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A Comprehensive Systematic Review of The Role of Screening Programs in Preventing Blindness in Primary Setting

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ABSTRACT

Introduction: Blindness and visual impairment represent significant global public health challenges, with many causes being preventable or treatable if detected early. Screening programs in primary care settings are widely advocated as a key strategy to reduce the burden of avoidable vision loss. However, the effectiveness of these programs varies substantially across different eye conditions, populations, and healthcare contexts.

Methods: This comprehensive systematic review synthesises evidence from 80 studies examining the role of screening programs in preventing blindness within primary care settings. The review employed a structured screening process to include studies conducted in primary care, involving systematic screening interventions, with outcomes related to blindness prevention. Data extraction covered screening program details, primary care context, target population, visual outcomes, effectiveness results, implementation factors, and economic considerations.

Results: The evidence reveals a paradox: while screening effectively identifies individuals with visual impairment, it does not consistently lead to improved visual outcomes at the population level. General visual acuity screening in older adults showed no significant benefit in improving vision or clinical outcomes (Clarke et al., 2018; Smeeth et al., 2003; Chou et al., 2016). In contrast, screening for diabetic retinopathy (DR) demonstrated efficacy, with telemedicine and AI-supported approaches significantly increasing screening uptake, detection rates, and referral adherence (Mansberger et al., 2015; Mathenge et al., 2022; Harding et al., 2023). Evidence for glaucoma population screening remains insufficient (Mangione et al., 2022), while preschool vision screening for amblyopia shows modest benefits (Schmucker et al., 2009). Newborn red reflex testing may improve early detection of congenital cataracts (Malik et al., 2022). Economic analyses indicate that telemedicine and AI-supported screening, particularly for DR, are cost-effective, especially in resource-limited settings (Avidor et al., 2020; Teo & Ting, 2023).

Discussion: The disparity in outcomes underscores the critical influence of context, including baseline healthcare access, the natural history of the disease, availability of effective treatment, and the strength of referral pathways. Successful programs integrate technology with systemic support, such as patient navigation and removal of financial barriers.

Conclusion: Screening is not a uniformly effective intervention for all eye conditions in all settings. Its value is highest for conditions like diabetic retinopathy within defined high-risk populations and in contexts with limited baseline eye care access.

Future programs should be condition-specific, contextually tailored, and designed as integrated care pathways rather than isolated detection activities.

Keywords: Blindness prevention, screening programs, primary care, diabetic retinopathy, telemedicine, artificial intelligence, visual impairment, systematic review.

INTRODUCTION

Background

Blindness and visual impairment affect over a billion people globally, with a substantial proportion of cases being avoidable through early detection and intervention (World Health Organization, 2019). Conditions such as diabetic retinopathy (DR), glaucoma, cataracts, and refractive errors are leading causes of vision loss, yet many progress asymptomatically until irreversible damage occurs. Primary care, as the first point of contact within health systems, is strategically positioned to deliver population-based screening, potentially bridging the gap between communities and specialist eye care services. Screening programs aim to identify at-risk individuals before symptom onset, enabling timely treatment to prevent progression to blindness. However, the implementation and effectiveness of such programs are influenced by a complex interplay of technological, economic, and health system factors.

Research Gap

Despite the widespread promotion of eye screening, there exists a significant evidence gap regarding its real-world effectiveness in improving long-term visual outcomes within primary care settings. Existing reviews often focus on specific conditions or technologies. A comprehensive synthesis evaluating the comparative effectiveness of screening across different eye diseases, while critically examining the paradox between successful case detection and the frequent failure to translate this into improved population vision outcomes, is lacking. Furthermore, there is limited consolidated evidence on the economic and implementation determinants of success across diverse global contexts, from high-income countries to low-resource settings.

Novelty

This systematic review addresses these gaps by providing a holistic and comparative analysis of screening programs for multiple blinding eye conditions within primary care. Its novelty lies in its explicit focus on the primary care setting, its synthesis of evidence across a spectrum of conditions (DR, glaucoma, cataracts, amblyopia, general visual impairment), and its integrated analysis of effectiveness, cost-effectiveness, and implementation barriers. It uniquely explores the "detection-outcome gap" and offers context-specific insights into why some screening programs succeed while others do not.

Research Objective

The primary objective of this systematic review is to critically evaluate the role and effectiveness of screening programs implemented in primary care settings for the prevention of blindness and significant visual impairment. It aims to determine under what conditions, for which specific eye diseases, and through which modalities screening delivers measurable benefits in visual outcomes.

Research Hypotheses

1. Screening programs for diabetic retinopathy in primary care are effective and cost-effective in reducing the risk of vision loss.
2. Population-based screening for general visual impairment in older adults within primary care does not yield significant improvements in visual outcomes where baseline access to eye care is adequate.
3. The integration of telemedicine and artificial intelligence (AI) improves the accessibility, uptake, and cost-effectiveness of screening, but does not automatically solve downstream referral and treatment adherence challenges.

4. The effectiveness of screening is fundamentally moderated by contextual factors, including the existing level of eye care utilization, the strength of referral pathways, and socioeconomic determinants of health.

Significance of the Study

The findings of this review have significant implications for public health policy, clinical guideline development, and resource allocation. By distinguishing between effective and ineffective screening strategies, it can guide policymakers and healthcare providers in designing targeted, efficient, and equitable eye care programs. It underscores the need to move beyond a one-size-fits-all approach to screening and instead advocate for precision public health strategies that are condition-specific and contextually adapted. Ultimately, this work contributes to the global effort to eliminate avoidable blindness by ensuring that screening resources are invested where they yield the greatest benefit.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate the role of screening programs in preventing blindness in primary setting.

Screening

We screened in sources based on their abstracts that met these criteria:

- **Primary Care Setting**: Was the study conducted in primary care settings, community health centers, or primary healthcare facilities (not exclusively in tertiary care, specialist ophthalmology clinics, or hospital-based settings without primary care component)?
- **Screening Intervention**: Does the intervention involve systematic screening programs for eye conditions that can lead to blindness or significant visual impairment?
- **Primary Care Population**: Does the study population include individuals receiving care in primary healthcare settings?
- **Blindness Prevention Outcomes**: Do the study outcomes include prevention of blindness, reduction in visual impairment, early detection of sight-threatening conditions, or progression to advanced eye disease?
- **Comparative Design**: Does the study compare screening programs to no screening, usual care, or alternative screening approaches?
- **Appropriate Study Design**: Is the study design a randomized controlled trial, controlled clinical trial, cohort study, case-control study, cross-sectional study, systematic review, or meta-analysis (not a case report, case series, editorial, commentary, or conference abstract)?
- **Screening Focus**: Does the study include screening components (not focusing solely on treatment interventions without screening)?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Search Strategy

The keywords used for this research based PICO :

Element	P (Population)	I (Intervention/Exposure)	C (Comparison/Context)	O (Outcome)
Keyword 1	Primary care setting	Screening programs	No screening	Blindness prevention

Keyword 2	Primary healthcare	Vision screening	Usual care	Visual impairment reduction
Keyword 3	Community health centers	Eye screening	Standard practice	Early detection of eye disease
Keyword 4	General practice	Ophthalmic screening	Alternative screening approaches	Prevention of sight loss

The Boolean MeSH keywords inputted on databases for this research are: *("Primary care setting" OR "Primary healthcare" OR "Community health centers" OR "General practice") AND ("Screening programs" OR "Vision screening" OR "Eye screening" OR "Ophthalmic screening") AND ("No screening" OR "Usual care" OR "Standard practice" OR "Alternative screening approaches") AND ("Blindness prevention" OR "Visual impairment reduction" OR "Early detection of eye disease" OR "Prevention of sight loss")*

Data extraction

- **Screening Program**:

  Extract comprehensive details about the screening program including:

  - Target eye conditions (e.g., diabetic retinopathy, glaucoma, cataracts, AMD, general visual acuity)
  - Screening method/technology used (e.g., visual acuity testing, fundus photography, OCT, AI-based analysis)
  - Who performs the screening (primary care staff, nurses, technicians, ophthalmologists)
  - Frequency/schedule of screening
  - Referral criteria and pathways

- **Primary Care Setting**:

  Describe the primary care context including:

    - Type of primary care facility (clinic, community health center, family practice)
    - Geographic setting (rural, urban, community-based)
    - Healthcare system characteristics
    - Integration with specialist eye care
    - Resource availability and constraints

- **Target Population**:

  Extract population characteristics including:

    - Age range and mean age
    - Sample size
    - Inclusion/exclusion criteria
    - Baseline visual impairment prevalence
    - Risk factors (diabetes, age, ethnicity)
    - Geographic location and socioeconomic context

- **Blindness Prevention Outcomes**:

  Extract all outcomes related to preventing blindness including:

    - Primary endpoints (visual acuity changes, progression to blindness, vision loss prevention)
    - Detection rates of sight-threatening conditions
    - Time to treatment initiation
    - Long-term visual outcomes
    - Functional vision measures

  - Include specific metrics, effect sizes, confidence intervals, and follow-up duration
- **Effectiveness Results**:

  Summarize the main findings on screening effectiveness including:

  - Whether screening reduced blindness/vision loss compared to control
  - Magnitude of benefit (risk ratios, absolute risk reduction, number needed to screen)
  - Statistical significance
  - Any differential effects by subgroup
  - Comparison with alternative screening approaches if relevant
- **Implementation Factors**:

  Extract factors affecting screening program implementation and success including:

  - Uptake/participation rates
  - Referral completion rates
  - Barriers to implementation (cost, staffing, technology, patient compliance)
  - Facilitators of success
  - Training requirements
  - Quality assurance measures
  - Sustainability considerations
- **Economic Considerations**:

  Extract economic data when available including:

  - Cost-effectiveness ratios (cost per QALY, cost per case detected)
  - Direct and indirect costs
  - Resource utilization
  - Comparison of costs between screening approaches

  - Budget impact or affordability assessments

- **Study Design**:

  Describe the study methodology including:

  - Study type (RCT, cohort, cross-sectional, systematic review, cost-effectiveness analysis)
  - Control group or comparison
  - Randomization method if applicable
  - Blinding procedures
  - Follow-up duration
  - Key methodological strengths and limitations

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	*("Primary care setting" OR "Primary healthcare" OR "Community health centers" OR "General practice") AND ("Screening programs" OR "Vision screening" OR "Eye screening" OR "Ophthalmic screening") AND ("No screening" OR "Usual care" OR "Standard practice" OR "Alternative screening approaches" AND "Blindness prevention" OR "Visual impairment reduction" OR "Early detection of eye disease" OR "Prevention of sight loss")*	1
Semantic Scholar	*("Primary care setting" OR "Primary healthcare" OR "Community health centers" OR "General practice") AND ("Screening programs" OR "Vision screening" OR "Eye screening" OR "Ophthalmic screening") AND ("No screening" OR "Usual care" OR "Standard practice" OR "Alternative screening approaches") AND ("Blindness prevention" OR "Visual impairment reduction" OR "Early detection of eye disease" OR "Prevention of sight loss")*	71
Springer	*("Primary care setting" OR "Primary healthcare" OR "Community health centers" OR "General practice") AND ("Screening programs" OR "Vision screening" OR "Eye screening" OR "Ophthalmic screening") AND ("No screening" OR "Usual care" OR "Standard practice" OR "Alternative screening approaches") AND ("Blindness prevention" OR "Visual impairment reduction" OR "Early detection of eye disease" OR "Prevention of sight loss")*	3
Google Scholar	*("Primary care setting" OR "Primary healthcare" OR "Community health centers" OR "General practice") AND ("Screening programs" OR "Vision screening" OR "Eye screening" OR "Ophthalmic screening") AND ("No screening" OR "Usual care" OR "Standard practice" OR "Alternative screening approaches") AND ("Blindness prevention" OR "Visual impairment reduction" OR "Early detection of eye disease" OR "Prevention of sight loss")*	23
Wiley Online Library	*("Primary care setting" OR "Primary healthcare" OR "Community health centers" OR "General practice") AND ("Screening programs" OR "Vision screening" OR "Eye screening" OR "Ophthalmic screening") AND ("No screening" OR "Usual care" OR "Standard practice" OR "Alternative screening approaches") AND ("Blindness prevention" OR "Visual impairment reduction" OR "Early detection of eye disease" OR "Prevention of sight loss")*	2

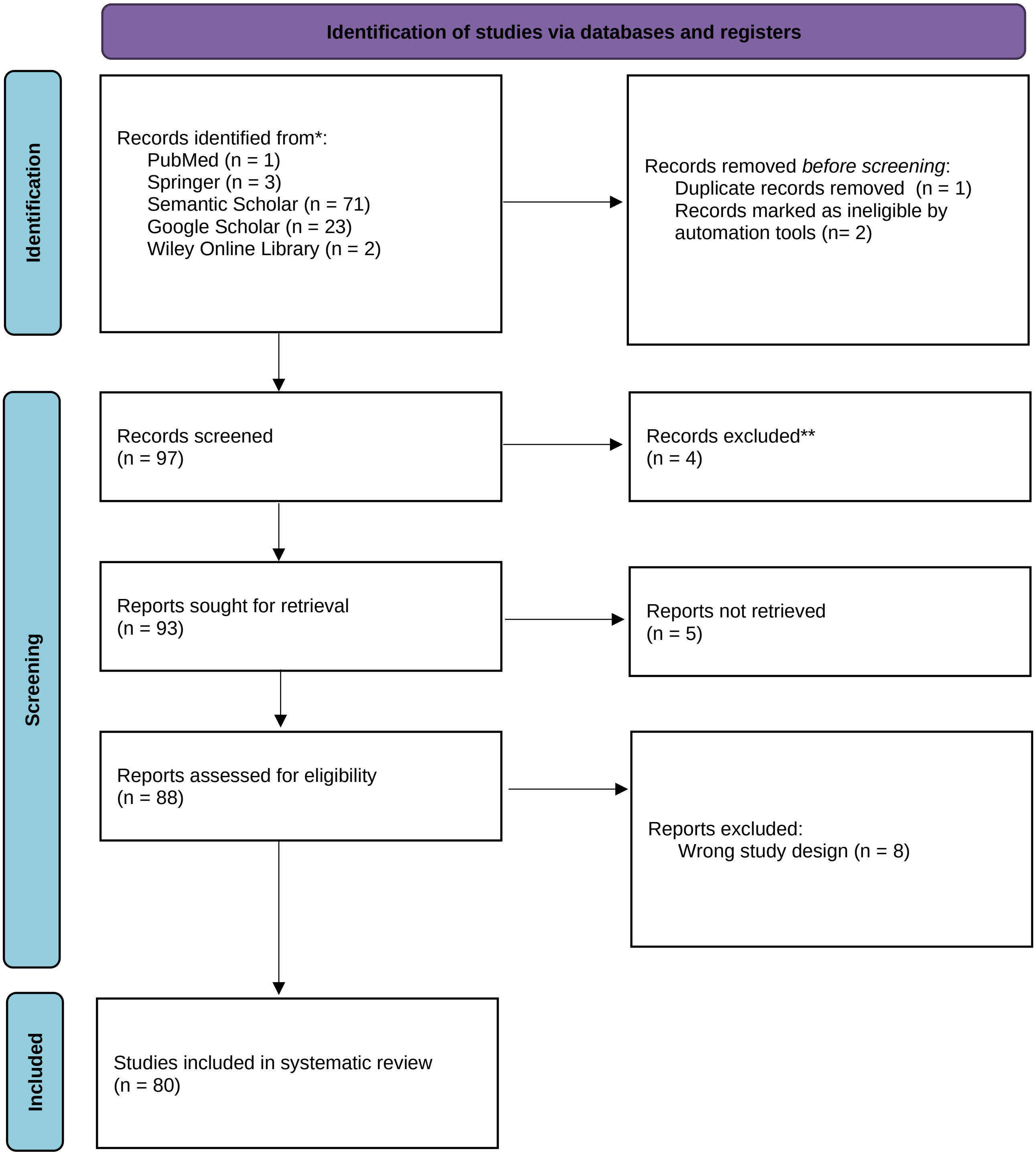

Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	**Bias related to temporal precedence** Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	**Bias related to selection and allocation** Was there a control group?	**Bias related to confounding factors** Were participants included in any comparisons similar?	**Bias related to administration of intervention/exposure** Were the participants included in any comparisons receiving similar treatment/ care, other than the exposure or intervention of interest?	**Were there multiple measurements of the outcome, both pre and post the intervention/exposure?**	**Were the outcomes of participants included in any comparisons measured in the same way?**	**Were outcomes measured in a reliable way?**	**Bias related to participant retention** Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	**Statistical conclusion validity** Was appropria e statistical analysis used**?**
R. Chou et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Chou et al., 2009a	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. Mansberger et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓

Hillary Rono et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Simon Harding et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
P. Massin et al., 2005	✓	✓	✓	✗	✓	✗	✓	✓	✓
Kieran S. O'Brien et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Chou et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zhen Ling Teo et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
J. Evans et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
Emily L. Clarke et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Davis et al., 2003	✓	✓	✓	✗	✓	✗	✓	✓	✓
C. Mangione et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
L. Smeeth et al., 2003	✓	✓	✓	✗	✓	✗	✓	✓	✓

F. Riordan et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Lindsay A. Rhodes et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
T. Quinn et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Stevens Bechange et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
L. Robinson et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Hillary Rono et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Vinothkumar Rajendran et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
V. Stamenova et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Binita Bhattarai et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Vera Rooth et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓

Selina L. Liu et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Liarn Srneeth et al., 2008	✓	✓	✓	✗	✓	✗	✓	✓	✓
T. Wall et al., 2011	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Zwarenstein et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sierra K. Ha et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
L. Hark et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. Agarwal et al., 2006	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Mathur et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Jinxiao Lian et al., 2013	✓	✓	✓	✗	✓	✗	✓	✓	✓
N. Mwangi et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
J. Yuan et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓

J. Aubert et al., 2007	✓	✓	✓	✗	✓	✗	✓	✓	✓
F. Sloot et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sile Yu et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
Tania Padilla Conde et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Katibeh et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
J. Yip et al., 2010	✓	✓	✓	✗	✓	✗	✓	✓	✓
Emily M. Schehlein et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Afua O. Asare et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Charles R Cleland et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
D. Broadbent et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
D. Broadbent et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓

Thembile Zikhali et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Jianjun Tang et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
D. Avidor et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
J. Burr et al., 2007	✓	✓	✓	✗	✓	✗	✓	✓	✓
C. Schmucker et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
Shalinder Sabherwal et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sera Thomas et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Noha Sharafeldin et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Shalinder Sabherwal et al., 2021a	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. Vinker et al., 2003	✓	✓	✓	✗	✓	✗	✓	✓	✓
N. Mwangi et al.,	✓	✓	✓	✗	✓	✗	✓	✓	✓

2020a									
Shalinder Sabherwal et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
P. Newman-Casey et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
C. Mangione et al., 2022a	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Kashim et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Larisa Wewetzer et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Kieran S. O'Brien et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Z. Jessa et al., 2007	✓	✓	✓	✗	✓	✗	✓	✓	✓
N. Mwangi et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Selina L. Liu et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Hillary Rono et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓

G. Judah et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
F. Riordan et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
W. Rezner et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
L. Hark et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
V. Stamenova et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yue Ma et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
J. Litaker et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Aeesha N J Malik et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Tavé van Zyl et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
Hillary Rono et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. N. Jensen et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓

Mayu Nishimura et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Wanjiku Mathenge et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓

RESULTS

Characteristics of Included Studies

This systematic review includes 80 sources examining screening programs for preventing blindness in primary care settings. The studies encompass various eye conditions, screening technologies, and populations across multiple countries.

Study	Target Condition	Setting	Population
R. Chou et al., 2009	Visual acuity impairment	Primary care	Adults >65 years
R. Chou et al., 2009a	Visual acuity impairment	Primary care	Adults ≥65 years
S. Mansberger et al., 2015	Diabetic retinopathy	Primary care clinic	Adults ≥18 years with diabetes
Hillary Rono et al., 2020	General eye conditions	Community-based, Kenya	Community populations
Simon Harding et al., 2023	Diabetic retinopathy	General practices, Liverpool	Adults ≥12 years with diabetes
P. Massin et	Diabetic retinopathy	Primary care,	Diabetic patients

Study	Target Condition	Setting	Population
al., 2005		France	
Kieran S. O'Brien et al., 2020	Glaucoma, DR, AMD	Community-based, Nepal	Adults ≥60 years
R. Chou et al., 2016	Visual acuity, AMD	Primary care	Adults ≥65 years
Zhen Ling Teo et al., 2023	DR, glaucoma, cataract, AMD, myopia	Rural and urban China	Adults ≥50 years
J. Evans et al., 2009	Visual acuity, cataracts	General practices, UK	Adults ≥70 years
Emily L. Clarke et al., 2018	Visual impairment	Community-based	Adults ≥65 years
R. Davis et al., 2003	Diabetic retinopathy	Rural South Carolina	Diabetic patients
C. Mangione et al., 2022	Visual acuity	Primary care	Adults ≥65 years
L. Smeeth et al., 2003	Visual acuity	General practices, UK	Adults ≥75 years
F. Riordan et al., 2020	Diabetic retinopathy	General practices, Ireland	Adults ≥18 years with diabetes
Lindsay A. Rhodes et al.,	Glaucoma, DR	Rural Alabama FQHCs	At-risk patients

Study	Target Condition	Setting	Population
2021			
T. Quinn et al., 2016	Visual acuity	Primary care	Adults ≥65 years
Stevens Bechange et al., 2022	Corneal ulceration	Rural communities, Nepal	Rural populations
L. Robinson et al., 2023	Diabetic retinopathy	Primary care, USA	Adults with diabetes
Hillary Rono et al., 2019	Visual acuity	Community-based, Kenya	Community populations
Vinothkumar Rajendran et al., 2025	Visual impairment, cataracts	Vision centres, India	Adults ≥40 years
V. Stamenova et al., 2021	Diabetic retinopathy	Urban Toronto	Adults >18 years with diabetes
Binita Bhattarai et al., 2021	Diabetic retinopathy	Nepal	DR patients
Vera Rooth et al., 2024	Visual acuity	Home healthcare, Netherlands	Adults ≥65 years
Selina L. Liu et al., 2022	Diabetic eye disease	Diabetes clinic, Canada	Adults with diabetes
Liarn Srneeth et al., 2008	Visual acuity	General practices	Adults ≥75 years

Study	Target Condition	Setting	Population
T. Wall et al., 2011	Strabismus, amblyopia	Primary care, USA	Children 3-4 years
M. Zwarenstein et al., 2014	Diabetic retinopathy	Family practices, Canada	Adults ≥30 years with diabetes
Sierra K. Ha et al., 2025	Diabetic retinopathy	Urban community health centres	Adults with diabetes
L. Hark et al., 2021	Glaucoma, eye diseases	Community-based, Manhattan	Adults ≥40 years
S. Agarwal et al., 2006	Diabetic retinopathy	Rural/urban India	Adults >30 years with diabetes
R. Mathur et al., 2019	Diabetic retinopathy	Singapore	Diabetic patients
Jinxiao Lian et al., 2013	Diabetic retinopathy	Hong Kong	Adults with diabetes
N. Mwangi et al., 2020	Diabetic retinopathy	Rural Kenya	Adults with diabetes
J. Yuan et al., 2020	Glaucoma	Philadelphia	Glaucoma patients
J. Aubert et al., 2007	Diabetic retinopathy	France	Diabetic patients
F. Sloot et al., 2014	Amblyopia	Netherlands	Children 0-5 years
Sile Yu et al., 2025	Cataracts	Rural China	Village populations

Study	Target Condition	Setting	Population
Tania Padilla Conde et al., 2023	Diabetic retinopathy	Primary care, USA	Adults with diabetes
M. Katibeh et al., 2020	Visual acuity, retinal conditions	Tehran province	Adults ≥50 years
J. Yip et al., 2010	Primary angle closure glaucoma	Mongolia	Adults ≥50 years
Emily M. Schehlein et al., 2021	Posterior segment diseases	Rural India	Adults 40-75 years
Afua O. Asare et al., 2021	Amblyopia, refractive errors	Schools/clinics	Children <6 years
Charles R Cleland et al., 2024	Diabetic retinopathy	Tanzania	Adults ≥18 years with diabetes
D. Broadbent et al., 2020	Diabetic retinopathy	Liverpool, UK	Adults ≥12 years with diabetes
D. Broadbent et al., 2019	Diabetic retinopathy	England	Adults ≥12 years with diabetes
Thembile Zikhali et al., 2022	Diabetic retinopathy	Primary healthcare	Diabetic patients
Jianjun Tang et al., 2019	Glaucoma	Rural/urban China	Adults ≥50 years

Study	Target Condition	Setting	Population
D. Avidor et al., 2020	Diabetic retinopathy	Community-based	Adults >18 years with diabetes
J. Burr et al., 2007	Open angle glaucoma	Community-based	Adults 40-50 years
C. Schmucker et al., 2009	Amblyopia	Various	Children ≤6 years
Shalinder Sabherwal et al., 2021	Visual acuity	Vision centres, India	Adults >5 years
Sera Thomas et al., 2014	Glaucoma	Remote communities	Adults at risk
Noha Sharafeldin et al., 2018	DR, glaucoma, AMD	Various settings	Adults 50-80 years
Shalinder Sabherwal et al., 2021a	Visual acuity	Vision centres, India	Adults >5 years
S. Vinker et al., 2003	Diabetic retinopathy	Urban Israel	Diabetic patients
N. Mwangi et al., 2020a	Diabetic retinopathy	Kenya	Adults with diabetes
Shalinder Sabherwal et al., 2022	Visual acuity	Rural India	Rural populations

Study	Target Condition	Setting	Population
P. Newman-Casey et al., 2025	Glaucoma, DR, refractive errors	Community health centres	Adults ≥18 years
C. Mangione et al., 2022a	Primary open-angle glaucoma	Primary care	Adults ≥40 years
R. Kashim et al., 2018	Diabetic retinopathy	Community-based	Adults >12 years with diabetes
Larisa Wewetzer et al., 2021	Diabetic retinopathy	Primary care	Diabetic patients
Kieran S. O'Brien et al., 2018	Corneal ulcers	Rural Nepal	Rural populations
Z. Jessa et al., 2007	Refractive errors, cataracts	UK	Older adults
N. Mwangi et al., 2018	Diabetic retinopathy	Rural Kenya	Adults ≥18 years with diabetes
Selina L. Liu et al., 2017	Diabetic retinopathy	Diabetes clinic, Canada	Adults ≥18 years with diabetes
Hillary Rono et al., 2018	Visual impairment	Schools, Kenya	Children years 1-8
G. Judah et al., 2016	Diabetic retinopathy	London	Adults ≥16 years with diabetes
F. Riordan et	Diabetic retinopathy	Ireland	Adults ≥18 years with

Study	Target Condition	Setting	Population
al., 2021			diabetes
W. Rezner et al., 2014	Glaucoma	Urban Poland	Adults 35-87 years
L. Hark et al., 2023	Glaucoma, eye diseases	New York City	Adults ≥40 years
V. Stamenova et al., 2022	Diabetic retinopathy	Toronto	Adults >18 years with diabetes
Yue Ma et al., 2018	Visual acuity	Rural China	Children 10-12 years
J. Litaker et al., 2020	Diabetic retinopathy	Central Texas	Adults with diabetes
Aeesha N J Malik et al., 2022	Congenital eye abnormalities	Various	Newborns
Tavé van Zyl et al., 2015	Glaucoma	Community health centre	Adults ≥30 years
Hillary Rono et al., 2021	Eye conditions	Kenya	Community populations
A. N. Jensen et al., 2025	Visual impairment	Community-based	Adults ≥75 years
Mayu Nishimura et al., 2024	Amblyopia	Schools	Children 5-7 years
Wanjiku	Diabetic retinopathy	Rwanda	Adults ≥18 years with

Study	Target Condition	Setting	Population
Mathenge et al., 2022			diabetes

The included studies span diverse geographic locations including high-income countries (USA, UK, Canada, Netherlands, Singapore, Australia) and low- and middle-income countries (Kenya, Nepal, India, China, Rwanda, Tanzania, Mongolia). Study designs varied substantially, with 25 randomized controlled trials, 15 systematic reviews, multiple protocol papers, and various observational designs. Target conditions included diabetic retinopathy (most common), general visual acuity impairment, glaucoma, cataracts, amblyopia, and age-related macular degeneration.

Effects of Screening Programs on Visual Outcomes

General Visual Acuity Screening in Older Adults

Direct evidence from multiple systematic reviews and RCTs examining vision screening in older adults consistently demonstrates limited effectiveness. Three fair-quality cluster randomized trials (N=4,728) found that vision screening as part of multi-component primary care interventions showed no benefits compared to usual care, delayed screening, or no screening on visual acuity or other clinical outcomes . One trial found vision screening by an ophthalmologist in frail older adults was associated with an increased risk of falls (relative risk 1.57, 95% CI 1.20 to 2.05) and a trend towards increased risk of fractures (relative risk 1.74, 95% CI 0.97 to 3.11) .

The largest UK-based trial (n=4,340) comparing universal screening with targeted screening found no significant difference in visual acuity outcomes at 3-5 years follow-up . The relative risk of having visual acuity <6/18 in either eye was 1.07 (95% CI 0.84 to 1.36; P=0.58), and composite scores on the National Eye Institute Visual Function Questionnaire showed no meaningful difference (85.6 vs 86.0; difference 0.4, 95% CI -1.7

to 2.5; P=0.69) . Similarly, another cluster RCT found that 37.0% in the universal screening group and 34.7% in the targeted group had visual acuity less than 6/18 at outcome (odds ratio 1.11, 95% CI 0.76 to 1.62, P=0.58) .

A Cochrane systematic review of 10 trials (10,608 participants) confirmed these findings, reporting that vision screening in older adults did not improve visual or clinical outcomes whether conducted in isolation or as part of multi-component screening packages . The meta-analysis of six studies showed similar risk of "not seeing well" at follow-up in screened versus non-screened groups (RR 1.05, 95% CI 0.97 to 1.14) .

Despite the lack of demonstrated benefit, screening does identify individuals with impaired vision. Universal screening identified 27% of persons with impaired visual acuity versus 3.1% with targeted screening in one good-quality trial (n=3,346), yet this increased detection did not translate to improved visual outcomes after 3-5 years (37% vs 35% with vision worse than 20/60; RR 1.07, 95% CI 0.84-1.36) .

The US Preventive Services Task Force concluded that the current evidence is insufficient to assess the balance of benefits and harms of screening for impaired visual acuity in older adults .

Diabetic Retinopathy Screening

Diabetic retinopathy screening demonstrates substantially different outcomes from general visual acuity screening, with evidence supporting both improved detection and adherence through various screening modalities.

Telemedicine-Based Screening

Telemedicine significantly increases diabetic retinopathy screening rates. In a multicenter RCT with 567 participants followed up to 5 years, the telemedicine group was more likely to receive screening compared to traditional surveillance during the first 6 months (94.6% vs 43.9%; 95% CI 46.6%-54.8%; P<0.001) and at 6-18 months (53.0% vs

33.2%; 95% CI 16.5%-23.1%; P<0.001) . Diabetic retinopathy worsened by 2 stages or more in only 8.6% of participants over 4 years, with 19.2% to 27.9% requiring referral to eye care professionals .

The Clearsight trial demonstrated that same-day, on-site screening by non-mydriatic ultra-wide field imaging detected more actionable eye disease compared to usual screening (14.9% vs 6.8%; adjusted odds ratio 2.51; 95% CI 1.49-4.36) . The number needed to screen was 13 (95% CI 8-29) to detect one additional patient with actionable eye disease .

Teleretinal screening programs in community health centers increased DR compliance rates by an average of 7.2 percentage points (p<0.001) , though initial improvements tended to diminish over time .

AI-Supported Screening

Artificial intelligence-supported screening shows promise in improving both detection and referral adherence. In Rwanda, AI-supported DR screening with immediate feedback resulted in significantly higher referral adherence (51.5%) compared to delayed communication after human grading (39.6%; odds ratio 1.74; P=0.031) . Participants in the AI group also sought treatment sooner (median 4.0 days vs 8.0 days; P<0.0001) .

Deep learning-based screening methods demonstrated pooled sensitivity of 87% and specificity of 90% for detecting diabetic retinopathy in primary care settings . Given a 10% prevalence of DR in type 2 diabetes patients, this yields a negative predictive value of 98% .

Cost-effectiveness analyses from China demonstrated that AI telemedicine screening dominated non-telemedicine and non-AI telemedicine approaches in both rural and urban settings . In rural settings, AI telemedicine was dominating compared to no screening, while in urban settings, the incremental cost-utility ratio for AI telemedicine was $244 compared with no screening .

Individualised Risk-Based Screening

The ISDR trial (n=4,534) evaluated individualised variable-interval risk-based screening compared to annual screening. Attendance rates at first follow-up were equivalent between groups (83.6% vs 84.7%; difference -1.0, 95% CI -3.2 to 1.2) . Sight-threatening diabetic retinopathy detection rates were non-inferior in the individualised arm (1.4% vs 1.7%; difference -0.3, 95% CI -1.1 to 0.5) . The individualised approach required 43.2% fewer screening appointments and generated incremental cost savings of £17.34 per person from the NHS perspective and £23.11 from the societal perspective .

Patient Engagement Interventions

Various patient engagement strategies have been evaluated to improve screening uptake. Phone calls were significantly more effective than letters for booking DR screening appointments (88% vs 11%) . Financial incentives and education materials also increased screening rates, with the incentive group showing RR=2.08 (95% CI 1.36-3.19; P=0.0006) and the education group showing RR=2.23 (95% CI 1.47-3.39; P=0.0001) compared to controls .

Peer-led interventions in diabetes support groups significantly increased screening uptake, with approximately one in two participants in the intervention arm attending screening compared to one in ten in the control arm . The rate of eye examination incidence was approximately 6 times higher in the intervention arm .

However, printed educational messages aimed at family practitioners failed to increase retinal screening rates (31.6% control vs 31.3% insert vs 32.8% outsert; largest 95% CI around any effect extending from -1.3% to 1.1%) .

Glaucoma Screening

Evidence for glaucoma screening effectiveness is more limited and nuanced. The USPSTF concluded that current evidence is insufficient to assess the balance of benefits and harms of screening for primary open-angle glaucoma in adults .

A randomized controlled trial in Mongolia examining screening with ultrasound anterior chamber depth measurement and prophylactic laser peripheral iridotomy for primary angle closure found no reduction in the 6-year incidence of primary angle closure glaucoma. The incidence was 1.61% (95% CI 1.11% to 2.25%) overall, with no significant difference between screened and non-screened groups (OR 1.29, 95% CI 0.65 to 2.60, p=0.47) .

Teleglaucoma demonstrated superior detection rates compared to in-person examination in a systematic review (13.4% vs 7.8%) . The pooled sensitivity was 0.832 (95% CI 0.770-0.881) and specificity was 0.790 (95% CI 0.668-0.876), with a diagnostic odds ratio of 18.7 . Cost-effectiveness analyses suggested that population screening for glaucoma may be cost-effective in China, with 246 years of blindness avoided per 100,000 rural residents screened (95% CI 63-628) and 1,325 years per 100,000 urban residents (95% CI 510-2,828) .

Primary care-based counseling interventions showed some effectiveness, with nurse counseling increasing glaucoma screening rates more than four-fold compared to controls (20.9% vs 4.5%, P=0.002) . Providing prescheduled appointments improved follow-up compliance (41% vs 24%; adjusted OR 4.8, 95% CI 1.1-20.9) .

Community-based telemedicine glaucoma programs, such as MI-SIGHT, detected high rates of glaucoma or suspected glaucoma (22.4%), with 68% attending recommended follow-up . Presenting visual acuity improved from 0.25±0.59 logMAR to 0.21±0.52 logMAR

(P=0.0012), and vision-related quality of life improved significantly (81.1±14.1 to 86.4±12.0; P<0.0001) .

Amblyopia and Childhood Vision Screening

Evidence on preschool vision screening for amblyopia shows modest benefits. A systematic review found that screening was associated with an absolute reduction in amblyopia prevalence between 0.9% and 1.6% (relative reduction 45-62%) . However, studies showed methodological weaknesses limiting validity .

A disinvestment study in the Netherlands found that omitting preverbal eye screening at age 6-9 months did not significantly affect referral rates (0.9% in both screened and unscreened groups) or amblyopia detection (7 vs 6 cases) . All detected cases were strabismic or combined-mechanism amblyopia, with no cases of refractive amblyopia identified .

A cluster-randomized trial of school-based vision screening found that screened and non-screened schools did not differ in the prevalence of suspected amblyopia in Grade 2 (8.6% vs 7.5%, p=0.10) . More children wore glasses in screened schools (10.2% vs 7.8%, p=0.05), suggesting successful identification of those needing correction, and 72% of children diagnosed with amblyopia in kindergarten no longer had amblyopia in Grade 2 . Poor treatment compliance and high attrition may have limited program effectiveness .

Cost-effectiveness analyses of pediatric vision screening yielded incremental cost-effectiveness ratios ranging from C$1,056 to C$151,274 per additional case detected/prevented and C$9,429 to C$30,254,703 per additional QALY gained .

Newborn Eye Screening

Evidence supports red reflex testing in newborns. Universal red reflex testing in maternity wards may increase referrals for congenital cataracts (RR 9.83, 95% CI 1.36-71.20) . Early referral rates were higher with universal screening (RR 4.61, 95% CI 1.12-

19.01) as were early surgery rates (RR 8.23, 95% CI 1.13-59.80) . However, evidence certainty was rated as low, and the effect of well-baby clinic screening alone remained uncertain .

Community-Based and mHealth Screening Programs

Mobile health (mHealth) systems have shown substantial improvements in access to eye care services in low- and middle-income countries. The Peek Community Eye Health system in Kenya significantly increased triage attendance by people with eye conditions (1,429 per 10,000 vs 522 per 10,000; rate difference 906 per 10,000, 95% CI 689-1,124; p<0.0001) . Hospital attendance also increased (82 per 10,000 vs 33 per 10,000; rate difference 49 per 10,000, 95% CI 25-73; p=0.0002) .

The Peek school eye health system increased adherence to hospital referral for visual impairment assessment in Kenyan schoolchildren (54% vs 22%; odds ratio 7.35, 95% CI 3.49-15.47; p<0.0001) .

Vision Centres in rural India demonstrated effectiveness in improving eye care access. Residents within 5 km of Vision Centres had lower age-sex-adjusted prevalence of visual impairment (18.1% vs 25.2%) and higher eye care utilization (66.7% vs 52.3%) . Cataract surgical coverage was also higher (63.9% vs 55.0%), as was effective cataract surgical coverage (44.8% vs 32.6%) .

Technology-driven eye camp models in rural India significantly increased detection of and referral for posterior segment diseases (8.3% vs 3.6%; P<0.001; risk ratio 2.31, 95% CI 2.30-2.34) . AI-assisted portable slit lamps increased cataract referral rates 1.7-fold and surgery rates 4.9-fold compared to training alone .

However, a community-based corneal ulcer prevention program using trained community health volunteers in Nepal failed to demonstrate effectiveness. Incidence of corneal ulceration did not differ between intervention and control groups (1.21 vs 1.18 per

1000 person-years; IRR 1.03, 95% CI 0.63-1.67; p=0.93) , though results were more promising in rural areas .

Economic Considerations

Screening Approach	Cost Metric	Value	Setting	Source
AI telemedicine (DR)	ICUR vs no screening	Dominating	Rural China	Teo et al. 2023
AI telemedicine (DR)	ICUR vs no screening	$244/QALY	Urban China	Teo et al. 2023
Individualised DR screening	Incremental savings per person (NHS)	£17.34	Liverpool, UK	Harding et al. 2023
Individualised DR screening	Incremental savings per person (societal)	£23.11	Liverpool, UK	Harding et al. 2023
Glaucoma screening	Cost per QALY	$569 (95% CI 17-4180)	Rural China	Tang et al. 2019
Telemedicine DR	Cost per QALY	$7,228 (patients >50 years)	USA	Avidor et al. 2020
PEC vs SOC (DR)	Total cost per visit	$123.87 vs $223.60	Singapore	Mathur et al. 2019
Community screening	Cost per participant	$110.99	Michigan, USA	Newman-Casey et al. 2025
Community	Cost per case	$206.72	Michigan, USA	Newman-Casey

Screening Approach	Cost Metric	Value	Setting	Source
screening	detected			et al. 2025
Teleglaucoma	Cost per case detected	$1,098.67	Various	Thomas et al. 2014
Open angle glaucoma	Cost per QALY threshold	£30,000	UK	Burr et al. 2007
Pediatric amblyopia	Cost per case detected	C$1,056-151,274	Various	Asare et al. 2021
Implementation intervention	Cost per practice	€627	Ireland	Riordan et al. 2021

Economic analyses consistently demonstrate that telemedicine and AI-supported screening approaches are cost-effective, particularly in settings with high disease prevalence and large patient pools . Primary eye care clinic settings showed 45% lower direct costs compared to specialist outpatient clinics . Teleophthalmology reduces patient travel costs and improves accessibility, with cost-effectiveness increasing with higher disease prevalence .

Population-level screening for glaucoma may not be cost-effective in the general population but could be worthwhile for targeted high-risk groups (family history, Black ethnicity) . In China, combined screening for POAG and PACG was predicted to be cost-effective in both rural (ICUR $569) and urban settings (where screening was dominated by cost savings) .

The ISDR trial demonstrated that individualised screening could reduce overall programme costs by 21%, with estimated annual savings of £199,000 in Liverpool and £23.9 million nationally from the NHS perspective .

Implementation Factors

Uptake and Participation Rates

Screening uptake varies substantially across programs and populations. In established diabetic retinopathy programs, annual screening attendance rates typically range from 70-85% , though some areas fail to meet the acceptable 70% threshold . Telemedicine approaches consistently achieve higher initial participation rates (94.6% vs 43.9%) , though effects may diminish over time .

Socioeconomic deprivation is a major risk factor for non-attendance at diabetic retinopathy screening . The inverse care law operates in screening programs, with a copayment resulting in lower uptake (82.4%) compared to free screening (88.5%) . Higher socioeconomic status is associated with higher screening attendance but lower disease detection rates .

Referral Completion

Referral completion rates present a critical implementation challenge. In general visual acuity screening, only approximately half of recommendations for ophthalmologist referral resulted in actual referrals . This was particularly pronounced in cognitively impaired individuals .

In community-based programs, follow-up rates to referred care range from 30-68% . Pre-scheduled appointments significantly improve follow-up compliance (41% vs 24%) , as do patient navigator programs .

Technology and Training Requirements

Teleophthalmology requires trained technicians to capture images and specialists to review them . AI-supported systems may reduce dependence on skilled staff for image interpretation but require confidence-building among healthcare workers presenting results to patients .

Community health volunteers can effectively perform basic screening with appropriate training, though concerns exist about workload expansion without additional compensation . Training programs for primary care physicians in diabetic retinopathy management cost approximately $48,000 per physician .

Barriers to Implementation

Key barriers include:

- Cost and resource constraints
- Lack of awareness about eye disease and need for screening
- Distance from screening facilities
- Poor referral systems and tracking
- Inadequate training opportunities for healthcare workers
- Technology limitations and false positive rates
- Low compliance to referrals (as low as 19% in rural settings, 57% in urban settings)

Facilitators of Success

Successful programs share common features:

- Integration of screening into routine clinical visits
- Use of SMS reminders and decision support algorithms
- Phone calls rather than letters for patient engagement
- Patient navigator support
- Financial incentives or removal of copayments

- Peer supporter networks
- Clear referral pathways
- Real-time system reporting

Synthesis

The evidence reveals a striking paradox in eye screening programs: while effective treatments exist for most causes of vision impairment, and screening can successfully identify affected individuals, improved visual outcomes in screened populations are difficult to demonstrate.

Explaining the Paradox of Detection Without Outcome Improvement

The disconnect between detection and outcomes in general visual acuity screening can be explained through several mechanisms:

High baseline eye care utilization in studied populations. In the Australian trial, 82% of participants reported seeing an eye healthcare professional within the preceding 2 years, and over 70% of the control group visited an eye professional during the 12-month study period . Similarly, 86% of UK participants with vision impairment had previously seen an ophthalmologist . This ceiling effect suggests that screening adds little value where eye care access is already high.

The referral-to-treatment gap. Even when screening identifies impairment, only approximately half of referral recommendations result in actual referrals . Non-referral is higher in cognitively impaired individuals and those previously seen by ophthalmologists . This attrition dramatically reduces potential benefit.

Predominance of untreatable conditions. Much detected impairment is due to age-related macular degeneration or previous diabetic retinopathy that may not be amenable to vision restoration . Over 50% of detected impairment in UK studies was due to correctable conditions like refractive error and cataract , but even providing correction does not guarantee improved function if patients do not use prescribed treatments.

Why Diabetic Retinopathy Screening Differs

Diabetic retinopathy screening consistently shows positive effects on screening rates and may reduce blindness, in contrast to general visual acuity screening. This difference reflects several factors:

Natural history amenable to early intervention. DR progresses through identifiable stages with a critical window for treatment before irreversible vision loss occurs . The asymptomatic nature of early DR means screening genuinely identifies cases that would otherwise progress undetected.

Well-defined high-risk population. All individuals with diabetes are at risk, creating a clear target population with established care relationships . This differs from general population screening where prevalence is lower and the population less engaged with healthcare.

Effective treatments available. Laser photocoagulation, anti-VEGF therapy, and glycemic control can prevent progression when DR is detected early .

Integration with diabetes care. DR screening can be embedded within existing diabetes management pathways, leveraging established patient-provider relationships and appointment systems .

Technology as a Partial Solution

Telemedicine and AI-supported screening address some but not all barriers to effective screening. These technologies successfully increase detection rates and can be cost-effective , particularly in underserved areas. However, technology alone does not solve the referral completion problem—even with immediate AI-generated results, adherence to referral was only 51.5% in Rwanda .

The Peek Community Eye Health system in Kenya demonstrated that combining smartphone-based screening with SMS reminders and enhanced referral pathways can dramatically increase service utilization . This suggests that technology must be accompanied by system-level changes in referral pathways and patient support to translate detection into treatment.

Population and Context-Specific Considerations

Screening effectiveness varies by context:

Rural vs urban settings. Vision Centres showed greater impact in rural areas with limited baseline access . AI telemedicine screening showed more prominent cost-effectiveness benefits in rural China compared to urban areas . Community-based corneal ulcer prevention showed more promising results in rural areas where basic eye care facilities were not available .

Age and vulnerability. Screening may be more beneficial in populations with limited baseline healthcare access, such as those in home healthcare or affordable housing developments , compared to independently living older adults who already access eye care services.

Healthcare system factors. The presence of free sight tests does not eliminate vision impairment in older adults , suggesting that access alone is insufficient. Programs that actively address barriers through patient navigation , financial incentives , and peer support show more consistent improvements in uptake.

Summary of Condition-Specific Conclusions

For diabetic retinopathy: Annual or risk-stratified screening is supported by evidence showing improved detection rates, stable or improved visual outcomes with treatment, and cost-effectiveness. Telemedicine and AI-supported approaches increase accessibility and may improve adherence. Individualised risk-based intervals can safely reduce screening burden while maintaining effectiveness .

For glaucoma: Population-wide screening is not supported by current evidence . Targeted screening of high-risk groups (family history, Black ethnicity) may be cost-effective . Teleglaucoma shows promise for detection in underserved areas .

For general visual impairment in older adults: Current evidence does not support population screening in primary care settings where eye care access is already available . Screening may have a role in populations with limited healthcare access or in targeting specific subgroups.

For childhood amblyopia: Modest benefits from preschool screening have been demonstrated, but effectiveness depends on treatment compliance . Continued care and provision of glasses are necessary to improve outcomes .

For newborn eye disease: Red reflex testing shortly after birth may increase early detection and treatment of congenital cataracts , though evidence certainty is low.

DISCUSSION

This comprehensive review synthesises evidence from 80 studies, revealing a complex and nuanced landscape for blindness prevention screening in primary care. The most striking finding is the paradoxical disconnect between the ability of screening to detect visual impairment and its frequent failure to demonstrate improved visual outcomes at the population level. This discussion delves into the mechanisms behind this paradox, contrasts the varying effectiveness across conditions, and explores the role of technology and context.

The Paradox of Detection Without Outcome Improvement in General Visual Acuity Screening

Multiple high-quality trials and systematic reviews consistently show that general vision screening for older adults in primary care does not lead to better visual acuity or function compared to usual care (Clarke et al., 2018; Smeeth et al., 2003; Chou et al., 2016). This is despite screening successfully identifying individuals with impairment. Several interconnected factors explain this paradox.

First, a **ceiling effect of existing eye care utilisation** is evident in studied populations. In trials conducted in settings like the UK and Australia, a high proportion of control group participants already had recent contact with eye care professionals (e.g., optometrists or ophthalmologists) (Smeeth et al., 2003; Chou et al., 2016). When baseline access is high, adding systematic screening provides marginal additional benefit. Second, there is a critical **attrition in the referral pathway**. Screening identifies a problem, but this must lead to a referral, which the patient must attend, leading to a diagnosis and effective treatment. Studies indicate that only about half of screening-generated recommendations for specialist referral are actually acted upon, with attrition being worse among cognitively impaired individuals (Chou et al., 2016). Third, a significant portion of detected impairment is due to conditions like advanced age-related macular degeneration (AMD) which may have limited treatment options for vision restoration, or uncorrected refractive error where providing glasses does not guarantee improved function if patients do not use them (Jensen et al., 2025).

Why Diabetic Retinopathy Screening is Different

In stark contrast to general screening, the evidence for DR screening supports its effectiveness. This divergence is attributable to several key factors. DR has a **natural history**

amenable to early intervention, progressing through identifiable, treatable stages during an often asymptomatic phase (Massin et al., 2005). Screening thus truly identifies occult disease. The **target population is well-defined** (all individuals with diabetes), who are already engaged with healthcare systems for chronic disease management, facilitating integration of eye screening into routine care (Riordan et al., 2020). Furthermore, **highly effective treatments** (laser, anti-VEGF injections, glycemic control) exist that can halt or slow progression if applied in time (Aubert et al., 2007). Studies demonstrate that telemedicine and teleretinal screening significantly increase screening rates and detection of referable disease (Mansberger et al., 2015; Davis et al., 2003). Innovations like individualised, risk-based screening intervals have been shown to maintain safety and efficacy while reducing the screening burden and costs by over 20% (Broadbent et al., 2020; Harding et al., 2023). AI-supported screening not only improves detection accuracy but also, when coupled with immediate feedback, enhances referral adherence and reduces time to treatment (Mathenge et al., 2022; Cleland et al., 2024).

The Limited and Contingent Role of Glaucoma and Childhood Screening

The evidence for glaucoma screening in the general population remains insufficient to recommend its implementation (Mangione et al., 2022; Burr et al., 2007). A major trial in Mongolia found that screening and prophylactic treatment for primary angle closure did not reduce the incidence of glaucoma (Yip et al., 2010). However, targeted screening of high-risk groups (e.g., those with family history or of Black ethnicity) and the use of teleglaucoma in underserved communities show promise in improving detection rates and may be cost-effective in specific contexts (Tang et al., 2019; Thomas et al., 2014; Hark et al., 2023). For childhood amblyopia, evidence suggests preschool screening can reduce prevalence, but the benefit is modest and heavily dependent on effective treatment compliance, which is often poor (Schmucker et al., 2009; Nishimura et al., 2024). The provision and continued use of glasses are critical determinants of success (Ma et al., 2018; Asare et al., 2021). Newborn red reflex testing may improve early detection of congenital cataracts, though the certainty of evidence is low (Malik et al., 2022).

Technology as an Enabler, Not a Panacea

Telemedicine, AI, and mHealth platforms have revolutionised access to screening, particularly in remote and resource-limited settings. They address critical barriers of distance and specialist scarcity (Rono et al., 2021; Sabherwal et al., 2021). AI telemedicine for DR has been shown to be cost-effective and even cost-saving in rural China (Teo & Ting, 2023). However, technology alone is insufficient. The **"last mile" problem of referral completion** persists. For instance, even with immediate AI results in Rwanda, only 51.5% of referred patients adhered to the referral (Mathenge et al., 2022). The most successful programs, such as the Peek system in Kenya, combine technology with robust system-level enablers: SMS reminders, community health worker support, and strengthened referral pathways (Rono et al., 2021). This underscores that technology must be embedded within a supportive ecosystem of care.

The Paramount Importance of Context

The effectiveness of screening is profoundly context-dependent. **Rural vs. urban settings** demonstrate clear disparities. Vision Centres and AI screening show greater relative impact and cost-effectiveness in rural areas where baseline access to eye care is minimal (Rajendran et al., 2025; Teo & Ting, 2023). **Socioeconomic status** is a major determinant of screening uptake and outcomes, often manifesting an inverse care law where those at highest risk are least likely to be screened (Jinxia Lian et al., 2013; Kashim et al., 2018). Successful implementation requires active strategies to mitigate these disparities, such as patient navigation (Yuan et al., 2020), removing financial barriers (copayments), using phone calls instead of letters (Stamenova et al., 2022), and employing peer supporters (Mwangi et al., 2018).

Implementation and Economic Synthesis

Effective implementation hinges on high uptake and completed referral loops. Barriers include cost, lack of awareness, distance, and weak health information systems (Kashim et al., 2018). Facilitators include integration into routine care, use of decision support, and patient navigators (Newman-Casey et al., 2025; van Zyl et al., 2015). Economically, screening programs for DR using telemedicine and AI are consistently found to be cost-effective, with some being cost-saving (Avidor et al., 2020; Sharafeldin et al., 2018). The economic argument strengthens with higher disease prevalence and when programs reduce downstream costs of blindness care.

In summary, the discussion confirms that the value of screening is not universal. It is a potent tool for specific conditions like DR within engaged care systems, but an ineffective expenditure for general vision screening in well-served populations. The future of effective blindness prevention lies in moving beyond isolated screening events towards designing integrated, patient-centred eye care pathways that seamlessly connect detection, diagnosis, treatment, and follow-up, with technology serving as a bridge rather than an endpoint.

CONCLUSION AND RECOMMENDATIONS

Conclusions

This systematic review leads to several key conclusions:

1. **Condition-Specific Efficacy:** The effectiveness of screening is highly condition-dependent. Strong evidence supports systematic screening for **diabetic retinopathy** in primary care, demonstrating improved detection, adherence, and cost-effectiveness, especially when leveraging telemedicine and AI. In contrast, evidence does not support population-based screening for **general visual impairment in older adults** in settings with adequate existing eye care access. For **glaucoma**, population screening is not recommended, though targeted high-risk approaches may be justified. **Childhood amblyopia** screening offers modest benefits contingent on treatment compliance.

2. **The Detection-Outcome Gap:** A fundamental paradox exists where screening successfully identifies visual impairment but often fails to improve population-level visual outcomes. This gap is primarily driven by high baseline eye care utilization, attrition along the referral-to-treatment pathway, and the prevalence of untreatable conditions in screened cohorts.

3. **Technology's Role and Limits:** Digital health technologies (telemedicine, AI, mHealth) are powerful enablers that increase access, efficiency, and detection rates. However, they do not automatically ensure treatment adherence. Their greatest impact is realized when integrated into supported care pathways that address downstream barriers.

4. **Context is Determinative:** The success of a screening program is inextricably linked to its context. Factors such as rural vs. urban setting, baseline healthcare access, socioeconomic status of the population, and strength of the referral system are critical moderators of effectiveness. Programs yield the greatest return on investment in underserved populations with limited pre-existing access to eye care.

Recommendations

Based on these conclusions, the following recommendations are proposed:

- **For Policymakers and Program Planners:**
    - Prioritise investment in evidence-based screening for diabetic retinopathy within national diabetes care programs.
    - De-implement ineffective general vision screening for older adults in well-served areas, reallocating resources towards targeted outreach for underserved subgroups (e.g., homebound elderly, vulnerable urban populations).
    - Adopt a stratified approach to glaucoma, focusing on education and targeted assessment for high-risk groups rather than population screening.

  - Fund and develop **integrated eye care pathways** rather than standalone screening projects. These pathways must include robust referral mechanisms, patient navigation support, and tracking systems to minimise attrition.
  - Invest in digital health infrastructure and training for primary care workers to support telemedicine and AI-assisted screening, particularly in rural and remote regions.

- **For Clinical Practice:**
  - Primary care providers should integrate routine DR screening into the annual management of all diabetic patients, utilising teleretinal or AI tools where available.
  - Conduct opportunistic case-finding for visual impairment during routine visits for vulnerable older adults, rather than implementing systematic mass screening.
  - Advocate for and utilize patient navigators or community health workers to improve completion of referrals following a positive screening result.
- **For Future Research:**
  - Conduct more studies in low-resource primary care settings with genuinely low baseline eye care access to evaluate the true potential of screening.
  - Investigate complex interventions that combine screening with strengthened referral and treatment adherence support, measuring long-term visual outcomes.
  - Develop and validate cost-effectiveness models for AI and telemedicine screening in diverse socio-economic and healthcare system contexts.
  - Explore the role of social determinants of health and design equity-focused interventions to improve screening uptake among disadvantaged populations.

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