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School-based Approaches to the Correction of Refractive Error in Children

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Abstract. The World Health Organization estimates that 13 million children aged 5–15 years worldwide are visually impaired from uncorrected refractive error. School vision screening programs can identify and treat or refer children with refractive error. We concentrate on the findings of various screening studies and attempt to identify key factors in the success and sustainability of such programs in the developing world. We reviewed original and review articles describing children's vision and refractive error screening programs published in English and listed in PubMed, Medline OVID, Google Scholar, and Oxford University Electronic Resources databases. Data were abstracted on study objective, design, setting, participants, and outcomes, including accuracy of screening, quality of refractive services, barriers to uptake, impact on quality of life, and cost-effectiveness of programs. Inadequately corrected refractive error is an important global cause of visual impairment in childhood. School-based vision screening carried out by teachers and other ancillary personnel may be an effective means of detecting affected children and improving their visual function with spectacles. The need for services and potential impact of school-based programs varies widely between areas, depending on prevalence of refractive error and competing conditions and rates of school attendance. Barriers to acceptance of services include the cost and quality of available refractive care and mistaken beliefs that glasses will harm children's eyes. Further research is needed in areas such as the cost-effectiveness of different screening approaches and impact of education to promote acceptance of spectacle-wear. School vision programs should be integrated into comprehensive efforts to promote healthy children and their families. (**Surv Ophthalmol** 57:272–283, 2012. © 2012 Elsevier Inc. All rights reserved.)

Key words. children • education • myopia • refractive error • school • screening • vision

Introduction

SCOPE AND IMPACT OF REFRACTIVE ERROR

Refractive errors (RE) are the second leading cause of blindness among all age groups after cataract and the leading cause of visual impairment in the world. The World Health Organization estimates that 12.8 million children aged 5–15 years worldwide are visually impaired from uncorrected refractive error.[55] Despite this, data from cross sectional studies and

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surveys from many parts of the world show that adults and children with RE are often without spectacles or are not wearing optimal correction.[12,13,26] In rural China the figure is 30–40%[12,26] but only 20% in South Africa.[13] Many school-based vision programs focus primarily on detecting inadequately corrected RE and prescribing and/or dispensing spectacles; children of school age may also have other eye health needs, however, as may their teachers and families. Ideally, school eye health programs should be comprehensive and integrated into the policies and practices of local Ministries of Education and Health. The World Health Organization's Global School Health Initiative[A] advocates promoting a healthy environment in schools and including locally relevant health education within the school curriculum. In some parts of the world, school-aged children and/or their younger siblings are affected by trachoma, vitamin A deficiency, allergic conjunctivitis, and other locally endemic conditions. Schools can and should play a key role in prevention and control of these conditions through locally appropriate activities, such as encouraging face washing and home gardening of vitamin A–rich foods, and use of the child-to-child approach.[B] In many parts of the world, teachers do not have access to eyecare or presbyopic correction. School vision programs can provide near spectacles, vision assessment, and appropriate referral for teachers. Whether a school-based program for RE is initiated will, therefore, depend on several factors, including competing demands for limited resources.

REQUIREMENTS FOR SCREENING

A comprehensive screening program has several requirements. Strong et al state that the target disorder should be well characterized and of public health importance, with a well-established natural history and known prevalence.[63] Treatment should be effective and inexpensive, and standards for treatment generally agreed upon. The screening test itself should be safe, simple, and acceptable and have high validity (i.e., high levels of sensitivity and specificity, and high positive predictive values). Lastly, the program should be sustainable, ongoing, cost-effective, and have high coverage of the target population. All of these issues—the definition of refractive error utilized and the prevalence of refractive error in different populations, cost of treatment, and validity and sustainability of screening approaches—are relevant to school-based programs for refractive error in children.

PURPOSE AND FOCUS OF THE REVIEW

We focus on the evidence supporting different approaches to screening for and correcting RE among school-going children. Our purpose is to provide the evidence base for program planners and managers seeking the best strategies for providing sustainable services for children, acknowledging that priorities, available resources, and the context vary from location to location (Fig. 1). This review does not address programs for preschool-aged children, where the aims, methods, logistics, and possible costs and benefits are different.

Methods

LITERATURE SEARCH

The database search was conducted in April 2010. The search engines used included the PubMed, Medline OVID, Google Scholar, and Oxford University Electronic Resources databases.

STUDY SELECTION AND ASSESSMENT

The following major and minor Medical Subject Heading (MeSH) terms were searched separately and then cross-matched: *refractive error, visual acuity, spectacles, refraction, mydriatic, quality, screening, program evaluations, barrier, costs, child, school, teacher, nurse, assistant,* and *optometrist,* while limiting the searches to *English* and *humans.* Non-English language articles were not reviewed.

From initial MeSH searches, 230 original articles and 12 review articles were obtained that had been published after January 1, 1990. Two reviewers performed an in-depth assessment of articles between May and July 2010. Citations from relevant key articles were used to identify additional publications. A total of 76 articles were suitable for different aspects of this review, according to the following criteria: all randomized trials were included; we excluded studies that enrolled fewer than 50 subjects; studies concerned primarily with technologies for refractive screening, but without significant programmatic information, were excluded.

All included articles then underwent assessment, which consisted of identifying and extracting the following data:

1. Objective of study: What feature of screening and service provision was studied?
2. Study design: Duration and nature of study: trial, pilot, retrospective/prospective evaluation of program.
3. Setting: Country, community.
4. Participants: Age and number of participants and comparison groups, if any.
5. Outcomes: These included accuracy of screening, quality of refractive services, acceptance of

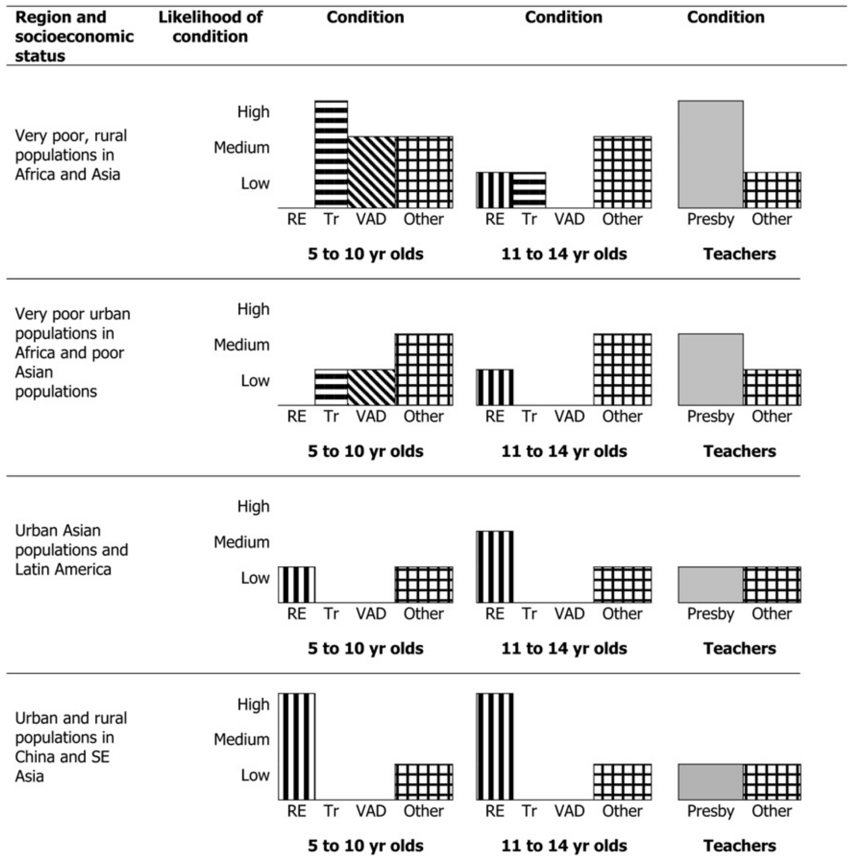

Fig. 1. Diagram representing elements of school eye health programmes for children in different regions and of different ages, and their teachers. RE = refractive error; Tr = trachoma; VAD = vitamin A deficiency; Presby = presbyopia.

services, barriers to uptake, improvement in quality of life with service delivery, and cost and cost-effectiveness of programs.

As a result of the large variation in study design, purpose, and outcomes measured, studies were often not directly comparable. Where appropriate the type of study has been indicated in the text, as this influences the robustness of the evidence. The varying sources of information limit generalizability to some extent, but the available information provides a summary of current knowledge and highlights where major evidence gaps exist.

Background and Rationale for Screening

PREVALENCE OF INADEQUATELY CORRECTED RE IN CHILDREN

Uncorrected RE is the leading cause of visual impairment among school-aged children in South Asia,[15,46,53,59] East Asia,[11,21,23,26,27,43,76] Latin America,[45] Africa,[47] Australia,[56] and Europe.[35,65] Eight of these studies were population-based (rather than school-based) and used the same rigorous methodology and definitions,[48] which make the findings directly comparable (Figs. 2, 3). The data indicate that there is considerable variation in the prevalence of RE between different countries, and in India and China between urban and rural populations. Children in urban China had the highest prevalence of RE, and children in South Africa had the lowest. In all these studies the prevalence of hypermetropia declined with age; astigmatism was fairly constant across the age range (5 or 7 to 15 years), whereas myopia increased with age. There were no consistent sex differences. The variation in age-specific prevalence has important implications for the optimal age for screening programs as well as the frequency at which screening should be undertaken.

In 2004, there were estimated to be 12.8 million children aged 5–15 years worldwide with visual impairment from uncorrected or inadequately corrected RE. In China alone, the figure was 5.9 million children, predominantly due to myopia.[55]

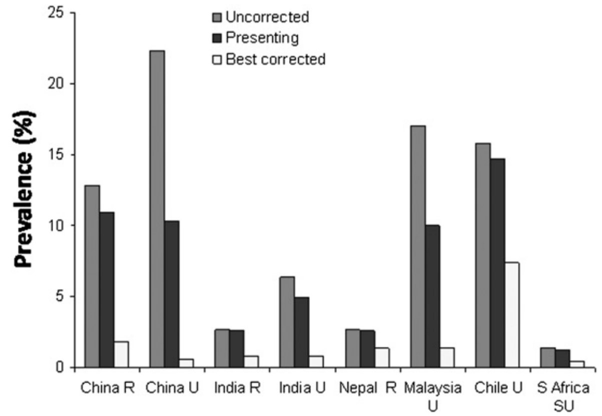

Fig. 2. Prevalence of refractive error in standardized population based surveys of children aged 5 or 7 years to 15 years. The difference between presenting visual acuity and best corrected visual acuity is the unmet need for spectacle correction. R = rural; U = urban; SU = semi-urban.

BENEFITS OF CORRECTING RE IN CHILDREN

Higher myopia is strongly associated with lower self-reported visual function in rural China,[11] and correction of even modest amounts of myopia (–1.25 D) and associated vision loss (≤6/9 in the better-seeing eye) has been associated with significant improvement in visual function in rural Mexico.[19] This echoes results among adults demonstrating significant enhancement of vision-specific quality of life after correction of refractive error.[9]

Basic science and animal experiments suggest that spectacle wear might in principal interfere with the process of emmetropization;[28,54] randomized trials in children have failed to demonstrate that a delay in spectacle wear can reduce, or early prescription of spectacles increase, the ultimate refractive power, however.[50,51]

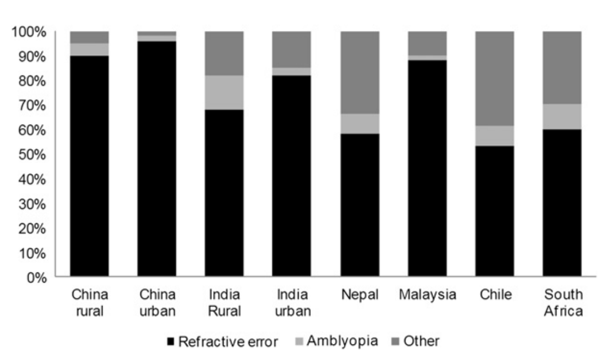

Fig. 3. Proportion of visual impairment (visual acuity of <6/12 in one or both eyes) due to uncorrected refractive errors in eight standardized population based surveys of children in different countries.

Practical Aspects of Screening for Inadequately Corrected RE in Children

VISUAL ACUITY, REFRACTIVE ERROR, AND SCREENING CHARTS

Visual Acuity as a Gold Standard in Screening

Despite extensive investigation of automated methods of detecting and measuring RE in children, such as photoscreening and autorefractors, the American Academy of Ophthalmology continues to recommend visual acuity testing (VA) as the standard of care for screening among children aged 3 years and older.[C] Although there is less than perfect correlation between the degree of RE and VA, distance VA at the 6/9.5 level had a high (>97%) sensitivity and specificity in the detection of myopic spherical equivalent of –1.00 D or more among Australian school children. The validity of VA testing for level of astigmatism (1.00 D or more) and hypermetropia (+2.00 D or more) was poor, however.[39] In Singapore, cutoffs of –0.50 D and –0.75 D for defining myopia had the best screening performance in predicting children with VA <6/12.[44]

Disadvantages of Snellen Vision Charts

Snellen VA charts in Roman or other scripts are usually used in school programs, whereas Logarithm of the Minimum Angle of Resolution (LogMAR) charts tends to be used in research and clinical settings. The Snellen chart has several design flaws, however, such as non-linear logarithmic progression in letter size between each row, unequal and unrelated spacing between optotypes and rows leading to varying degrees of letter crowding, and unequal numbers of optotypes per row.[20,29,36,58] More research is needed to determine which chart is better suited for school programs and whether testing using a single row of optotypes corresponding to the VA cutoff selected may be sufficient to warrant referral for refraction and further examination. Should a single row of optotypes be used, then it is important to adhere closely to protocols regarding the number of optotypes correctly identified necessary to pass. This is particularly critical with tumbling E charts, as there is a 1 in 4 probability that the direction of each E will be correctly indicated by chance alone even if the letter cannot be seen.

Monocular Versus Binocular Vision Screening

Only one unpublished study has, to our knowledge, addressed the validity of monocular versus binocular VA measurement as the screening test.[62] Positive predictive value for binocular vision testing at a level of 6/12 in the detection of any refractive error (myopia, –1.00 D or greater; hypermetropia,

+3.00 D or more; and astigmatism, 1.50 D or more) was 71.4% and negative predictive value 99.7% among 2,700 secondary school pupils in Tanzania. The failure rate of binocular acuity testing to detect eyes with other treatable ocular pathology was not assessed. Although binocular vision screening can offer time savings, more research is needed to determine the potential impact of missed uniocular pathology, the prevalence of which will vary by population. In young children, bilateral VA testing would fail to detect potentially treatable unilateral amblyopia if ocular alignment and/or stereopsis were not measured.[37]

WHO SHOULD CARRY OUT SCREENING?

Vision screening for school-aged children has been carried out by a range of professionals and groups trained for the task—for example, optometry students,[2] school and public health nurses,[14,16,30,34,38,57,67,72] teachers,[4,7,8,14,42,52,61,69] parents and other volunteers,[13,17,52,67,71] health technicians,[1,32] and even computer programs[5,64] (Table 1). The results vary widely; for example, nurses[34,57,67,72] and lay screeners[67] achieved sensitivities of 37% to 71% at specificities of 70% to 90% in detecting visual impairment. As might be expected, vision testing is more accurate[34] among older (secondary school age) than younger children (primary school age).

Teachers may be ideal vision screeners as they are available and experienced in interacting with children and their parents. A report from China suggests that sensitivity and specificity greater than 90% can be achieved by teachers as compared to vision professionals screening uncorrected vision among secondary school students. Results were worse for presenting vision, because of failure to identify children owning, but not wearing, glasses and teacher bias towards better vision among children wearing spectacles.[61] These results may be applicable primarily in areas where spectacle wear is common. The Chinese study also reported that 87.5% of teachers felt vision screening in school was useful.[61] Support of teachers for participating in school-based screening is likely to vary among settings and will likely be an important determinant of the success of such programs.

Refraction, Prescribing, and Cutoffs for Dispensing

CYCLOPLEGIA FOR ASSESSMENT OF REFRACTIVE ERRORS IN CHILDREN

For accurate RE measurement in children, there is evidence that cycloplegia prior to refraction is necessary, especially for children with hyperopia.[22] Non-cycloplegic automated refraction resulted in an average inaccuracy of 0.84 D in Australian children[22] and greater than 1.00 D among Chinese children,[75] both resulting in an overestimation of myopia. A clinical trial among children in Nigeria showed that cyclopentolate with tropicamide was more effective than cyclopentolate alone and slightly less effective, but better-accepted, than atropine for children under 15 years in age.[18] Subjective refinement of the auto-refractor or retinoscopy value by a specialist trained in refraction may be an alternative to cycloplegia among older children and where cycloplegia is impractical or not widely accepted.

VISUAL ACUITY AND REFRACTIVE CUT-OFFS FOR SCREENING PROGRAMS

Lack of VA cutoffs for screening and protocols for prescribing can lead to more children being refracted than is required, over-prescribing on a large scale (particularly if provision of spectacles is franchised to the private sector), and low spectacle-wearing rates in the face of minimal improvement in VA. All undermine the cost effectiveness and credibility of programs. The goal of screening is to choose VA and refractive power cutoffs such that correction would improve visual function sufficiently to ensure at least part-time compliance with spectacle wear. There is very little evidence on the relationship between VA screening cut-offs and prescribing criteria, and their impact on rates of spectacle wear and self-reported visual function. A study in Mexico, which used a self reported visual function questionnaire, showed that improvement in self-reported visual function after provision of spectacles was significant for baseline visual acuity ≤6/9.[19] Analysis of data from a school-based program in South Africa suggested that children with –0.75 D or more of myopia, +1.00 D or more of hyperopia, and/or +0.75 D or more of astigmatism were significantly more likely to have improvement in VA than children with milder degrees of RE after adjusting for age, sex, and rural versus urban residence.[13]

Utilization of Spectacles

RATES OF SPECTACLE WEAR

Only a few studies have investigated spectacle-wearing rates within the context of a program (Table 2).[7,13,33,70] In Mexico[7] and Tanzania,[70] fewer than half of children prescribed spectacles were actually wearing them or had them at school at the time of unannounced visits several months after the

TABLE 1

Performance of Non-vision Professionals in Visual Acuity Screening of School-aged and Preschool-aged Children

Region	Country and year	Personnel screening	Screening protocol	Condition screened for	Visual acuity cut-off for referral	Age group	Sample size	Screening accuracy
NORTH AMERICA	USA, 1998 (Bailey 1998[2])	Optometry students	Modified clinical technique vision screening—pediatric exam	Vision disorders	VA < 6/12 in either eye Hyperopia: ≥ +1.50 D, Myopia ≥ –0.50 D, Astigmatism: ≥ 1.00 D, Anisometropia: ≥ 1.00 D	Elementary school children	391	Sensitivity 69%
	USA, 1998 (Pizzarello et al 1998[52])	Parent volunteers	Snellen visual acuity	Poor presenting distance vision	VA < 6/12 in either eye	9–15 years	5851	Sensitivity 93%
	Canada, 1992 (De Becker et al 1992[16])	Public health nurses	Vision screening test for strabismus, amblyopia, and high refractive error	Vision-threatening ocular conditions	VA ≤ 6/9	4.5–5.5 years	157	NPV: 98%
EUROPE	Sweden, 2001 (Kvarnstrom et al 2001[38])	School nurses	Initial pediatric exam, then VA testing by nurse at age 4, 5.5, 7, and 10 yrs	Various ophthalmic conditions	VA at 4 yrs, < 6/7.5: at 5.5 yrs < 6/6, at 7 yrs < 6/7.5 with the E chart and < 6/6 with the HVOT- chart, and at 10 yrs < 6/6	4–10 years	3126	Sensitivity age 4–30% age 5–55% age 7–35% age 10–70%
	UK, 1994 (Jewell et al 1994[30])	School nurses	Presenting Snellen visual acuity	Undiagnosed visual disorders	VA < 6/12 in either eye	13–15 years	1069	Sensitivity 77%
	UK, 1999 (Thomson et al 1999[64])	Computer / automated screening software	Questionnaires, distance LogMAR VA and stereopsis on the computer screen, color vision	Poor distance visual acuity, color vision, and stereoacuity	VA < 6/9.5 in either eye, or ≥ 1 line difference between two eyes	5–8 years	245	Sensitivity 94% Specificity 96%

(*continued on next page*)

TABLE 1
Continued

Region	Country and year	Personnel screening	Screening protocol	Condition screened for	Visual acuity cut-off for referral	Age group	Sample size	Screening accuracy
ASIA	India, 1999 (Limburg et al 1999[42])	School teachers	Snellen visual acuity	Poor distance visual acuity	VA $<$ 6/9 in either eye	6–5 years	205,082	PPV: 24% (using number of spectacles prescribed as a proxy for accuracy of referral)
	China, 2008 (Sharma et al 2008[61])	Teachers	Snellen distance visual acuity	Uncorrected and presenting distance VA	VA $<$ 6/12 in either eye	12–17 years	1892	Uncorrected VA: Sensitivity 93.5% Specificity 91.2% Presenting VA: Sensitivity 85.2% Specificity 84.8%
	Oman, 2004 (Khandekar et al 2004[34])	School nurses vs national eye health care supervisors with at least 5 yrs experience	Presenting Snellen visual acuity	Refractive error	Direct comparison of nurse versus professional: Disagreement = VA in one eye differed by $>$ 1 line compared to professional	6–17 years	1719	Sensitivity 68% Specificity 99% PPV: 85% NPV: 98%
AFRICA	Tanzania, 2000 (Wedner et al 2000[69])	Teachers	Snellen visual acuity	Presenting distance visual acuity	VA $<$ 6/12 in either eye	7–19 years	1386	Sensitivity 80% Specificity 91%

VA = visual acuity; PPV = positive predictive value; NPV = negative predictive value.

TABLE 2

Studies of Compliance with Spectacles and Self-reported Reasons for Non-wear

Country (Reference)	Mexico (Castanon Holguin et al 2006[7])		Tanzania (Wedner et al 2002[70])			China (Congdon et al 2008[12])		China (Li et al 2008[41])		Oman (Khandekar R et al 2002[33])	
RATES OF COMPLIANCE											
Outcome	Wear of free glasses 6 months after distribution		Wear of free or purchased glasses	Free	Purchased	Use of glasses among children with VA ≤ 6/12 in at least one eye		Purchase of spectacles among children with baseline VA ≤ 6/12 after educational intervention		Wear of prescribed glasses	
Rate of spectacle wear or	Wearing	13%	Wearing	31%	16%	Did not own	39%	Had no glasses at baseline	37% bought	Wearing	61%
purchase	Have at school	34%	Have at school	15%	10%	Owned, did not wear	18%	Had inaccurate glasses at baseline	43% bought	Have at school	19%
	Total	47%	Total	46%	26%	Wore, did not improve VA to > 6/12	25%	Had bilateral presenting VA ≤ 6/18 at baseline	46% bought	Total	80%
Factors associated with spectacle	Myopia more than–1.25D		Myopia of any severity			More myopic spherical equivalent		Presenting VA < 6/12		N/A	
wear or purchase in regression	Hyperopia more than + 0.5D		Poor visual acuity in both eyes			Worse uncorrected vision		Myopia of–2.00D or more		N/A	
models	Older age		Free spectacles			Older age		Amount willing to pay for glasses		N/A	
	Rural location					Female sex				N/A	
Visual acuity cutoff for screening	≤6/12		<6/12			≤6/12		≤6/12			

Country (Reference)	Mexico (Castanon Holguin et al 2006[7])	Tanzania (Odedra et al 2008[49])	China (Congdon et al 2008)	China (Li et al 2008)	China (Li et al 2010[40])
REASONS FOR NON-COMPLIANCE					
Study design	Closed-ended questionnaire	Focus group discussion	Closed-ended questionnaire	Closed-ended questionnaire	Focus group discussion
Reasons	Appearance/teasing	Appearance/teasing	No perceived need	Price	Parents and children: Glasses harm the eyes
	Broke/lost/forgot glasses	Glasses harm eyes	Glasses harm eyes	Parental disapproval	Children: Glasses inconvenient
	Use glasses only occasionally	Mistrust of opticians	Parents disapprove	Glasses harm the eyes	Parents: Too busy to get eye exam for children, don't know if glasses needed
	No need for glasses	Prefer diet/traditional methods	Cost		
	Parents disapprove	Not a health priority			
	Glasses cause headaches	Cost			

spectacles were dispensed. In Tanzania a cluster randomized trial showed that children given free spectacles were significantly more likely to be wearing spectacles than children who had to purchase them (31% vs 16%).[68] Other factors associated with better spectacle-wearing have included poor visual acuity in both eyes (Tanzania)[70] and older age (Mexico).[7] In Mexico, children provided spectacles for less than –0.50 D of myopia were very unlikely to be wearing them at an unannounced visit at 6 months.[7]

BARRIERS TO SPECTACLE WEAR

Factors associated with non-wear include concerns over appearance, being teased by schoolmates, discomfort, negative parental attitudes, cost, beliefs that glasses will harm the eyes, and lack of perceived need (Table 2).[7,13,33,40,70] Focus group discussions in Tanzania among children, parents, and teachers concluded that peer pressure, parental concerns that spectacles would make the eyes weak, cost, and mistrust of opticians were key barriers to uptake of refractive services.[49] In China, separate focus groups comprising rural school children, parents, and teachers showed that the main barriers were lack of knowledge about myopia among parents and a widespread belief that spectacle wear would harm children's eyes.[40] All the children's groups identified accurate power as their single most important requirement for spectacles.[40] This concern appears warranted in view of the recent finding among rural children in China wearing spectacles that nearly 50% were inaccurate by $\geq$ 1.00D, while nearly one in five were inaccurate by $\geq$ 2.00D and more than 6% by $\geq$ 3.00D.[74] These findings may partly be an effect of shift in refractive power with age, but also appear to reflect inaccurate prescriptions, as over a third of spectacles prescribed $<$ 3 months prior to assessment were incorrect by $\geq$ 1.00D.

Economic Evaluation of School RE Programs

EXISTING DATA

Cost-utility analyses have been used to evaluate service delivery for conditions such as cataract and amblyopia in a variety of settings.[6] Cost-effectiveness analysis for RE depends on the ability to measure the consequences of visual impairment and the benefits of correction, such as educational achievement or employment over the long term. These are, however, influenced by a host of other variables, making attribution of cause and effect difficult.[60] Unfortunately there is little evidence of the cost-effectiveness of existing programs for RE among children in developing countries,[66] although there is some evidence of the cost benefit of pre–school age vision screening in the USA.[31] The balance of cost and benefit for school-based RE screening programs is likely to be different in resource-poor settings and will depend heavily on factors such as RE prevalence and severity, the degree to which service for RE have already been met, school attendance rates, and acceptance of services.

Limburg et al reported that screening by an ophthalmic team in India was 60% more expensive than screening by local teachers.[42] A modeling study suggested that school-based vision screening programs can be a cost-effective strategy in countries with sufficiently high prevalence of RE[3,68] but the Baltussen study[3] did not consider countries in East Asia that have the highest prevalence of uncorrected myopia among children and where programs are likely to be the most cost effective.

PROGRAMS WITH FREE SPECTACLE DISTRIBUTION VERSUS THOSE THAT SELL GLASSES

An important aspect of program cost is whether spectacles are provided free or sold to children and their families to facilitate cost recovery. Examples of both models exist. It has been demonstrated that beneficiaries may be willing to pay modest amounts for spectacles for children in some settings.[41] As with cataract surgery,[24] setting locally appropriate prices on the basis of willingness to pay surveys is recommended. Selling spectacles may not be acceptable or practical in schools in some areas, which means that children needing glasses must to be referred to external facilities to purchase glasses, potentially resulting in losses to follow-up. The decision of whether or not to charge for glasses in the context of school programs is an important one that must be made after careful consideration of local conditions.

Use of Ready-made Glasses and Adjustable Spectacles

READY-MADE SPECTACLES

Zeng et al observed that 80% of secondary school children in China had RE amenable to the use of ready-made spectacles, having minimal astigmatism and anisometropia. This study also reported no difference in spectacle wear, perceived value, or symptoms among Chinese children randomly assigned to ready-made versus customized spectacles.[73] This suggests that the large majority of children needing RE correction could benefit from ready-made spectacles. The use of ready-made spectacles allows glasses to be delivered at the same time as screening for the majority of children, resulting in potentially significant savings to programs and families. Further work which takes into account the costs of separate service delivery for the minority of children requiring custom glasses on the cost-effectiveness of such strategies is needed.

ADJUSTABLE GLASSES

Several different models of adjustable spectacles are under development. A recent report has examined the use of adjustable glasses by secondary school children without cycloplegia and under the supervision of their classroom teachers. Over 90% of children with an uncorrected VA $\leq$ 6/12 from refractive error were capable of achieving corrected VA $\geq$ 6/7.5 in the better eye, while apparently avoiding inaccuracy from accommodation associated with non-cycloplegic auto-refraction.[25] The relative advantage of adjustable spectacles over ready-made spectacles is that they can correct anisometropia and may reduce the demands on scarce resources of trained refractionists. Manufacturing costs, however, are likely to be higher. Further studies on the cost effectiveness, cosmetic acceptability, safety, and stability of refractive power of such glasses are needed. The potential ability to adjust refractive power as a child ages is of particular interest, although this is not possible with all models.

Conclusion and Recommendations

The evidence suggests that VA can be measured accurately by teachers, after training and with support. It is imperative that the spectacle frames used in the program be cosmetically desirable and that the spectacles are accurate and provided in a timely and easy manner at an affordable price. Health education concerning the benefits of spectacle wearing and to counter misconceptions that spectacles harm children's vision is also essential. A recently completed randomized controlled trial of educational interventions to promote spectacle wear among children in rural China failed to demonstrate any effect, underscoring the difficulty in achieving behavior change.[10]

There are other considerable gaps in the evidence which need to be addressed, particularly in relation to the costs and benefits of different vision screening cutoffs and prescribing protocols. No studies have addressed the frequency with which the same school should be revisited, but it would seem logical that repeat VA testing should occur more frequently in settings where the prevalence of myopia increases more markedly with age, as in China, than in communities where the change is more gradual.

The age groups to be included in a program will vary from location to location, being influenced not only by the prevalence of visual impairment due to uncorrected RE at different age groups, but also by the presence of other endemic eye conditions among children, school attendance rates, and competing demands for resources. In Africa, where the prevalence of significant uncorrected RE is low, inclusion of RE in school eye health programs may not be warranted. This is in contrast to countries in Asia, where the prevalence of RE is high. In China, RE programs should probably include primary as well as secondary school children, whereas in other parts of Asia and Latin America the principal focus would be on children of secondary school age (Figure 1).

In all areas the final goal of school vision and RE screening should be that the eye health of children becomes the responsibility of the Ministries of Education and Health, with incorporation of relevant topics into the school curriculum. In addition to treating children's RE, programs should ideally support a healthy school environment, provide eye services for teachers where needed, ensure the management of children with simple complaints, such as conjunctivitis and chalazia, and play a role in the prevention and treatment of locally endemic eye conditions.

Method of Literature Search

A search of Pubmed, Medline, OVID, Google Scholar, and Oxford University Electronic Resources Databases was conducted independently by two authors during April–May 2010 using the following key words and MeSH terms: *refractive error, visual acuity, spectacles, refraction, mydriatic, quality, screening, program evaluations, barrier, costs, child, school, teacher, nurse, assistant,* and *optometrist.* The searches were limited to English and humans, covering the years 1990 to 2010. In-depth analysis of 230 articles and 12 reviews was conducted by two reviewers, and 44 articles were selected for use in this review. Additional studies were obtained from literature referenced in the original set of articles.

Disclosure

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References

1. Report of Council on Physical Therapy. Betts charts not acceptable. JAMA. 1939;113:29–37
2. Bailey RN. Assessing the predictive ability of the test—positive findings of an elementary school vision screening. Optom Vis Sci. 1998;75:682–91
3. Baltussen R, Naus J, Limburg H. Cost-effectiveness of screening and correcting refractive errors in school children in Africa, Asia, America and Europe. Health Policy. 2009;89: 201–15
4. Blum HL, Peters HB, Bettman JW, et al. Design and evaluation of a vision screening program for elementary school children. Am J Public Health Nations Health. 1959;49:1670–81
5. Briscoe D, Lifshitz T, Grotman M, et al. A new computer program for mass screening of visual defects in preschool children. Br J Ophthalmol. 1998;82:415–8
6. Brown MM, Brown GC. How to interpret a healthcare economic analysis. Curr Opin Ophthalmol. 2005;16:191–4
7. Castanon Holguin AM, Congdon N, Patel N, et al. Factors associated with spectacle-wear compliance in school-aged Mexican children. Invest Ophthalmol Vis Sci. 2006;47:925–8
8. Ciner EB, Dobson V, Schmidt PP, et al. A survey of vision screening policy of preschool children in the United States. Surv Ophthalmol. 1999;43:445–57
9. Coleman AL, Yu F, Keeler E, et al. Treatment of uncorrected refractive error improves vision-specific quality of life. J Am Geriatr Soc. 2006;54:883–90
10. Congdon N, Li L, Zhang M, et al. Randomized, controlled trial of an educational intervention to promote spectacle use in rural China: The See Well to Learn Well Study. Ophthalmology. 2011;118(12):2343–50
11. Congdon N, Wang Y, Song Y, et al. Visual disability, visual function, and myopia among rural chinese secondary school children: the Xichang Pediatric Refractive Error Study (X-PRES)—report 1. Invest Ophthalmol Vis Sci. 2008;49: 2888–94
12. Congdon N, Zheng M, Sharma A, et al. Prevalence and determinants of spectacle nonwear among rural Chinese secondary schoolchildren: the Xichang Pediatric Refractive Error Study Report 3. Arch Ophthalmol. 2008;126:1717–23
13. Congdon NG, Patel N, Esteso P, et al. The association between refractive cutoffs for spectacle provision and visual improvement among school-aged children in South Africa. Br J Ophthalmol. 2008;92:13–8
14. Crane MM, Scobee RG, Foote FM, et al. Study of procedures used for screening elementary school children for visual defects; referrals by screening procedures versus ophthalmological findings. Am J Public Health Nations Health. 1952;42:1430–9
15. Dandona R, Dandona L, Srinivas M, et al. Refractive error in children in a rural population in India. Invest Ophthalmol Vis Sci. 2002;43:615–22
16. De Becker I, MacPherson HJ, LaRoche GR, et al. Negative predictive value of a population-based preschool vision screening program. Ophthalmology. 1992;99:998–1003
17. Donahue SP, Baker JD, Scott WE, et al. Lions Clubs International Foundation Core Four Photoscreening: results from 17 programs and 400,000 preschool children. J AAPOS. 2006;10:44–8
18. Ebri A, Kuper H, Wedner S. Cost-effectiveness of cycloplegic agents: results of a randomized controlled trial in nigerian children. Invest Ophthalmol Vis Sci. 2007;48:1025–31
19. Esteso P, Castanon A, Toledo S, et al. Correction of moderate myopia is associated with improvement in self–reported visual functioning among Mexican school-aged children. Invest Ophthalmol Vis Sci. 2007;48:4949–54
20. Falkenstein IA, Cochran DE, Azen SP, et al. Comparison of visual acuity in macular degeneration patients measured with Snellen and early treatment diabetic retinopathy study charts. Ophthalmology. 2008;115:319–23
21. Fan DS, Lam DS, Lam RF, et al. Prevalence, incidence, and progression of myopia of school children in Hong Kong. Invest Ophthalmol Vis Sci. 2004;45:1071–5
22. Fotedar R, Rochtchina E, Morgan I, et al. Necessity of cycloplegia for assessing refractive error in 12-year-old children: a population-based study. Am J Ophthalmol. 2007;144:307–9
23. Goh PP, Abqariyah Y, Pokharel GP, et al. Refractive error and visual impairment in school-age children in Gombak District, Malaysia. Ophthalmology. 2005;112: 678–85
24. He M, Chan V, Baruwa E, et al. Willingness to pay for cataract surgery in rural Southern China. Ophthalmology. 2007;114:411–6
25. He M, Congdon N, MacKenzie G, et al. The child self-refraction study results from urban Chinese children in Guangzhou. Ophthalmology. 2011;118:1162–9
26. He M, Huang W, Zheng Y, et al. Refractive error and visual impairment in school children in rural southern China. Ophthalmology. 2007;114:374–82
27. He M, Zeng J, Liu Y, et al. Refractive error and visual impairment in urban children in southern china. Invest Ophthalmol Vis Sci. 2004;45:793–9
28. Hung LF, Crawford ML, Smith EL. Spectacle lenses alter eye growth and the refractive status of young monkeys. Nat Med. 1995;1:761–5
29. Hussain B, Saleh GM, Sivaprasad S, et al. Changing from Snellen to LogMAR: debate or delay? Clin Experiment Ophthalmol. 2006;34:6–8
30. Jewell G, Reeves B, Saffin K, et al. The effectiveness of vision screening by school nurses in secondary school. Arch Dis Child. 1994;70:14–8
31. Joish VN, Malone DC, Miller JM. A cost-benefit analysis of vision screening methods for preschoolers and school-age children. J AAPOS. 2003;7:283–90
32. Kasmann-Kellner BW, Ruprecht KW. Vision screening survey of all children starting primary school in 1998 in the Federal State of Saarland, Germany. Strabismus. 2000;8:201–7
33. Khandekar R, Mohammed AJ, Al-Raisi A. Compliance of spectacle wear and its determinants among schoolchildren of Dhakhiliya region of Oman: a descriptive study. J Sci Res Med Sci. 2002;4:5–39
34. Khandekar R, Al Harby S, Abdulmajeed T, et al. Validity of vision screening by school nurses in seven regions of Oman. East Mediterr Health J. 2004;10:528–36
35. Kleinstein RN, Jones LA, Hullett S, et al. Refractive error and ethnicity in children. Arch Ophthalmol. 2003;121: 1141–7
36. Kniestedt C, Stamper RL. Visual acuity and its measurement. Ophthalmol Clin North Am. 2003;16:155–70,v.
37. Kulp MT, Vision in Preschoolers Study Group. Findings from the Vision in Preschoolers (VIP) Study. Optom Vis Sci. 2009;86:619–23
38. Kvarnstrom G, Jakobsson P, Lennerstrand G. Visual screening of Swedish children: an ophthalmological evaluation. Acta Ophthalmol Scand. 2001;79:240–4
39. Leone JF, Mitchell P, Morgan IG, et al. Use of visual acuity to screen for significant refractive errors in adolescents: is it reliable? Arch Ophthalmol. 2010;128:894–9
40. Li L, Lam J, Lu Y, et al. Attitudes of students, parents, and teachers toward glasses use in rural China. Arch Ophthalmol. 2010;128:759–65
41. Li L, Song Y, Liu X, et al. Spectacle acceptance among secondary school students in rural China: the Xichang Pediatric Refractive Error Study (X-PRES)—report 5. Invest Ophthalmol Vis Sci. 2008;49:2895–902
42. Limburg H, Kansara HT, d'Souza S. Results of school eye screening of 5.4 million children in India—a five-year follow-up study. Acta Ophthalmol Scand. 1999;77:310–4
43. Lin LL, Shih YF, Hsiao CK, et al. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. Ann Acad Med Singapore. 2004;33:27–33

44. Luo HD, Gazzard G, Liang Y, et al. Defining myopia using refractive error and uncorrected logMAR visual acuity >0.3 from 1334 Singapore school children ages 7–9 years. Br J Ophthalmol. 2006;90:362–6
45. Maul E, Barroso S, Munoz SR, et al. Refractive Error Study in Children: results from La Florida, Chile. Am J Ophthalmol. 2000;129:445–54
46. Murthy GV, Gupta SK, Ellwein LB, et al. Refractive error in children in an urban population in New Delhi. Invest Ophthalmol Vis Sci. 2002;43:623–31
47. Naidoo KS, Raghunandan A, Mashige KP, et al. Refractive error and visual impairment in African children in South Africa. Invest Ophthalmol Vis Sci. 2003;44:3764–70
48. Negrel AD, Maul E, Pokharel GP, et al. Refractive Error Study in Children: sampling and measurement methods for a multi-country survey. Am J Ophthalmol. 2000;129:421–6
49. Odedra N, Wedner SH, Shigongo ZS, et al. Barriers to spectacle use in Tanzanian secondary school students. Ophthalmic Epidemiol. 2008;15:410–7
50. Ong E, Grice K, Held R, et al. Effects of spectacle intervention on the progression of myopia in children. Optom Vis Sci. 1999;76:363–9
51. Parssinen O, Hemminki E, Klemetti A. Effect of spectacle use and accommodation on myopic progression: final results of a three-year randomised clinical trial among schoolchildren. Br J Ophthalmol. 1989;73:547–51
52. Pizzarello L, Tilp M, Tiezzi L, et al. A new school-based program to provide eyeglasses: childsight. J AAPOS. 1998;2:372–4
53. Pokharel GP, Negrel AD, Munoz SR, et al. Refractive Error Study in Children: results from Mechi Zone, Nepal. Am J Ophthalmol. 2000;129:436–44
54. Powell C, Wedner S, Richardson S. Screening for correctable visual acuity deficits in school-age children and adolescents. Cochrane Database Syst Rev 2005;(1):CD005023
55. Resnikoff S, Pascolini D, Mariotti SP, et al. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. Bull World Health Organ. 2008;86:63–70
56. Robaei D, Kifley A, Rose KA, et al. Refractive error and patterns of spectacle use in 12-year-old Australian children. Ophthalmology. 2006;113:1567–73
57. Robinson B, Bobier WR, Martin E, et al. Measurement of the validity of a preschool vision screening program. Am J Public Health. 1999;89:193–8
58. Rosser DA, Laidlaw DA, Murdoch IE. The development of a "reduced logMAR" visual acuity chart for use in routine clinical practice. Br J Ophthalmol. 2001;85:432–6
59. Sapkota YD, Adhikari BN, Pokharel GP, et al. The prevalence of visual impairment in school children of upper-middle socioeconomic status in Kathmandu. Ophthalmic Epidemiol. 2008;15:17–23
60. Saw SM, Gazzard G, Au Eong KG, et al. Utility values and myopia in teenage school students. Br J Ophthalmol. 2003;87:341–5
61. Sharma A, Li L, Song Y, et al. Strategies to improve the accuracy of vision measurement by teachers in rural Chinese secondary schoolchildren: Xichang Pediatric Refractive Error Study (X-PRES) report no. 6. Arch Ophthalmol. 2008;126:1434–40
62. Shilio B. Screening for refractive errors requiring spectacles in urban Moshi secondary schools, Kilimanjaro Region, Tanzania. Dissertation for Masters in Community Eye Health. International Center for Eye Health, London, UK, 2000
63. Strong K, Wald N, Miller A, et al. Current concepts in screening for noncommunicable disease: World Health Organization Consultation Group Report on methodology of noncommunicable disease screening. J Med Screen. 2005;12:12–9
64. Thomson WD, Evans B. A new approach to vision screening in schools. Ophthalmic Physiol Opt. 1999;19:196–209
65. Villarreal MG, Ohlsson J, Abrahamsson M, et al. Myopisation: the refractive tendency in teenagers. Prevalence of myopia among young teenagers in Sweden. Acta Ophthalmol Scand. 2000;78:177–81
66. Vincent JE, Pearce MG, Leasher J, et al. The rationale for shifting from a voluntary clinical approach to a public health approach in addressing refractive errors. Clin Exp Optom. 2007;90:429–33
67. Vision in Preschoolers Study Group. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the vision in preschoolers study. Invest Ophthalmol Vis Sci. 2005;46:2639–48
68. Wedner S, Masanja H, Bowman R, et al. Two strategies for correcting refractive errors in school students in Tanzania: randomised comparison, with implications for screening programmes. Br J Ophthalmol. 2008;92:19–24
69. Wedner SH, Ross DA, Balira R, et al. Prevalence of eye diseases in primary school children in a rural area of Tanzania. Br J Ophthalmol. 2000;84:1291–7
70. Wedner SH, Ross DA, Todd J, et al. Myopia in secondary school students in Mwanza City, Tanzania: the need for a national screening programme. Br J Ophthalmol. 2002;86:1200–6
71. Wick B, O'Neal M, Ricker P. Comparison of vision screening by lay and professional personnel. Am J Optom Physiol Opt. 1976;53(9 Pt 1):474–8
72. Wong SG. Comparison of vision screening performed by optometrists and nurses. Am J Optom Physiol Opt. 1978;55:384–9
73. Zeng Y, Keay L, He M, et al. A randomized, clinical trial evaluating ready-made and custom spectacles delivered via a school-based screening program in China. Ophthalmology. 2009;116:1839–45
74. Zhang M, Lv H, Gao Y, et al. Visual morbidity due to inaccurate spectacles among school children in rural China: the See Well to Learn Well Project, report 1. Invest Ophthalmol Vis Sci. 2009;50:2011–7
75. Zhao J, Mao J, Luo R, et al. Accuracy of noncycloplegic autorefraction in school-age children in China. Optom Vis Sci. 2004;81:49–55
76. Zhao J, Pan X, Sui R, et al. Refractive error study in children: results from Shunyi District, China. Am J Ophthalmol. 2000;129:427–35

Other Cited Material

A. WHO. Global School Health Initiative.
B. Child-to-Child. Available at www.child-to-child.org/about/approach.html. Accessed 13 December 2011
C. AAO 2007, September 2007-last update, *American Academy of Ophthalmology Preferred Practice Patterns, Pediatric Eye Evaluations: Screening and Comprehensive Ophthalmic Evaluation PPP - September 2007*. Available at http://one.aao.org/CE/PracticeGuidelines/PPP_Content.aspx?cid=621682dc-7871-4351-830e-545b1273d84c. Accessed 13 December 2011

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