Screening for Visual Impairment in Children Ages 1–5 Years: Update for the USPSTF

abstract

CONTEXT: Screening could identify preschool-aged children with vision problems at a critical period of visual development and lead to treatments that could improve vision.

OBJECTIVE: To determine the effectiveness of screening preschool-aged children for impaired visual acuity on health outcomes.

METHODS: We searched Medline from 1950 to July 2009 and the Cochrane Library through the third quarter of 2009, reviewed reference lists, and consulted experts. We selected randomized trials and controlled observational studies on preschool vision screening and treatments, and studies of diagnostic accuracy of screening tests. One investigator abstracted relevant data, and a second investigator checked data abstraction and quality assessments.

RESULTS: Direct evidence on the effectiveness of preschool vision screening for improving visual acuity or other clinical outcomes remains limited and does not adequately address whether screening is more effective than no screening. Regarding indirect evidence, a number of screening tests have utility for identification of preschool-aged children with vision problems. Diagnostic accuracy did not clearly differ for children stratified according to age, although testability rates were generally lower in children 1 to 3 years of age. Treatments for amblyopia or unilateral refractive error were associated with mild improvements in visual acuity compared with no treatment. No study has evaluated school performance or other functional outcomes.

CONCLUSIONS: Although treatments for amblyopia or unilateral refractive error can improve vision in preschool-aged children and screening tests have utility for identifying vision problems, additional studies are needed to better understand the effects of screening compared with no screening. *Pediatrics* 2011;127:e442–e479

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KEY WORDS

impaired visual acuity, vision screening, vision tests, preschool children, refractive errors, amblyopia, amblyogenic risk factors, random dot E stereoacuity test, MTI photoscreener, patching, systematic review

ABBREVIATIONS

USPSTF—US Preventive Services Task Force
logMAR—logarithmic minimal angle of resolution
ALSPAC—Avon Longitudinal Study of Parents and Children
RR—relative risk
CI—confidence interval
VIP—Vision in Preschoolers
PLR—positive likelihood ratio
NLR—negative likelihood ratio
MTI—Medical Technology and Innovations
OR—odds ratio
D—diopter(s)
PEDIG—Pediatric Eye Disease Investigator Group
MeSH—Medical Subject Headings
RCT—randomized controlled trial

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TABLE 1 Amblyogenic Risk Factors

Anisometropia* (spherical or cylindrical) > 1.50 D
Any manifest strabismus
Hyperopia > 3.50 D in any meridian
Any media opacity > 1 mm in size
Astigmatism > 1.5 D at 90° or 180° > in oblique axis (>10° eccentric to 90° or 180°)
Ptosis ≤ 1 mm margin reflex distance—the distance from the corneal light reflex to the upper lid margin; a standard objective measurement of ptosis
Visual acuity: per age-appropriate standards

D = diopter.

* Anisometropia is a difference in the refractive power of the two eyes.

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TABLE 2 Visual Acuity Tests

Test	Description	Applicable Age, y
Allen cards	Test involving 4 flash cards that contain 7 schematic figures; the figures are identified from various distances	2–4
HOTV	Test involving identification of the letters H, O, T, and V; the letters decrease in size from the top to the bottom of the chart	>4
Lea symbols	Test involving matching the symbols from the cards to the symbols on the wall; the symbols decrease in size from the top to the bottom of the chart	2–4
Snellen	Test involving a chart with 11 lines of letters; the first line consists of 1 very large letter, and each row below it has increasing numbers of letters that decrease in size	>4
Tumbling E	Test involving the letter E presented with the arms pointing in different directions; the letters decrease in size from the top to the bottom of the chart	>4

Data sources: American Academy of Pediatrics[11] and Prevent Blindness America.[12]

Visual impairment in young children can reduce quality of life[1] and may affect function and school performance. In the United States, 1% to 5% of preschool-aged children are estimated to have vision impairment that is most commonly related to amblyopia, strabismus, and refractive errors.[2–5] Vision impairment associated with amblyopia is not immediately correctable with refractive lenses, is unlikely to resolve spontaneously,[6] and can become irreversible.[7,8] Strabismus is the most common amblyogenic risk factor (Table 1). Strabismus can also inhibit development of normal binocular vision in the absence of amblyopia and result in psychosocial consequences.[9] Preschool vision screening (Table 2), which typically includes a measurement of visual acuity (Table 3), could help identify children who might benefit from early interventions.

In 2004, the US Preventive Services Task Force (USPSTF) recommended screening to detect amblyopia, strabismus, and defects in visual acuity in children younger than 5 years of age ("B recommendation").[14] In 2009, the USPSTF commissioned a new evidence review to update its recommendations. The purpose of this report is to systematically evaluate the current evidence on preschool vision screening.

TABLE 3 Measurements of Visual Acuity

Snellen		Decimal	LogMAR
ft	m		
20/20	6/6	1.00	0.00
20/30	6/9	0.67	−0.18
20/40	6/12	0.50	−0.30
20/60	6/18	0.33	−0.48
20/80	6/24	0.25	−0.60
20/100	6/30	0.20	−0.70
20/160	6/48	0.13	−0.90
20/200	6/60	0.10	−1.00

Visual impairment is 20/50 or worse; legal blindness is 20/200 or worse.

Data source: Holladay.[13]

METHODS

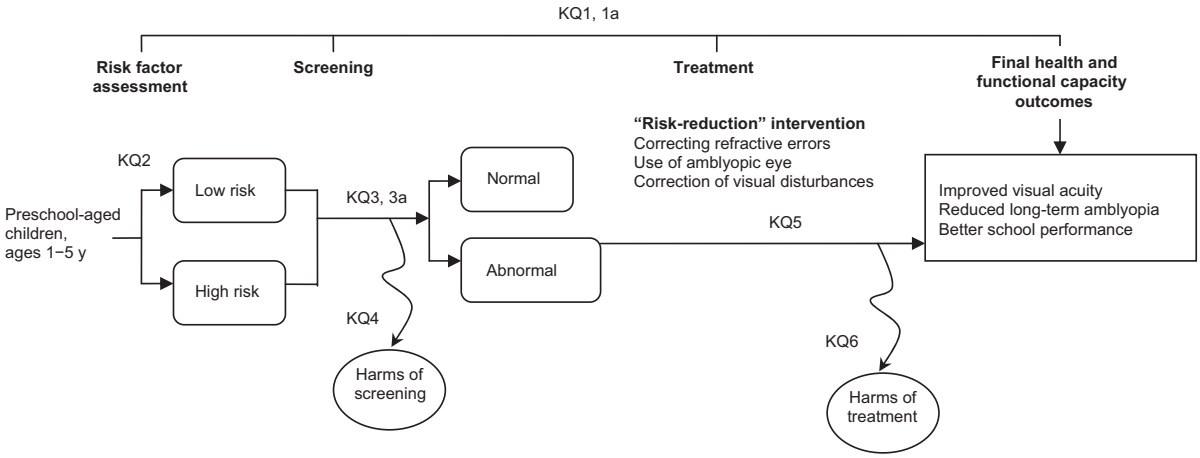
Using the methods developed by the USPSTF, we developed an analytic framework and key questions (Fig 1) to guide our literature search and review.[15] We searched Ovid Medline from 1950 to July 2009 and the Cochrane Central Register of Controlled Trials and the Cochrane Database of Systematic Reviews through the third quarter of 2009 (Appendix 1). We supplemented electronic searches with reviews of reference lists and by consulting experts.

Fig 2 shows the flow of studies from initial identification of titles and abstracts to final inclusion or exclusion. We selected studies that pertained to screening, diagnosis, and treatment of visual impairment in children 1 to 5 years of age (for details, see Appendixes 2 and 3). Two reviewers evaluated each study to determine eligibility for inclusion. This review was limited to the published, English-language studies available.

Data from full-text articles were abstracted by 1 investigator and verified by a second investigator. We converted visual acuity from Snellen to logarithmic minimal angle of resolution (logMAR) measurements by using published conversion charts.[13] Two authors independently rated the internal validity of each study as "good," "fair," or "poor" on the basis of criteria developed by the USPSTF (Appendix 4).[15,16] Discrepancies were resolved by discussion and consensus. For diagnostic accuracy studies, we used the diagti procedure in Stata 10 (Stata Corp, College Station, TX) to calculate sensitivities, specificities, and likelihood ratios. When the reference standard was applied in a random sample of negative screens, we corrected for verification bias by using the method of Begg and Greenes.[17] We classified likelihood ratios as shown in Table 4.[18]

We evaluated applicability to populations likely to be encountered in primary care screening settings on the basis of recruitment from primary care settings, the prevalence of visual conditions, and the severity of visual impairment.

We assessed the overall strength of the body of evidence for each key question (good, fair, or poor) by using



Key questions:

1. Is vision screening in children aged 1–5 y associated with improved health outcomes?

   1a. Does effectiveness of vision screening in children aged 1–5 y vary in different age groups?

2. What is the accuracy and reliability of risk-factor assessment for identifying children aged 1–5 y at increased risk for vision impairment?

3. What is the accuracy of screening tests for vision impairment in children aged 1–5 y?

   3a. In children aged 1–5 y, does accuracy of screening tests for vision impairment vary in different age groups?

4. What are the harms of vision screening for children aged 1–5 y?

5. What is the effectiveness of treatment for vision impairment in children aged 1–5 y?

6. What are the harms of treatment for children aged 1–5 y at increased risk for vision impairment or for vision disorders?

FIGURE 1
Analytic framework and key questions (KQs).

methods developed by the USPSTF on the basis of the number, quality, and size of studies, consistency of results, and directness of evidence.[15] We did not pool studies of diagnostic test accuracy because of differences in populations, screening cutoffs applied, and target conditions evaluated, as well as between-study heterogeneity in results. There were too few trials of treatments to perform meta-analysis.

This research was funded by the Agency for Healthcare Research and Quality (AHRQ) under a contract to support the work of the USPSTF. AHRQ staff and liaisons from the USPSTF helped develop and refine the key questions and analytic framework and reviewed draft reports. We also distributed an earlier draft of the report for review by external experts who were not affiliated with the USPSTF.

RESULTS

Key Question 1: Is Vision Screening in Children Aged 1 to 5 Years Associated With Improved Health Outcomes?

No randomized trial evaluated preschool vision screening compared with no screening. One large (n = 3490), fair-quality randomized trial nested within a population-based cohort study (the Avon Longitudinal Study of Parents and Children [ALSPAC]) revealed that intensive, periodic orthoptist screening (a clinical examination, age-specific visual acuity testing, and cover-uncover test) from 8 through 37 months of age reduced prevalence of amblyopia at 7.5 years of age by ~1% compared with 1-time screening at 37 months of age, but the difference was only statistically significant for 1 of 2 prestated definitions (Table 5) for amblyopia (amblyopia A, 1.45% vs 2.66%, relative risk [RR]: 0.55 [95% confidence interval (CI): 0.29–1.04]; amblyopia B, 0.63% vs 1.81%, RR: 0.35 [95% CI: 0.15–0.86]).[19,20] Visual acuity at 7.5 years in the amblyopic eye in patched children was better in the intensive-screening group than in the 1-time-screening group by an average of ~1 Snellen line (mean logMAR: 0.15 [95% CI: 0.08–0.22] vs 0.26 [95% CI: 0.17–0.35]; $P < .001$). The major methodologic shortcoming of this trial was high loss to follow-up (close to 50%) (Appendix 5).

A large (n = 6081), fair-quality (high-loss-to-follow-up) prospective cohort study from the ALSPAC revealed that 1-time orthoptist screening at 37 months of age was associated

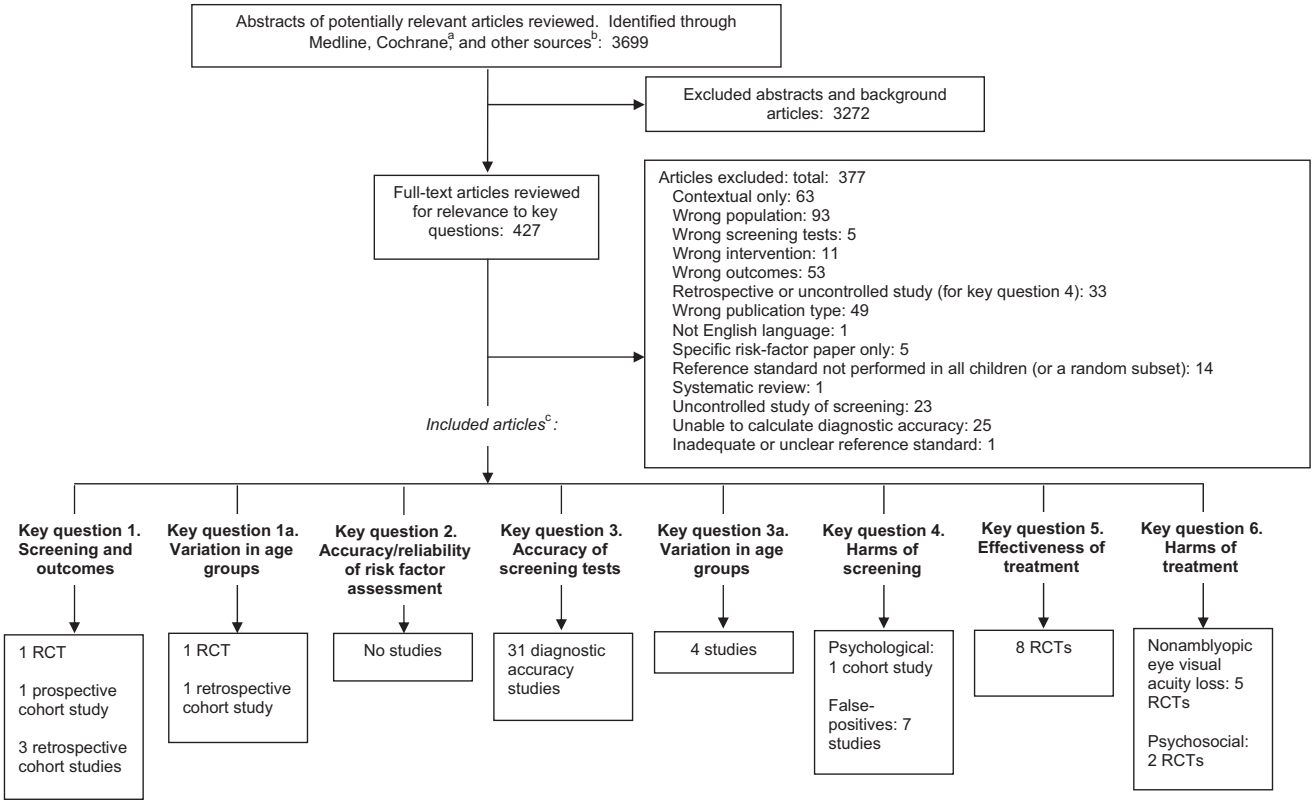


FIGURE 2

Article flow according to key question. [a] Cochrane databases include the Cochrane Central Register of Controlled Trials and the Cochrane Database of Systematic Reviews. [b] Other sources include reference lists, suggested by peer reviewers, etc. [c] Some articles are included for more than 1 key question.

TABLE 4 Interpretation of Likelihood Ratios

Positive Likelihood Ratio	Negative Likelihood Ratio	Interpretation
>10	≤0.1	Large/strong
>5 and ≤10	>0.1 and ≤2	Moderate
>2 and ≤5	>0.2 and ≤0.5	Small/weak

with no significant difference in amblyopia risk at 7.5 years compared with school-entry screening when using any of 3 prestated amblyopia definitions (Table 5).[21] Three poor-quality cohort studies revealed that preschool screening was associated with improved school-aged vision outcomes compared with no screening.[22–24] Besides the use of a retrospective design, methodologic shortcomings in these studies include failure to adjust for potential confounders and varying duration of follow-up. No study evaluated school performance or other functional outcomes.

Key Question 1a: Does Effectiveness of Vision Screening in Children Aged 1 to 5 Years Vary in Different Age Groups?

No randomized trial directly evaluated effectiveness of screening at different age groups in preschool-aged children. The ALSPAC randomized trial initiated screening at different ages (8 vs 37 months), but it is not possible to determine if differences in outcomes should be attributed to the age at which screening was started or the enhanced frequency of screening in the younger group.[19,20] One poor-quality retrospective cohort study of Alaskan children found no significant difference in risk of at least mild vision impairment (visual acuity worse than 20/40) between screening at the age of 2 to 4 years and screening before 2 years of age after 2 to 10 years' follow-up, but estimates were imprecise (RR: 3.10 [95% CI: 0.72–13]).[25] In addition, the authors only reported outcomes for 94 children from >10 000 screened and did not adjust for potential confounders. One other retrospective cohort study revealed that the rate of false-positives was approximately twice as high (25% vs 13%) for children screened at 1.5 years compared with those screened at 3.5 years.[26]

Key Question 2: What Is the Accuracy and Reliability of Risk-Factor Assessment for Identifying Children Aged 1 to 5 Years at Increased Risk for Vision Impairment?

No study evaluated the accuracy or reliability of demographic or clinical features to identify children at higher risk for vision impairment or amblyogenic risk factors before screening, and no study evaluated the yield or outcomes

TABLE 5 RCTs and Controlled Observational Studies of Preschool Vision Screening

Study (Year); Design	No. of Treatment and Control Subjects (No. Approached, No. Eligible, No. Enrolled, No. Lost to Follow-up)	Subject Age, Gender, and Diagnosis	Country	Setting	Screening Intervention	Results	Quality Rating
Williams et al[20,21] (2002 and 2003); RCT	Number approached and eligible not reported: 3490 enrolled (2029 intensive screening, 1490 1-time screening); 1929 analyzed at 7.5 y	Age: cohort initially tested at age 8–37 mo and followed to age 7.5 y; female: 48% (in those who attended final outcome assessment); diagnosis: baseline amblyopia or amblyogenic risk factors not reported	United Kingdom	Hospital eye services clinic	Screening at 8, 12, 18, 25, 31, and 37 mo: cover testing, Cardiff cards at 8 and 12 mo, Cardiff and Kays pictures test at 18, 25, and 31 mo, Kays picture test and HOTV test at 37 mo, noncycloplegic autorefraction (performed at all visits, but only used for referral at 37 mo) Screening at 37 mo: cover testing, Kays picture test and HOTV test, noncycloplegic autorefraction	Screening at 8, 12, 18, 25, 31, and 37 mo vs screening at 37 mo only; amblyopia A at 7.5 y of age: 1.4% (16/1088) vs 2.7% (22/826), RR: 0.55 (95% CI: 0.29–1.04); amblyopia B at 7.5 y of age: 0.6% (69/1088) vs 1.8% (15/876), RR: 0.35 (95% CI: 0.15–0.86) Residual amblyopia A among children treated with occlusion: 25% (10/40) vs 8% (3/40); OR: 1.56 (95% CI: 0.62–3.92); residual amblyopia B among children treated with occlusion: OR: 4.11 (95% CI: 1.04–16.29) Mean visual acuity in the worse eye after patching treatment (adjusted for confounding variables): 0.15 (95% CI: 0.083–0.22) vs 0.26 (0.17–0.35), $P < .001$ Amblyopia A: interocular difference in acuity ≥0.2 logMAR (2 lines on the chart); amblyopia B: interocular difference in acuity ≥0.3 logMAR	Fair
Williams et al[21] (2003); prospective cohort study	8042 evaluated for inclusion; 1917 excluded because of inclusion in quasi-randomized trial and 44 because of developmental delay or organic eye disease; 6081 included (1516 offered screening at 37 mo, 4565 not offered screening at 37 mo); loss to follow-up not described	Age: cohort tested at 7.5 y; were offered or not offered screening at 37 mo; female: 49%; diagnosis: baseline amblyopia or amblyogenic risk factors not reported	United Kingdom	Hospital eye services clinic	Screening at 37 mo: Kay's pictures or Sheridan Gardiner singles visual acuity test, cover test, and 20 D prism or test of stereopsis (or both) No screening at 37 mo	Offered and received screening at 37 mo vs school-entry screening; amblyopia A at 7.5 y of age: 1.1% (11/1019) vs 2.0% (100/5062), adjusted OR: 0.63 (95% CI: 0.32–1.23); amblyopia B at 7.5 y of age: 0.7% (7/1019) vs 1.3% (65/5062), adjusted OR: 0.72 (95% CI: 0.32–1.60); amblyopia C at 7.5 y of age: 1.9% (19/1019) vs 3.4% (171/5062), adjusted OR: 0.65 (0.38–1.10); mean visual acuity in the worse eye after patching treatment (adjusted for confounding variables): 0.14 (95% CI: 0.11–0.18; $n = 25$) vs 0.22 (95% CI: 0.20–0.23; $n = 166$), $P < .0001$ Amblyopia A: interocular difference in acuity ≥0.2 logMAR (2 lines on the chart); amblyopia B: visual acuity in amblyopic eye 0.3 logMAR or worse (6/12 or worse); amblyopia C: visual acuity in amblyopic eye 0.18 logMAR or worse (6/9 or worse)	Fair
Eibschitz-Tsimhoni et al[22] (2000); retrospective cohort study	988 examined in "screening" city, 808 had attended screening at 1–2.5 y of age and included in analyses; 782 children examined in "nonscreening" city; loss to follow-up not described	Age: 8 y; gender not reported; diagnosis: 1% vs 2.6% amblyopia	Israel	Preschool screening	Ophthalmologic examination by an ophthalmologist or orthoptist, including Hirschberg corneal reflex text, monocular fixation and following test, ductions and versions examination, cover-uncover test, alternative cover test, and retinoscopy without cycloplegia	Screening vs no screening at 1–2.5 y Amblyopia at 8 y of age: 1.0% (8/808) vs 2.6% (20/782); RR: 0.39 (95% CI: 0.17–0.87); amblyopia with visual acuity worse than 20/60 at 8 y of age: 0.1% (1/808) vs 1.7% (13/782); RR: 0.07 (95% CI: 0.01–0.57)	Poor

TABLE 5 Continued

Study (Year); Design	No. of Treatment and Control Subjects (No. Approached, No. Eligible, No. Enrolled, No. Lost to Follow-up)	Subject Age, Gender, and Diagnosis	Country	Setting	Screening Intervention	Results	Quality Rating
Feldman et al[23] (1980); retrospective cohort study	Number approached and eligible not reported; 1508 enrolled (745 screening 6–12 mo before school entry and 763 no screening before school entry); loss to follow-up not described	Age: mean 6 y; gender not reported; diagnosis: 13% had at least mild (visual acuity 20/40 or worse) best-corrected vision impairment	Canada	Preschool and school screening	Illiterate E visual acuity test, administered by school nurse	RR for at least mild vision impairment (visual acuity 20/40 or worse) upon school entry, screened 6–12 mo previously vs not screened: 10% (78/763) vs 15% (112/745); RR: 0.68 (95% CI: 0.52–0.89)	Poor
Kohler et al[24] (1978); retrospective cohort study	Number approached and eligible not reported; 2178 enrolled (619 screened at 4 y of age and 1519 not screened); loss to follow-up not described	Age: 7 y; gender not reported; diagnosis: 49% had vision disorders classified as requiring treatment, functional amblyopia, or strabismus	Sweden	Preschool and school screening	Linear E-chart, administered by school nurse	RR for newly diagnosed vision disorder, amblyopia, or strabismus at 7 y of age, not screened at age 4 vs screened: 0.7% (11/1519) vs 5% (29/619); RR: 0.15 (95% CI: 0.08–0.31)	Poor

of targeted versus universal preschool vision screening.

Key Question 3: What Is the Accuracy of Screening Tests for Vision Impairment in Children Aged 1 to 5 Years?

Thirty-one studies evaluated the diagnostic accuracy of various preschool vision screening tests (Tables 6 and 7).[27–58] Cycloplegic refraction was included in the reference-standard examination in all but 5 studies.[28,29,38,40,50] Four studies were rated poor quality,[35,38,45,50] and the other 23 were rated fair quality; the degree to which studies met quality criteria was variable (Appendix 6). The most frequent shortcomings were exclusion of noncompliant children or those with uninterpretable screening tests, failure to describe random or consecutive enrollment of subjects, high or unclear rate of screening failures, and failure to enroll a representative spectrum of subjects.

Nineteen studies evaluated children recruited from pediatric ophthalmology clinics.* In these studies, the median prevalence of amblyogenic risk factors was 48% (range: 6%–81%).† In 8 studies of children recruited from primary care, community, or school settings, the median prevalence of amblyogenic risk factors was 12% (range: 2%–20%) in 5 studies,[27,29,37,43,51] and the prevalence of amblyopia was 2% in 3 studies.[28,32,50] The large ($n = 2588$) Vision in Preschoolers (VIP) Study preferentially enrolled children from Head Start with visual conditions (prevalence of amblyopia: 3%; prevalence of any target visual condition: 29%).[55,60]

Visual Acuity Screening

In the VIP Study, crowded Lea symbols visual acuity testing was associated

*Refs 30, 31, 34–36, 38–42, 44, 45, 48, 49, 52, 53, and 56–58.

†Refs 30, 31, 34, 38, 39, 41, 42, 44, 45, 48, 49, 52, 53, and 57.

TABLE 6 Diagnostic Accuracy Studies

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Arthur et al[27] (2009)	PlusOptix autorefractor (previously the Power Refractor) Anisometropia >1 D, astigmatism >1.25 D, myopia >3 D, hyperopia >3.5 D, anisocoria >1 mm, abnormal alignment	Comprehensive eye examination with cycloplegic refraction	Anisometropia >1 D; astigmatism >1.25 D; myopia >3 D; hyperopia >3.5 D; anisocoria >1 mm; strabismus	Cross-sectional; 4–5 y; $N = 307$; amblyogenic risk factors: 13% (36/275)	Screener, kindergarten, Canada, dental assistant
Barry and Konig[28] (2001)	Retinomax autorefractor Acuity outside −1 to 3 D, cylindric power >1.5 D, or anisometropia >1 D	Second orthoptic examination (Lea single-symbol test, cover-uncover test, eye motility, and abnormal head posture), followed by ophthalmologic examination for abnormal, missing, or inconsistent results	Any newly administered patching therapy or any newly administered patching therapy (visual acuity ≤ 0.4 [20/50] in either eye, or difference of visual acuity between eyes ≥2 log steps)	Cross-sectional; 3 y; $N = 404$; amblyopia: 2.5% (10/404)	Kindergarten, Germany, orthoptist
Barry and Konig[29] (2003)	Visual inspection, cover-uncover test, eye motility and head-posture examination, Lea symbols visual acuity test Anatomic abnormality, manifest strabismus, or unstable refusion after uncovering, anomalies of eye motility and head posture, visual acuity worse than 10/25 or >1 line of difference between eyes and visual acuity in worse eye 10/20 to 10/17	Second orthoptic examination (Lea single-symbol test, cover-uncover test, eye motility, and abnormal head posture) using more stringent criteria, followed by ophthalmologic examination for abnormal, missing, or inconsistent results	Newly administered spectacle therapy if the corrected visual acuity is ≤020/50 in either eye or difference of visual acuity of >2 logarithmic lines (except for myopia); any newly administered patching therapy in presence of risk factors such as monolateral strabismus or high refractive error (≥1.5 D, or astigmatism ≥3 D)	Cohort; 3 y; $N = 1180$; amblyopia or amblyogenic risk factors: 2.3% (26/1114)	Kindergarten, Germany, orthoptist
Berry et al[30] (2001)	MTI photoscreener Presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent	Comprehensive eye examination with cycloplegic refraction	Myopia ≥1.00 D, hyperopia ≥2.75 D, astigmatism >1.50 D, anisometropia >1.50 D, >1-mm difference in pupil size, any strabismus, any media opacity, any ptosis, any fundus abnormality	Cross-sectional; preschool (subgroup); $N = 51$; amblyogenic risk factors: 45% (23/51)	Pediatric ophthalmology clinic, United States, screener not described
Bertuzzi et al[31] (2006)	Lea symbols visual acuity test Various cutoffs evaluated; results shown for: A, acuity (decimal score) 0.80; B, acuity (decimal score) 0.63	Comprehensive eye examination with cycloplegic refraction	Bilateral myopia ≥3 D, unilateral myopia >1.5 D, bilateral hyperopia ≥3 D, unilateral hyperopia ≥1 D, unilateral/bilateral astigmatism >1.5 D, lack of media transparency, any retinal or optic nerve abnormality; strabismus	Cross-sectional; 38–54 mo; $N = 149$; amblyogenic risk factors: 16% (23/143)	Pediatric ophthalmology clinic, Italy, 38–54 mo, screener not described
Chang et al[32] (2007)	A, distance visual acuity; B, near visual acuity; C, NTU random-dot stereogram A1, distance visual acuity worse than 0.5 at 3 y of age, 0.6 at 4 y of age, 0.7 at 5 y of age, and 0.8 at 6 y of age; A2, distance visual acuity worse than 0.7 at 3 y of age, 0.8 at 4 y of age, 0.9 at 5 y of age, and 1.0 at 6 y of age; B, near visual acuity worse than 0.7 at 3 y of age, 0.8 at 4 y of age, 0.9 at 5 y of age, and 1.0 at 6 y of age; C, stereoacuity worse than 300 s-arc	Comprehensive eye examination with cycloplegic refraction	Best corrected distance visual acuity worse than 1.0	Cross-sectional; preschool; $N = 5232$; amblyopia: 2.2% (115/5232)	Public health service stations, Taiwan, preschool, nurse

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Chui et al[33] (2004)	Lea symbols visual acuity test, Frisby stereoacuity test, and external visual inspection Visual acuity 6/12 to 2 or worse in 1 or both eyes, difference in visual acuity of ≥2 lines between eyes, stereoacuity worse than 600 in on Frisby or worse than 400 in on Titmus, presence of constant or intermittent tropia, monofixation syndrome, myopia greater than −0.75 D, hyperopia >3.50 D, astigmatism ≥1.50 D, anisometropia ≥1.00 D, any other anomaly or inability to complete gold-standard examination	Comprehensive eye examination with cycloplegic refraction	Lea symbols visual acuity of 6/12 to 2 or worse in 1 or both eyes; difference in visual acuity of ≥2 lines between eyes; stereoacuity worse than 600 in on Frisby or worse than 400 in on Titmus; constant or intermittent tropia, monofixation syndrome; myopia −0.75 D or greater; hyperopia ≥3.50 D; astigmatism ≥1.50 D; anisometropia ≥1.00 D; any other abnormality that warranted follow-up; unable to complete gold-standard examination	Cross-sectional; 35–58 mo; *N* = 178; amblyogenic risk factors: 13% (18/141)	Not described, Canada, 35–58 mo, nurse
Cogen and Ottemiller[34] (1992)	Visiscreen 100 photoscreener Presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent	Comprehensive eye examination with cycloplegic refraction ("when possible")	Hyperopia >4 D; myopia >5 D; astigmatism >2 D; anisometropia >1 D; strabismus; media opacity	Cross-sectional; 6 mo to 6 y; *N* = 127; any visual condition: 12% (13/113); refractive error: 5% (6/113); strabismus: 4% (5/113); refractive error + strabismus: 1% (1/113); media opacity: 1% (1/113)	Pediatric ophthalmology clinic, United States, technician
Cooper et al[35] (1999)	A, Fortune Optical VRB-100, photoscreener; B, MTI photoscreener Presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent	Comprehensive eye examination with cycloplegic refraction	Hyperopia >3.5 D; anisometropia >1 D; myopia >2 D; astigmatism >2 D; any media opacity or fundus abnormality affecting vision; manifest strabismus	Case-control; 12–44 mo; *N* = 105; 61 cases (amblyopia), 44 controls	Pediatric ophthalmology clinic, Australia, technician
Dahlmann-Noor et al[36] (2009)	PlusOptix autorefractor (previously called the Power Refractor) Not reported	Comprehensive eye examination with cycloplegic refraction	Myopia >1 D; hyperopia >3 D; anisometropia >1 D; astigmatism >1.5 D	Cross-sectional; 4–7 y; *N* = 126; A, myopia: 3% (3/108); B, hypermetropia: 39% (42/108); C, astigmatism: 12% (13/108); D, anisometropia: 24% (28/117)	Pediatric ophthalmology clinic, United Kingdom, ophthalmologist, orthoptist, or ophthalmic nurse
Dahlmann-Noor et al[37] (2009)	PlusOptix autorefractor (previously called the Power Refractor) Spherical component less than −1.0 D or >3.0 D, cylinder power >1.5 D, anisometropia of spherical component or of cylinder power >1.0 D	Orthoptist screening with distance acuity testing, cover test, extraocular movements, prism test, and Lang stereotest; comprehensive eye examination with cycloplegic refraction for abnormal autorefractor or orthoptist screening results	Hyperopia >3.0 D; myopia >1.0 D; strabismus; ptosis	Cross-sectional; 4–7 y; *N* = 288; reduced vision in 1 or both eyes, manifest strabismus, or ptosis: 12% (36/288)	Preschool/kindergarten, United Kingdom
Ehrt et al[38] (2007)	Power Refractor autorefractor (now called the PlusOptix autorefractor) Hyperopia ≥3.0 D, myopia ≤2.0 D, astigmatism ≥1.0 D, anisometropia ≥1 D	Comprehensive eye examination with cycloplegic refraction	Hyperopia ≥3 D; myopia ≥2 D; astigmatism ≥1 D; anisometropia ≥1 D	Cross-sectional; 0–7 y; *N* = 161; amblyogenic risk factors: 43% (70/161)	Pediatric ophthalmology clinic, Germany

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Guo et al[39] (2000)	A, Computer-photorefractor; B, noncycloplegic retinoscopy Presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent	Comprehensive eye examination with cycloplegic refraction	Myopia ≥1.50 D; hyperopia ≥2.75 D; astigmatism ≥1.75 D; anisometropia ≥2.00 D; media opacity ≥1.5 mm; strabismus ≥5°	Cross-sectional; 9–50 mo; *N* = 300; amblyogenic risk factors: 56% (168/300)	Pediatric ophthalmology clinic, China, screener not described
Hope and Maslin[40] (1990)	Random dot E stereogram Unable to correctly identify the E at least 4 times in succession at 1 mo	Comprehensive eye examination with cycloplegic refraction for visual acuity worse than 4/4 with the letter-matching test or worse than 6/6 for Kays picture cards in children who failed random dot E stereogram, visual acuity screen, or near cover test; otherwise visual acuity screen or near cover test used as reference standard	Visual acuity 6/12 or worse in either eye; manifest strabismus	Cross-sectional; 3–4 y; *N* = 176; refractive error or strabismus: 5% (9/168); refractive error: 5% (9/168); strabismus: 0.6% (1/168)	Pediatric ophthalmology clinic, New Zealand, screener not described
Kemper et al[41] (2005)	SureSight autorefractor SureSight manufacturer referral criteria (hyperopia >2.00 D, myopia >1.00 D, cylinder >1.00 D, or difference >1.00 D)	Comprehensive eye examination with cycloplegic refraction	Anisometropia >1.5 D; hyperopia >3.50 D; myopia >3.00 D; media opacity >1 mm; astigmatism >1.5 D at 90° or 180° or >1.0 D in oblique axis; ptosis ≤1 mm margin reflex distance; visual acuity per age-appropriate standards; manifest strabismus	Cross-sectional; 0–5 y; *N* = 170; amblyopia: 17% (29/170); refractive error: 26% (45/170); strabismus: 18% (30/170); any visual impairment: 36% (62/170)	Pediatric ophthalmology clinic, United States, orthoptist or pediatric ophthalmologist
Kennedy and Sheps[42] (1989)	A, Otago-type photoscreener (noncommercial); B, Snellen E or Stycar graded balls visual acuity test and Titmus stereotest A, presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent; B, vision <20/40 in either eye or stereoacuity <80 s of arc	Comprehensive eye examination with cycloplegic refraction	Refractive error >3.00 D; astigmatism >2.00 D; corneal or lens opacity; fundus abnormality; strabismus	Cross-sectional; ≤6 y; *N* = 236; amblyogenic risk factor: 42% (98/236)	Pediatric ophthalmology clinic, Canada, technician
Kennedy et al[43] (1995)	iScreen photoscreener Presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent	Comprehensive eye examination without cycloplegic refraction	Visual acuity worse than 20/30; constant tropia present; refractive error greater than ±3.00 D in either eye with ±2 D astigmatism; corneal, lens, or fundus abnormality	Cross-sectional; age not reported; *N* = 264; any visual condition: 8% (21/264); strabismus: 1.1% (3/264); refractive error: 4.2% (11/264); strabismus and refractive error: 0.8% (2/264); structural: 0.4% (1/264)	Kindergarten, Canada, health care aide
Kennedy and Thomas[44] (2000)	A, Lea symbols visual acuity test; B, Retinomax K-plus autorefractor Age 2–4 y: myopia >2.50 D, hyperopia >4.00 D, astigmatism >2.00 D, anisometropia >1.50 D; age 4–7 y: myopoia >1.50 D, hyperopia >4.00 D, astigmatism >1.50 D, anisometropia >1.50 D	Comprehensive eye examination with cycloplegic refraction (in patients <4 y old)	Tropia, intermittent or otherwise; refractive error >3.50 D in both eyes; myopia >0.50 D; anisometropia >2.00 D; astigmatism >2.00 D; corneal or lens opacity; fundus abnormality	Cross-sectional; 45% ≤6 y old; *N* = 449; amblyogenic risk factors: 64% (273/423)	Pediatric ophthalmology clinic, Canada, technician

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Matta et al[45] (2008)	PlusOptix autorefractor (previously called the Photo Refractor) A, manufacturer's referral criteria: anisometropia ≥1.0 D, astigmatism ≥0.75 D, myopia ≥2.0 D for 1–2 y and ≥1.0 D for 3–5 y, hyperopia ≥1.0 D, anisocoria ≥1 mm; B, revised referral criteria: anisometropia ≥1.25 D, astigmatism ≥1.0 D, myopia ≥2.0 D for 1–2 y and ≥1.0 D for 3–5 y, hyperopia ≥1.25 D, anisocoria ≥1 mm	Comprehensive eye examination with cycloplegic refraction	Anisometropia >1.5 D; any manifest strabismus; hyperopia >3.50 D; myopia >3.00 D; media opacity >1 mm; astigmatism >1.5 D; ptosis less than −1-mm margin reflex distance; visual acuity: per age-appropriate standards	Cross-sectional or retrospective; 1–5 y (data obtained for this subgroup); $N = 80$; amblyogenic risk factors: 50% (40/80)	Pediatric ophthalmology clinic, United States, screener not reported
Miller et al[46] (1999)	A, Lea symbols visual acuity test; B, MTI photoscreener; C, Nidek KM-500 Keratometry screener; D, Retinomax K-Plus autorefractor A, visual acuity worse than 20/40; B, presence of abnormal red reflex, asymmetric corneal light reflection, opacity, or crescent; C, astigmatism ≥2.25 D in either eye; D, astigmatism ≥1.50 D in either eye	Cycloplegic refraction and retinoscopy	For ages <2, 2–4, and 4–7 y, respectively; myopia: >4.00 D, >2.50 D, or >1.50 D; hyperopia: >5.00 D, >4.00 D, or >1.50 D; astigmatism: >2.50 D, >2.00 D, or >1.50 D; anisometropia: >1.50 D (all age groups)	Cross-sectional; 3–5 y; $N = 245$; significant refractive error: 31% (76/245); all had astigmatism	Head Start program, United States (Native American population), Head Start staff
Miller et al[47] (2001)	Visiscreen 100 photoscreener Media opacity, crescent, asymmetric corneal reflex	Cycloplegic refraction	Astigmatism ≥2.00 D for children <48 mo of age and ≥1.50 D for children ≥48 mo of age	Cross-sectional; 3–5 y; $N = 379$; astigmatism ≥1.00 D: 48% (182/379)	Head Start program, United States (Native American population); trained testers
Molteno et al[48] (1993)	Otago-type photoscreener Yellow or white fundal reflex, deviation of papillary light reflex, inequality of pupil size, any other visible defect	History, inspection, cover test, examination of ocular media, and fundoscopy through undilated pupils; cycloplegic refraction, dilated fundoscopy, and orthoptic examination with any abnormalities	Corrected visual acuity worse than 20/20 in the worse eye; heterophoria, either marked with good binocular vision or moderate with some defect of binocular vision and including intermittent squint with well-developed binocular vision; anisometropia ≥0.5 D	Cross-sectional; not reported ("infants and children"); $N =$ 1000; yellow or white fundal reflex, deviation of papillary light reflex, inequality of pupil size, any other visible defect: 34% (340/1000)	Pediatric ophthalmology clinic, New Zealand, ophthalmologist
Morgan and Johnson[49] (1987)	Visiscreen 100 Photoscreener Media opacity; crescent; asymmetric corneal reflex	Comprehensive eye examination with cycloplegic refraction	Hyperopia ≥2.50 D; myopia ≥1 D; anisometropia >1 D; astigmatism >2 D	Cross-sectional; 3 mo to 8 y; $N = 63$; any visual condition: 60% (34/57)	Pediatric ophthalmology clinic, United States, technician
Newman and East[50] (1999)	Sheridan-Gardiner visual acuity; cover-uncover test; ocular movements and convergence; prism test; TNO screening plate; Snellen visual acuity Visual acuity 6/6 or worse; manifest strabismus; decompensating heterophoria; abnormality of ocular movements; abnormal response to 20 base-out prism test; negative response to TNO screening-plate stereotest; any other ocular abnormality	Comprehensive eye examination	Best corrected Snellen line acuity of 6/12 or worse in either eye and/or an interocular difference of ≥2 Snellen lines	Retrospective cohort; 3.5 y and at 5–6 y; $N = 597$; amblyopia: 2.5% (15/597)	"Community setting," United Kingdom, orthoptist

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Ottar et al[51] (1995) and Donahue et al[59] (2002)	MTI photoscreener A, media opacity; strabismus; myopic crescent ≥1 mm; hyperopic crescent ≥2.5 mm; astigmatism ≥2 mm; difference between horizontal and vertical photographs of same eye; B, media opacity >1 mm; strabismus; myopic crescent ≥2.5 mm (4-mm pupillary diameter), ≥4.5 mm (6-mm pupillary diameter), or ≥6.5 mm (8-mm pupillary diameter); hyperopic crescent ≥2.5, ≥4.5, or ≥6.5 mm; astigmatism >1.5, >2.0, or >2.5 mm; anisometropia (no crescent in fellow eye): crescent ≥2.0, ≥3.5, or ≥4 mm; anisometropia (crescent in fellow eye): crescent ≥1 mm in fellow eye and 1-mm difference between eyes, ≤2.5 mm in fellow eye and 2-mm difference between eyes or ≥3 mm in fellow eye and 1-mm difference between eyes, or ≤3.5 mm in fellow eye and 2-mm difference between eyes or ≥4-mm crescent in fellow eye and 1-mm difference between eyes	Comprehensive eye examination with cycloplegic refraction	A, myopia >1.00 D; hyperopia >2.75 D; astigmatism >1.00 D; anisometropia >1.50 D; any media opacity; any strabismus; any abnormality of posterior pole; B, myopia >3.00 D; hyperopia >3.50 D; astigmatism >1.50 D; anisometropia >1.00 D	Cross-sectional; 6–59 mo; $N = 949$; amblyogenic risk factors: 20% (192/949); higher-magnitude amblyogenic risk factors: 9% (88/939)	Public health and pediatric clinics, United States, orthoptist or pediatrician
Rogers et al[52] (2008)	MTI photoscreener; SureSight autorefractor A, SureSight manufacturer referral criteria (hyperopia >2.00 D, myopia >1.00 D, cylinder >1.00 D, or difference >1.00 D); B, SureSight 90% VIP specificity referral criteria (≥4.00, ≥1.00, ≥1.50, or ≥3.00); C, SureSight 94% VIP specificity referral criteria (≥4.25, ≥1.00, ≥1.75, ≥3.50); D, SureSight Rowatt et al[87] referral criteria (≥4.25, ≥1.00, ≥2.20, ≥3.00); E, MTI gold-standard referral criteria (≥3.50, >3.00, >1.50, >1.00)	Comprehensive eye examination with cycloplegic refraction	Anisometropia >1.5 D; hyperopia >3.50 D; myopia >3.00 D; media opacity >1 mm; astigmatism >1.5 D at 90° or 180° or >1.0 D in oblique axis; ptosis ≤1-mm margin reflex distance; visual acuity per age-appropriate standards; manifest strabismus	RCT; 1–6 y; $N = 100$; clinically significant amblyopia: 58% (58/100)	Pediatric ophthalmology clinic, United States, trained layperson

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Shallo-Hoffmann et al[53] (2004)	Lea symbol and HOTV charts, and random dot E stereoacuity test Required to pass threshold for 1 visual acuity test (Lea symbol chart: correct identification of 4 of 5 symbols on the passing line for age; HOTV chart: all or 1 less than all of the optotypes on the passing line for age), and stereoacuity test (random dot E test: 4 of 5 correct responses)	Comprehensive eye examination with cycloplegic refraction	2–3 y; isometropia: myopia ≥3.00 D, hyperopia ≥4.50 D, hyperopia with esotropia >1.50 D, astigmatism >2.00 D; anisometropia: myopia ≥2.00 D, hyperopia ≥1.50 D, astigmatism ≥2.00 D; 3–5 y; isometropia: myopia ≥3.00 D, hyperopia ≥3.50 D, hyperopia with esotropia >1.00 D, astigmatism >1.50 D; anisometropia: myopia ≥2.00 D, hyperopia ≥1.00 D, astigmatism ≥1.50 D; any age; intermittent or constant strabismus; 2-line difference in monocular visual acuities in association with monocular strabismus or amblyogenic refractive error; any pathology	Cross-sectional; 2–6 y; *N* = 269; any vision condition: 6% (5/81)	Pediatric ophthalmology clinic, United States (mostly attendees at Caribbean-American preschool and children of indigent Spanish-speaking farmworkers), screener not described
Tong et al[56] (2000)	MTI photoscreener Abnormal external examination, media opacity, strabismus, or refractive error (hyperopia ≥2.0 D, myopia ≥2.0 D, anisometropia ≥2.0 D, astigmatism ≥2.0 D)	Comprehensive eye examination with cycloplegic refraction	Not described	Cross-sectional; <4 y old; *N* = 387; strabismus: 49% (190/387); refractive error: 55% (211/387)	Pediatric ophthalmology clinic, United States, screener not described

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
VIP Study Group[55] (2004)	Crowded linear Lea symbols and linear HOTV visual acuity tests A, 10/32 for age 3 y, 10/20 for age 4 or 5 y; B, 10/32 for age 3 y, 10/25 for age 4 y, 10/20 for age 5 y Random dot E stereoacuity test A, nonstereo card for age 3 y, stereo card at 50 cm for age 4 y, stereo card at 100 cm for age 5 y; B, nonstereo card for age 3 or 4 y, stereo card at 50 cm for age 5 y Stereo Smile II stereoacuity test A, 240-arc s card for age 3 or 4 y, 120-arc s card for age 5 y; B, 480-arc s card for age 3 or 4 y, 240-arc s card for age 5 y Retinomax autorefractor A, hyperopia ≥1.50 D, myopia ≥2.75 D, astigmatism ≥1.50 D, anisometropia ≥2.00 D (year 1) or ≥1.75 D (year 2); B, hyperopia ≥1.75 D (year 1) or ≥2.50 (year 2), myopia ≥2.75 D, astigmatism ≥2.00 D (year 1) or ≥1.75 D (year 2), anisometropia ≥2.75 D (year 1) or ≥2.50 D (year 2) SureSight autorefractor A1, manufacturer criteria: hyperopia ≥2.00 D, myopia >1.00 D, astigmatism >1.00 D, anisometropia >1.00 D SE; A2, VIP criteria: hyperopia ≥4.00 D, myopia ≥1.00 D, astigmatism ≥1.50 D, anisometropia ≥3.00 D; B, VIP criteria: hyperopia ≥4.25 D, myopia ≥1.00 D, astigmatism ≥1.75 D, anisometropia ≥3.50 D iScreen photoscreener As specified by manufacturer or interpreter of iPower photoscreener MTI photoscreener As specified by manufacturer or interpreter of MTI photoscreener Power Refractor II A, hyperopia ≥3.50 D, myopia ≥3.00 D, astigmatism ≥2.00 D, anisometropia ≥1.50 D; B, hyperopia ≥5.00 D, myopia ≥3.75 D, astigmatism ≥2.25 D, anisometropia ≥2.75 D Cover-uncover test Heterotropia	Comprehensive eye examination with cycloplegic refraction	Amblyopia: ≥2-line interocular difference in visual acuity and unilateral amblyogenic factor; or visual acuity worse than 20/50 (3 y old) or 20/40 (4–5 y old) in 1 eye, worse than 20/40 (20/30) in contralateral eye, and bilateral amblyogenic factor; reduced visual acuity: worse than 20/50 (20/40) in 1 eye, worse than 20/40 (20/30) in contralateral eye, and no bilateral amblyogenic factor; or worse than 20/50 (20/40) in 1 eye or ≥2-line difference between eyes (except 20/16 and 20/25), and no unilateral amblyogenic factor; strabismus; significant refractive error: astigmatism >1.50 D, hyperopia >3.25 D, myopia >2.00 D, anisometropia (interocular difference >1.00 D for hyperopia, >3.00 for myopia, >1.50 D for astigmatism, anisometropia (defined)	Cross-sectional; 3, 4, or 5 y; $N =$ 3121; any target vision condition: 29% (755/2588); "very important to detect and treat early" conditions: 5.4% (135/2588); amblyopia: 2.9% (75/2588); reduced visual acuity: 5.1% (132/2588); strabismus: 1.9% (48/2588); refractive error: 9.3% (240/2588)	Customized Head Start screening vans

TABLE 6 Continued

Study (Year)	Screening Test Definition of a Positive Screening Test	Reference Standard	Definition of a Case	Type of Study, Age of Enrollees, Sample Size, and Proportion With Condition	Setting
Weinand et al[57] (1998)	MTI photoscreener Crescent at least half the pupil diameter, asymmetry of light reflexes, or organic abnormalities	Comprehensive eye examination with cycloplegic refraction	Refractive error ≥2 D; manifest strabismus; any organic anomaly	Cross-sectional; 6–18 mo; N = 112; any abnormality: 81% (83/102); refractive error: 41% (41/102); strabismus without refractive error: 7% (7/102); strabismus with refractive error: 21% (21/102); organic anomaly: 13% (13/102)	Pediatric ophthalmology clinic, Germany, screener not described
Williams et al[58] (2000)	Topcon PR2000 autorefractor Various cutoffs evaluated, cutoffs not predefined	Comprehensive eye examination with cycloplegic refraction	Spherical error >3.75 D; anisometropia >1.25 D; astigmatism >1.25 D	Cross-sectional; 12–69 mo; N = 222; A, spherical error, >3.75 D: 19% (36/189); B, anisometropia, >1.25 D: 12% (23/189); C, astigmatism, >1.25 D: 16% (30/189)	Pediatric ophthalmology clinic, United Kingdom, orthoptist

NTU indicates National Taiwan University; TNO, a Dutch stereoacuity test.

with a positive likelihood ratio (PLR) of 6.1 (95% CI: 4.8–7.6) and negative likelihood ratio (NLR) of 0.43 (95% CI: 0.38–0.50).[55] A smaller (n = 149) study of children who were attending a pediatric ophthalmology clinic reported moderate-to-strong PLRs (5.7–12) and NLRs (0.05–0.23) depending on the screening cutoff used.[31] Two studies of Native American children revealed that Lea-symbols testing very weakly increased the likelihood of significant refractive error or astigmatism in high-prevalence settings (PLR: 1.6 and 1.9).[46,47]

In the VIP Study, the crowded HOTV test (a test that involves identification of the letters H, O, T, and V) was associated with similar accuracy compared with crowded Lea symbols (PLR: 4.9 [95% CI: 3.9–6.1]; NLR: 0.52 [95% CI: 0.46–0.58]).[60]

Stereoacuity Screening

In 3 fair-quality studies of the random dot E test, the median PLR was 4.2 (range: 3.6–11.4) and the median NLR was 0.65 (range: 0.15–0.81).[32,40,55] The VIP Study had similar results for the random dot E and Stereo Smile II tests (PLR: 4.2 [95% CI: 3.3–5.3] and 4.9 [95% CI: 3.9–6.1]; NLR: 0.65 [95% CI: 0.59–0.71] and 0.62 [95% CI: 0.56–0.67], respectively).[55]

Cover-Uncover Test

In the VIP Study, the cover-uncover test was associated with a PLR of 7.9 (95% CI: 4.6–14) and an NLR of 0.86 (95% CI: 0.82–0.90).[55]

Autorefractors

In 2 studies, the Retinomax autorefractor was associated with a median PLR of 3.4 (range: 1.9–6.1) and median NLR of 0.38 (range: 0.35–0.41).[28,55] From 2 studies of Native American children with astigmatism[47] or a high prevalence of refractive error,[46] stronger likelihood ratios (PLR: 6.7 and 18; NLR: 0.11 and 0.08) were reported.

TABLE 7 Diagnostic Accuracy of Preschool Vision-Screening Tests

Test	Target Condition	Sensitivity (95% CI)	Specificity (95% CI)	PLR (95% CI)	NLR (95% CI)
Visual acuity tests					
Crowded Lea symbols visual acuity test (4 studies)					
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.61 (0.56–0.66)[a]	0.90 (0.88–0.92)[a]	6.1 (4.8–7.6)[a]	0.43 (0.38–0.50)[a]
Bertuzzi et al[31] (2006)	Amblyogenic risk factors	0.96 (0.78–1.00)[b]	0.83 (0.75–0.90)[b]	5.7 (3.8–8.6)[b]	0.05 (0.01–0.36)[b]
				5.9 (5.7–6.1)[c]	0.15 (0.05–0.43)[c]
Miller et al[46] (1999)	Significant refractive error	0.91 (0.82–0.96)[d]	0.44 (0.37–0.52)[d]	1.6 (1.4–1.9)[d]	0.21 (0.10–0.43)[d]
Miller et al[47] (2001)	Astigmatism	0.93 (0.87–0.97)[d]	0.51 (0.44–0.57)[d]	1.9 (1.6–2.2)[d]	0.14 (0.08–0.27)[d]
Crowded HOTV visual acuity test (1 study)					
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.54 (0.49–0.59)[a]	0.89 (0.87–0.91)[a]	4.9 (3.9–6.1)[a]	0.52 (0.46–0.58)[a]
Stereoacuity tests					
Random dot E stereogram (3 studies)					
Chang et al[32] (2007)	Amblyopia	0.20[e]	0.98[e]	11.4[e]	0.81[e]
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.42 (0.37–0.47)[a]	0.90 (0.88–0.92)[a]	4.2 (3.3–5.3)[a]	0.65 (0.59–0.71)[a]
Hope and Maslin[40] (1990)	Refractive error or strabismus	0.89 (0.52–1.0)	0.76 (0.68–0.82)	3.6 (2.5–5.2)	0.15 (0.02–0.94)
				4.2 (3.6–11.4)[c]	0.65 (0.15–0.81)[c]
Stereo Smile II (1 study)					
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.44 (0.39–0.49)[a]	0.91 (0.89–0.93)[a]	4.9 (3.9–6.1)[a]	0.62 (0.56–0.67)[a]
Ocular alignment test					
Cover-uncover test (1 study)					
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.16 (0.12–0.20)	0.98 (0.97–0.99)	7.9 (4.6–14.0)	0.86 (0.82–0.90)
Combined clinical tests (5 studies)					
Kennedy et al[43] (1995)	Amblyogenic risk factors	0.09 (0.04–0.20)	1.00 (0.99–1.0)	17 (5.5–54)	0.91 (0.84–0.99)
Barry and Konig[29] (2003)	Amblyopia or amblyogenic risk factors	0.91 (0.71–0.99)	0.94 (0.92–0.95)	15 (11–19)	0.10 (0.03–0.36)
Newman and East[50] (1999)	Amblyopia	1.00 (0.78–1.0)	0.93 (0.91–0.95)	14 (10–19)	0.03 (0.002–0.51)
Shallo-Hoffmann et al[53] (2004)	Amblyogenic risk factors	0.73 (0.13–0.98)	0.94 (0.90–0.96)	12 (4.7–28)	0.28 (0.03–2.4)
Chui et al[33] (2004)	Amblyogenic risk factors	0.67 (0.41–0.87)	0.86 (0.79–0.92)	4.8 (2.8–8.4)	0.39 (0.20–0.75)
				14 (4.8–17)[c]	0.28 (0.03–0.91)[c]
Autorefractors					
Retinomax (4 studies)					
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.64 (0.60–0.67)[a]	0.90 (0.88–0.91)[a]	6.1 (5.2–7.0)[a]	0.41 (0.37–0.45)[a]
Barry and Konig[28] (2001)	Amblyopia	0.80 (0.44–0.98)	0.58 (0.53–0.62)	1.9 (1.4–2.6)	0.35 (0.10–1.2)
				3.4 (1.9–6.1)[c]	0.38 (0.35–0.41)[c]
Miller et al[46] (1999)	Significant refractive error	0.91 (0.82–0.96)[d]	0.86 (0.80–0.91)[d]	6.7 (4.5–9.8)[d]	0.11 (0.05–0.22)[d]
Miller et al[47] (2001)	Astigmatism	0.93 (0.88–0.96)[d]	0.95 (0.91–0.98)[d]	18 (10–34)[d]	0.08 (0.04–0.13)[d]
SureSight autorefractor (3 studies)					
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.85 (0.81–0.88)[f]	0.62 (0.59–0.65)[f]	2.2 (2.0–2.4)[f]	0.24 (0.19–0.30)[f]
		0.63 (0.59–0.65)[a,d]	0.90 (0.88–0.92)[a,d]	6.3 (5.2–7.7)[a,d]	0.41 (0.36–0.47)[a,d]
Kemper et al[41] (2005)	Amblyogenic risk factors	0.85 (0.69–0.95)	0.52 (0.40–0.63)	1.8[e]	0.29[e]
Rogers et al[52] (2008)	Amblyogenic risk factors	0.97 (0.88–1.0)[f]	0.38 (0.24–0.54)[f]	1.6 (1.2–2.0)[f]	0.09 (0.02–0.37)[f]
		0.79 (0.67–0.89)[d,g]	0.64 (0.48–0.78)[d,g]	2.2 (1.4–3.4)[d,g]	0.32 (0.18–0.52)[d,g]
				1.8 (1.6–2.2)[c,f]	0.24 (0.09–0.29)[c,f]
Topcon PR 2000 (1 study)					
Williams et al[58] (2000)	Spherical error > 3.75 D	0.50 (0.33–0.67)	0.95 (0.90–0.98)	9.6 (4.5–20)	0.53 (0.38–0.73)
	Anisometropia	0.74 (0.52–0.90)	0.95 (0.91–0.98)	15 (7.5–32)	0.27 (0.14–0.55)
	Astigmatism	0.47 (0.28–0.66)	0.96 (0.92–0.99)	12 (5.2–30)	0.55 (0.40–0.78)
PlusOptix/Power Refractor (6 studies)					
Dahlmann-Noor et al[36] (2009)	Decreased visual acuity, strabismus, and ptosis	0.45 (0.29–0.62)	1.0 (0.98–1.0)	230 (14–3680)	0.56 (0.42–0.74)
Arthur et al[27] (2009)	Amblyogenic risk factors	0.83 (0.67–0.93)	0.95 (0.92–0.98)	18 (10–33)	0.17 (0.08–0.36)
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.54 (0.49–0.59)[a]	0.90 (0.88–0.92)[a]	5.4 (4.4–6.6)[a]	0.51 (0.46–0.57)[a]
Ehrt et al[38] (2007)	Amblyogenic risk factors	0.71 (0.59–0.82)	0.78 (0.68–0.86)	3.2 (2.2–4.9)	0.37 (0.25–0.54)

TABLE 7 Continued

Test	Target Condition	Sensitivity (95% CI)	Specificity (95% CI)	PLR (95% CI)	NLR (95% CI)
Matta et al[45] (2008)	Amblyogenic risk factors	0.98 (0.85–1.0)	0.68 (0.51–0.81)	3.0 (1.9–4.7)[f]	0.04 (0.01–0.26)[f]
		0.98 (0.85–1.0)	0.88 (0.74–0.96)	8.4 (3.7–19)[a,d]	0.03 (0.00–0.20)[a,d]
				5.4 (3.0–230)[c]	0.17 (0.04–0.56)[c]
Dahlmann-Noor et al[37] (2009)	Myopia	0.88 (0.30–1.0)	0.96 (0.89–0.99)	21 (7.8–55)	0.13 (0.01–1.7)
	Hyperopia	0.20 (0.10–0.35)	0.99 (0.92–1.0)	26 (1.6–450)	0.81 (0.70–0.94)
	Astigmatism	0.75 (0.36–0.96)	0.93 (0.86–0.97)	11 (4.7–24)	0.27 (0.08–0.89)
	Anisometropia	0.50 (0.31–0.69)	0.87 (0.77–0.93)	3.7 (1.9–7.1)	0.58 (0.40–0.84)
Photoscreeners					
MTI photoscreener (8 studies)					
Ottar et al[51] (1995) and Donahue et al[59] (2002)	Amblyogenic risk factors	0.82 (0.76–0.87)	0.91 (0.88–0.93)	8.7 (6.9–11)	0.20 (0.15–0.27)
Rogers et al[52] (2008)	Amblyogenic risk factors	0.95 (0.86–0.99)	0.88 (0.74–0.96)	8.0 (3.5–18)	0.06 (0.02–0.18)
Tong et al[56] (2000)	Amblyogenic risk factors	0.56 (0.50–0.62)	0.91 (0.84–0.96)	6.4 (3.4–12)	0.48 (0.42–0.56)
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.37 (0.32–0.42)	0.94 (0.92–0.95)	6.2 (4.7–8.1)	0.67 (0.62–0.72)
Cooper et al[35] (1999)	Amblyopia	0.62 (0.56–0.68)[h]	0.83 (0.80–0.86)[h]	3.7 (2.8–4.9)[h]	0.45 (0.37–0.55)[h]
Berry et al[30] (2001)	Amblyogenic risk factors	0.83 (0.61–0.95)	0.68 (0.48–0.84)	2.6 (1.4–4.5)	0.26 (0.10–0.65)
Weinand et al[57] (1998)	Amblyogenic risk factors	0.83 (0.72–0.94)[h]	0.66 (0.42–0.74)[h]	2.4 (1.6–3.0)[h]	0.26 (0.14–0.38)[h]
				6.2 (2.4–8.7)[c]	0.26 (0.06–0.67)[c]
Miller et al[47] (2001)	Significant refractive error	0.66 (0.59–0.73)[a]	0.71 (0.64–0.78)[a]	2.3 (1.8–2.9)[a]	0.48 (0.38–0.60)[a]
Ottar et al[51] (1995) and Donahue et al[59] (2002)	Higher-magnitude amblyogenic risk factors	0.50 (0.39–0.61)	0.98 (0.97–0.99)	33 (18–58)	0.51 (0.41–0.63)
iScreen Photoscreener (2 studies)					
Kennedy and Thomas[44] (2000)	Amblyogenic risk factors	0.92 (0.88–0.95)	0.89 (0.83–0.94)	8.6 (5.4–14)	0.09 (0.06–0.13)
VIP Study Group[55] (2004)	Amblyogenic risk factors or significant nonamblyogenic refractive error	0.37 (0.32–0.42)	0.94 (0.92–0.95)	6.2 (4.7–8.1)	0.67 (0.62–0.72)
				7.3 (6.2–8.6)[c]	0.25 (0.09–0.67)[c]
Visiscreen 100 photoscreener (2 studies)					
Cogen and Ottemiller[34] (1992)	Amblyogenic risk factors	0.85 (0.55–0.98)	0.94 (0.87–0.98)	14 (6.3–32)	0.16 (0.05–0.59)
Morgan and Johnson[49] (1987)	Amblyogenic risk factors	0.91 (0.76–0.98)	0.74 (0.52–0.90)	3.5 (1.7–7.0)	0.12 (0.04–0.36)
				7.0 (3.5–14)[c]	0.14 (0.12–0.16)[c]
Fortune Optical VRB-100 photoscreener (1 study)					
Cooper et al[35] (1999)	Amblyopia	0.64 (0.60–0.69)[h]	0.81 (0.76–0.86)[h]	3.5 (2.5–4.9)[h]	0.44 (0.37–0.52)[h]
Computer photoscreener (1 study)					
Guo et al[39] (2000)	Amblyogenic risk factors	0.95 (0.90–0.98)	0.90 (0.84–0.95)	9.6 (5.7–16)	0.06 (0.03–0.11)
Otago (noncommercial) photoscreener (3 studies)					
Kennedy et al[43] (1995)	Amblyogenic risk factors	0.46 (0.22–0.72)	1.0 (0.99–1.0)	110 (38–310)	0.54 (0.33–0.89)
Kennedy and Sheps[42] (1989)	Amblyogenic risk factors	0.94 (0.87–0.98)	0.94 (0.89–0.98)	16 (8.2–32)	0.06 (0.03–0.14)
Molteno et al[48] (1993)	Amblyogenic risk factors	0.89 (0.86–0.91)	0.61 (0.55–0.66)	2.3 (2.0–2.6)	0.18 (0.14–0.22)
				16 (2.3–110)[c]	0.18 (0.06–0.54)[c]

[a] Based on 90% specificity.
[b] Based on 0.80 acuity score cutoff.
[c] Values are median (range).
[d] Excluded from calculation of median.
[e] CIs not calculable.
[f] Based on manufacturer's referral criteria.
[g] Based on VIP Study 90% specificity criteria.
[h] Based on median results from multiple readers (numbers in parentheses are ranges).

In 3 fair-quality studies, the SureSight autorefractor was associated with a median PLR of 1.8 (range: 1.6–2.2) and median NLR of 0.24 (range: 0.09–0.29) on the basis of the manufacturer's referral criteria.[41,52,55] In the VIP Study, modification of referral criteria to attain a specificity of 0.90 or 0.94 increased the PLR,[55] but in another study, application of the VIP criteria had little effect on diagnostic accuracy compared with using the manufacturer's criteria.[52]

In 6 studies of the PlusOptix (previously the Power Refractor), the median PLR was 5.4 (range: 3.0–230) and the median NLR was 0.17 (range: 0.04–0.56).[27,36–38,45,55] Excluding the poor-quality study[38] did not reduce the variability in estimates. One fair-quality study was an outlier, with a PLR of 230 (95% CI: 14–3680).[36] Specificity was 100% (252 of 252) in this study, but

children with negative screen results did not undergo cycloplegic refraction unless they failed an orthoptist examination. The authors of 1 study reported an improved PLR (from 3.0 to 8.4) when the manufacturer's referral criteria were modified to enhance specificity.[45]

The VIP study revealed slightly stronger likelihood ratios for the Retinomax and SureSight autorefractors compared with the Power Refractor when SureSight screening cutoffs were set to achieve a specificity of 0.90 or 0.94.[55,60]

Photoscreeners

In 8 studies of the Medical Technology and Innovations (MTI) photoscreener, the median PLR was 6.2 (range: 2.4–8.7) and the median NLR was 0.26 (range: 0.06–0.67).[30,35,47,51,52,55–57] One study of Native American children revealed that the MTI photoscreener was associated with a PLR of 2.3 (95% CI: 1.8–2.9) and an NLR of 0.48 (95% CI: 0.38–0.60) for identification of astigmatism (prevalence: 48%).[47]

From 2 studies of the iScreen photoscreener a median PLR of 7.3 (range: 6.2–8.6) and median NLR of 0.25 (range: 0.09–0.67) were reported.[44,55] Two studies of the Visiscreen 100 photoscreener resulted in a median PLR of 7.0 (range: 3.5–14) and median NLR of 0.14 (range: 0.12–0.16).[34,49] Other studies evaluated photoscreeners that are not (or were never) commercially available in the United States.[35,39,42,43,48]

The VIP Study resulted in identical diagnostic accuracy for the MTI and iScreen photoscreeners.[55]

Combinations of Screening Tests

In 5 studies that evaluated combinations of screening tests, the median PLR was 14 (range: 4.8–17) and the median NLR was 0.28 (range: 0.03–0.91).[29,33,43,50,53] All of the studies included tests of visual acuity, stereoacuity, and ocular alignment, although the specific tests varied.

The VIP study found that addition of an ocular alignment test (cover-uncover test, the Stereo Smile II, or the MTI photoscreener) to a test of visual acuity or refractive error (crowded Lea symbols or HOTV tests or the Retinomax or SureSight autorefractors) increased sensitivity for detection of strabismus by 6% to 31%.[61]

Direct Comparisons of Different Types of Screening Tests

The VIP Study found that the random dot E stereoacuity test, the Stereo Smile II, the iScreen photoscreener, and the MTI photoscreener had lower sensitivity compared with crowded Lea symbols or HOTV visual acuity tests and the Retinomax, SureSight, or Power Refractor (PlusOptix), but differences in likelihood-ratio estimates were generally small.[55] The cover-uncover test was associated with markedly lower sensitivity but higher specificity than the other tests, which resulted in a stronger PLR and weaker NLR.

Key Question 3a: In Children Aged 1 to 5 Years, Does Accuracy of Screening Tests for Vision Impairment Vary in Different Age Groups?

Four studies found no clear differences in the diagnostic accuracy of various screening tests in preschool-aged children stratified according to age (Appendix 7).[33,41,44,56] Testability rates generally exceeded 80% in 3-year-olds, and there were small increases through 5 years of age.[62–65] In the VIP Study, random dot E testability was 86% in 3-year-olds and 93% in 5-year-olds,[65] and HOTV and Lea-symbols testability was >95% at all ages between 3 and 5 years.[66] Overall testability was nearly 100% with the MTI photoscreener and various autorefractors.[55] Most (93%) 3-year-olds in the VIP Study were 42 to 47 months of age, so the applicability of results to younger 3-year-olds is uncertain. Four studies found substantially lower testability (range: 33%–56%) with the random dot E stereotest, Lea symbols, and the SureSight autorefractor in children 1 to <3 years of age compared with those who were older.[41,53,67,68] On the other hand, 1 large study of statewide screening with the MTI photoscreener found that testability was 93% in 1-year-old children.[69]

Key Question 4: What Are the Harms of Vision Screening in Children Aged 1 to 5 Years?

Only 1 controlled study evaluated potential psychosocial effects of screening. In the ALSPAC population-based cohort, children offered screening at 37 months of age were reported to have a 50% decreased odds of being bullied at the age of 7.5 years compared with those who were not offered screening.[70] Benefits were observed among children who received patching treatment (adjusted odds ratio [OR]: 0.39 [95% CI: 0.16–0.92]) but not among those treated with eyeglasses.

In populations in which the prevalence of visual conditions was <10%, 6[28,29,32,40,50,53] of 7[43] studies that applied the reference standard in all screened children (or a random subset) resulted in false-positive rates of >70% (Appendix 8). One large (n = 102 508) study of a statewide preschool photoscreening program found that 20% of children with positive screen results who did not meet criteria for amblyogenic risk factors were prescribed glasses.[71] In approximately one-quarter of the cases, the refractive error was clinically insignificant (anisometropia ≤ 0.75 diopter [D], hyperopia ≤ 2.00 D, myopia ≤ 0.75 D, and astigmatism ≤ 0.75 D). The remainder had higher-magnitude refrac-

tive errors but did not meet standard criteria for amblyogenic risk factors. No study evaluated the effects of unnecessary corrective lenses or treatment for amblyopia on long-term vision or functional outcomes.

Key Question 5: What Is the Effectiveness of Treatment for Vision Impairment in Children Aged 1 to 5 Years?

In children with unilateral refractive errors, 1 good-quality trial ($n = 177$) found patching plus eyeglasses and eyeglasses alone each more effective than no treatment by ~1 line on the Snellen eye chart after 1 year (mean difference versus no treatment: 0.11 logMAR [95% CI: 0.05–0.17] and 0.08 logMAR [95% CI: 0.02–0.15], respectively) (Table 8 and Appendix 9). Children were enrolled on the basis of abnormal results of 2 Snellen visual acuity tests but did not necessarily have amblyopia. The average improvement from baseline in logMAR visual acuity was ~0.17 for eyeglasses plus patching, 0.13 for eyeglasses alone, and 0.06 for no treatment, from an average baseline logMAR of 0.36.[72] In children with moderate (0.48 logMAR or worse) baseline refractive error, patching plus eyeglasses was associated with a larger improvement compared with no treatment (0.27 logMAR [95% CI: 0.14–0.39]).

Two trials evaluated patching versus no patching in children with amblyopia after pretreatment with eyeglasses.[73,74] One good-quality trial ($n = 180$) by the Pediatric Eye Disease Investigator Group (PEDIG) found that 2 hours daily of patching was associated with improved visual acuity in the amblyopic eye compared with no patching after 5 weeks (mean logMAR: 0.44 [equivalent Snellen 20/50] vs 0.51 [20/63] with no patching; adjusted mean difference: 0.07 [95% CI: 0.02–0.12]).[74] Forty-five percent of the children in the patching group experienced an improvement of ≥2 lines of visual acuity compared with 23% in the no-treatment group ($P = .003$). A smaller, fair-quality trial ($n = 60$) revealed a trend toward better visual acuity among children (mean baseline logMAR: 0.64) who were allocated to receive 3 or 6 hours of patching compared with no treatment after 12 weeks (mean change in logMAR: 0.29, 0.34, and 0.24, respectively; $P = .11$ for either treatment versus no treatment).[73]

All 3 trials evaluated older (4- to 5-year-old) preschool-aged children. No trial evaluated the effects of treatment on school performance or other measures of function.

Five fair- or good-quality trials found no differences in visual acuity improvement in the amblyopic eye between shorter and longer daily patching regimens (2 trials),[75,76] different atropine regimens (2 trials),[77,79] or between patching and atropine (1 trial).[78]

Evidence on whether age affects treatment outcomes is mixed. Two trials[74,75] found no interaction between age and amblyopia treatment effects among preschoolers aged 3 to 7 years, and 1 trial[72] found delayed treatment for 1 year associated with similar outcomes compared with immediate treatment in children aged 3 to 5 years. A trial of patching versus atropine revealed no interaction between age and visual acuity outcomes in preschoolers aged 3 to 7 years through 2 years of follow-up,[80,81] but at 10 years of age, an age of <5 years at study entry was associated with significantly increased likelihood of amblyopic eye visual acuity of 20/25 or better (57% vs 38%; $P = .004$).[82] One other trial found that younger preschoolers (3 years old) required fewer hours per day of patching to reach significant improvements in visual acuity compared with older preschool-aged children (4–8 years old).[76]

Key Question 6: What Are the Harms of Treatment for Children Aged 1 to 5 Years at Increased Risk for Vision Impairment or Vision Disorders?

Although 1 short-term (5-week) trial found no increased risk of nonamblyopic eye visual acuity loss associated with patching versus no patching,[74] another trial found patching to be associated with increased risk of ≥2 lines of visual acuity loss compared with the results of atropine (9% vs 1.4%; $P < .001$)[78]; and 1 trial found atropine plus a plano lens to be associated with increased risk of ≥1 line of visual acuity loss compared with the results of atropine alone (17% vs 4%; $P = .005$).[79] In both trials, nonamblyopic eye visual acuity subsequently returned to baseline in almost all children. Two other trials found no difference in risk of nonamblyopic eye visual acuity loss in direct comparisons of different patching or atropine regimens.[75,77]

Evidence on adverse psychosocial effects of amblyopia treatments is limited. One fair-quality follow-up study from a randomized trial found that children were more upset by patching plus eyeglasses compared with eyeglasses alone,[83] and 1 good-quality trial found patching to be associated with worse emotional well-being compared with atropine.[84]

DISCUSSION

Results for all key questions are summarized in Table 9.

As in the previous USPSTF review,[85] direct evidence on improved visual acuity or other health outcomes that result from preschool vision screening remains limited. The only randomized trial to date compared more intensive to less intensive screening rather than screening versus no screening.[20] Al-

TABLE 8 RCTs of Amblyopia Treatments

	Population	Follow-up	Intervention: Mean Change in logMAR Visual Acuity From Baseline	Quality Rating
Patching + eyeglasses vs eyeglasses alone vs no treatment				
Clarke et al[72] (2003)	$n = 177$; mean age 4.0 y; mean logMAR visual acuity in worse eye 0.36 (approximate Snellen equivalent 20/45)	1 y	Patching (hours/day not reported) + eyeglasses: 0.18; mean difference vs no treatment: 0.109 (95% CI: 0.005 to 0.17); eyeglasses only: 0.13; mean difference vs no treatment: 0.085 (95% CI: 0.02 to 0.15); no treatment: 0.06; $P = .001$ (ANOVA) Results stratified according to baseline severity; mild acuity loss at baseline: patching + eyeglasses: 0.23; mean difference vs no treatment: 0.04 (95% CI: −0.06 to 0.13); eyeglasses only: 0.24; mean difference vs no treatment 0.05 (95% CI: −0.03 to 0.13); no treatment: 0.19; $P = .38$ (ANOVA); moderate acuity loss at baseline: patching + eyeglasses: 0.52; mean difference vs no treatment: 0.27 (95% CI: 0.14 to 0.39); eyeglasses only: 0.35; mean difference vs no treatment: 0.11 (95% CI: −0.03 vs 0.24); no treatment: 0.25; $P < .001$ (ANOVA)	Good
Patching vs no patching, all children pretreated with eyeglasses if indicated				
Awan et al[73] (2005)	$n = 60$; mean age 4.6 y; mean logMAR visual acuity amblyopic eye 0.64 (approximate Snellen equivalent 20/90); 55/60 (92%) received eyeglasses for correction of refractive error	12 wk	3-h patching: 0.29 ($P = .32$ vs no treatment); 6-h patching: 0.34 ($P = .09$ vs no treatment); no treatment: 0.24 ($P = .11$ vs both treatments)	Fair
PEDIG[74] (2006)	$n = 180$; mean age 5.3 y; mean logMAR visual acuity amblyopic eye 0.55 (approximate Snellen equivalent 20/70); 155/180 (86%) received eyeglasses for correction of refractive error	5 wk	2-h patching: 0.12; no treatment: 0.04; mean between-group difference: 0.07 (95% CI: 0.02 to 0.12; $P = .006$)	Good
Occlusion regimens				
PEDIG[75] (2003)	$n = 189$; mean age 5.2 y; mean logMAR visual acuity amblyopic eye 0.48 (approximate Snellen equivalent 20/63)	4 mo	2-h patching: 0.24; 6-h patching: 0.24; mean between-group difference: 0.001 (95% CI: 0.040 to 0.042; $P = .9$)	Good
Stewart et al[76] (2007)	$n = 97$; mean age 5.6 y; mean logMAR visual acuity amblyopic eye 0.44 (approximate Snellen equivalent 20/70)	Mean: 9 wk (range: 5–26)	6-h patching: 0.26; 12-h patching: 0.24; mean between-group difference: 0.02 (95% CI: 0.0 to 0.04; $P = .64$)	Fair
Atropine regimens				
PEDIG[77] (2004)	$n = 168$; mean age 5.3 y; mean logMAR visual acuity amblyopic eye 0.46 (approximate Snellen equivalent 20/60)	4 mo	Daily atropine: 0.23; weekend atropine: 0.25; mean between-group difference: 0.02 (95% CI: −0.21 to 0.09; $P = .52$)	Good
Patching vs atropine				
PEDIG[78] (2002)	$n = 419$; mean age 5.3 y; mean logMAR visual acuity amblyopic eye 0.53 (approx Snellen equivalent 20/65)	Initial trial: 6 mo; voluntary follow-up up to age 10 y	6-mo results: mean age 5.2 y; patching 0.25; atropine 0.21; mean between-group difference 0.04 (95% CI: 0.005 to 0.064) 2-y results: mean age 7.2 y; follow-up of 363/419 (86.6%) of patients in original study; patching 0.16; atropine 0.17; mean between-group difference 0.01 (95% CI: −0.04 to 0.02; $P = .57$) 5-y results: mean age 10.3 y; follow-up of 176/419 (42.0%) of patients in original study; patching 0.19; atropine 0.16; mean between-group difference 0.03 (95% CI: −0.02 to 0.07; $P = .2$)	Good

ANOVA indicates analysis of variance.

TABLE 9 Summary of Evidence According to Key Question

No. of Studies: Overall Quality Ratings	Limitations	Consistency	Primary Care Applicability	Summary of Findings
KQ1: Is vision screening in children aged 1–5 y associated with improved health outcomes? Screening vs no screening: 4 cohort studies Intensive periodic vs 1-time screening: 1 RCT Overall quality rating: fair-poor	No study evaluated school performance or other functional outcomes besides vision outcomes 3 of the 4 cohort studies were retrospective and had important methodologic shortcomings; the 1 prospective cohort study compared 1-time screening with no screening	Not applicable (not enough studies addressing the same question to judge consistency)	High	No randomized trial evaluated outcomes of preschool vision screening compared to no screening. One large, fair-quality randomized trial nested within a population-based cohort study found intensive, periodic orthoptist screening from 8 through 37 mo of age associated with reduced likelihood of amblyopia at 7.5 y of age compared with 1-time orthoptist screening at 37 mo of age by ~1%, but the difference was only statistically significant for 1 of 2 definitions of amblyopia. A large prospective cohort study from this population found 1-time orthoptist screening at 37 mo of age associated with no significant difference in risk of amblyopia at 7.5 y compared with school-entry screening when using any of 3 prestated definitions for amblyopia. Three retrospective cohort studies found preschool screening associated with improved school-aged vision outcomes compared with no screening.
KQ1a: Does effectiveness of vision screening in children aged 1–5 y vary in different age groups? Earlier vs later screening: 1 RCT, 1 cohort study Overall quality rating: poor	In the RCT, it was not possible to determine whether differences in outcomes should be attributed to the earlier age at which screening was started or to the increased frequency of screening that also took place; in the retrospective cohort study, estimates were imprecise and based on a very small sample of children screened	Not applicable	High	No randomized trial directly compared outcomes of preschool vision screening in different age groups. In 1 randomized trial, screening was initiated earlier in 1 group (8 mo of age) compared with the control group (37 mo of age), but the earlier group also received periodic screening. One poor-quality retrospective cohort study found no difference between screening at 2–4 y of age vs screening before 2 y in risk of at least mild vision impairment.
KQ2: What is the accuracy and reliability of risk-factor assessment for identifying children aged 1–5 y at increased risk for vision impairment? No studies				No study evaluated the accuracy or reliability of risk-factor assessment in preschool vision screening, and no study evaluated outcomes of targeted vs universal preschool vision screening.

TABLE 9 Continued

No. of Studies: Overall Quality Ratings	Limitations	Consistency	Primary Care Applicability	Summary of Findings
KQ3: What is the accuracy of screening tests for vision impairment in children aged 1–5 y? 31 diagnostic accuracy studies Overall quality rating: good	Estimates of the diagnostic accuracy of different types of screening tests as well as specific screening tests within the different categories varied substantially across studies, which makes it difficult to judge comparative diagnostic utility with certainty	Some inconsistency in diagnostic accuracy estimates	Moderate (mostly specialty or enriched populations with high prevalence)	Thirty-one studies evaluated the diagnostic accuracy of various preschool vision-screening tests. Four studies evaluated visual acuity tests (Lea symbols and HOTV tests), 3 evaluated stereoacuity tests (random dot E stereogram and Stereo Smile II), 1 evaluated the cover-uncover test, 4 evaluated some combination of clinical examination screening tests, 12 evaluated autorefractors, and 15 evaluated photoscreeners. Diagnostic accuracy estimates for all of these screening tests suggest utility for identification of children at higher risk for amblyogenic risk factors or specific visual conditions, although differences between studies in the populations evaluated, screening tests evaluated, screening thresholds applied, and target conditions sought make it difficult to reach strong conclusions about how they compare with one another. Studies that evaluated combinations of clinical tests (visual acuity, stereoacuity, and ocular alignment) generally showed superior likelihood ratios compared with studies of individual tests. In the largest study to directly compare the diagnostic accuracy of different individual screening tests (the VIP Study), differences in likelihood-ratio estimates between the various tests evaluated were generally small with overlapping 95% CIs.
KQ3a: In children aged 1–5 y, does accuracy of screening tests for vision impairment vary in different age groups? 4 studies Overall quality rating: fair	Limited numbers of studies with some inconsistency	Some inconstancy	Moderate (mostly specialty of enriched populations with high prevalence)	Evidence on the comparative accuracy of preschool vision tests in different age groups among children aged 1–5 y is limited. Four studies found no clear differences in the diagnostic accuracy of various screening tests in preschool-aged children stratified according to age. Testability using common visual acuity tests, stereoacuity tests, photoscreening, and autorefractors generally exceeds 80%–90% in children ≥3 y of age, and there are small increases in testability through 5 y of age. Four studies found substantially lower testability with the random dot E stereotest, Lea symbols visual acuity testing, and the SureSight autorefractor in preschool-aged children 1–3 y of age, compared with those 3–5 y of age. One large study of statewide screening with the MTI photoscreener found that testability was 94% at 1 y of age.

TABLE 9 Continued

No. of Studies: Overall Quality Ratings	Limitations	Consistency	Primary Care Applicability	Summary of Findings
KQ4: What are the harms of vision screening in children aged 1–5 y? Psychosocial: 1 large cohort study, poor quality False-positives: 7 studies Overall quality rating: poor	Sparse evidence, except for positive predictive values	Not applicable (not enough studies addressing the same question to judge consistency)	High	Evidence on harms of preschool vision screening is limited. Although preschool vision screening is associated with potential psychosocial harms related to the treatments, 1 large cohort study found a 50% reduction in odds of being bullied at the age of 7.5 y among children offered screening compared with those who were not offered screening. In populations with a prevalence of visual conditions of <10%, 6 of 7 studies reported false-positive rates of >70%. One large study of a statewide preschool photoscreening program found that 20% of children with positive screen results who did not meet criteria for amblyopia or amblyogenic risk factors (false-positives) were prescribed glasses. No study evaluated effects of unnecessary corrective lenses or treatment for amblyopia on long-term vision or functional outcomes.
KQ5: What is the effectiveness of treatment for vision impairment in children aged 1–5 y? Treatment vs no treatment: 1 RCT Patching vs no treatment (>85% received eyeglasses): 2 RCTs Comparisons of treatment: 5 RCTs Overall quality rating: fair	All trials evaluated older (≥3-y-old) preschool-aged children No trial evaluated effects of treatment compared with no treatment on school performance or other measures of function besides vision outcomes	Consistent	High	In children with unilateral refractive errors, 1 good-quality trial found patching plus eyeglasses and eyeglasses alone more effective than no treatment by an average of ~1 line on the Snellen eye chart after 1 y. Effects were larger (1–2 lines of visual acuity improvement) in the subgroup of children with worse baseline visual impairment. One fair-quality and 1 good-quality trial found that patching resulted in a statistically significant but small (<1 line on the Snellen eye chart) average improvement in visual acuity after 5–12 wk of follow-up in children with amblyopia who were pretreated with eyeglasses if needed. Five fair- or good-quality trials found no differences in visual acuity improvement in the amblyopic eye between shorter and longer daily patching regimens (2 trials), different atropine regimens (2 trials), or between patching and atropine (1 trial). Three trials found no interaction between age and amblyopia treatment effects among preschoolers 3–7 y old, and 1 trial found that delaying treatment for 1 y was associated with similar outcomes compared with immediate treatment in children 3–5 y old. One other trial found younger (3-y-old) preschoolers required fewer hours per day of patching to experience optimal improvements in visual acuity compared with older preschool-aged children (4–8 y old).

TABLE 9 Continued

No. of Studies: Overall Quality Ratings	Limitations	Consistency	Primary Care Applicability	Summary of Findings
KQ6: What are the harms of treatment for children aged 1–5 y at increased risk for vision impairment or for vision disorders?				
Nonamblyopic eye visual acuity loss: 5 RCTs	Sparse evidence on adverse psychosocial effects or effects of compliance on clinical outcomes	Consistent	High	Although 1 short-term (5-wk) trial found no increased risk of decreased nonamblyopic eye visual acuity associated with patching vs no patching, 1 trial found patching associated with increased risk of ≥2 lines of visual acuity loss compared with atropine (9% vs 1.4%; $P < .001$), and 1 trial found atropine plus a plano lens associated with increased risk of ≥1 line of visual acuity loss compared with atropine alone (17% vs 4%; $P = .005$). In both trials, nonamblyopic eye visual acuity subsequently returned to baseline in almost all children. Two other trials found no difference in risk of nonamblyopic eye visual acuity loss in direct comparisons of different patching or atropine regimens.
Overall quality rating for these 5 studies: fair				
Adverse psychosocial effects: 2 RCTs				Evidence on adverse psychosocial effects of amblyopia treatments is limited. One fair-quality follow-up study from a randomized trial found that children were more upset by patching plus eyeglasses compared with eyeglasses alone, and 1 good-quality trial found patching associated with worse emotional well-being compared with atropine.
Overall quality rating for these 2 studies: poor				

though it found that repeated preschool screening reduced the prevalence of subsequent (school-aged) amblyopia by ~1% compared with 1-time screening, the difference was only statistically significant for 1 of 2 definitions of amblyopia used in the trial. One fair-quality prospective cohort study found no significant difference between 1-time screening at 37 months of age compared with school-entry screening on risk of amblyopia at 7.5 years of age[21] but a 50% reduction in the odds of being bullied,[70] perhaps related to earlier completion of patching regimens. Retrospective cohort studies found preschool vision screening to be more effective than no screening, but they had important methodologic shortcomings.[22–24]

More evidence is now available on the accuracy of various preschool vision-screening tests. There is good evidence that commonly used visual acuity tests, stereoacuity tests, the cover-uncover test, autorefractors, and photoscreeners are useful for screening. In the largest study to directly compare many screening tests (the VIP Study), differences in likelihood-ratio estimates were generally too small to clearly distinguish superior from inferior tests.[55] In addition to diagnostic accuracy, other factors that may affect the choice of screening tests include testability rates at the age being screened, convenience, costs, and how well different tests perform in combination.[29,33,43,53,61] Screening tests are associated with a high rate of false-positive results in low-prevalence populations,[28,29,32,40,50,53] which could result in unnecessary prescription of eyeglasses.[71]

There is good evidence that there are effective treatments for visual impairment in preschool-aged children. Although benefits of patching compared with no patching averaged ≤1 line of visual acuity, some trials pretreated

all children with eyeglasses, and benefits seemed larger (1–2 lines) for children with more severe baseline vision impairment.[72–74] All of the trials enrolled children aged 3 years or older, so applicability to younger preschool-aged children is uncertain. Factors that may affect interpretation of the magnitude of treatment benefits are that the visual impairment associated with amblyopia can become irreversible, is not correctable with refraction, and potentially affects function over the life span of a child.

Evidence on when to initiate preschool screening remains limited. One randomized trial initiated screening at different ages, but the effects of age could not be separated from the effects of repeated versus 1-time screening.[20] Results of other studies indicate a lower rate of false-positive screens in children screened at 3.5 years compared with those screened at 1.5 years[26] and no clear association between age at which treatment was started and effectiveness among preschool-aged children aged 3 years and older.[72,74–76,80–82]

Our evidence review has some potential limitations. First, we excluded non–English-language studies, which could introduce language bias. However, we identified no relevant non–English-language studies in our literature searches. Second, there were too few studies to assess for publication bias. Third, a number of studies evaluated diagnostic accuracy of screening tests or screening programs in community-based settings and specialty eye clinics, which could limit their applicability to primary care settings.

Well-designed studies are needed to better understand the effects of screening compared with no screening, to identify optimal methods for vision screening, to clarify when to begin screening, to define appropriate screening intervals, and to develop effective strategies for linking preschool-aged children with vision impairment to appropriate care while avoiding unnecessary use of eyeglasses and other treatments. In addition, almost all of the trials have focused on effects of preschool vision screening and treatment on visual acuity. Trials that also address function are needed to clarify how preschool vision screening may affect school performance and other aspects of child development.

CONCLUSIONS

Direct evidence on the effectiveness of preschool vision screening for improving visual acuity or other clinical outcomes remains limited and does not adequately address the question of whether screening is more effective than no screening. However, good evidence on diagnostic accuracy and treatments suggest that preschool vision screening could lead to increased detection of visual impairment and greater improvement in visual outcomes than if children were never screened.

APPENDIX 1: LITERATURE SEARCH STRATEGIES

Overall Searches

Database: EBM Reviews—Cochrane Central Register of Controlled Trials

1. amblyopia.mp. [mp = title, original title, abstract, Medical Subject Headings (MeSH), heading words, key word]
2. strabismus.mp. [mp = title, original title, abstract, MeSH, heading words, key word]
3. refractive error.mp. [mp = title, original title, abstract, MeSH, heading words, key word]
4. 1 or 2 or 3
5. 4 and (child$ or pediatri$ or preschool).mp. [mp = title, original title, abstract, MeSH, heading words, key word]
6. limit 5 to yr = "2003–2008"

Database: EBM Reviews—Cochrane Database of Systematic Reviews

1. amblyopia.mp. [mp = title, short title, abstract, full text, key words, caption text]
2. strabismus.mp. [mp = title, short title, abstract, full text, key words, caption text]
3. refractive error.mp. [mp = title, short title, abstract, full text, key words, caption text]
4. 1 or 2 or 3
5. 4 and (child$ or pediatri$ or preschool).mp. [mp = title, short title, abstract, full text, key words, caption text]

Risk Search

Database: Ovid Medline

1. exp Amblyopia/
2. exp Refractive Errors/
3. exp Vision Disorders/
4. or/1–3
5. limit 4 to ("newborn infant [birth to 1 month]" or "infant [1–23 months]" or "preschool-aged child [2–5 years]")
6. exp Risk/ or exp Risk Factors/
7. 5 and 6
8. limit 7 to yr = "1999–2008"
9. Case Reports/
10. 8 not 9

Screening Search

Database: Ovid Medline

1. vision tests/ or refraction, ocular/ or vision screening/
2. limit 1 to ("newborn infant (birth to 1 month)" or "infant (1–23 months)" or "preschool-aged child (2–5 years)")
3. limit 2 to yr = "1999–2008"
4. limit 3 to humans
5. limit 4 to English language
6. limit 4 to abstracts

7. 5 or 6
8. Case Reports/
9. 7 not 8
10. English abstract.mp.
11. 9 not 10

Treatment Search

Database: Ovid Medline

1. exp Amblyopia/dt, pc, th [Drug Therapy, Prevention & Control, Therapy]
2. exp Refractive Errors/dt, th, pc [Drug Therapy, Therapy, Prevention & Control]
3. 1 or 2
4. limit 3 to ("newborn infant [birth to 1 month]" or "infant [1–23 months]" or "preschool-aged child [2–5 years]")
5. limit 4 to English language
6. limit 4 to abstracts
7. 5 or 6
8. limit 7 to yr = "1999–2008"

APPENDIX 2: DETAILS OF STUDY SELECTION

We defined the target population as children 1 to 5 years of age who were evaluated in primary care or community-based settings without known visual impairment or obvious symptoms. We included studies of screening in specialty eye settings but evaluated their applicability to primary care settings. Although the term "visual impairment" is broad, conditions covered in this review are amblyopia, amblyogenic risk factors (Table 1), strabismus, and simple refractive errors.

For screening tests, we included tests of visual acuity, ocular alignment, and stereoacuity; photoscreeners; and autorefractors. Preschool vision screening typically includes measurement of visual acuity (Table 3), ocular alignment, and stereoacuity.[86] Recommended visual acuity tests vary according to age (Table 2). Potential advantages of more automated screening methods such as photoscreeners and autorefractors over traditional screening are that they may reduce testing time, increase objectivity of screening, or enhance testability rates in younger children. Children who fail a preschool vision-screening test are typically referred for a full ophthalmologic examination to confirm the presence of vision problems. We excluded tests not commonly used in primary care, including cycloplegic refraction and retinoscopy.

For treatments, we focused on correction of refractive errors and use of patching or atropine. Outcomes of interest were visual acuity, risk of amblyopia, vision-related function, school performance, and adverse events related to screening or treatment. We excluded children with severe congenital conditions or developmental delay, retinopathy of prematurity, glaucoma, congenital cataract, and high myopia.

APPENDIX 3: INCLUSION AND EXCLUSION CRITERIA FOR KEY QUESTIONS

All Key Questions

Ages

- Include children aged 1 to 5 years
- Exclude newborns and children younger than 1 year of age and children aged 6 years and older

Diseases

- Include amblyopia, amblyogenic risk factors, refractive error
- Exclude children with severe congenital conditions or developmental delay, retinopathy of prematurity, glaucoma, congenital cataract, pathologic myopia

Language/Publication Status

- Include full-text (ie, not available only as a conference abstract) journal article published in English

Settings

- Include studies performed in primary care, community-based, and school settings
- Exclude countries with populations not similar to that of the United States

Study Designs

- Exclude systematic reviews

Key Questions 1 (Screening and Outcomes) and 1a (Variation in Age Groups)

Interventions/Diagnostic Tests

- Include studies of screening tests used or available in primary care settings (eg, visual acuity tests, tests of stereopsis, tests for strabismus, photoscreeners, autorefractors)
- Exclude studies of screening tests not used or available in primary care settings (eg, contrast sensitivity testing, fundoscopic examination, visual acuity testing with cycloplegia) or not intended to detect amblyopia, amblyogenic risk factors, or refractive errors (eg, white reflex screening)

Outcomes

- Include visual acuity, long-term amblyopia, school performance, function, quality of life

Study Designs

- Include randomized controlled trials (RCTs) and controlled observational studies

Key Question 2 (Accuracy/Reliability of Risk-Factor Assessment)

Outcomes

- Include studies on accuracy or yield of risk-factor assessment for targeted screening, or clinical out-

comes associated with use of targeted versus universal screening

Study Designs

- Include RCTs and controlled observational studies

Key Questions 3 (Accuracy of Screening Tests) and 3a (Variation in Age Groups)

Diagnostic Tests

- Include studies of screening tests used or available in primary care settings (eg, visual acuity tests, tests of stereopsis, tests for strabismus, photoscreeners, autorefractors)
- Exclude studies of screening tests not used or available in primary care settings (eg, contrast sensitivity testing, fundoscopic examination, visual acuity testing with cycloplegia) or not intended to detect amblyopia, amblyogenic risk factors, or refractive errors (eg, white reflex screening)

Outcomes

- Include sensitivity, specificity, positive and negative predictive values, likelihood ratios, diagnostic ORs (or able to calculate such outcomes from data provided)

Study Designs

- Include studies on diagnostic accuracy of a screening question or diagnostic test compared with a credible reference standard (ie, cycloplegic refraction)
- Exclude studies that do not attempt to perform the reference standard in all patients, or a random sample

Key Question 4 (Harms of Screening)

Interventions/Diagnostic Tests

- Include studies of screening tests used or available in primary care settings (eg, visual acuity tests, tests of stereopsis, tests for strabismus, photoscreeners, autorefractors)
- Exclude studies of screening tests not used or available in primary care settings (eg, contrast sensitivity testing, fundoscopic examination, visual acuity testing with cycloplegia) or not intended to detect amblyopia, amblyogenic risk factors, or refractive errors (eg, white reflex screening)

Outcomes

- Include harms, including psychological distress, labeling, anxiety, other psychological effects, false-positive results, adverse effects on nonimpaired eye vision

Study Designs

- Include RCTs and controlled observational studies

Key Question 5 (Effectiveness of Treatment)

Interventions/Treatments

- Include correction of refractive errors (eyeglasses), patching, and atropine

Outcomes

- Include visual acuity, long-term amblyopia, school performance, function, quality of life

Study Designs

- Include RCTs

Key Question 6 (harms of treatment)

Interventions/Treatments

- Include correction of refractive errors and penalization of the nonamblyogenic eye (patching and atropine)

Outcomes

- Include harms, including psychological distress, labeling, anxiety, other psychological effects, false-positive results, adverse effects on nonimpaired eye vision

Study Designs

- Include RCTs and controlled observational studies

APPENDIX 4: USPSTF QUALITY RATING CRITERIA FOR RANDOMIZED CONTROLLED TRIALS AND OBSERVATIONAL STUDIES

Diagnostic Accuracy Studies

Criteria

- Screening test relevant, available for primary care, adequately described
- Study uses a credible reference standard, performed regardless of test results
- Reference standard interpreted independently of screening test
- Handles indeterminate results in a reasonable manner
- Spectrum of patients included in study
- Sample size
- Administration of reliable screening test
- Random or consecutive selection of patients[16]
- Screening cutoff predetermined[16]
- All patients undergo the reference standard[16]

Definition of Ratings Based on Criteria Listed Above

Good: Evaluates relevant available screening test; uses a credible reference standard; interprets reference standard independently of screening test; reliability of test assessed; has few or handles indeterminate results

in a reasonable manner; includes large number (>100) of broad-spectrum patients with and without disease; study attempts to enroll a random or consecutive sample of patients who meet inclusion criteria[16]; screening cutoffs prestated[16]

Fair: Evaluates relevant available screening test; uses reasonable although not best standard; interprets reference standard independent of screening test; moderate sample size (50–100 subjects) and a "medium" spectrum of patients (ie, applicable to most screening settings)

Poor: Has important limitation such as uses inappropriate reference standard; screening test improperly administered; biased ascertainment of reference standard; very small sample size of very narrowly selected spectrum of patients

RCTs and Cohort Studies

Criteria

- Initial assembly of comparable groups: RCTs—adequate randomization, including concealment and whether potential confounders were distributed equally among groups; cohort studies—consideration of potential confounders with either restriction or measurement for adjustment in the analysis; consideration of inception cohorts
- Maintenance of comparable groups (includes attrition, cross-overs, adherence, contamination)
- Important differential loss to follow-up or overall high loss to follow-up
- Measurements: equal, reliable, and valid (includes masking of outcome assessment)
- Clear definition of interventions
- Important outcomes considered
- Analysis: adjustment for potential confounders for cohort studies, or intention-to-treat analysis for RCTs; for cluster RCTs, correction for correlation coefficient

Definition of Ratings Based on Criteria Listed Above

Good: Meets all criteria: comparable groups are assembled initially and maintained throughout the study (follow-up at least 80%); reliable and valid measurement instruments are used and applied equally to the groups; interventions are spelled out clearly; important outcomes are considered; and appropriate attention to confounders in analysis

Fair: Studies will be graded "fair" if any or all of the after problems occur, without the important limitations noted in the "poor" category below: generally comparable groups are assembled initially, but some question remains whether some (although not major) differences occurred in follow-up; measurement instruments are acceptable (although not the best) and generally applied equally; some but not all important outcomes are considered; and some but not all potential confounders are accounted for

Poor: Studies will be graded "poor" if any of the following major limitations exists: groups assembled initially are not close to being comparable or maintained throughout the study; unreliable or invalid measurement instruments are used or not applied at all equally among groups (including not masking outcome assessment); and key confounders are given little or no attention

Case-Control Studies

Criteria

- Accurate ascertainment of cases
- Nonbiased selection of cases/controls with exclusion criteria applied equally to both
- Response rate
- Diagnostic testing procedures applied equally to each group
- Measurement of exposure accurate and applied equally to each group
- Appropriate attention to potential confounding variable

Definition of Ratings Based on Criteria Listed Above

Good: Appropriate ascertainment of cases and nonbiased selection of case and control participants; exclusion criteria applied equally to cases and controls; a response rate of ≥80%; diagnostic procedures and measurements accurate and applied equally to cases and controls; and appropriate attention to confounding variables

Fair: Recent, relevant, without major apparent selection or diagnostic workup bias but with a response rate of <80% or attention to some but not all important confounding variables

Poor: Major selection or diagnostic workup biases, response rates of <50%, or inattention to confounding variables

Sources: Harris et al[15] and Leeflang et al.[16]

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APPENDIX 5 Screening Quality Ratings

Study (Year)	Random Assignment	Allocation Concealed	Groups Similar at Baseline	Eligibility Criteria Specified	Blinding: Outcome Assessors or Data Analysts	Intention-to-Treat Analysis	Reporting of Attrition, Contamination, etc	Differential Loss to Follow-up or Overall High Loss to Follow-up	Appropriate Analysis Including Cluster Correlation	Funding Source	External Validity	Quality Rating
Williams et al[20] (2002) and Williams et al[21] (2003)	No	Yes	Yes	Yes	Cannot tell	No	No	Yes	Not applicable	Medical Research Council; R&D Directorate; National Health Service Executive South West; National Eye Research Centre	High	Fair

APPENDIX 6 Diagnostic Accuracy Quality Ratings

Study (Year)	Representative Spectrum	Random or Consecutive Sample	Screening Test Adequately Described	Screening Cutoffs Predefined	Credible Reference Standard	Reference Standard Applied to All Screened Patients	Same Reference Standard Applied to All Patients	Reference Standard and Screening Examination Interpreted Independently	High Rate of Uninterpretable Results or Noncompliance With Screening Test	Analysis Includes Patients With Uninterpretable Results or Noncompliance	Quality Rating
Arthur et al[27] (2009)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	No	NA	Fair
Barry and Konig[28] (2001)	Yes	Yes	Yes	Yes	Cannot tell	No	No	Cannot tell	Cannot tell	Cannot tell	Fair
Barry and Konig[29] (2003)	Yes	Yes	Yes	Yes	Cannot tell	No	No	Yes	Yes	No	Fair
Berry et al[30] (2001)	No	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Fair
Bertuzzi et al[31] (2006)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	No	Fair
Chang et al[32] (2007)	Yes	Cannot tell	No	Yes	Yes	Yes	Yes	Cannot tell	No	Cannot tell	Fair
Chui et al[33] (2004)	Yes	Cannot tell	Yes	Yes	Yes	No	Yes	Yes	Cannot tell	Yes	Fair
Cogen and Ottemiller[34] (1992)	Yes	Cannot tell	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Fair
Cooper et al[35] (1999)	No	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Poor
Dahlmann-Noor et al[36] (2009)	No	Cannot tell	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Fair
Dahlmann-Noor et al[37] (2009)	Yes	Cannot tell	Yes	Yes	Cannot tell	Yes	No	Cannot tell	No	NA	Fair
Ehrt et al[38] (2007)	No	Cannot tell	Yes	Yes	Cannot tell	Cannot tell	No	Cannot tell	Yes	Yes	Poor
Guo et al[39] (2000)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Fair
Hope and Maslin[40] (1990)	Yes	Cannot tell	Yes	Yes	Yes	Yes	No	Cannot tell	No	No	Fair
Kemper et al[41] (2005)	No	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Kennedy and Sheps[42] (1989)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	NA	Fair
Kennedy et al[43] (1995)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	NA	Fair
Kennedy and Thomas[44] (2000)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Fair
Matta et al[45] (2008)	No	Cannot tell	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Fair
Miller et al[46] (1999)	No (high-prevalence population)	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Fair
Miller et al[47] (2001)	No (high-prevalence population)	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Fair
Molteno et al[48] (1993)	No	Cannot tell	Yes	Yes	No	Yes	No	Cannot tell	Cannot tell	Cannot tell	Poor
Morgan and Johnson[49] (1987)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Fair
Newman and East[50] (1999)	Yes	Yes	Yes	Yes	Cannot tell	No	Yes	Cannot tell	Cannot tell	Cannot tell	Poor
Ottar et al[51] (1995)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Yes	Cannot tell	No	Yes	Fair
Rogers et al[52] (2008)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Fair
Shallo-Hoffmann et al[53] (2004)	Yes	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Fair
Tong et al[56] (2000)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Fair
VIP Study Group[55] (2004)	No	Cannot tell	Yes	No	Yes	Yes	Yes	Yes	No	No	Fair
Weinand et al[57] (1998)	No	Cannot tell	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Fair
Williams et al[58] (2000)	Yes	Cannot tell	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Fair

NA indicates not applicable.

APPENDIX 7 Diagnostic Accuracy of Screening Tests Stratified According to Age

Study (Year)	Screening Test	Sensitivity (95% CI)	Specificity (95% CI)	PLR (95% CI)	NLR (95% CI)	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)	Diagnostic OR (95% CI)
Chui et al[33] (2004)	Lea symbols visual acuity test, Frisby stereoacuity test, and external visual inspection	0.67 (0.41–0.87); <41 mo: 0.75 (0.43–0.94); ≥41 mo: 0.50 (0.12–0.88)	Overall: 0.86 (0.79–0.92); <41 mo: 0.90 (0.52–0.82); ≥41 mo: 0.95 (0.88–0.99)	Overall: 4.8 (2.8–8.4); <41 mo: 2.4 (1.4–4.1); ≥41 mo: 10 (3.0–36)	Overall: 0.39 (0.20–0.75); <41 mo: 0.37 (0.13–1.0); >41 mo: 0.53 (0.24–1.2)	Overall: 0.41 (0.24–0.61); <41 mo: 0.41 (0.21–0.64); ≥41 mo: 0.43 (0.10–0.82)	Overall: 0.95 (0.89–0.98); <41 mo: 0.90 (0.74–0.98); ≥41 mo: 0.96 (0.90–0.99)	Overall: 12 (3.6–45); <41 mo: 6.5 (1.3–42); ≥41 mo: 20 (1.8–180)
Kemper et al[41] (2005)	SureSight autorefractor	Overall: 0.85 (0.69–0.95); <3 y old ($n = 80$): 0.80 (0.44–0.97); 3–5 y old ($n = 90$): 0.88 (0.68–0.97)	Overall: 0.52 (0.40–0.63); <3 y old: 0.41 (0.24–0.61); 3–5 y old: 0.58 (0.42–0.71)	Overall: 1.8[a]; <3 y old: 1.4[a]; 3–5 y old: 2.1[a]	Overall: 0.29[a]; <3 y old: 0.49[a]; 3–5 y old: 0.21[a]	Not calculable	Not calculable	Overall: 6.2[a]; <3 y old: 2.9[a]; 3–5 y old: 10[a]
Kennedy and Thomas[44] (2000)	iScreen photoscreener	Overall: 0.92 (0.88–0.95); ≤3 y 1.0[a]; 4–6 y 0.92[a]	Overall: 0.89 (0.83–0.94); ≤3 y 0.97[a]; 4–6 y 0.95[a]	Overall: 8.6 (5.4–14); ≤3 y 33[a]; 4–6 y 18[a]	Overall: 0.09 (0.06–0.13); ≤3 y not calculable; 4–6 y 0.08[a]	Overall: 0.94 (0.90–0.96); ≤3 y 0.97[a]; 4–6 y 0.97[a]	Overall: 0.86 (0.80–0.91)	Overall: 100 (48–210); ≤3 y not calculable; 4–6 y: 220[a]
Tong et al[56] (2000)	MTI photoscreener	All photographs: 0.56 (0.50–0.62); informative subset of 313 photographs: 0.65 (0.59–0.71)	All photographs: 0.91 (0.84–0.96); informative subset of 313 photographs: 0.87 (0.76–0.94)	All photographs: 6.4 (3.4–12); informative subset of 313 photographs: 4.9 (2.6–9.1)	All photographs: 0.48 (0.42–0.56); informative subset of 313 photographs: 0.40 (0.33–0.47)	All photographs: 0.95 (0.90–0.98); informative subset of 313 photographs: 0.95 (0.90–0.98)	All photographs: 0.43 (0.36–0.50); informative subset of 313 photographs: 0.41 (0.33–0.49)	All photographs: 13 (6.3–31); informative subset of 313 photographs: 12 (5.6–29)

[a] CIs not calculable.

APPENDIX 8 Positive Predictive Values of Screening Tests

Study (Year)	Screening Test	Age of Enrollees	*N*	Proportion With Condition	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)
Barry and Konig[28] (2001)	Retinomax autorefractor	3 y	404	Amblyopia: 2.5% (10/404)	0.05 (0.02–0.09)	0.99 (0.97–1.0)
Barry and Konig[29] (2003)	Visual inspection, cover-uncover test, eye motility and head posture examination, Lea symbols visual acuity test	3 y	1180	Amblyopia or amblyogenic risk factors: 2.3% (26/1114)	0.25 (0.16–0.36)	1.0 (0.9 9–1.0)
Berry et al[30] (2001)	MTI photoscreener	Preschool (subgroup)	51	Amblyogenic risk factors: 45% (23/51)	0.68 (0.48–0.84)	0.83 (0.61–0.95)
Bertuzzi et al[31] (2006)	Lea symbols visual acuity test	38–54 mo	149	Amblyogenic risk factors: 16% (23/143)	A, 0.52 (0.36–0.68); B, 0.69 (0.48–0.86)	A, 0.99 (0.95–1.0); B, 0.96 (0.90–0.99)
Chang et al[32] (2007)	A, Distance visual acuity; B, near visual acuity; C, NTU random-dot stereogram	Preschool	5232	Amblyopia: 2.20% (115/5232)	A1, 0.12[a]; A2, 0.04[a]; B, 0.13[a]; C, 0.17[a]	A1, 0.995[a]; A2, 0.996[a]; B, 0.988[a]; C, 0.986[a]
Chui et al[33] (2004)	Lea symbols visual acuity test, Frisby stereoacuity test, and external visual inspection	35–58 mo	178 (141 completed gold-standard evaluation)	Amblyogenic risk factors: 13% (18/141)	0.41 (0.24–0.61); <41 mo: 0.41 (0.21–0.64); ≥41 mo: 0.43 (0.10–0.82)	0.95 (0.89–0.98); <41 mo: 0.90 (0.74–0.98); ≥41 mo: 0.96 (0.90–0.99)
Cogen and Ottemiller[34] (1992)	Visiscreen 100 photoscreener	6 mo to 6 y	127	Any visual condition: 12% (13/113); refractive error: 5% (6/113); strabismus: 4% (5/113); refractive error + strabismus: 1% (1/113); media opacity: 1% (1/113)	0.65 (0.38–0.86)	0.98 (0.93–1.0)
Cooper et al[35] (1999)	A, Fortune Optical VRB-100 photoscreener; B, MTI photoscreener	12–44 mo	105	61 cases (amblyopia), 44 controls	A (reader 1): 0.76 (0.61–0.87); A (reader 2): 0.86 (0.72–0.95); B (reader 1): 0.78 (0.62–0.89); B (reader 2): 0.88 (0.74–0.96)	A (reader 1): 0.60 (0.46–0.72); A (reader 2): 0.69 (0.54–0.80); B (reader 1): 0.59 (0.46–0.72); B (reader 2): 0.65 (0.50–0.78)
Ehrt et al[38] (2007)	Vision Screener video refractor	0–7 y	161	Amblyogenic risk factors: 43% (70/161)	0.71 (0.59–0.82)	0.78 (0.68–0.86)
Guo et al[39] (2000)	A, Computer-photorefractor; B, noncycloplegic retinoscopy	9–50 mo	300	Amblyogenic risk factors: 56% (168/300)	A, 0.92 (0.87–0.96); B, 0.85 (0.79–0.90)	A, 0.93 (0.87–0.97); B, 0.82 (0.74–0.88)
Hope and Maslin[40] (1990)	Random dot E stereogram	3–4 y	176	Refractive error or strabismus: 5% (9/168); refractive error: 5% (9/168); strabismus: 0.6% (1/168)	0.17 (0.08–0.31)	0.99 (0.96–1.0)
Kennedy and Sheps[42] (1989)	A, Otago-type photoscreener (noncommercial); B, Off-axis-type photoscreener (noncommercial)	≤6 y	236	Any amblyogenic risk factor: 42% (98/236); strabismus only: 14% (33/236); strabismus + refractive error or anisometropia: 18% (42/236); refractive error or anisometropia: 8% (18/236); anisocoria or lid tumor: 2% (5/236)	Any condition; A, 0.92 (0.85–0.96); B, 0.82 (0.73–0.89)	Any condition; A, 0.96 (0.91–0.98); B, 0.89 (0.82–0.94)
Kennedy et al[43] (1995)	A, Otago-type photoscreener (noncommercial); B, Snellen E or Stycar graded balls visual acuity test and Titmus stereotest	Not reported	264	Any visual condition: 8% (21/264); strabismus: 1.1% (3/264); refractive error: 4.2% (11/264); strabismus and refractive error: 0.8% (2/264); structural: 0.4% (1/264)	A, 0.77 (0.60–0.95); B, 0.54 (0.28–0.81)	A, 0.98 (0.91–1.00); B, 0.94 (0.91–0.97)

APPENDIX 8 Continued

Study (Year)	Screening Test	Age of Enrollees	*N*	Proportion With Condition	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)
Kennedy and Thomas[44] (2000)	iScreen photoscreener	45% ≤6 y	449	Amblyogenic risk factors: 64% (273/423)	0.94 (0.90–0.96); ≤3 y 0.97[a]; 4–6 y 0.97[a]	0.86 (0.80–0.91)
Miller et al[46] (1999)	A, Lea symbols visual acuity test; B, Retinomax K-plus autorefractor	3–5 y	245	Significant refractive error: 31% (76/245); all had astigmatism	A, 0.42 (0.35–0.50); B, 0.75 (0.65–0.83)	A, 0.92 (0.83–0.96); B, 0.95 (0.901–0.98)
Miller et al[47] (2001)	A, Lea symbols visual acuity test; B, MTI photoscreener; C, Nidek KM-500 Keratometry Screener; D, Retinomax K-Plus autorefractor	3–5 y	379	Astigmatism ≥1.00 D: 48% (182/379)	A, 0.48 (0.41–0.54); B, 0.68 (0.60–0.75)[b]; C, 0.79 (0.73–0.84); D, 0.94 (0.90–0.97)	A, 0.93 (0.88–0.97); B, 0.70 (0.63–0.76)[b]; C, 0.94 (0.90–0.97); D, 0.94 (0.89–0.96)
Morgan and Johnson[49] (1987)	Visiscreen 100 photoscreener	3 mo to 8 y	63	Any visual condition: 60% (34/57)	0.84 (0.68–0.94)	0.85 (0.62–0.97)
Newman and East[50] (1999)	Sheridan-Gardiner visual acuity; cover-uncover test; ocular movements and convergence; prism test; TNO screening plate; Snellen visual acuity	3.5 y and at 5–6 y	Cohort of 936 children; data reported on 597	Amblyopia: 2.5% (15/597)	0.27 (0.16–0.41)	1.0 (0.99–1.0)
Ottar et al[51] (1995) and Donahue et al[59] (2002)	MTI photoscreener	6–59 mo	949	Amblyogenic risk factors: 20% (192/949)	A, 0.69 (0.62–0.75); B, 0.77 (0.64–0.87)[c]	A, 0.95 (0.93–0.97); B, 0.95 (0.93–0.96)[c]
Rogers et al[52] (2008)	MTI photoscreener SureSight autorefractor	1–6 y	100	Clinically significant amblyopia: 58% (58/100)	A, 0.68 (0.57–0.78); B, 0.75 (0.63–0.86); C, 0.75 (0.61–0.86); D, 0.77 (0.62–0.88); E, 0.92 (0.82–0.97)	A, 0.89 (0.65–0.99); B, 0.69 (0.52–0.83); C, 0.60 (0.45–0.74); D, 0.58 (0.44–0.72); E, 0.92 (0.80–0.98)
Shallo-Hoffmann et al[53] (2004)	Lea symbol and HOTV charts and random dot E stereoacuity test	2–6 y	269	Any vision condition: 6% (5/81)	0.24 (0.08–0.47)	1.00 (0.94–1.0)
Tong et al[56] (2000)	MTI photoscreener	<4 y old	387	Strabismus: 49% (190/387); refractive error: 55% (211/387)	All photographs: 0.95 (0.90–0.98); informative subset of 313 photographs: 0.95 (0.90–0.98)	All photographs: 0.43 (0.36–0.50); informative subset of 313 photographs: 0.41 (0.33–0.49)

APPENDIX 8 Continued

Study (Year)	Screening Test	Age of Enrollees	*N*	Proportion With Condition	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)
VIP Study Group[55] (2004)	Crowded linear Lea symbols visual acuity test	3, 4, or 5 y old	3121	Any vision condition: 29% (755/2588); "very important to detect and treat early" conditions: 5.4% (135/2588); amblyopia: 2.9% (75/2588); reduced visual acuity: 5.1% (132/2588); strabismus: 1.9% (48/2588); refractive error: 9.3% (240/2588)	Any condition; A, 0.73 (0.67–0.78); B, 0.78 (0.72–0.83)	Any condition; A, 0.84 (0.82–0.86); B, 0.81 (0.78–0.83)
	Crowded linear HOTV visual acuity test	—	—	—	Any condition; A, 0.68 (0.62–0.74); B, 0.69 (0.62–0.76)	Any condition; A, 0.82 (0.79–0.84); B, 0.77 (0.74–0.80)
	Random dot E stereoacuity test	—	—	—	Any condition; A, 0.64 (0.58–0.71); B, 0.54 (0.46–0.63)	Any condition; A, 0.78 (0.75–0.81); B, 0.80 (0.78–0.83)
	Stereo Smile II stereoacuity test	—	—	—	Any condition; A, 0.66 (0.60–0.72); B, 0.68 (0.62–0.75)	Any condition; A, 0.73 (0.70–0.76); B, 0.78 (0.76–0.80)
	Retinomax autorefractor	—	—	—	Any condition; : 0.71 (0.68–0.75); B, 0.78 (0.74–0.82)	Any condition; A, 0.86 (0.84–0.87); B, 0.83 (0.81–0.84)
	SureSight autorefractor	—	—	—	Any condition; A1, 0.47 (0.43–0.51); A2, 0.71 (0.66–0.76); B, 0.77 (0.72–0.82)	Any condition; A1, 0.91 (0.89–0.93); A2, 0.86 (0.84–0.88); B, 0.83 (0.81–0.85)
	iScreen photoscreener	—	—	—	Any condition; 0.71 (0.64–0.77)	Any condition; 0.79 (0.77–0.81)
	MTI photoscreener	—	—	—	Any condition; 0.71 (0.64–0.77)	Any condition; 0.79 (0.77–0.81)
	Power Refractor II	—	—	—	Any condition; A, 0.68 (0.65–0.73); B, 0.70 (0.64–0.76)	Any condition; A, 0.83 (0.81–0.85); B, 0.79 (0.76–0.81)
	Cover-uncover test	—	—	—	Any condition; 0.78 (0.66–0.86)	Any condition; 0.73 (0.70–0.76)
Weinand et al[57] (1998)	MTI photoscreener	6–48 mo	112	Any abnormality: 81% (83/102); refractive error: 41% (41/102); strabismus without refractive ; error: 7% (7/102); strabismus with refractive error: 21% (21/102); organic anomaly: 13% (13/102)	A (pediatrician interpreter): 0.88 (0.79–0.94); B (orthoptist interpreter): 0.93 (0.84–0.98); C (ophthalmologist 1 interpreter): 0.92 (0.83–0.98); D (ophthalmologist 2 interpreter): 0.90 (0.81–0.96)	A (pediatrician interpreter): 0.62 (0.32–0.86); B (orthoptist interpreter): 0.45 (0.27–0.64); C (ophthalmologist 1 interpreter): 0.38 (0.22–0.55); D (ophthalmologist 2 interpreter): 0.48 (0.27–0.69)
Williams et al[58] (2000)	Topcon PR2000 autorefractor	12.5–68.7 mo	222	A, spherical error >3.75 D: 19% (36/189); B, anisometropia >1.25 D: 12% (23/189); C, astigmatism >1.25 D: 16% (30/189)	A, 0.69 (0.48–0.86); B, 0.68 (0.46–0.85); C, 0.70 (0.46–0.88)	A, 0.89 (0.83–0.93); B, 0.96 (0.92–0.99); C, 0.91 (0.85–0.94)

TNO indicates a Dutch stereoacuity test.

[a] Raw data not provided; unable to calculate CIs.

[b] Calculation based on $n = 379$, median sensitivity and specificity.

[c] Based on reported sensitivity and specificity; do not match values reported in article.

APPENDIX 9 Treatment Trials Quality Ratings

Study (Year)	Random Assignment	Allocation Concealed	Groups Similar at Baseline	Eligibility Criteria Specified	Blinding Patients	Blinding Providers	Blinding Outcome Assessors or Data Analysts	Intention-to-Treat Analysis	Reporting of Attrition, Contamination	Differential Loss to Follow-up, Overall High Loss to Follow-up, or Incomplete Follow-up	Funding Source	External Validity	Quality Rating
Awan et al[73] (2005)	Cannot tell	Yes	Yes	Yes	No	No	No	Yes	Yes	No	National Eye Research Center; Ulverscroft Foundation	Mean age: 4.6 y; mean logMAR visual acuity, amblyopic eye: 0.64; mean logMAR visual acuity, sound eye: 0.02; strabismus: 27/60 (45%); mixed amblyopia 25/60 (42%)	Fair
Clarke et al[72] (2003)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	National Health Service Research and Development	Mean age: 4.0 y; proportion of patients with anisometropia: 127/177 (72%); baseline logMAR visual acuity amblyopic eye[a]: 58/177 (33%) 0.18; 52/177 (29%) 0.30; 42/177 (24%) 0.48; 12/177 (7%) 0.60; 13/177 (7%) 0.78	Good
PEDIG[74] (2006)	Yes	Cannot tell	Yes	Yes	No	No	Yes	Yes	Yes	No	National Eye Institute	Mean age: 5.3 y; 49.4% female; 81% white; 6% black; 9% Hispanic/Latino; 1% Asian; 3% mixed race; <1% unknown ethnicity; 89% no previous amblyopia treatment; 8% previous patching; <1% previous atropine; 2% previous patching and atropine; 23% strabismus; 47% anisometropia; 30% strabismus and anisometropia; mean logMAR visual acuity, amblyopic eye: 0.55 (SD: 0.23); approximate Snellen equivalent: 20/80; mean logMAR visual acuity, sound eye: 0.03 (SD: 0.11); approximate Snellen equivalent 20/20; mean refractive error, amblyopic eye: 4.92 (SD: 2.13); mean refractive error, sound eye: 2.72 (SD: 1.93)	Good

APPENDIX 9 Continued

Study (Year)	Random Assignment	Allocation Concealed	Groups Similar at Baseline	Eligibility Criteria Specified	Blinding Patients	Blinding Providers	Blinding Outcome Assessors or Data Analysts	Intention-to-Treat Analysis	Reporting of Attrition, Contamination	Differential Loss to Follow-up, Overall High Loss to Follow-up, or Incomplete Follow-up	Funding Source	External Validity	Quality Rating
PEDIG[77] (2004)	Yes	Cannot tell	Yes	Yes	No	No	Yes	Yes	Yes	No	National Eye Institute	Mean age: 5.3 y; 39% female; 79% white; 4% black; 12% Hispanic; 2% Asian; 1% American Indian/Alaskan Native; 1% mixed race; 2% unknown/not reported; strabismus 33%; anisometropia 41%; strabismus and anisometropia 23%; mean distance visual acuity (logMAR), amblyopic eye: 0.46 (SD: 0.10); mean distance visual acuity (logMAR), sound eye: 0.05 (SD: 0.10); mean refractive error, amblyopic eye: 4.22 (SD: 2.37); mean: refractive error, sound eye: 3.03 (SD 2.16)	Good
PEDIG[75] (2003)	Yes	Cannot tell	Yes	Yes	No	No	Yes	Yes	Yes	No	National Eye Institute	Mean age: 5.2 y; 44% female; 85% white; 4% African American; 6% Hispanic; 1% Asian-American; 2% mixed race; 2% other; strabismus 40%; anisometropia 33%; strabismus and anisometropia 27%; mean sound eye visual acuity (logMAR): 0.07 (SD: 0.10); mean amblyopic eye visual acuity (logMAR): 0.48 (SD: 0.10); mean sound eye refractive error: 3.07 (SD: 2.35); Mean amblyopic eye refractive error: 4.12 (SD: 3.00)	Good

APPENDIX 9 Continued

Study (Year)	Random Assignment	Allocation Concealed	Groups Similar at Baseline	Eligibility Criteria Specified	Blinding Patients	Blinding Providers	Blinding Outcome Assessors or Data Analysts	Intention-to-Treat Analysis	Reporting of Attrition, Contamination	Differential Loss to Follow-up, Overall High Loss to Follow-up, or Incomplete Follow-up	Funding Source	External Validity	Quality Rating
PEDIG[78] (2002)	Yes	Cannot tell	Yes	Yes	No	No	Yes	Yes	Yes	No	National Eye Institute	Mean age: 5.3 y; 47% female; 83% white; 5% African American; 6% Hispanic; 2% Asian; 2% mixed; 2% other; 74% no previous amblyopia treatment; 20% previous patching; 2% previous atropine use; 0.2% previous patching + atropine use; 5% other previous treatment (including use of spectacle occluder and fogging); cause of amblyopia: 38% strabismus; 37% amblyopia; 24% strabismus and anisometropia; mean logMAR visual acuity, amblyopic eye: 0.53 (SD: 0.13); mean logMAR visual acuity, sound eye: 0.09 (SD: 0.11); mean intereye acuity difference (lines): 4.4 (SD: 1.3); mean refractive error, amblyopic eye: 4.46 (SD: 2.13); mean refractive error, sound eye: 2.82 (SD: 2.00)	Good
Stewart et al[76] (2007)	Yes	Cannot tell	Yes	Yes	No	No	Cannot tell	Yes	Yes	No	Fight for Sight United Kingdom	Mean age: 5.6 y gender not reported; anisometropia 42/97 (43%); strabismus 21/97 (22%); mixed anisometropia and strabismus 34/97 (35%)	Fair

[a] Converted from Snellen metric measures.