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OPHTHALMOLOGY | RESEARCH ARTICLE

Visual acuity screening in schools: A systematic review of alternate screening methods

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Abstract: *Purpose:* Visual acuity (VA) screening in schools has been widely adopted by eye programs around the world. This review evaluates the efficacy and cost of alternate VA screening methods to identify school-age children with undetected visual deficits due to refractive error and other visual disorders. *Methods:* Published studies were identified from Ovid MEDLINE, MEDLINE In-Process, and EMBASE for trials from 1974 to March 2015 as well as from reference and author searches. All controlled studies were included. Data extraction tables were developed a priori for key screening test performance indicators, including compliance. *Results:* Three trials met the inclusion criteria, two comparing alternate teacher models and one compared teachers to primary eye care workers using three different VA thresholds. School vision screening using “all class teachers” (ACTs) found significantly fewer screen-positive children than select teachers (STs) (9.9 vs. 16.6% [$p < 0.001$] respectively) and significantly more children with visual disorders (5.7 vs. 4.0% [$p < 0.001$] respectively) at 30% of the cost and improved compliance. Teachers performed similarly to primary eye care workers in detecting children with visual disorders with 6/12 the optimal cut-off level. *Conclusions:* Using detection of children with visual disorders as outcome, evidence supports school screening using “ACTs” and a 6/12

ABOUT THE AUTHORS

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PUBLIC INTEREST STATEMENT

Visual acuity (VA) screening in schools has been widely adopted by eye programs around the world. This review evaluates efficacy and cost of alternate VA screening methods to identify school-age children with undetected visual deficits due to refractive error and other visual disorders. This study compared alternate use of teachers, comparing selected teachers (STs) to all class teachers (ACTs). The study found that school screening with class teachers identified significantly more ocular conditions requiring intervention including refractive error. In addition, the ACT model significantly increased the number of children attending follow-up within 3 months compared to the ST model. Presumably, in the ACT model, teachers have more opportunity to motivate parents and children to comply with recommended referrals to an ophthalmologist or optometrist. Therefore, a small change in the role of teachers, for example, was shown to improve care of children while reducing program costs.

VA threshold. Using the proportion of students with visual disorders who attend follow up at the referral hospital within three months as outcome, one study supports use of ACTs. Using cost per child detected with visual disorders as outcome, one study supports use of ACTs.

Subjects: Community Health; Ophthalmology; Pediatrics & Child Health

Keywords: systematic review; alternate vision screening; school screening methods; childhood; blindness; visual acuity screening

1. Introduction

Recognizing the importance of visual acuity (VA) for educational and behavioral development from an early age, health care policy in many countries has strongly promoted school eye health programs (Rosner & Rosner, 1986). Central to these eye health programs is some form of VA screening designed to detect refractive errors and other ocular disorders. VA screening programs have become a central component of the World Health Organization's Vision 2020 goals in most of the developing world (Resnikoff & Pararajasegaram, 2001).

The value of VA screening after the age for school entry has been queried. Hall and Elliman (2003) pointed out that the disability caused by living with an uncorrected VA deficit has not been quantified, and the optimum age and number of occasions for screening have not been established. Evidence for the effectiveness of screening in reducing the proportion of school-age children and adolescents with a correctable VA deficit has been reviewed (Powell, Wedner, & Hatt, 2004). They concluded that the effectiveness of school screening in different settings has not been examined in proper scientific studies. Nevertheless, questions remain including the optimal vision screening method in terms of efficacy and cost.

A school-based VA screening program is substantially more effective and less costly for delivering eye care to school going children compared to another primary eye care models (Lester, 2007). Due to a scarcity of ophthalmic professionals, especially ophthalmologists and optometrists, in almost all low and middle-income settings, school screening programs have been modeled around non-eye care personnel; most commonly school teachers and occasionally school nurses who are trained to conduct the VA testing (Jose & Sachdeva, 2009).

The primary objective of this review is to compare peer reviewed studies that investigated alternate methods of VA screening to detect VA deficits found in children and adolescents. Methods are defined broadly to include student identification, person performing test, test mechanics and referral process. Secondary objectives are to compare the literature as it relates to the cost of the alternate screening methods and compliance with treatment recommendations.

2. Methods

We included randomized and non-randomized controlled trials as well as studies using concurrent control groups, of any size and in any language involving all types of school screening programs. Studies could assess screening carried out by VA assessment using any age-appropriate vision test, any threshold for failure and administered by any testing personnel, measuring: (1) monocular VA or binocular VA, or both; (2) distance VA only; or (3) near and distance VA. Those who fail screening must be referred to confirm diagnosis and to recommend treatment.

The following comparisons were planned:

- Alternate testing personnel, that is nurses, teachers, or health worker.
- Different failure thresholds.

Inclusion criteria for observational studies: (1) sample size greater than 1,000 to create a manageable number for description and summary, (2) screening methods sufficiently described and (3) screen positive children subjected to gold standard examination (We included children 5 years and above who were enrolled in school. In some major studies, a small sample likely fell under 5 years old but they were all already enrolled in school).

Exclusion criteria: Studies of screening at preschool and school entry were excluded, because it is difficult for non-eye care personnel to reliably conduct VA screening in the younger age groups.

2.1. Types of outcome measures

- (1) *Primary outcome*: relative accuracy of VA deficit detection methods in comparable populations. Assessment includes the degree of compliance with screening and treatment recommendations. Vision must be tested with prescribed spectacles in place.
- (2) *Secondary outcome*: accuracy of alternate VA detection methods at different VA thresholds.
- (3) *Cost outcomes costs*: associated with alternate screening methods.

2.2. Search strategy

- (1) Database of Abstracts of Reviews of Effectiveness (DARE) for related reviews.
- (2) Ovid MEDLINE (1946 to 15 March 2015) and Ovid EMBASE (1974 to 15 March 2015) for primary studies (Appendix A).
- (3) Electronic databases were searched using a strategy combining MeSH terms and free text terms. No language or date restrictions were used. The MEDLINE search strategy was translated into EMBASE using the appropriate controlled vocabulary as applicable. We searched the reference lists of all relevant studies and systematic reviews for additional studies.

2.3. Data collection and analysis

One of the two reviewers checked the search results and selected all reports of studies that made reference to refractive error, any eye disease and vision screening. Any reports that were clearly not relevant were excluded at first viewing. Both the reviewers then screened the remaining titles and abstracts to establish if they met the inclusion criteria. Three reports had no abstract so full papers were obtained.

Trial quality was assessed using the guidelines in Section 6 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Lefebvre, Manheimer, & Glanville, 2008) and the Cochrane Eyes and Vision Group Review Development Guidelines. We assessed three main sources of bias (most applicable to controlled trials of screening methods):

- (1) Selection bias: Controlled by random population-based selection of schools and random allocation of schools to alternate screening methods, or non-random matching of school samples.
- (2) Detection bias: Were clinical examiners masked to the screening group allocation?
- (3) Attrition bias: Were clinical assessment proportions similar for groups? Were all children accounted for?

Two authors independently extracted data using a predefined data collection form. Both authors entered studies selected into Endnote X7 using a double data-entry system to check for discrepancies.

A meta-analysis was not performed. Subgroup analyses were performed for trials with different failure thresholds and of trials carried out by different types of personnel, that is teachers, school

nurses or general (non-ophthalmic) health professionals. Within each group, the proportion of students who failed screening was reported as a dichotomous outcome variable. Risk ratio is used to measure effect.

3. Results

The electronic searches identified a total of 1483 reports and studies of school based vision screening. Full text copies were obtained for 100 articles that met the initial inclusion criteria. Of these, 30 provided sufficient details of the screening methods for inclusion in the report (Table 1). Only 3 studies evaluated alternative screening methods using a control group (Priya et al., 2015; Sartika Apulina et al., 2011; Saxena et al., 2015) (Table 2). These studies are used to draw conclusions regarding the relative efficacy and cost of school vision screening methods.

The retrieved literature consists mainly of observational, cross-sectional and cohort studies. A selection of these observational studies were included that met the inclusion criteria in terms of size and completeness (Table 3). These studies are used in the Discussion Section to characterize preferred practices.

3.1. Description of controlled studies (Table 2)

3.1.1. Priya et al. (2015)

A prospective, non-randomized control study of alternative school screening methods in southern India involving 80,463 students, from a convenience sample of schools, compared all class teachers (ACTs) to a limited number of selected teachers (STs) to screen for visual acuity < 20/30 in either eye or obvious ocular abnormalities. STs are the teachers selected by headmasters usually from a less work-intensive course (e.g., physical education) to screen approximately 250 students.

Group of STs were trained at the base hospital. ACTs are all the classroom teachers in the school and they are trained by the hospital team at their school. Training of the STs and ACTs was carried out in a uniform manner by the same personnel in two sessions. In the first session, ophthalmologists lectured on recognition of eye problems, with an emphasis on pediatric diseases, and provided the teachers with posters and pictures. In this session, teachers were also specifically given awareness about obvious ocular abnormalities like squint, nystagmus, corneal opacities, ptosis, conjunctivitis and external hordeolum so that they identified these children as defective even though their visual acuity was normal. In the second session, optometrists instructed teachers on vision screening procedures using eye charts and provided them with basic tools for testing visual acuity.

Unlike STs, ACTs need to screen only their own students (30–50). The result of ophthalmic team examination showed that ACTs found significantly fewer screen-positive children ($n = 3,806$, 9.7%) than the STs ($n = 6,387$, 16.6%; $p < 0.001$) but had a significantly larger number of children with actual vision loss and other ocular pathology (2,231[5.7%] and 1,554[4.0%] for ACTs and STs, respectively, $p < 0.001$). ACTs had the maximum interaction with students in their own class and had a better opportunity to identify students with visual impairment than STs. Greater numbers of children from ACTs than STs were compliant to referral and reached the base hospital for further investigation within 3 months ($p < 0.001$). The ACTs likely spoke to individual parents more about their child's performance and had an opportunity to explain possible challenges such as vision problems and encourage them to use available eye care services. The cost of screening a child was estimated at US\$0.11 and US\$0.20 for ACTs and STs respectively. The cost of screening per child with actual ocular pathology was estimated to be US\$1.91 for ACTs and US\$4.83 for STs. With total cost of US\$4,253 and US\$7,507 for the two groups, this translates into US\$1.91 (4,253/2,231) and US\$4.83 (7,507/1,554) per child with actual ocular pathology in the ACTs and STs, respectively.

The primary limitation of this study is that it did not determine the number and condition of children who were falsely screen negative. Therefore, it could not calculate sensitivity and specificity.

3.1.1.1. Risk of bias.

- (1) Selection bias: schools not randomly selected from population; control and intervention schools not randomly assigned (controls matched to intervention schools).
- (2) Detection bias: ophthalmological examiners knew whether ACTs or STs conducted screening.
- (3) Attrition bias: minimal; >95% of children screened; >95% screen-positive examined by ophthalmic team.

3.1.2. Sartika Apulina et al. (2011)

A Prospective study of alternate teacher models in Indonesia involving 23,427 students, from non-representative schools, randomly compared Model A (3–5 teachers per school) to Model B (more classroom teachers). Screen failure children received a detailed evaluation by an ophthalmic personnel. Overall, teacher screening was 79% sensitive and 91% specific in identifying students. The sensitivities were 80 vs. 76% and specificities were both 93% in Model A (fewer) and Model B (more) teachers, respectively. The cost of training teachers per school in Model A was US\$ 108 in Model B was US\$ 232.

3.1.2.1. Risk of bias.

- (1) Selection bias: schools invited to participate; randomly assigned to either Model A or B.
- (2) Detection bias: minimal; accuracy assessment involved selecting children from original population, not referrals.
- (3) Attrition bias: minimal; not relevant to this study design.

3.1.3. Saxena et al. (2015)

A cross-sectional study in northern India, involving 9,838 students from representative schools, compared teachers to primary eye care workers (PECWs) using different vision acuity thresholds. They compared teachers to ophthalmic personnel with sensitivity 79.2% and specificity 93.3%. Saxana also compared primary eye care workers to ophthalmic personnel with sensitivity 77.0% and specificity of 97.1%, with both comparisons using the 30/60 optotype. The referral proportions were 17.3, 9.6 and 4.6% at the <6/9.5, <6/12, and <6/15 visual acuity cut-offs, respectively. The 6/9.5 cut off almost doubled the number of referrals with only marginal increase in sensitivity (79.2 and 77.0% for <6/9.5 and <6/12 respectively).

3.1.3.1. Risk of bias.

- (1) Selection bias: schools randomly selected from population. No real control group, rather test-retest of school teacher and PECW accuracy vs. gold standard, at different VA thresholds.
- (2) Detection bias: PECW not aware of school teacher finding.
- (3) Attrition bias: minimal; >95% of children screened; >95% screen-positive saw ophthalmic team.

Table 1. Summary of 30 included studies of school-based visual acuity testing

S. No.	Article (Country)	N	Age group	Study method	VA testing personnel	Diagnostic examination
1	Adhikari et al. (2013) (Nepal)	2,000	5–16	A cross-sectional prevalence study	Ophthalmic team	Ophthalmic team
2	Ajaiyeoba et al. (2005) (Nigeria)	1,144	5–19	School based field study	Teachers & nurses	Ophthalmologists
3	Aldebasi (2014) (Saudi Arabia)	5,176	6–13	A cross-sectional prevalence study	Ophthalmic team	Ophthalmic team
4	Sartika Apulina et al. (2011) (Indonesia)	23,427	7–15	Prospective study alternate teacher models	Teachers & class teachers	Refractionists
5	Bagchi et al. (2008) (India)	45,087	5–15	Retrospective analysis of school screening program performance	Teachers (219)	Optometrist
6	Faran (1992) (Saudi Arabia)	3,590	6–17	School screening performance study	Nurses	Ophthalmic team
7	Fotouhi et al. (2007) (Iran)	5,544	7–15	A cross-sectional prevalence study/ random sampling	Ophthalmic team	Ophthalmic team
8	He et al. (2014) (China)	9,512	6–10	Random sampling	Ophthalmic team	Ophthalmic team
9	Jin et al. (2015) (China)	4,416	6–12	A cross sectional prevalence study	Ophthalmic team	Ophthalmic team
10	Kemper et al. (1999) (United States)	2,726	5–10	A cross sectional prevalence study	The certified screeners (nurses + lay volunteers)	Team at base hospital
11	Khandekar et al. (2004) (Oman)	1,719	7–13	A cross sectional prevalence study	School nurses	National eyehealth care supervisors
12	Khandekar et al. (2004) #631(Oman)	416,157	6–17	Review of cross sectional data, school screening performance	Trained physicians	Ophthalmic team
13	Kumah et al. (2013) (Ghana)	2,454	12–15	Random cluster sampling, cross sectional prevalence study	Ophthalmic team	Ophthalmic team
14	Limburg et al. (1999) (India)	5,390,000	5–15	Prospective study school screening performance	Teachers (32,865)	Refractionists
15	Limburg et al. (1995) (India)	46,672	10–14	Prospective study school screening performance	Teachers (292)	Refractionists (only 1,385 screened)
16	Lindquist et al. (2011) (Australia)	8,201	12–20	Prevalence study, random sampling	Refractionists	Refractionists
17	Lu et al. (2008) (China [Tibetan])	1,084	6–14	Cohort study	Ophthalmic team	Ophthalmic team
18	Okoye et al. (2013) (Nigeria)	2,092	6–16	A cross sectional prevalence study	Ophthalmic assistant	Ophthalmic team
19	Ore et al. (2009) (Israel)	1,975	6–7 & 13–14	A cross-sectional school screening performance	Nurse	Ophthalmic team
20	Pizzarello et al. (1998) (United States)	5,851	11–14	A cross-sectional study of screening performance	Parent volunteers & school nurse	Optometrist
21	Priya et al. (2015) (India)	80,463	6–17	A prospective, non-randomized controlstudy of alternative school screening methodologies	Teachers	Ophthalmic team
22	Rewri et al. (2013) (India)	7,411	10–19	Pilot study of self-assisted vision examination (SAVE)	Self-assisted by school children	Optometrist
23	Rushood et al. (2013) (Sudan)	671,119	6–15	School-based survey/total coverage survey	Optometrists	Ophthalmic team
24	Rustagi et al. (2012) (India)	1,123	11–17	Intervention study	Single experienced optometrist	Ophthalmologist
25	Saxena et al. (2015) (India)	9,838	5–14	A cross-sectional study alternate VA thresholds	Teachers	Primary eye care worker
26	Sharma et al. (2008) (China)	1,892	11–17	School-based survey/Cluster-based random sampling	32 class teachers	Ophthalmic team
27	Sudhan et al. (2009) (India)	77,778	7–15	School screening performance study	530 Teachers	Ophthalmic assistant
28	Tananuvat et al. (2004) (Thailand)	6,898	6–7	School based study/Prevalence study	Ophthalmic team	Ophthalmic team
29	Teerawattananon et al. (2014) (Thailand)	5,885	5–12	Cross-sectional descriptive and analytical study	Teachers	Ophthalmic team
30	Wedner et al. (2008) (Tanzania)	6,904	11–25	Cluster randomized selection, prevalence study	Ophthalmic team	Ophthalmic team

Table 2. Summary of controlled studies of visual acuity screening methods involving school teachers

Article (country)	N	Age range	Study methods	Screening personnel	Students per teacher (average)	VA level	Screen positive	True positive	Ocular pathology	Refractive Error	Compliance rate	Time between screening & examination
Sartika Apulina et al. (2011) (Indonesia)	23,427	7-15	A prospective, non-randomized control study of alternative school screening methodologies	Selected teachers	STs 135	20/40	23%	16.4%	1.5	22%	N/A	Unknown
					MTs 28		24%	16.6%	3.4%	22%	N/A	
Priya et al. (2015) (Southern India)	80,463	6-17	A prospective, non-randomized control study of alternative school screening methodologies	Selected teachers	STs 247	20/30	6387(16%)	1554 (4%)	0.9%	3%	12%	1-6 months
					ACTs 52		3806 (9%)	2231 (6%)	1.6%	4%	59.2%	1-2 weeks
Saxena et al. (2015) (Northern India)	9,838	5-14	A cross-sectional study alternate VA thresholds	Teachers	Unknown	20/30	17.3%	10.6%	Unknown	Unknown	Unknown	Unknown
						20/40	9.6%	6.6%				

Table 3. Summary of included observational studies of school screening programs, teachers or school nurse screeners

Article (Country)	N	Age group	Screening method	Initial VA Screening personnel	Students per Screener	VA measured using	VA Level	Screen positive (VA level)	Follow-up Diagnostic Examinations by	True positive	RE (%)	Compliance rate	Time to complete total programme
Ajayibeoba et al. (2005) (Nigeria)	1,144	5–19	School based field study	Teachers & nurses	Unknown	Snellen's Chart	20/60	60 (5%)	Ophthalmologists	49 (4%)	10 (0.87%)	Unknown	Unknown
Bagchi et al. (2008) (India)	45,087	5–15	Retrospective analysis of school screening program performance	Teachers	229	Snellen's Chart	20/40	2,126 (4.71%)	Optometrist	1,856 (4.11%)	1,819 (4.03%)	Unknown	4.5–180 days
Kemper et al. (1999) (United States)	2,726	5–10	Cross sectional study prevalence	The certified screeners (nurses + lay volunteers)	Unknown	HOTV chart	20/50	209 (8%)	Team at base hospital	209 (8%)	106 (4%)	Unknown	Unknown
Khandekar et al. (2004) (Oman)	1,719	7–13	Review of cross sectional data, school screening performance	School nurses	Unknown	Snellen E acuity test	20/30	87 (5%)	National eye health care supervisors	74 (4.30%)	33 (2%)	Unknown	Unknown
Limburg et al. (1999) (India)	5,390,000	5–15	Prospective study, school screening performance	Teachers (32,865)	164	Snellen's distant vision E chart	20/30	230,282 (4%)	Refractionists	81,937 (1.5%)	50,096 (1%)	Spectacles 96.5%	Unknown
Limburg et al. (1995) (India)	46,672	10–14	Prospective study, school screening performance	Teachers (292)	160	Snellen's distant vision E chart	20/30	2,125 (5%)	Refractionists (only 1385 screened)	822 (2%)	593 (1%)	Unknown	Unknown
Pizzarello et al. (1998) (United States)	5,851	11–14	Cross-sectional study of screening performance	Parent volunteers	Unknown	Snellen's Chart	20/40	1,614 (28%)	Licensed optometrist.	1,096 (19%)	1,082 (18%)	Unknown	3 months
Sharma et al. (2008) (China)	1,892	11–17	School-based survey/ Cluster-based random sampling	Class teachers	60	Snellen's chart	20/40	985 (52%)	Ophthalmic team	674 (36%)	674 (35.6%)	Unknown	Unknown
Sudhan et al. (2009) (India)	77,778	7–15	School screening performance study	Teachers	147	Illiterate E card	20/30	3,822 (4.91%)	Ophthalmic assistant	1,242 (1.80%)	496 (1%)	Unknown	1 year
Teerawat-tanon et al. (2014) (Thailand)	5,885	5–12	Cross-sectional descriptive and analytical study	Teachers	24	Snellen chart	20/40	624 (11.5%)	Ophthalmic team	425 (7%)	363 (6%)	Unknown	Unknown

4. Discussion

Visual acuity screening of children in resource poor settings usually takes place in schools where it is most affordable and feasible and teachers are trained to conduct VA measurement, because ophthalmic professionals are too scarce and too expensive and are reserved for examining children who fail screening (Limburg, Kansara, & d'Souza, 1999).

Several studies have examined the accuracy of VA testing by teachers compared to ophthalmic personnel (Sartika Apulina et al., 2011; Saxena et al., 2015; Sharma et al., 2008). The studies all report sensitivities around 80% and specificity over 90%, with the sensitivity level seen as acceptable for detection of a condition such as refractive error, but recognized as less than optimal for more serious, blinding conditions. One study assessed the accuracy of school nurse screening of 1,719 students in Oman (Khandekar & Abdu-Helmi, 2004) reporting sensitivity of 68% and specificity 99%. School nurses, while more affordable than ophthalmic personnel, are more expensive and less commonly available for screening than teachers.

Visual acuity screening by teachers includes a number of components: examiner competence, awareness of students examined, examination tools and location, and referral system for screen failures. Each factor has the potential to influence screening test performance parameters, but few have been standardized and even fewer evaluated in control studies. Without standardization of methods, evaluation across programs is not possible. Therefore, studies to date have been limited to evaluating variations in methods within a single program, where methods are usually more standardized. This review sought randomized and non-randomized controlled trials that evaluated the effectiveness and cost of alternate VA screening methods.

Evidence from controlled studies is very limited leaving unstudied most school VA screening program components. However, two studies do compare alternate use of teachers, comparing selected teachers (STs) to all class teachers (ACTs) or “more” class teachers (MCTs) (Priya et al., 2015; Sartika Apulina et al., 2011). Both studies found that school screening with classroom teachers (fewer children screened per teacher) identified significantly more ocular conditions requiring intervention, other than refractive error. In both instances, the improved accuracy was achieved without increasing the portion of referred children. In fact, in Priya et al. (2015) ACTs found more true positive children with significantly lower proportion of false positive referrals (9.7 vs. 16.7% [$p < 0.001$] for ACTs and STs respectively). These studies show the value to programs of conducting simple controlled studies of vision screening methods. A small change in the role of teachers, for example, improved care of children while reducing program costs.

One study examined VA testing at two different VA cut-off thresholds (Saxena et al., 2015). The similar sensitivity and higher specificity led the authors to concluded in favour of the more restrictive 6/12 VA cutoff, which reduced the number of referrals by about 50%. However, further comparative studies are needed to determine the optimal VA cutoff in each context.

One study compared the teacher-based school visual acuity testing in terms of the proportion of children that complied with hospital referrals. The study reports that the All Class Teacher (ACT) model significantly increased the number of children attending follow-up within 3 months compared to the Select Teacher (ST) model. A possible explanation is that ACTs had the maximum interaction with students in their own class.

and probably had the best opportunity to refer the students for follow-up. Presumably, in the ACT model, teachers have more opportunity to motivate parents and children to comply with recommended referrals to an ophthalmologist or optometrist (Priya et al., 2015). Although compliance with hospital referral is beyond the focus of this review on screening methods, the finding is important for developing preferred practices for school screening programs.

Two studies noted the time between the initial screening by teachers and follow-up examination by eye care personnel (Priya et al., 2015; Sudhan et al., 2009). In the study in India, the selected teachers (STs) took up to 6 months to finish screening assigned students, while schools with class teachers (ACTs) usually finished within a month. The longer delays may result in problems for children who need urgent attention (Priya et al., 2015). In another study in Northern India the follow up diagnostic examination of screen failure children by ophthalmic personnel was up to one month. As a result, only 77% of children received ophthalmic examination (Sudhan et al., 2009).

School visual acuity screening costs depend primarily on the time spent by eye care professionals dealing with screen positive referrals. Because of their direct effect on the proportion of children referred to the ophthalmic team, visual acuity cut-offs have the greatest impact on cost, with false positive students adding to that cost by having un-necessary examinations. Only one study compared the impact of different screening methods on program cost (Saxena et al., 2015). The combination of greater accuracy for ACTs and fewer children referred (9.7% for ACTs vs. 16.7% for STs) resulted in substantial savings (Priya et al., 2015). This translates into US\$1.91 (4,253/2,231) and US\$4.83 (7,507/1,554) per child with actual ocular pathology in the ACTs and STs, respectively. This cost estimate in India contrasts greatly with a study in the United Kingdom that estimated the total cost of screening for a school group of 2,800 children to be between £3,461 and £6,922, taking into account both clerical and nursing costs (Cummings, 1996). The estimated cost for testing and recording each new significant abnormality was between £165 and £330.

Ten large (>1,000 students) uncontrolled, observational studies provide additional details of school vision acuity screening programs involving teachers (Ajaiyeoba, Isawumi, Adeoye, & Oluleye, 2005; Bagchi, Sarkar, Chattopadhyaya, & Dan, 2008; Limburg et al., 1999; Limburg, Vaidyanathan, & Dalal, 1995; Sharma et al., 2008; Sudhan et al., 2009; Teerawattananon et al., 2014) or school nurses (Kemper, Margolis, Downs, & Bordley, 1999; Khandekar, Al Harby, Abdulmajeed, Helmi, & Shuailli, 2004; Pizzarello, Tilp, Tiezzi, Vaughn, & McCarthy, 1998) as vision screeners (Table 3). The studies typically provide details of the screening methods in terms of location, personnel, testing instruments (charts), VA thresholds, referral structure and screening test referral accuracy compared to ophthalmic gold standard.

The ten observational studies describe referral examinations by various different eye care professionals: refractionists/optometrists (7), ophthalmic assistant (1) and primary eye care workers (2). No meaningful difference could be determined between the various eye care professional performance, other than the obvious preference for rationing the scarce highly trained optometrists and ophthalmologists and utilizing more common, but competent professional cadres such as refractionists and ophthalmic assistants.

Three of the 10 programs report on spectacle compliance, two not involving teachers as screeners (Rewri, Kakkar, & Raghav, 2013; Rustagi, Taneja, & Uppal, 2012) and one involving teachers as screeners (Limburg et al., 1999). Limburg et al. (1999) reports that spectacle compliance in India ranged from 40 to 90% of students who failed the teachers' screening. Of the 7 programs involving school teachers, 4 used 20/30, 2 used 20/40 and one used 20/60 VA screening thresholds. No study compared the impact of different thresholds on referral patterns or program performance.

Other school screening program features were commonly reported in these programs. Teachers were generally accepted as the most cost-effective visual acuity (VA) testers and were most commonly trained at the school by ophthalmic professional and provided with a VA testing kit. The optimal time for VA testing was prior to mid-term exams. The children referred by the teachers were seen by ophthalmic personnel at the school within a month. Glasses were provided within a week almost always free of cost. Children identified with conditions other than refractive error were provided referral cards and advised to visit the base hospital. Teachers assisted to a varying degree with counselling of parents to take the referred children to the hospital. In some programs, community coordinators visited schools about 3 months after screening to assess compliance with glasses and

referrals. Programs recommended annual VA testing for children with eye and every 2 years for those without eye conditions.

5. Conclusions

Using detection of children with visual disorders as the outcome, the limited evidence supports school screening methods using “all class teachers” and a 6/12 visual impairment threshold. Using the proportion of students with visual disorders who attend follow up at the referral hospital within three months as the outcome, one study supports use of all class teachers. Using cost per child detected with visual disorders as the outcome, one study supports use of all class teachers. Using the visual acuity threshold that optimizes screen test performance and minimizes cost of training teachers as the outcome, one study supports the 6/12 optotype.

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Competing Interests

The authors declare no competing interest.

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Appendix A

Database: Ovid MEDLINE(R) 1946 to Present with Daily Update

Search Date: 10 March 2015

-
- 1 Schools/(21,731)
 - 2 (kindergarten\$ or preschool\$ or school\$).tw. (199,273)
 - 3 or/1-2 (203,199)
 - 4 Child Health Services/(17,638)
 - 5 Child/(1,382,454)
 - 6 Child, Preschool/(762,392)
 - 7 (adolesc\$ or child\$ or juvenile\$).tw. (1,097,792)
 - 8 or/4-7 (1,939,469)
 - 9 exp Strabismus/(13,845)
 - 10 Amblyopia/(5,749)
 - 11 exp Refractive Errors/(26,441)
 - 12 ((eye\$ or sight\$ or vision\$ or visual\$) adj4 (defect\$ or defici\$ or impair\$ or problem\$ or reduc\$)).tw. (36,695)
 - 13 lazy eye\$.tw. (33)
 - 14 (amblyopi\$ or ammetropi\$ or anisometripi\$ ormyopi\$ or astigmati\$ or hypermetropi\$ or hyperopi\$ or squint\$ or strabism\$).tw. (23,206)
 - 15 or/9-14 (80,858)
 - 16 Vision Screening/(1,755)
 - 17 exp Vision Tests/(81,585)
 - 18 exp Vision Disorders/di, pc (14,428)
 - 19 ((vision or visual) adj4 (acuity or assess\$ or diagnos\$ or screen\$ or test\$)).tw. (61,875)
 - 20 or/16-19 (117,163)
 - 21 3 and 8 and 15 and 20 (1,320)
 - 22 animals/not (humans/and animals/) (3,907,952)
 - 23 21 not 22 (1,318)
 - 24 remove duplicates from 23 (1,309)

Database: Embase < 1974 to 2015 March 09>

Search Date: 10 March 2015

-
- 1 School/(47,058)
 - 2 High School/or Kindergarten/or Primary School/or Nursery School/or Middle School/(18,920)
 - 3 (kindergarten\$ or preschool\$ or school\$).tw. (265,408)

- 4 or/1-2 (63,127)
- 5 Child Health Care/(31,777)
- 6 exp Child/(2,156,603)
- 7 (adolesc\$ or child\$ or juvenile\$).tw. (1,459,519)
- 8 or/1-7 (2,786,814)
- 9 exp Strabismus/(20,495)
- 10 Amblyopia/(8,693)
- 11 exp Refraction Error/(37,413)
- 12 ((eye\$ or sight\$ or vision\$ or visual\$) adj4 (defect\$ or defici\$ or impair\$ or problem\$ or reduc\$)).tw. (49,990)
- 13 lazy eye\$.tw. (44)
- 14 (amblyopi\$ or ammetropi\$ or anisometripi\$ or myopi\$ or astigmati\$ or hypermetropi\$ or hyperopi\$ or squint\$ or strabism\$).tw. (29,362)
- 15 or/9-14 (110,477)
- 16 exp Vision Test/(32,199)
- 17 exp Visual Disorder/di, pc (18,043)
- 18 ((vision or visual) adj4 (acuity or assess\$ or diagnos\$ or screen\$ or test\$)).tw. (82,371)
- 19 or/16-18 (116,350)
- 20 4 and 8 and 15 and 19 (256)
- 21 (exp animal/or animal.hw. or nonhuman/) not (exp human/or human cell/or (human or humans).ti.) (5,548,003)
- 22 20 not 21 (256)
- 23 remove duplicates from 22 (253)



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