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Costs and effectiveness of two models of school-entry visual acuity screening in the UK

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ABSTRACT

Cost effectiveness of different visual screening modalities cannot be calculated without long-term outcome data. This paper reports detailed outcomes from a gold-standard UK recommended orthoptist-delivered screening (ODS) at 4–5 years in school, compared to a neighboring school-nurse delivered screening (SNDS), both feeding into the same treatment pathway. The target condition was reduced visual acuity (VA) of worse than logMAR 0.2 in either eye.

Available records from screening databases and hospital records were analyzed, comparing the two services wherever possible.

More screening data was available from the ODS. ODS: 5706 screened, 3.5% referred. False positives 6.5%, PPV 91.4%, sensitivity 97.9%, and specificity 99.8% for reduced VA. Cost per child with reduced vision detected £195.22, and per amblyope detected £683.28. The mean treatment cost per child with reduced VA was £331.68 and for amblyopia treatment was £458.65.

SNDS: 5630 screened and 3.8% referred (plus some referrals to local optometrists lost to follow up). False positives 34%, PPV 53.2%, sensitivity and specificity estimated as 89.3% and 98.67%. Costs to secondary services of false positives were seven times greater. The cost per child with confirmed reduced vision seen at the hospital was 46% more; and per amblyope detected was 39% more.

Outcomes for treatment post referral in both groups were similar and excellent. 86% of genuine referrals improved to within normal limits with glasses alone. Of 221 genuine referrals with final outcome data, all now have better than 0.2logMAR acuity in the better eye and only two (0.9%) have residual amblyopia in one eye worse than 0.4logMAR.

About 14–18% of children with reduced VA would have passed AAPOS photoscreening referral criteria.

An orthoptist-delivered single VA screen at 4–5 years is highly cost effective with good outcomes. The main contributing factors to success appear to be training and experience in accurate VA testing, the opportunity to rescreen equivocal results, and monitoring, audit, and feedback of outcomes.

KEYWORDS

Child vision screening; orthoptist; amblyopia; cost; effectiveness

Introduction

The United Kingdom National Screening Committee (UKNSC) recommends that beyond neonatal screening, the next child vision screening should be a linear visual acuity (VA) test in the first year of compulsory education at 4–5 years, delivered or led by orthoptists. [1]

The EUscreen study[2] is highlighting how cost effectiveness modeling of different screening modalities is severely hampered by lack of reports of long-term costs and outcomes, in comparison to shorter-term outcomes such as positive predictive values (PPVs) for a specific diagnosis (for reviews see.[3,4]) Even if data are audited locally, they are not shared.

Cost effectiveness is particularly important for publicly funded health services paying for the whole patient journey from detection to discharge. Low screening costs may not be matched by equally cost-effective follow-up, and outcomes may differ between different screening timings and methods. A particular issue in children's vision screening is comparative costs of early automated photoscreening for refractive *risk factors* for treatable reduced vision and amblyopia, versus later visual acuity (VA) testing by a skilled tester which detects *actual reduction* in vision. Because more children will have risk factors than will be amblyopic, low-cost photoscreening[5] might be less cost effective in the long term due to more, less precise referrals, and

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Supplemental data for this article can be accessed on the publisher's website.

more expensive visits to secondary services, without clear evidence of better outcomes at a population level.[4]

This paper describes a long-term audit of outcomes and costs associated with referrals from two established neighboring school-entry vision screening services in southern England from one academic year, one following national guidelines more closely than the other. Both populations are majority White British, but with significant and similar numbers of ethnic diversity including South Asian, Afro-Caribbean and Eastern European families (see Supplemental File) in both areas. There are some areas of socio-economic deprivation in both areas, but the whole region is relatively economically prosperous.

Both services test 4–5-year-old children in their first year of compulsory school, use the same validated linear logMAR test (the 3 m Sonksen test[6] with a pass threshold of 0.2logMAR in either eye). They feed into the same healthcare provider managed by the same National Health Service (NHS) team, using common treatment protocols free at point of delivery, and common records software. All treatment of uncomplicated amblyopia and refractive error is carried out by a joint orthoptist/optometrist service managed by orthoptists. The receiving hospital trust covers the whole county, so few referrals go elsewhere, and local optometrists generally refer any amblyopic child to hospital.

Orthoptist delivered screening (ODS)

This service is run by the orthoptic service and delivered by five experienced orthoptists. Each orthoptist travels to many schools in the area to test large numbers of children (60–70 (two classes) per session, >1000 per year), screening once or twice a week, interleaved with hospital practice. Children already in glasses are not screened and do not feature in the analysis of the data. Children are retested in school in the next term if the test is a borderline fail (0.225–0.3 logMAR), or the orthoptist is not confident the VA is accurate. As long as the child was rescreened in the same academic year, their data were included in the analysis. Audit and feedback from the screenings are integrated with hospital patient records, orthoptists can access records of children they have screened, and formal feedback from the service is shared regularly.

School nurse delivered screening (SNDS)

This service is administered by the school nursing service based in the local authority, not the health authority, and feedback is patchier. The training is not orthoptist led or delivered, as is recommended by the UKNSC. Records held by the school nursing service are difficult to access by the health services due to data protection issues, and the health services only feed back very basic data about referral outcomes (and no treatment outcomes) to the screening service.

The VA screen is part of other school entry health checks, and each nurse is based in a small number of schools, so they will test many fewer children's VA per session and per year. There is no rescreen option, so all children not passing the screen are referred.

Children with mild deficits of vision (0.3logMAR in one eye and 0.2 in the other, 0.3 in both eyes, 0.4 in one eye, and 0.3 in the other) are referred to local optometrists. For this study, we were unable to establish how many children were referred down this route, and this unknown number of children are lost to follow up.

For further details of procedures and differences between the services see the Supplemental File.

Methods

Outcomes from all referrals from children screened in the academic year 2018–19 were scrutinized from hospital records and data provided by the screening services. As it was an audit, Ethics Committee approval was not sought, but ethical principles were followed, such as early anonymization of identifiable data, and involvement of stakeholders. Data from the ODS was much more complete than the SNDS, both for structural reasons and COVID-19-related difficulties in accessing data.

Amblyopia was diagnosed on the first visit on return 6–8 weeks after being prescribed any glasses if the VA remained worse than 0.2 in one or both eyes in the absence of pathology. To try to capture

some idea of false negatives, which is not collected systematically, all orthoptists in the county were asked how many late-presenting children with reduced VA they had seen from the cohort who they considered to have been missed by the screening (not moved into the area later, presenting with mild, non-amblyopic myopia which was likely to have developed between the screening and referral, or failed offered diagnostic appointments after screening referral). The ODS service keeps the screening records for audit purposes so it was possible to confirm if a child had passed the original screen and orthoptists are encouraged to check.

Statistical analysis

Descriptive statistics were collected from available records of children screened, referred, followed to diagnosis, and followed to discharge. Where the data were reliable, calculations or best estimates were made for sensitivity, specificity, and positive predictive values for the target condition of VA worse than 0.2 in either eye.

Costs

Cost per screen included staff, administration, postage, screener travel, and any replacement equipment. In this pre-COVID-19 period, there were few disposables. Costs reported were based on median pay points on national salary scales, travel at £0.25 per mile, national postage rates, published NHS appointment unit costs,[7] payment made to local opticians to supply spectacles at a national voucher rate, occlusion patches, and manufacturer's listed equipment prices. At the time of analysis, the currency exchange rate was £1 = €1.12 = 1.25 USD. Any additional cost for the few children needing further pediatric ophthalmology opinions were not included.

Results

Orthoptist-led service

5878 children entered school in the year (for details see Table 1). 5839 (99.3%) were successfully screened, including. 202 (3.5%) children who were recalled for a second screening of equivocal results before passing successfully. The remainder had either special needs so were referred elsewhere (10), were sick or from traveling families, so were not in school on the testing day and were deferred to the next year (25). Four were untraceable.

199 (3.5%) children were referred from screening. 48 (24.1%) of these were lost to first follow up and a further 11 failed to attend during treatment, leaving 140 (70.4%) children traced to discharge on the audit date (July 2020).

Mean age at the new case visit was 5 years 0.3 months, with a mean time from referral to reduced VA diagnosis of 42 days (range 8–122). Mean age at audit was 6 years 3 months and most had completed any active amblyopia treatment. Fifteen children were still being monitored early in 2020 when nonurgent appointments were canceled due to the COVID pandemic, so their final outcome is slightly delayed.

Of the 151 children whose screening results were followed up to diagnosis, 138 had confirmed reduced vision (91.4% true positive for reduced acuity). Thirteen (6.5%) were false positives, having failed the screening but had good equal vision and normal orthoptic assessment on their diagnostic visit, and were discharged.

It is not possible to be certain of the number of false negatives, but the poll of orthoptic department staff suggests it is never more than three per year. If this reasonable estimate is used, sensitivity for confirmed reduced VA and amblyopia of less than 0.2 logMAR in one or both eyes was 98%, specificity was 99%. PPV was 91%.

129 children were refracted under cycloplegia and 126 were given spectacles. Two subsequently achieved normal VA without glasses, four were diagnosed with pathology.

Twenty children (14.9% of children with confirmed reduced VA) had refractive errors which would have passed the American Association of Pediatric Ophthalmology & Strabismus (AAPOS) refractive risk factor screening criteria (astigmatism >1.5 D, anisometropia >1.5 D, and hyperopia >3.5 D)[8] if they had been photoscreened, but had significant reduced vision or amblyopia.

On the follow-up visit 6–8 weeks later 74% of the referrals reached better than 0.2 VA in each eye with glasses alone. Thirty-six (26%) of the children with confirmed reduced vision on their first visit were still amblyopic, but 17 normalized after

Table 1. Numbers and percentages of children targeted by the orthoptist-led (ODS) and School Nurse Led (SNDS) screening services. n/a = data not available.

	Orthoptist (ODS)		School nurse (SNDS)	
	n	%	n	%
SCREENED				
Elligible	5878		n/a	
Present at screening	5839		n/a	
Parents declined (% of elligible)	4	(0.01)	n/a	
Already in gls so not screened (% of elligible)	133	(2.3)	n/a	
Absent on first screen (% of elligible)	256	(4.5)	n/a	
Recalled (% of elligible)	202	(3.5)	not done	
Special needs so referred elsewhere/sick /traveler/to be screened next year/ untraceable (% of elligible)	39	(0.7)	n/a	
Total screened	5706		5630	
REFERRALS				
Referred (% of screened)	199	(3.5)	215	(3.8)
Followed to diagnosis (% of referrals)	151	(75.9)	173	(80.5)
Traced to final outcome or audit date (% of referrals)	140	(70.4)	170	(79.1)
Observed further without refraction then discharged (% of referrals)	0		14	(6.5)
True +ve for reduced VA (% followed to diagnosis)	138	(91.3)	83	(38.6)
True -ve (estimated)	5504	(96.5)	5405	(96.0)
True +ve for amblyopia after first glasses	36	(26.1)	25	(30.1)
False +ve for reduced VA	13	(6.5)	90	(41.9)
False -ve (later presenting low VA) (estimated)	3		(10)?	
Cycloplegic refraction	129		99	
Spectacles prescribed	126		89	
Parents declined treatment/went elsewhere	5		4	
Good VA with glasses from optometrist on new case visit (discharged)	6		5	
VA on screening below 0.3 both eyes (%of referrals)	29	(14.6)	29	(13.5)
(of the above not myopia or myopic (so likely poor Near VA too))	1		10	
Low VA under AAPOS refractive risk factor referral threshold (% of children with low VA)	20	(14.5)	15	(18.1)
Age at follow up (years/months)	5 yrs 0mths		5 yrs 3mths	
Age at full diagnosis (on return with glasses)(years/months)	5 yrs 2mths		5 yrs 5 mths	
Mean delay from referral to diagnosis (weeks (range))	6 weeks (1–17)		9 weeks (1–25)	
Sensitivity for reduced VA	97.9%	95%CI 93.9%–99.6%		
Specificity for reduced VA	99.8%	95%CI 99.6%–99.9%		
Positive Predictive Value (PPV) for reduced VA	91.4%	95%CI 86.0%–94.8#%	53.2%	47.25%–59.07%
OUTCOMES				
Followed to discharge or audit (% of referrals)	119	(59.8)	170	(79.1)
Pathology (% of referrals)	4	(2.0)	0	0
Needed occlusion after "refractive adaptation" (% of referrals)	19	(9.5)	11	(5.1)
Lost to full f/u (failed appointments or moved away after initial Dx) (% of genuine referrals)	80	(57.9)	25	(30.1)
Final VA worse than 0.2 in the worse eye	8	(4.0)	6	All ongoing
Final VA worse than 0.4 in the worse eye	1	(0.7)	2	All ongoing
Final VA worse than 0.2 in the better eye	0	0	0	0
In final stages of treatment (% of genuine referrals)	15	(7.5)	18	(21.7)
Median number of visits (all children)	3	Range 1–9	3	Range 1–6
Median number of visits (amblyopes)	5	Range 3–9	5	Range 3–6

a longer period of "refractive adaptation."[9] So, of the 138 children with confirmed reduced vision on their first hospital visit, 79% improved with glasses alone or spontaneously (no glasses indicated on refraction).

Only 19 (13.7%) needed occlusion. Only one child (with strabismic and anisometropic amblyopia) had final VA worse than 0.4 (0.7 logMAR) and eight others are still in the very final stages of treatment with 0.3 VA or better. Four children had subtle pathology on further investigation. The remainder of the referrals are either stable with no, or minimal, amblyopia and are discharged, or in the final stages of observation before discharge to their community optometrist.

The median number of visits for all children was 3 (range 1–9). Of children still amblyopic on return with their first spectacles, the median number of visits was 5 (range 3–9), although 8 are still under supervision.

Costs (based on 2019–20 rates)

The total cost per screening test was £4.21 per child (Table 2). The cost of a hospital appointment to confirm reduced vision was £70 and the mean cost of a glasses voucher for all the children prescribed glasses was £46.59. The false positive screening

Table 2. Actual costs at 2019–2020 published rates. Costs per child of screening and postreferral treatment of SNDS and ODS are likely to be similar.

COSTS (2019–2020 published rates) Exhange rate £1 = €1.12 = $1.25	£	£
Per screen (£)	4.21	
Hospital appointment (£)	70	
Per screen (£)	46.59	
Box of patches (£)	8.75	
Cost to amblyopia diagnosis (£)	189.8	
Mean reduced VA treatment cost, diagnosis to discharge (£)	331.68	
Mean amblyopia treatment cost, diagnosis to discharge (£)	458.65	
	ODS	**SNDS**
Cost to service per child with low vision (£)	195.22	285.70
Cost to service per child with amblyopia (£)	683.28	948.09
Total cost of false referrals (£)	910.00	6300.00

referrals cost the NHS £910 in total. The cost to full amblyopia diagnosis (screen + two hospital visits + spectacles) was £189.80 per child. The cost per child detected with confirmed reduced vision was £195.22, and per amblyope detected was £683.28.

School nurse delivered service

Data collected, and available, was much less comprehensive, and over the COVID lockdown some still is impossible to obtain (see Table 1).

About 5630 children were screened and 215 (3.8%) were referred, so referral rates were similar. 170 (79%) were followed to discharge or audit and 11 failed to attend during treatment. 20% were lost to initial follow up. However only 83 referred children had reduced vision confirmed at their new case visit (true positive for reduced acuity 48%). Seventy-three (34%) were clearly false positives (VA 0.1 logMAR or better in either eye) and were discharged after the first visit with normal VA (compared to 9% for the ODS). A further 14 (8%) had marginally reduced VA (0.125–0.2 logMAR in one or both eyes) felt to be due to immaturity or poor cooperation so were observed without refraction and were subsequently discharged without treatment as their VA improved to 0.1 logMAR or better. They were included as true or false positive numbers at the time an accurate diagnosis was made

An unknown number with mildly reduced vision (see Supplement) were advised to go to the optician and lost to follow up. From this cohort, which is of a similar size to the ODS, 138 children with confirmed reduced VA were referred by the ODS, but only 83 were referred by the SNDS, suggesting that many children were missed. If any with mildly reduced VA went to an optometrist, none were referred back for occlusion.

PPV was only 53%. Lack of data from optometrist referrals and the high false positive rate reduces our confidence in the accuracy of the data, and thus sensitivity and specificity, but they are likely to be lower in this service.

Seventy-four children with confirmed reduced vision were followed to discharge or the audit date, and 8 still being occluded at the onset of the 2020 COVID lockdown, so final outcomes are not available. Only two children still have VA in the amblyopic eye of 0.4 or worse and both are still being treated.

Fifteen (18.5%) of children with reduced VA would have passed the AAPOS amblyopia risk factor referral threshold.

Costs

The actual screening costs cannot be identified because the screening is part of a general health screening, but they are carried out by personnel on similar pay bands, so are likely to be similar. The main difference in costs was in the higher costs of the false positive referrals. Although costs per genuine case and final VA outcomes for referred children were similar, the cost of the 73 false referrals was nearly seven times that of the other service, while it is likely other children have been missed and so remain untreated.

Assuming similar screening costs, the cost per child with confirmed reduced vision seen at the hospital was £285.70 (46% more); and per amblyope detected was £948.09 (39% more), and this does not consider the cost and outcomes of the unknown number of children referred to local optometrists.

Discussion

A single visual acuity screen at 4–5 years, led and administered by orthoptists is unusual worldwide, when many countries screen repeatedly, or earlier, or use automated screening for refractive risk factors, rather than reduced VA itself.[10,11] The

UKNSC recommends that screeners should be orthoptists, or those trained by orthoptists, and this paper reports two ends of this spectrum – orthoptist screeners vs. minimal orthoptist input in two otherwise similar populations. The SNDS training is not supervised by orthoptists as is recommended. Data were much more accessible for the ODS and full audit and feedback more embedded, the importance of which is one of the messages of this paper. Tight audit has led to many small refinements of the ODS over the years, for example, recalling children in school, and going into the schools with a high proportion of disadvantaged or non-English speaking children later in the screening cycle to allow them a better chance of complying with testing because they had been in school longer.

A single screening by an orthoptist followed by orthoptist/hospital optometrist follow-up appears to be highly efficient and very low cost, both per screen, and per patient journey and per amblyope detected, compared to other alternatives.[12–14] It is often assumed that highly skilled VA screening is more expensive,[5] but these data suggest that it is not necessarily the case. The current UKNSC recommendation to not specifically test for strabismus, as is carried out in many countries[11,15] seems supported. All children with significant newly diagnosed strabismus also had reduced VA.

The SNDS resulted in many more false referrals, and therefore inefficient use of expensive hospital services, and probably more false negatives. The prevalence of refractive error is likely to be similar in both areas, so more children with reduced vision are probably missed. The ODS had a slightly lower referral rate (3.41% vs. 3.82%), and the local authority figures do not include the approximately 0.65% of the cohort (using the ODS criteria) who might have been expected to be sent to local opticians, not hospital services, so the true local authority referral rate could have been nearer 4.5%.

The school nurses seem less expert in detecting genuine reduced vision. The UKNSC recommends that if orthoptists do not do the screening, they should train and monitor the screeners very carefully, but that is not the case for the SNDS described here. Orthoptists are particularly skilled in testing children's vision, but they too had to learn. If orthoptists are not available, careful training to a gold standard, regular supervised practice, feedback, and audit seem to be the issue that defines the ability to test vision accurately, whoever does it.

A common argument for early or repeated screenings is that early treatment leads to better outcomes, and some cases of amblyopia can be prevented. Children start compulsory schooling at 4–5 in England, so they are still well within the critical period; but still much older than proponents of earlier screening would like.[16] Nevertheless, of the 126 children with confirmed, previously-undiagnosed reduced vision followed to discharge, all improved with treatment, which was usually glasses alone. 95% reached at least 0.2 logMAR acuity (the lower 95% CI of normal acuity at age 6[6]) in each eye, and a few more have slowly improving unilateral amblyopia. All children without other pathology now have vision in at least one eye well within normal ranges and there is only one child with VA worse than 0.4 in an amblyopic eye who could suffer any significant functional disadvantage (e.g. unable to drive a car) if they were to lose their better eye. Children with strabismus either present earlier,[17] would have been picked up by VA testing, or have small or intermittent strabismus with minimal amblyopia.

Photoscreening is often advocated because it can be carried out earlier, by less skilled testers. But it can result in high referral rates,[18] more appointments from screen to discharge and other potential disadvantages (for review see Horwood et al.[4]) Importantly, in this study, 14–18% of children with reduced VA would have been missed by earlier photoscreening.

Some might argue that those with 0.2 final logMAR VA might have been ended up a line better if treated earlier,[19] or that good acuity is necessary for general development in the toddler years, but none of these children's parents had noticed any visual problem, and concerned parents had already sought treatment, so any disadvantage is likely to be small. Parents sometimes report improvements in behavior or performance after new glasses. This evidence is often anecdotal and very prone to placebo effects, but does need further research. There is little evidence that slightly blurred vision before school entry holds children back, or that minimal reduction in final best corrected acuity carries any

lifetime disadvantage. In a public health context such marginal gains may not be cost effective.

The main barrier to universal care was loss to follow-up, and with the SNDS, legal and practical barriers to data sharing. Data-protection laws prevent health services contacting parents of screened children directly, so if a parent does not return their details, children cannot be sent appointments.

The main limitation of the study was data availability for the SNDS, but any COVID-related difficulties in accessing some screening data do not account for the differences in outcomes or costs. Using estimates of false negatives is not ideal, but in the case of the ODS they do seem realistic because it is so rare to see any child that passed screening who presents later with amblyopia. The orthoptists generally check back to screening records and remember doing so.

A further limitation is that the analysis did not include the 2.3% of children who were wearing glasses on the day of screening. When setting up the service, it was decided not to test the vision of these children as it was being professionally monitored elsewhere, and any amblyopia would have been detected and treated. This is an audit, not a prevalence study, and the focus of the service is the detection of previously undetected children at minimum cost and maximum efficacy. We also did not have the means to access these children's diagnosis or prescription, and had no means to tell whether they would have passed the screening before they received the glasses (e.g. mild astigmatism or hypermetropia might be corrected by some optometrists). We were therefore unable to analyze their data further, and it does mean that the data should not be used as a precise measure of prevalence in the population.

The point at which amblyopia is diagnosed can vary. It could be on the day of refraction if VA does not improve with lenses, on the first visit on return with glasses or after full adaptation to glasses as recommended by many research studies.[20,21] In this study, we chose the most common clinical definition (after 6–8 weeks of full-time glasses) and many children had achieved equal VA at this point.

It is possible that within the data there are differences between the communities, such as in socio-economic or ethnic disadvantage, that could explain some of the differences between the outcomes. Although in the SNDS area there is one town with a very high proportion of South Asian and socio-economically disadvantaged families, it sits in an otherwise largely White British, affluent area, whereas in the ODS area the socio-economic and ethnic groupings are more widely spread. On average, the areas are broadly similar. While screening and follow-up may need to address specific at-risk groups,[22] it was beyond the remit of this audit.

These results strongly support the UKNSC model as being highly cost effective. A single, accurate screen by an experienced tester, at a site where high coverage and a retest is possible, and a joined-up service from screen to discharge seem key to success. Training, feedback, and audit allow refinements to improve services.

If more resources are to be allocated, it might be better to use them to share best practice, improve training, audit, quality assurance, follow-up attendance rates, feedback, and local and national data sharing, than add earlier, or more, screening events.

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