3%	67 2.0%	1015 29.8%	5 0.2%	-	1164 34.2%	-
Donahue et al. (2000)[19] Tennessee, US	6 months - 3.9 years	15,059	-	-	-	31 0.2%	High: 48 0.3%	High: 4 0.03%	48 0.3%	-	-	80 0.5%	-

Study Author/date	Age	Sample size	Abnormal find	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism	Cataract	Refractive error	Anisometropia	Squint
Lim et al. (2000)[9] Bedok, Bukit Batok & Geylang, Singapore	4--4.5 years	450	-	8 1.8%	-	-	-	-	-	-	63 14.0%	-	-
Vision in Preschoolers Study Group (2005)[12] US	3-5 years	1,452	-	77 5.3%	-	31 2.1%	109 9.7%	19 1.3%	195 13.6%	-	74 5.1%	-	-
Newman and East (1999)[8] Cambridge, UK	3.5-5.5 years	597	-	15 2.5%	-	6 1.0%	-	-	-	-	10 1.7%	-	-
Vision in Preschoolers Study Group (2007)[120] US	3-5 years	4,040	-	-	-	157 3.9%	-	-	-	-	-	-	-
Thorburn and Roland (2000)[27] UK	3-3.5 years	2,041	-	-	-	-	-	-	-	-	25 1.2%	-	-
	5 years	2,423	-	-	-	-	-	-	-	-	51 2.1%	-	-

Study Author/date	Age	Sample size	Abnormal find	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism	Cataract	Refractive error	Anisometropia	Squint
Drover et al. (2008)[11] Newfoundland, Canada	4.2 years	946	-	4.7%	-	4.3%	4.8%	1.1%	3.1%	-	-	1.4%	-
Preslan and Novak (1996)[13] Baltimore, US	4-8 years	680	68 10%	27 3.9%	-	21 3.1%	-	21 3.1%	17 2.5%	-	-	18 2.6%	-
Robinson et al. (1999)[10] Ontario, Canada	4.4 years	Year 1 1,174	-	12 1.0%	-	14 1.2%	-	-	-	-	124 10.6%	-	-
		Year 2 1,110	-	10 1.0%	-	15 1.4%	-	-	-	-	132 11.9%	-	-
		Year 3 1,150	-	14 1.2%	-	12 1.0%	-	-	-	-	128 11.1%	-	-
Yawn et al. (1996)[121] Rochester, Minnesota, US	5 years	2,601	1.2%	-	-	-	-	-	-	-	-	-	-
	13 years	1,829	9.1%	-	-	-	-	-	-	-	-	-	-
Donnelly et al. (2005)[22] Northern Ireland	8-9 years	1,582	198 12.5 %	-	-	63 4.0%	54 3.4%	22 1.4%	53 3.4%	-	-	-	-

Study Author/date	Age	Sample size	Abnormal find	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism	Cataract	Refractive error	Anisometropia	Squint
Cummings (1996)[15] Cambridge, UK	8 & 10 years	1,809	-	Mild: 15 0.8% Marked: 11 0.6%	-	-	-	148 8.2%	-	-	-	-	-
Jewell et al. (1994)[45] Oxfordshire, UK	13 years	371	-	-	VA worse than 6/12: 1 or both eyes: 2.7%	-	-	-	-	-	-	-	-
	14 years	377	-	-	VA worse than 6/12: 1 or both eyes: 3.7%	-	-	-	-	-	-	-	-
	15 years	321	-	-	VA worse than 6/12: 1 or both eyes: 5.3%	-	-	-	-	-	-	-	-
Bailey (1998)[28] Texas, US	5-7 years	Total: 391	-	-	9 2.3%	-	-	-	-	-	24 6.1%	-	-
	8-10 years	-	-	-	12 3.1%	-	-	-	-	-	21 5.4%	-	-
	11-13 years	-	-	-	15 3.8%	-	-	-	-	-	29 7.4%	-	-
Blum et al. (1959)[29] (study in 1993)	6 years	-	-	-	-	-	-	4%	-	-	-	-	-

Study Author/date	Age	Sample size	Abnormal find	Amblyopia	Diminished visual acuity	Strabismus	Hyperopia	Myopia	Astigmatism	Cataract	Refractive error	Anisometropia	Squint
California, US	12 years	-	-	-	-	-	-	20%	-	-	-	-	
Zhang et al. (2000[30]; Chung et al. (1996)[31]; Lam and Goh (1991)[32]; Fan et al. (2004)[33]; Yap et al. (1998) China & Hong Kong	5-7 years	DK	-	-	-	-	-	Rural China: 5% Chinese Malays: 24% Urban Hong Kong: 30%	-	-	-	-	-
	11-12 years	DK	-	-	-	-	-	Rural China: 23% Urban China: 40% Chinese Malays: 47% Urban Hong Kong: 57%	-	-	-	-	-
Ganz et al. 2006[122] US	Under 18 years	46,042	6.8%	-	-	-	-	-	-	-	-	-	-
Reskinoff et al. (2008)[49] 5 - 15 years: visual impairment global prevalence 1.0%													

Appendix F AGREE Instrument for appraising guidelines for research and evaluation

	Strongly Agree 4	Agree 3	Disagree 2	Strongly Disagree 1
Scope and Purpose				
The overall objective(s) of the guideline is (are) specifically described				
The clinical question(s) covered by the guideline is (are) specifically described				
The patients to whom the guideline is meant to apply are specifically described				
Stakeholder involvement				
The guideline development group includes individuals from all the relevant professional groups				
The patients' views and preferences have been sought				
The target users of the guideline are clearly defined				
The guideline has been piloted among target users				
Rigour of development				
Systematic methods were used to search for evidence				
The criteria for selecting the evidence are clearly described				
The methods used for formulating the recommendations are clearly described				
The health benefits, side effects and risks have been considered in formulating the recommendations				
There is an explicit link between the recommendations and the supporting evidence				
The guideline has been externally reviewed by experts prior to its publication				
Clarity and presentation				
The recommendations are specific and unambiguous				
The different options for management of the condition are clearly presented				
Key recommendations are clearly identifiable				
The guideline is supported with tools for application				
Applicability				
The potential organisational barriers in applying the recommendations have been discussed				
The potential cost implications of applying the recommendations have been considered				
The guideline presents key review criteria for monitoring and/or audit purposes				
Editorial independence				
The guideline is editorially independent from the funding body				
Conflicts of interest of guideline development members have been recorded				

Source: The Appraisal of Guidelines for Research and Evaluation (AGREE) Collaboration 2001.

Appendix G Australian and international guidelines and policy statements on children's vision screening

Author/Organisation (Year)	Name	Appraisal score	Recommendations
American Academy of Ophthalmology (2002)[123]	Pediatric eye evaluations	RD*: 95 SI#: 58	0-3 months: red reflex, inspection. 3-6 months: fix and follow, red reflex, inspection. 6-12 months: fix and follow, red reflex, inspection, alternate occlusion, corneal light reflex. 3 years: visual acuity (monocular), corneal light reflex, cover/uncover, red reflex, inspection. Repeat these tests at 5 years of age and every 1 to 2 years after age 5. If abnormalities detected, perform comprehensive medical eye examination.
American Academy of Pediatrics (2002)[124]	Red reflex examinations in infants	RD: 29 SI: 17	0-2 months: red reflex (pediatrician or trained primary care clinician). Abnormal result followed up by: (a) red reflex preceded by pupil dilation with eye-drop or spray or (b) examination by ophthalmologist, including ocular fundus examination using indirect ophthalmoscopy after pupil dilation.
American Academy of Pediatrics (2003)[125]	Eye examination in infants, children and young adults by paediatricians	RD: 57 SI: 58	0-3 years: ocular history, vision assessment, external inspection of the eyes/lids, ocular motility assessment (corneal reflex test, cross cover test, random dot E test), pupil examination, and red reflex examination. 3-5 years: visual acuity (Snellen letters, Snellen numbers, Tumbling E, HOTV, picture tests – Allen figures, Lea symbols, ocular alignment (cross cover test, Random dot E test, simultaneous red reflex test/Bruckner test), ocular media clarity (red reflex). 6+ years: as per 3-5 years. Visual acuity testing recommended from age 3. Uncooperative children aged 4 years and older to be retested 1 month later. Referral of uncooperative children or abnormal results to paediatric ophthalmologist or eye care specialist.
American Optometric Association (2002)[126]	Paediatric eye and vision examination	RD: 38 SI: 33	0-2 years 11 months: patient history, 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, Bruckner test, versions, near point of convergence). Preschool aged: as above, except visual acuity with Lea symbols, broken wheel acuity cards, HOTV test, refraction with static retinoscopy, cycloplegic retinoscopy, accommodation and ocular motility with cover test, positive and negative fusional vergences, near point of convergence, stereopsis, monocular estimation method retinoscopy, versions. School aged: as Preschool aged, except visual acuity with Snellen, modified for children 6-8 years, subjective refraction, ocular motility as Preschool aged but also with accommodative amplitude and facility.
American Public	Improving early	Not	Encourages comprehensive eye examinations at 6 months, 2 years and 4 years (as

Author/Organisation (Year)	Name	Appraisal score	Recommendations
Health Association (2001)[127]	childhood eyecare	reviewed as a guideline (policy statement)	opposed to just screening) based on the onset of strabismus and amblyopia. Encourages paediatricians to recommend all children receive exams which have the ability to detect all cases of strabismus, amblyopia, and refractive errors, and refer children at high-risk.
Colorado Department of Education (2006)[2]	Guidelines for school vision screening programs: Kindergarten through to Grade 12	RD: 29 SI: 25	K: history and observation, distance visual acuity and alternate cover test. Grade 1: as above, plus lens, near vision card, near point convergence, stereo/depth and colour vision. Grades 2, 3, 5, 7, 9 and Special Education: medical history, observation and distance visual acuity test. New or referred students: full array of tests.
Community Paediatrics Committee (1998)[128]	Vision screening in infants, children and youth	RD: 29 SI: 16	0-3 months: examination of external eye structure, red reflex, corneal light reflex, tests for signs of posterior eye disease. 6-12 months: as above, plus ocular alignment, fixation and following. 3-5 years: as above, plus visual acuity with optotype test (E acuity card or Allen chart) Referral criteria = less than 6/9. Visual acuity assessed every 2 years until age 10, then every 3 years (Snellen chart).
Friedman and Kaufman(2003)[129]	Guidelines for paediatrician referrals to the ophthalmologist	RD: 38 SI: 25	Refer to ophthalmologist: (1) children with no eye complaints, no eye findings, no significant family ocular history, no systemic risk factors for eye diseases, but are aged 4 years. (2) children with no eye complaints, no eye findings, but a positive family history of hereditary eye disease. (3) children with no eye complaints, no eye findings, but positive for a systemic disease (either confirmed or ruled out) with possible ocular involvement. (4) children with positive ocular complaints and no eye findings. (5) children with positive eye findings or failed vision or eye screening.
Hartmann et al. (2001)[130]	Maternal and child health bureau and national eye institute task force on vision screening in the preschool child. Preschool vision screening: summary of a task force report	Not reviewed (interim guidelines only)	3-4 years: monocular visual acuity (HOTV, Lea symbols, tumbling E charts or isolated optotypes with surround bars). Stereopsis testing for detection of strabismus (Random Dot E test).
Missouri Department of Health and Senior Services (2004)[131]	Guidelines for vision screening	RD: 43 SI: 25	0-2 years: functional assessments at any visit. 3 years: visual acuity, then yearly through age 7, then at least every 2 years. Priority screening: new, referred, special education and high-risk students. Grades 3, 5, 7, 9 and 11: screen as resources permit.

Author/Organisation (Year)	Name	Appraisal score	Recommendations
Ressel (2003)[132]	Practice guidelines; AAP releases policy statement on eye examinations	RD: 29 SI: 25	0-3 years: fix and follow (binocularly and monocularly), ocular history, family history, corneal reflex test, cross cover test, random dot E test. 3 years: visual acuity. Uncooperative children tested in another 4-6 months, unless aged 4 years or older, in which case retested after 1 month.
Royal Australian and New Zealand College of Ophthalmology (RANZCO) (2006)[133]	Position statement – eye examinations	Not reviewed (position statement, not guideline)	Children: all newborn's eyes examined by skilled professional. All children screened by age 5 years, or earlier if family history or outward signs Puberty to age 39: eye examination if experience any ocular symptoms, such as visual changes, flashes of light, pain and so on.
Royal Australian and New Zealand College of Ophthalmology (RANZCO) and Orthoptic Association of Australia (OAA) (Year: Not stated)[134]	Guidelines for Paediatric Vision Screening	RD: 71 SI: 50	Newborn and 6 weeks: eye health check, red reflex using ophthalmoscope by paediatrician or trained medical officer, referral if problems suspected or high-risk infant. 0-3 years: at-risk children only, screening by orthoptist if family history, developmentally delayed, turned eye, frequently closing one eye, excessive squinting or clumsiness. School entry: visual acuity at 6 m by nurse with Sheridan Gardiner linear vision chart. Referral if less than 6/9 to orthoptist.
US Preventative Services Task Force (2005)[95]	Screening for visual impairment in children younger than five years	RD: 71 SI: 17	The USPSTF found no direct evidence that screening improves visual acuity in preschool children. However, it found fair evidence that screening tests have 'reasonable accuracy' in identifying strabismus, amblyopia, and refractive error. Also, more intensive screening compared to usual screening leads to improved visual acuity, and early detection and treatment of amblyopia and amblyogenic risk factors can improve visual acuity. The USPSTF found no evidence of harms of screening, and judged the potential for harms to be small. These recommendations are 'B level' which indicates that fair evidence was found that the outcomes of preschool vision screening can outweigh the harms, and this service should be provided

*** RD = Rigour of Development**

#SI = Stakeholder Involvement

Appendix H Australian eye health practitioner workforce

Profession	Total workforce	Registered	Can test vision	Can prescribe glasses	Can prescribe contact lenses	Services can be provided under Medicare	Referral required?
Ophthalmologist[135]	10221	Yes	Yes	Yes	Yes	Yes	Yes
Optometrist[136]	39502	Yes	Yes	Yes	Yes	Yes	No
Orthoptist*[137]	2813	Not mandatory	Yes	With current referral/under supervision: varies between States	No	No	Provide secondary or tertiary care

*This figure represents the number of orthoptists registered with the Australian Orthoptic Board. It may not be representative of the number of orthoptists currently practising.

Appendix I   Economic evaluation assessment form

	Yes	Can't tell	No
Was a well-defined question posed in answerable form?			
Did the study examine both costs and effects of the service or program?			
Did the study involve comparisons of alternatives?			
Was the viewpoint of the analysis stated, and was the study placed in any decision-making context?			
Was a comprehensive description of the competing alternatives given: who did what to whom, where and how often?			
Were any important alternatives omitted?			
Was (should) a 'do nothing' alternative (be) considered?			
Was there any evidence that the programs' clinical effectiveness had been established?			
Was this done through a randomised controlled trial? If not, how strong was the evidence of effectiveness?			
Were all the important and relevant costs and effects for each alternative identified?			
Was the range of costs and effects wide enough for the research question at hand?			
Did it cover all relevant viewpoints (e.g. patients, health service, society)?			
Were capital as well as operating costs included?			
Were costs and effects measured accurately in appropriate physical units (e.g. hours of nursing time, life-years gained?			
Were any identified items omitted from measurement? If so, did this affect the subsequent analysis?			
Were there any special circumstances (e.g. shared use of resources) that made measurement difficult? If so, were these handled appropriately?			
Were costs and consequences valued credibly?			
Were sources of values identified (e.g. market prices, patients' valuations…)?			
Were market values used for changes involving resources gained or depleted?			
Where market values were absent (e.g. volunteer labour), were adjustments made to approximate market values?			
Was the valuation of consequences appropriate for the research question (i.e. was the appropriate analysis used – cost-effectiveness, cost-benefit, etc)?			
Was an incremental analysis of costs and consequences of alternatives performed?			
Were the additional incremental costs generated by one alternative over another compared to the additional effects, benefits or utilities generated?			
Were costs and consequences adjusted for differential timing?			
Were costs and effects occurring in the future adjusted (i.e. 'discounted')?			
Was there any justification for the discount rate used?			
Were a range of discount rates used, including no zero?			

Was a sensitivity analysis performed?			
Was there any justification for the range of values for key study parameters used in the sensitivity analysis?			
Were study results sensitive to changes in values within the assumed range?			
Did the presentation and discussion of study results include all issues of concern to users?			
Were the conclusions of the analysis based on some overall index or ratio of costs to effects (e.g. cost-effectiveness ratio)? If so, was the index interpreted intelligently or mechanistically?			
Were the results compared with those of others who have investigated the same question?			
Did the study discuss the generalisability of the results?			
Did the study discuss or take account of other important factors in the decision under consideration (e.g. ethical or equity issues)?			
Did the study discuss issues of implementation, such as the feasibility of adopting the 'preferred' solution in practice?			

Source: Adaptation of a checklist produced by Drummond, M., Stoddart, G., Torrance, G. in *Methods for the Economic Evaluation of Health Care Programmes*. Oxford: Oxford University Press, 1987. Adapted by Appelby, J. (1997). Critically appraising economic evaluations. Evidence-Based Health Policy and Management, 1 (3), 54-55.

Glossary

Vision terms

Accommodation: The adjustment of the focus of the eye for varying distances to allow a sharp image to be formed on the retina. This occurs by altering the shape of the lens.

Amblyopia: Reduced visual acuity in the absence of organic disease, which cannot be improved by spectacles.

Ametropia: A condition such as hypermetropia, myopia or astigmatism in which a refractive error prevents the eye from focusing light on the retina.

Anisometropia: A difference in refractive error of the two eyes. In a clinical context, anisometropia is used to describe a clinically significant refractive error between the eyes.

Aqueous humour: The transparent fluid that circulates in the eye chamber between the back of the cornea and the front of the iris and pupil.

Astigmatism: Refractive error which prevents light rays from coming to a single focus on or near the retina.

Binocular: Involving or using both eyes, or relating to vision using both eyes.

Binocular single vision: The simultaneous use of both eyes so that each eye contributes to a common singular perception.

Cataract: An eye disease in which part or all of the lens becomes ‘opaque’, eventually causing total loss of sight.

Congenital: Describes an unusual condition present at birth.

Conjunctivitis: Inflammation of the conjunctiva (membrane covering the internal eyelid and visible white part of the eye) caused by infection, injury, or allergy.

Cortical blindness: The total or partial loss of vision in a normal-appearing eye caused by damage to the visual area in the brain's occipital cortex.

Cover-uncover test: A test used to detect squint. Each eye is covered in turn while the child is asked to fixate on a target, and the tester observes the movements of the eye.

Cycloplegic drugs: Drugs that block action of the ciliary muscle, preventing accommodation. The pupil also dilates.

Dioptre (D): Unit of measurement of the power of a lens.

Diplopia: Double vision or seeing two images of the one object simultaneously.

Emmetropia: Light rays are brought to a focus on the retina without using accommodation.

Glaucoma: An eye disorder that may be associated with high pressure within the eyeball that leads to damage of the optic disc.

Goniotomy: An operation to treat glaucoma by cutting into the narrow angle between the back of the cornea and the root of the iris to allow drainage of aqueous humour.

Heterotropia: An alignment of the eyes that differs from the usual.

Hypermetropia (long sightedness): Refractive error when the focal point of light rays is behind the retina when the eye is not accommodating.

Hyperopia: Long-sightedness, as above.

Intermittent squint: Manifest squints apparent at some times or distances but the visual axes are aligned at others.

Latent squint (heterophoria): With both eyes open the visual axes are aligned. When one eye is covered, the undercover eye deviates. When the cover is removed, the eye comes back into alignment.

LogMAR scale: Scale used to measure visual acuity. Refers to the log of the minimum angle of resolution.

Manifest squint (heterotropia): With both eyes open the visual axis of one eye is deviated from the fixation point. It may be constant or intermittent.

Microsquint (microtropia): A small angle heterotropia usually of 10 prism dioptres or less, associated with amblyopia, eccentric fixation, or anomalous retinal correspondence.

Microtropia: see *Microsquint*

Myopia (short sightedness): Refractive error where light rays come to focus in front of the retina.

Nystagmus: An involuntary rhythmic movement of the eyes, usually from side to side, caused by some illnesses that affect the nerves and muscles behind the eyeball.

Occlusion: Obscuring the vision of one eye, totally or partially, to prevent or reduce visual stimulation.

Ophthalmologist: A medical doctor who is educated, trained and registered to provide total care of the eyes, from performing comprehensive eye examinations to prescribing corrective lenses, diagnosing diseases and disorders of the eye, and carrying out the medical and surgical procedures necessary for their treatment.

Optic Nerve Hypoplasia: The failure of the optic nerve to grow or develop fully.

Optometrist: Primary eye care practitioner trained to assess the eye and the visual system, and diagnose refractive disorders and eye disease. An optometrist prescribes and dispenses corrective and preventative devices and works with other eye care professionals to ensure that patients are referred appropriately for diagnostic and therapeutic needs. Optometrists also prescribe drugs for certain eye conditions and monitor long-term eye conditions.

Orthoptist: Specialises in diagnosing and managing disorders of eye movements and associated vision problems. An orthoptist performs investigative procedures appropriate to disorders of the eye and visual system and assist with rehabilitating patients with vision loss. Orthoptists also diagnose refractive disorders and prescribe glasses on referral from an ophthalmologist or optometrist.

Presbyopia: Progressive reduction in the eye's ability to alter focus, with consequent difficulty in reading at the normal distance, associated with ageing.

Refractive error: The powers of the corrective lenses needed to focus a distant object on the retina in the absence of accommodation.

Retinoblastoma: A malignant tumour of the eye, usually resulting from a genetic disorder and appearing in early childhood.

Snellen scale: Scale used to measure visual acuity.

Squint: Lay term for strabismus. A condition in which the eyes are not aligned in parallel, causing a cross-eyed appearance.

Stereoacuity: The ability to detect differences in distance using stereoscopic cues that is measured by the smallest difference in the images presented to the two eyes that can be detected reliably.

Stereopsis: The blending of two slightly different images seen by both eyes into one single image, resulting in a three-dimensional image.

Strabismus: The misalignment of the visual axes of the two eyes (manifest or latent).

Trachoma: A contagious bacterial eye disease in which scar tissue forms inside the eyelid, eventually causing it to curve inwards and the eyelashes to scrape the eye and cause infection.

Visual acuity: The finest detail that an eye can distinguish using LogMar or Snellen scales.

Epidemiological terms

Controlled clinical trial: A clinical study that compares people getting treatment (treatment group) to people who do not receive this treatment (control group).

False negatives: Participants who receive a negative test result, but who really do have the condition.

False positives: Participants who receive a positive test result, but who actually do not have the condition.

Intention to treat: An intention to treat analysis requires that participants be analysed in the groups they were randomised into, regardless of whether they complied with the treatment they were given.

Negative predictive value: Proportion of participants who received a negative test result and who did not have the condition.

Non-randomised controlled trial: 1. A comparative study with concurrent controls: Non-randomised, experimental trial; Cohort study; Case-control study; Interrupted time series with a control group. 2. A comparative study without concurrent controls: Historical control study; Two or more single arm study; Interrupted time series without a parallel control group.

Positive predictive value: Proportion of participants who received a positive test result and who did have the condition.

Prevalence: Occurrence rates.

Randomised controlled trial: The unit of experimentation (e.g., people, or a cluster of people) is allocated to either an intervention (the factor under study) group or a control group, using a random mechanism (such as a coin toss, random number table, computer-generated random numbers) and the outcomes from each group are compared.

Screening: Presumptive identification of unrecognised disease/defect by the administration of tests, exams or other procedures which can be applied promptly to a whole population.
Sensitivity (true positive): Proportion of children with the condition in a population who are correctly identified by the screen.

Specificity (true negative): Proportion of children without the condition in a population who are correctly identified by the screen.

Systematic review: Systematic location, appraisal and synthesis of evidence from scientific studies.

Yield: The proportion of children in a screened population who are found to have a condition.

Common screening tests

Corneal reflex test (Hirschberg test): Test performed by shining a light in the person's eyes and observing where the light reflects off the corneas. In a person with normal ocular alignment the light lands on the centre of both corneas. For an abnormal result, the examiner can detect if there is an exotropia (abnormal eye is turned out), esotropia (abnormal eye is turned in), hypertropia (abnormal eye higher than the normal one) or hypotropia (abnormal eye is lower than the normal one).

Cover-uncover test: A test to detect strabismus; the person's attention is directed to a small fixation object, one eye is covered and after a few seconds, uncovered; if the uncovered eye moves to see the picture, strabismus is present.

HOTV chart: Test to measure visual acuity. Chart made up of the letters "H", "O", "T", and "V". The child needs to match the indicated symbols on a wall chart with those on the response card.
Lea Symbols: A complete set of visual acuity tests for near and far distance vision. LEA symbols are based on four symbols: circle, square, house, and apple. The child needs to match the indicated symbols on a wall chart with those on the response card.

MIST (Melbourne Initial Screening Test): The test has been designed as a simplified vision screening test for 3.5 to 4.5 year olds to be performed by maternal and child health nurses in Victoria. It is a letter matching test, and has a pass/fail method of assessment rather than a threshold of visual acuity. There are 5 test letters.

Photoscreening: A vision screening technique used to screen for amblyogenic factors in one or both eyes in children. Using a camera or video system appropriately equipped for photoscreening, images of the pupillary reflexes (reflections) and red reflexes (Brückner test) are obtained. The child is asked to fixate on an appropriate target long enough for the photoscreening. Data are then analysed by the evaluator, reviewing centre, or computer for amblyogenic factors.

Red reflex: The red reflex refers to the reddish-orange reflection from the eye's retina that is observed when using an ophthalmoscope or retinoscope. Many eye problems may be detected by this test, such as cataracts and retinoblastoma.

Sheridan Gardiner test: Measures visual acuity. Contains both near vision and distance vision tests and reduced Snellen tests. Testing depends on matching shapes rather than identifying or naming letters.

Snellen chart: A chart for testing visual acuity, usually consisting of letters, numbers, or pictures printed in lines of decreasing size which a person is asked to read or identify at a fixed distance.

Treatment terms

Atropine: A poisonous alkaloid obtained from the deadly nightshade plant that can be used as a muscle relaxant.

Occlusion: Something that obstructs or occludes (in this case, obstruction of the eye).

Patching: A method of occlusion (i.e. to place a patch over the eye).

References

1. Wilson, J. and G. Jungner, *Principles and practice of screening for disease*. 1968, Geneva: WHO.
2. Colorado Department of Education, *Guidelines for school vision screening programs: Kindergarten through to Grade 12.* 2006.
3. Thyer, S., *Health promoting schools: Primary school teachers' perceptions of their need for information related to child health issues.* Masters Thesis. University of Western Sydney, Nepean. , 1993.
4. MacKinnon, J.R., et al., *Primary infantile glaucoma in an Australian population.* Clinical & Experimental Ophthalmology, 2004. **32**(1): p. 14-8.
5. Ip, J.M., et al., *Prevalence of eye disorders in young children with eyestrain complaints.* American Journal of Ophthalmology, 2006. **142**(3): p. 495-7.
6. Robaei, D., et al., *Causes and associations of amblyopia in a population-based sample of 6-year-old Australian children.* Archives of Ophthalmology, 2006. **124**(6): p. 878-884.
7. Bolger, P.G., et al., *Vision screening in preschool children: Comparison of orthoptists and clinical medical officers as primary screeners.* British Medical Journal, 1991. **303**(6813): p. 1291-1294.
8. Newman, D.K. and M.M. East, *Preschool vision screening: negative predictive value for amblyopia.* British Journal of Ophthalmology, 1999. **83**(6): p. 676-9.
9. Lim, H.C., et al., *Vision screening of 4-year-old children in Singapore.* Singapore Medical Journal, 2000. **41**(6): p. 271-8.
10. Robinson, B., et al., *Measurement of the validity of a preschool vision screening program.* American Journal of Public Health, 1999. **89**(2): p. 193-8.
11. Drover, J.R., et al., *Prevalence of amblyopia and other vision disorders in young Newfoundland and Labrador children.* Canadian Journal of Ophthalmology, 2008. **43**(1): p. 89-94.
12. The Vision in Preschoolers Study Group, *Preschool vision screening tests administered by nurse screeners compared with lay screeners in the vision in preschoolers study.* Investigative Ophthalmology & Visual Science, 2005. **46**(8): p. 2639-48.
13. Preslan, M.W. and A. Novak, *Baltimore vision screening project.* Ophthalmology, 1996. **103**(1): p. 105-109.
14. Robaei, D., et al., *Impact of amblyopia on vision at age 12 years: findings from a population-based study.* Eye, 2008. **22**: p. 496-502.
15. Cummings, G.E., *Vision screening in junior schools.* Public Health, 1996. **110**(6): p. 369-72.
16. Junghans, B., et al., *Referral rates for a functional vision screening among a large cosmopolitan sample of Australian children.* Ophthalmic & Physiological Optics, 2002. **22**(1): p. 10-25.
17. Anker, S., et al., *Identification of infants with significant refractive error and strabismus in a population screening program using noncycloplegic videorefraction and orthoptic examination.* Investigative Ophthalmology & Visual Science, 2003. **44**(2): p. 497-504.
18. Juttmann, R., *The Rotterdam AMblyopia Screening Effectiveness Study (RAMSES): compliance and predictive value in the first 2 years.* British Journal of Ophthalmology, 2001. **85**(11): p. 1332-5.
19. Donahue, S.P., T.M. Johnson, and T.C. Leonard-Martin, *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): p. 1637-1646.
20. Arnold, R.W. and S.P. Donahue, *The yield and challenges of charitable state-wide photoscreening.* Binocular Vision and Strabismus Quarterly, 2006. **21**(2): p. 93-100.

21. The Vision In Preschoolers Study Group, *Impact of confidence number on the screening accuracy of the retinomax autorefractor.* Optometry & Vision Science, 2007. **84**(3): p. 181-8.
22. Donnelly, U.M., N.M. Stewart, and M. Hollinger, *Prevalence and outcomes of childhood visual disorders.* Ophthalmic Epidemiology, 2005. **12**(4): p. 243-50.
23. Junghans, B.M. and S.G. Crewther, *Prevalence of myopia among primary school children in eastern Sydney.* Clinical & Experimental Optometry, 2003. **86**(5): p. 339-45.
24. Junghans, B.M. and S.G. Crewther, *Little evidence for an epidemic of myopia in Australian primary school children over the last 30 years.* BMC Ophthalmology, 2005. **5**(1): p. 1.
25. Robaei, D., et al., *Visual acuity and the causes of visual loss in a population-based sample of 6-year-old Australian children.* Ophthalmology, 2005. **112**(7): p. 1275-1282.
26. Ip, J.M.I., et al., *Prevalence of Hyperopia and Associations with Eye Findings in 6- and 12-Year-Olds.* Ophthalmology, In press.
27. Thorburn, R. and M. Roland, *Research study. The effectiveness of preschool vision screening by health visitors.* British Journal of Community Nursing, 2000. **5**(1): p. 41-4.
28. Bailey, R.N., *Assessing the predictive ability of the testpositive findings of an elementary school vision screening.* Optometry and Vision Science, 1998. **75**(9): p. 682-691.
29. Blum, H., H. Peters, and J. Bettman, *Vision screening for elementary schools*. 1959, Berkeley: University of California Press.
30. Zhang, M.Z., et al., *Refractive errors in Singapore and Xiamen, China--a comparative study in school children aged 6 to 7 years.* Optometry & Vision Science, 2000. **77**(6): p. 302-8.
31. Chung, K.M., et al., *Prevalence of visual disorders in Chinese schoolchildren.* Optometry & Vision Science, 1996. **73**(11): p. 695-700.
32. Lam, C.S. and W.S. Goh, *The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components.* Clinical & Experimental Ophthalmology, 1991. **74**(3): p. 97-103.
33. Fan, D., et al., *Prevalence, incidence, and progression of myopia of school children in Hong Kong.* Investigative Ophthalmology & Visual Science, 2004. **45**(4): p. 1071-1075.
34. Yap, E.Y., et al., *Ophthalmic manifestations in Asian patients with systemic lupus erythematosus.* Singapore Medical Journal, 1998. **39**(12): p. 557-9.
35. Robaei, D., et al., *Refractive Error and Patterns of Spectacle Use in 12-Year-Old Australian Children.* Ophthalmology, 2006. **113**(9): p. 1567-1573.
36. Atkinson, J., et al., *Two infant vision screening programmes: prediction and prevention of strabismus and amblyopia from photo- and videorefractive screening.* Eye, 1996. **10**(Pt 2): p. 189-98.
37. Atkinson, J., et al., *Infant hyperopia: detection, distribution, changes and correlates-outcomes from the cambridge infant screening programs.* Optometry & Vision Science, 2007. **84**(2): p. 84-96.
38. Fathy, V.C. and P.J. Elton, *Orthoptic screening for three- and four-year-olds.* Public Health, 1993. **107**(1): p. 19-23.
39. Williams, C., et al., *Screening for amblyopia in preschool children: results of a population-based, randomised controlled trial. ALSPAC Study Team. Avon Longitudinal Study of Pregnancy and Childhood.* Ophthalmic Epidemiology, 2001. **8**(5): p. 279-95.
40. Williams, C., et al., *Amblyopia treatment outcomes after screening before or at age 3 years: follow up from randomised trial.* BMJ, 2002. **324**(7353): p. 1549.
41. Eibschitz-Tsimhoni, M., et al., *Early screening for amblyogenic risk factors lowers the prevalence and severity of amblyopia.* Journal of Aapos: American Association for Pediatric Ophthalmology & Strabismus, 2000. **4**(4): p. 194-9.

42. Williams, C., et al., *Amblyopia treatment outcomes after preschool screening v school entry screening: observational data from a prospective cohort study.[see comment].* British Journal of Ophthalmology, 2003. **87**(8): p. 988-93.
43. Kvarnstrom, G., P. Jakobsson, and G. Lennerstrand, *Screening for visual and ocular disorders in children, evaluation of the system in Sweden.* Acta Paediatrica, 1998. **87**(11): p. 1173-9.
44. Kvarnstrom, G., P. Jakobsson, and G. Lennerstrand, *Visual screening of Swedish children: an ophthalmological evaluation.* Acta Ophthalmologica Scandinavica, 2001. **79**(3): p. 240-4.
45. Jewell, G., et al., *The effectiveness of vision screening by school nurses in secondary school.* Archives of Disease in Childhood, 1994. **70**(1): p. 14-8.
46. Powell, C., S. Wedner, and S. Hatt, *Vision screening for correctable visual acuity deficits in school-age children and adolescents.* Cochrane Database of Systematic Reviews, 2004. **4**.
47. Powell, C., et al., *Screening for amblyopia in childhood.* Cochrane Database of Systematic Reviews, 2005(3): p. CD005020.
48. Weinstock, V.M., D.J. Weinstock, and S.P. Kraft, *Screening for childhood strabismus by primary care physicians.* Canadian Family Physician, 1998. **44**: p. 337-43.
49. Resnikoff, S., et al., *Global magnitude of visual impairment caused by uncorrected refractive errors in 2004.* Bulletin of the World Health Organization, 2008. **86**(1): p. 63-70.
50. Kemper, A.R., R.L. Uren, and S.J. Clark, *Barriers to follow-up eye care after preschool vision screening in the primary care setting: findings from a pilot study.* Journal of Aapos: American Association for Pediatric Ophthalmology & Strabismus, 2006. **10**(5): p. 476-8.
51. Yawn, B.P., et al., *Barriers to seeking care following school vision screening in Rochester, Minnesota.* Journal of School Health, 1998. **68**(8): p. 319-24.
52. Kimel, L.S., *Lack of follow-up exams after failed school vision screenings; an investigation of contributing factors.* Journal of School Nursing, 2006. **22**(3): p. 156-62.
53. Mark, H. and T. Mark, *Parental reasons for non-response following a referral in school vision screening.* Journal of School Health, 1999. **69**(1): p. 35-8.
54. Rahi, J.S. and C. Dezateux, *National cross sectional study of detection of congenital and infantile cataract in the United Kingdom: role of childhood screening and surveillance. The British Congenital Cataract Interest Group.* BMJ, 1999. **318**(7180): p. 362-5.
55. Smith, L.K., J.R. Thompson, and G. Woodruff, *Children's vision screening: Impact on inequalities in central England.* Journal of Epidemiology and Community Health, 1995. **49**(6): p. 606-609.
56. Milne, C., *An evaluation of cases referred to hospital by the Newcastle pre-school orthoptic service.* Br Orthoptic J, 1994. **51**: p. 1-5.
57. Concannon, P. and F. Robinson, *Teacher's questionnaire for vision problems: is it a help or a hindrance for school health screening?* Australian & New Zealand Journal of Public Health, 1997. **21**(1): p. 37-9.
58. Scherrer, S. and J.A. Stevens, *An evaluation of the accuracy and efficiency of a school screening model that uses a questionnaire.* International Journal of Nursing Practice, 1997. **3**(2): p. 89-96.
59. Edgecombe, G.A., et al., *School nurse assessment of primary school children: analysis of data from the school entrant health questionnaire.* International Journal of Nursing Practice, 1998. **4**(1): p. 40-50.
60. Bradley, L.J. and M.L. Riederer, *The Vision First Check Program in British Columbia: a preschool vision screening program for children age two and age three.* Canadian Journal of Public Health, 2000. **Revue Canadienne de Sante Publique. 91**(4): p. 252-5.
61. Filipovic, T., R. Grzetic, and D. Sviderek-Stalekar, *Earlier detection of amblyopia and strabismus by ophthalmologic screening card attached to the vaccination card.* Canadian Journal of Ophthalmology, 2003. **38**(7): p. 587-92.

62. Lennerstrand, G., P. Jakobsson, and G. Kvarnstrom, *Screening for ocular dysfunction in children: approaching a common program.* Acta Ophthalmologica Scandinavica Supplement, 1995(214): p. 26-38; discussion 39-40.
63. Castanes, M.S., *Major review: The underutilization of vision screening (for amblyopia, optical anomalies and strabismus) among preschool age children.* Binocular Vision & Strabismus Quarterly, 2003. **18**(4): p. 217-32.
64. Pattison, B. and K. Plymat, *Vision screening of school children: should it be continued?* Contemporary Nurse, 2001. **10**(3-4): p. 163-71.
65. Snowdon, S.K. and S.L. Stewart-Brown, *Preschool vision screening.* Health Technology Assessment, 1997. **1**(8): p. i-iv.
66. Bray, L.C., et al., *Preschool vision screening: a prospective comparative evaluation.[see comment].* Eye, 1996. **10**(Pt 6): p. 714-8.
67. Jarvis, S.N., et al., *Preschool vision screening.* Archives of Disease in Childhood, 1990. **65**(3): p. 288-94.
68. Wormald, R.P., *Preschool vision screening in Cornwall: performance indicators of community orthoptists.* Archives of Disease in Childhood, 1991. **66**(8): p. 917-20.
69. Paech, M. and H. Calabretto, *Screening the vision of school-aged children: an interdisciplinary research approach.* Australian Journal of Advanced Nursing, 1999. **17**(2): p. 7-12.
70. Yazawa, K., et al., *The Tokyo Metropolitan home vision screening program for amblyopia in 3- year-old children.* American Journal of Ophthalmology, 1992. **114**(4): p. 416-419.
71. Hartmann, E.E., et al., *Project Universal Preschool Vision Screening: a demonstration project.* Pediatrics, 2006. **117**(2).
72. Spowart, K.M., A. Simmers, and D.M. Tappin, *Vision testing in schools: an evaluation of personnel, tests, and premises.* Journal of Medical Screening, 1998. **5**(3): p. 131-2.
73. Atkinson, J., et al., *Infant vision screening predicts failures on motor and cognitive tests up to school age.* Strabismus, 2002. **10**(3): p. 187-198.
74. Atkinson, J., et al., *Refractive errors in infancy predict reduced performance on the movement assessment battery for children at 3 1/2 and 5 1/2 years.* Developmental Medicine & Child Neurology, 2005. **47**(4): p. 243-51.
75. Roch-Levecq, A.-C., et al., *Ametropia, preschoolers' cognitive abilities, and effects of spectacle correction.* Archives of Ophthalmology, 2008. **126**(2): p. 252-8; quiz 161.
76. Williams, W.R., et al., *Hyperopia and educational attainment in a primary school cohort.* Archives of Disease in Childhood, 2005. **90**(2): p. 150-3.
77. Krumholtz, I., *Results from a pediatric vision screening and its ability to predict academic performance.[erratum appears in Optometry. 2000 Aug;71(8):489].* Optometry, 2000. **71**(7): p. 426-30.
78. Maples, W.C., *Visual factors that significantly impact academic performance.[erratum appears in Optometry. 2003 Feb; 74(2):74.].* Optometry, 2003. **74**(1): p. 35-49.
79. Johnson, R., et al., *The vision screening of academically and behaviorally at-risk pupils.* Journal of Behavioral Optometry, 1996. **7**(2): p. 39.
80. Goldstand, S., K.C. Koslowe, and S. Parush, *Vision, visual-information processing, and academic performance among seventh-grade schoolchildren: a more significant relationship than we thought?* American Journal of Occupational Therapy, 2005. **59**(4): p. 377-89.
81. Kulp, M.T. and P.P. Schmidt, *Visual predictors of reading performance in kindergarten and first grade children.* Optometry & Vision Science, 1996. **73**(4): p. 255-62.
82. Stifter, E., et al., *Monocular and binocular reading performance in children with microstrabismic amblyopia.* British Journal of Ophthalmology, 2005. **89**(10): p. 1324-9.
83. Scheiman, M.M., et al., *Randomized trial of treatment of amblyopia in children aged 7 to 17 years.[see comment].* Archives of Ophthalmology, 2005. **123**(4): p. 437-47.

84. Clarke, M.P., et al., *Randomised controlled trial of treatment of unilateral visual impairment detected at preschool vision screening.[see comment].* BMJ, 2003. **327**(7426): p. 1251.
85. Bowman, R.J., et al., *An inner city preschool visual screening programme: long-term visual results.* British Journal of Ophthalmology, 1998. **82**(5): p. 543-8.
86. Pediatric Eye Disease Investigator Group, *A comparison of atropine and patching treatments for moderate amblyopia by patient age, cause of amblyopia, depth of amblyopia, and other factors.* Ophthalmology, 2003. **110**(8): p. 1632-7; discussion 1637-8.
87. Stewart, C.E., et al., *Objectively monitored patching regimens for treatment of amblyopia: randomised trial.[see comment].* BMJ, 2007. **335**(7622): p. 707.
88. Awan, M., F.A. Proudlock, and I. Gottlob, *A randomized controlled trial of unilateral strabismic and mixed amblyopia using occlusion dose monitors to record compliance.* Investigative Ophthalmology & Visual Science, 2005. **46**(4): p. 1435-9.
89. Mohan, K., V. Saroha, and A. Sharma, *Successful Occlusion Therapy for Amblyopia in 11- to 15-Year-Old Children.* Journal of Pediatric Ophthalmology and Strabismus, 2004. **41**(2): p. 89-95.
90. Newman, D.K., et al., *Preschool vision screening: Outcome of children referred to the hospital eye service.* British Journal of Ophthalmology, 1996. **80**(12): p. 1077-1082.
91. Holmes, J.M., et al., *Risk of amblyopia recurrence after cessation of treatment.* Journal of Aapos: American Association for Pediatric Ophthalmology & Strabismus, 2004. **8**(5): p. 420-8.
92. Holmes, J.M., et al., *Factors associated with recurrence of amblyopia on cessation of patching.* Ophthalmology, 2007. **114**(8): p. 1427-32.
93. Ingram, R.M., et al., *Emmetropisation, squint, and reduced visual acuity after treatment.* British Journal of Ophthalmology, 1991. **75**(7): p. 414-6.
94. Atkinson, J., et al., *Normal emmetropization in infants with spectacle correction for hyperopia.* Investigative Ophthalmology & Visual Science, 2000. **41**(12): p. 3726-31.
95. Force, U.P.S.T., *Screening for visual impairment in children younger than five years.* 2005.
96. Birch, E.E., et al., *Outcome after very early treatment of dense congenital unilateral cataract.* Investigative Ophthalmology & Visual Science, 1993. **34**(13): p. 3687-99.
97. Preslan, M.W. and A. Novak, *Baltimore vision screening project: Phase 2.* Ophthalmology, 1998. **105**(1): p. 150-153.
98. Hard, A.-L., et al., *Preschool vision screening in a Swedish city region: results after alteration of criteria for referral to eye clinics.* Acta Ophthalmologica Scandinavica, 2002. **80**(6): p. 608-11.
99. Hard, A.L., *Results of vision screening of 6-year-olds at school: A population-based study with emphasis on screening limits.* Acta Ophthalmologica Scandinavica, 2007. **85**(4): p. 415-418.
100. Williamson, T.H., et al., *Assessment of an inner city visual screening programme for preschool children.* British Journal of Ophthalmology, 1995. **79**(12): p. 1068-1073.
101. Stocks, N.P., J.E. Hiller, and H. Newland, *Visual acuity in an Australian aboriginal population.* Australian & New Zealand Journal of Ophthalmology, 1997. **25**(2): p. 125-31.
102. Blair, E.M., et al., *The Western Australian Aboriginal Child Health Survey: findings to date on adolescents.* Medical Journal of Australia, 2005. **183**(8): p. 433-5.
103. Paterson, B., A. Ruben, and V. Nossar, *School screening in remote aboriginal communities--results of an evaluation.* Australian & New Zealand Journal of Public Health, 1998. **22**(6): p. 685-9.

104. Tellis, B., J.E. Keeffe, and H.R. Taylor, *Surveillance report for active trachoma, 2006: National Trachoma Surveillance and Reporting Unit.* Communicable Diseases Intelligence, 2007. **31**(4): p. 366-74.
105. Currie, B.J. and D.R. Brewster, *Childhood infections in the tropical north of Australia.* Journal of Paediatrics & Child Health, 2001. **37**(4): p. 326-30.
106. Access Economics Pty Ltd, *The economic impact and cost of vision loss in Australia*, in *Clear Insight*, E.R. Australia, Editor. 2004.
107. Gutierrez, P., et al., *Influence of glaucomatous visual field loss on health-related quality of life.* Archives of Ophthalmology, 1997. **115**(6): p. 777-84.
108. White, A.J., Abt Associates, *Eye exams for children: their impact and cost effectiveness*, in *Vision Council of America*. 2005: Alexandria (VA).
109. Ganz, M., Z. Xuan, and D.G. Hunter, *Patterns of eye care use and expenditures among children with diagnosed eye conditions.* Journal of Aapos: American Association for Pediatric Ophthalmology & Strabismus, 2007. **11**(5): p. 480-7.
110. Carlton, J., et al., *The clinical effectiveness and cost-effectiveness of screening programmes for amblyopia and strabismus in children up to the age of 4-5 years: a systematic review and economic evaluation.* Health Technology Assessment, 2008. **12**(25): p. 1-214.
111. Konig, H.H., et al., *Cost-effectiveness of orthoptic screening in kindergarten: a decision-analytic model.* Strabismus, 2000. **8**(2): p. 79-90.
112. Konig, H. and J. Barry, *Economic evaluation of different methods of screening for amblyopia in kindergarten.* Pediatrics, 2002. **109**(4).
113. Konig, H.-H., et al., *Economic evaluation of orthoptic screening: results of a field study in 121 German kindergartens.* Investigative Ophthalmology & Visual Science, 2002. **43**(10): p. 3209-15.
114. Konig, H.-H. and J.-C. Barry, *Cost-utility analysis of orthoptic screening in kindergarten: a Markov model based on data from Germany.[see comment].* Pediatrics, 2004. **113**(2): p. e95-108.
115. Miller, J.M., et al., *Cost-efficient vision screening for astigmatism in Native American preschool children.* Investigative Ophthalmology and Visual Science, 2003. **44**(9): p. 3756-3763.
116. Joish, V.N., D.C. Malone, and J.M. Miller, *A cost-benefit analysis of vision screening methods for preschoolers and school-age children.[see comment].* Journal of Aapos: American Association for Pediatric Ophthalmology & Strabismus, 2003. **7**(4): p. 283-90.
117. Magnusson, G. and U. Persson, *Screening for congenital cataracts: a cost-consequence analysis of eye examination at maternity wards in comparison to well-baby clinics.* Acta Paediatrica, 2005. **94**(8): p. 1089-95.
118. Gandjour, A., et al., *A cost-effectiveness model of screening strategies for amblyopia and risk factors and its application in a german setting.* Optometry & Vision Science, 2003. **80**(3): p. 259-69.
119. Robaei, D., et al., *Correctable and Non-Correctable Visual Impairment in a Population-Based Sample of 12-Year-Old Australian Children.* American Journal of Ophthalmology, 2006. **142**(1): p. 112-118.e1.
120. Vision in Preschoolers Study, G., *Does assessing eye alignment along with refractive error or visual acuity increase sensitivity for detection of strabismus in preschool vision screening?* Investigative Ophthalmology & Visual Science, 2007. **48**(7): p. 3115-25.
121. Yawn, B.P., et al., *Is school vision screening effective?* Journal of School Health, 1996. **66**(5): p. 171-5.
122. Ganz, M.L., Z. Xuan, and D.G. Hunter, *Prevalence and correlates of children's diagnosed eye and vision conditions.* Ophthalmology, 2006. **113**(12): p. 2298-306.
123. American Academy of Ophthalmology, *Pediatric eye evaluations: preferred practice pattern.* 2002.
124. American Academy of Pediatrics, *Red reflex examination in infants.* Pediatrics, 2002. **109**: p. 2.
125. American Academy of Ophthalmology, *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): p. 860-5.
126. American Optometric Association, *Pediatric eye and vision examination. 2nd ed.* 2002, St. Louis (MO): American Optometric Association.

127. American Public Health Association, *Improving Early Childhood Eyecare.* 2001.
128. Community Paediatrics Committee Canadian Paediatric Society, *Vision screening in infants, children and youth.* 1998.
129. Friedman, L. and L. Kaufman, *Guidelines for paediatrician referrals to the ophthalmologist.* 2003.
130. Hartmann, E.E., et al., *Preschool vision screening: summary of a task force report.* Ophthalmology, 2001. **108**(3): p. 479-86.
131. Services, M.D.o.H.a.S., *Guidelines for vision screening.* 2004.
132. Ressel, G., *Practice guidelines; AAP releases policy statement on eye examinations.* 2003.
133. Royal Australian and New Zealand College of Ophthalmology (RANZCO), *Position statement – eye examinations*. 2006.
134. Royal Australian and New Zealand College of Ophthalmology (RANZCO) and Orthoptic Association of Australia (OAA), *Guidelines for Paediatric Vision Screening*.
135. The Royal Australian New Zealand College of Ophthalmologists, *The Royal Australian New Zealand College of Ophthalmologists Annual Report 2006-2007.*
136. Optometrists Association Australia, *Optometrists Association Australia Member Database 2008.*
137. Australian Orthoptic Board, *Australian Orthoptic Board data, 2008*