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Screening efficacy of a simplified logMAR chart

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Background: Snellen acuity charts are the most commonly used method for visual acuity (VA) testing in screening programmes despite comparative studies verifying that the logarithm of minimum angle of resolution (logMAR) acuity measurement charts are more accurate than the Snellen chart acuity measurements. LogMAR acuity measurement charts however are not well implemented in routine clinical practice because of the increased testing time and the complexity of scoring. To implement the logMAR method in a screening programme, there has to be some simplification of it.

Aim: This study evaluates the efficacy of a simplified logMAR chart, designed for VA testing over the conventional Snellen chart, in a school-based vision-screening programme.

Methods: We designed a simplified logMAR chart by employing the principles of the Early Treatment Diabetic Retinopathy Study (ETDRS) chart in terms of logarithmic letter size progression, inter-letter spacing, and inter-line spacing. Once the simplified logMAR chart was validated by students in the Elite school vision-screening programme, we set out to test the chart in 88 primary and middle schools in the Tiruporur block of Kancheepuram district in Tamil Nadu. One school teacher in each school was trained to screen a cross-sectional population of 10 354 primary and secondary school children (girls: 5488; boys: 4866) for VA deficits using a new, simplified logMAR algorithm. An experienced paediatric optometrist was recruited to validate the screening methods and technique used by the teachers to collect the data.

Results: The optometrist screened a subset of 1300 school children from the total sample. The optometrist provided the professional insights needed to validate the clinical efficacy of the simplified logMAR algorithm and verified the reliability of the data collected by the teachers. The mean age of children sampled for validation was 8.6 years (range: 9–14 years). The sensitivity and the specificity of the simplified logMAR chart when compared to the standard logMAR chart were found to be 95% and 98%, respectively. Kappa value was 0.97. Sensitivity of the teachers' screening was 66.63% (95% confidence interval [CI]: 52.73–77.02) and the specificity was 98.33% (95% CI: 97.49–98.95). Testing of VA was done under substandard illumination levels in 87% of the population. A total of 10 354 children were screened, 425 of whom were found to have some form of visual and/or ocular defect that was identified by the teacher or optometrist.

Conclusion: The simplified logMAR testing algorithm proved to be less time consuming than the standard logMAR test. This suggests that the simplified logMAR chart is effective in vision-screening programmes and would be a reliable alternative to the standard logMAR chart and therefore replace the use of Snellen chart acuity tests in vision-screening programmes. The study also showed that non-healthcare providers, such as teachers, can reliably administer the simplified logMAR test.

Introduction

Globally, 32.4 million people are blind and 191 million have impaired vision,[1] approximately 18 million of whom are children who are between the ages 0 and 14 years.[2] India stands second in the world, holding the maximum number of visually impaired population, next to China.[2] Uncorrected refractive errors are the primary cause of visual impairment amongst all age groups.[2] The World Health Organization (WHO) estimates that approximately 12.8 million children aged 5–15 years have impaired vision from uncorrected refractive error.[3] It has been concluded by these studies that noncorrection of refractive errors in the age group of 5–14 years is attributed to the lack of screening and the availability and affordability of refractive corrections.[3]

Detecting ocular disorders in children is important because ocular disorders can present a serious health problem. Children with learning difficulties related to vision problems have deficits in visual efficiency or visual information processing.[4] A child's vision is essential for successful learning in school, and when the child's vision is impaired, routine schoolwork and day-to-day activities are affected[5]; thus, the child's quality of life is affected.[6] Vision problems are common amongst school-age children because of many reasons including unhygienic living conditions, malnutrition, watching television, playing computer games and diminishing parental care.[5]

Many studies have shown the need for appropriate vision screening and its correction in children.[7,8,9] Visual acuity (VA) screening is widely used to identify children with reduced vision. Screening programmes aimed at detecting correctable VA deficits will inevitably identify some children with reduced vision because of causes other than refractive error, for example cataract or amblyopia (a condition that could become permanent if not identified and treated early).[9] For early detection and treatment of eye conditions, vision screening should routinely be done at school entry, midway through school and at completion of primary school.[10] VA screening programmes vary with regard to the person carrying out the testing, for example teachers, nurses, the defined threshold for failure and the setting.[7]

Vision problems can have an adverse effect on children's comprehension and performance in reading and writing[11] that constitute nearly three quarters of a typical school day. Teachers interact frequently with children and their parents and thus may be ideal vision screeners.[12] However, an important determinant of teacher screening programmes in schools is the support received from teachers for participating in vision-screening programmes, which varies with each setting.[12] Using school teachers to detect pupil's vision related problems was first documented in 1975; however, since then many studies have documented the reliability and effectiveness of teacher's involvement in screening.[12,13,14,15,16,17,18]

The advantages of VA testing using logarithm of minimum angle of resolution (logMAR) acuity measurement charts, over the use of Snellen charts, are well known. LogMAR acuity measurement utilizes the letter-by-letter scoring principle in contrast to Snellen where the acuity will be obtained by the line-by-line scoring method. Charts designed using logMAR principles are always more sensitive as the scoring scale gets finer in it. The between-letter spacing and between-line spacing in logMAR charts control the crowding phenomenon, which usually varies throughout the Snellen chart.[19] A complete Early Treatment Diabetic Retinopathy Study (ETDRS)-type logMAR chart cannot be used for screening purposes, as it is time consuming and not a cost-effective option.[20] Presuming that we can achieve better reliability by standardizing the type of vision testing methodology used, we decided to study the efficacy of a simplified logMAR algorithm to improve teachers' screening of VA deficits in rural school children.

Materials and methods

This study used a cross-sectional population-based approach. The target population was children in the primary and middle schools of the Tiruporur block of Kancheepuram district in Tamil Nadu. The sample included 88 primary and middle schools comprising 10 354 children. Ethical approval for conducting the study was received from the Medical and Vision Research Foundation Institutional Review Board. The study followed the tenets outlined in the Declaration of Helsinki[21]. As the study population needed cycloplegic refraction and fundus evaluation, the informed consent was obtained from parents or guardians for the instillation of homatropine eye drops. All parents or guardians were presented with an information document detailing the study aim, objectives, methods, participants right to refuse to participate and right to their anonymity.

The study employed a stratified, systematic random sampling technique to select the children who would participate in the VA screening by teachers. An optometrist in approximately 12% of the sampled population validated the simplified logMAR chart and the efficiency of the teacher's performing the screening. In order to conduct the validation, the list of children screened in a school was taken first. A rupee was then pulled out from the pocket of the social worker and the last digit of the serial number of the rupee indicated the first child who was to be screened by the optometrist in that school. Every tenth child from that first child who were all screened by teachers in that school, from first to last grade, were screened by an experienced paediatric optometrist first, with the simplified logMAR chart, and then with the standard logMAR chart under the same testing setup as followed by the teacher in that school. We tested the children in the same venue where the teachers performed the testing. In each school, one classroom was dedicated for the testing. Children were screened and tested between 9 am and 12 pm. We assumed that the room lighting might not vary much during this time. This procedure was followed in all the schools that participated in the study.

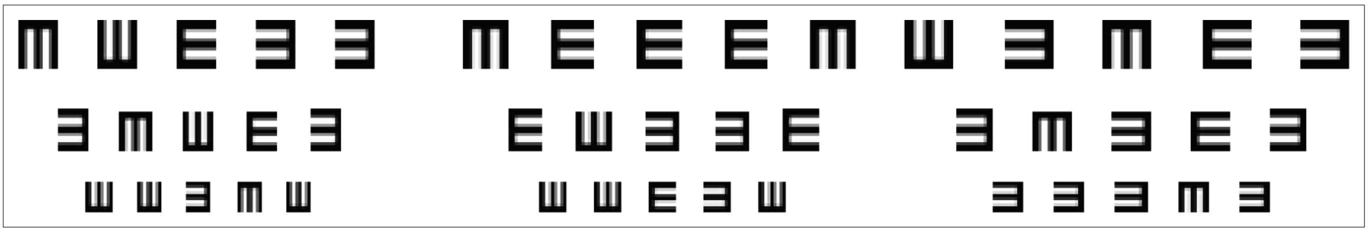
Eye examination

The simplified logMAR chart employed the design principles of the ETDRS chart in terms of logarithmic letter size progression, inter-letter spacing and inter-line spacing. It is designed to test at 3 m and it is an externally lit chart. The simplified logMAR chart differed from the ETDRS chart in the use of tumbling 'E' optotypes. Table 1 shows the

TABLE 1: Difference between the standard logMAR chart and the simplified logMAR chart.

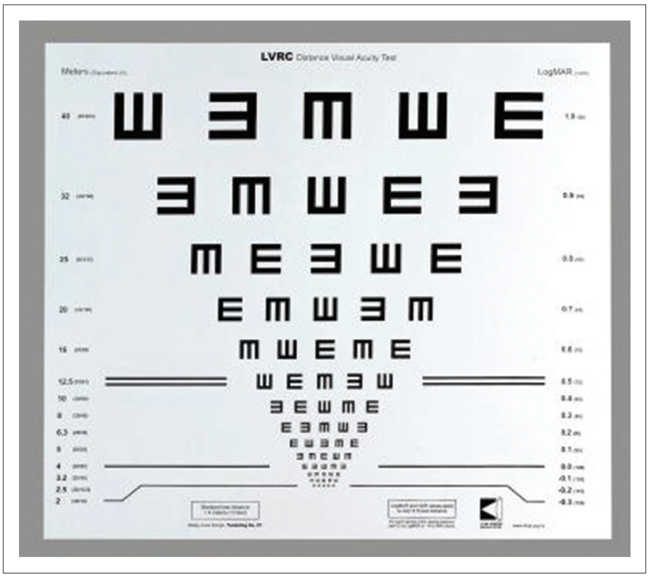
Standard logMAR chart	Simplified logMAR chart
Comprises 14 rows with 5 letters in a line	Contains 3 rows with 5 letters in a line
Designed for testing at a distance of 4 m	Designed for testing at a distance of 3 m
Cost of a standard logMAR chart is $121	The cost of a simplified logMAR chart is less than $1
Chart is printed on acrylic material	Chart is printed on A4-sized paper and pasted on a cardboard

logMAR, logarithm of minimum angle of resolution.



Source: Authors' own creation

FIGURE 1: Simplified logMAR chart which author designed and used for screening. Design principle is based on logMAR.



Source: Brien Holden Vision Institute, www.brienholdenvison.org

FIGURE 2: Standard logMAR chart used for screening.

differences between a standard logMAR chart and the simplified logMAR chart.

Three versions of the simplified logMAR chart were used, differing only in the orientation of the optotypes (Figure 1). The simplified logMAR chart had three lines with five optotypes in a line, whereas a standard ETDRS chart has 14 lines with 5 letters in a line (Figure 2). Each version of the simplified chart has three lines corresponding to 0.2, 0.3 and 0.4 log units. Simplified logMAR charts were printed on a white chart paper using a laser jet printer and then pasted onto a cardboard. The charts were validated with 30 students, who were between the ages 19 and 22 years, from the Elite School of Optometry before being distributed to the teachers from the sampled schools. The validation of the charts showed that the agreement between the simplified logMAR and the standard logMAR chart was 0.93 (kappa). The positive likelihood ratio for the simplified logMAR chart was 95%/1 – 98% = 0.97.

Training of teachers

One teacher from each of the sampled schools (88 schools) was selected by the school principal and was summoned for half-day training on VA screening (for their respective school children) at the tertiary eye care centre. One school (of the total 88) had two teacher representatives, as their school enrolment exceeded 500. Eighty-nine (89) teachers from 88 schools attended the training programme. An awareness session on the common eye disorders prevalent amongst children was conducted for the teachers. Teachers were educated on the basics of VA screening, namely on the appropriate screening set up and the VA testing procedure. The importance of asking all the children about spectacles ownership was emphasized, and the teachers were told to measure corrected vision in those children who had spectacles. During the training, the teachers were provided with a screening kit, which includes a pen, 3-m tape measure, a simplified logMAR chart, a demo 'E' chart to teach the children, educational material and pro forma for entering the results of their screenings. There were no refusals amongst the teachers selected for inclusion. Teachers were remunerated with 100 rupees each for their participation.

Eye examination procedures followed by teachers

We used the WHO definition of visual impairment. Visual impairment is defined as presenting VA less than 6/12 (20/40) in the better eye, for children up to 15 years of age.[22] Uncorrected VA and VA habitual correction, when available, was measured in a well-lighted classroom or during daytime light hours at a distance of 3-m uniocularly. Using a simplified logMAR chart that was pasted on the wall, the school teachers tested all the children. Children were made to familiarise themselves with the different orientation of optotypes using a demo chart before their vision was checked with a simplified logMAR chart. Children who did not have their spectacles at school were asked to bring them for vision assessment by the teachers on a separate day. The right eye of the school children were tested first and the children being tested were asked to cover their unexamined eye with their palm. The school children were asked to read only the middle line, which corresponds to 0.3 logMAR units (6/12 Snellen) in all three charts that were provided to prevent covert memorization of the optotypes. The VA screening test was considered negative (successful) if the child identified four out of five optotypes in the middle line in any of the two charts with both eyes separately. Results were recorded on a pro forma, which was collected from the teachers by a social worker and brought to the base hospital. The teachers screened the total sample population (10 354 children) from the 88 schools in 15 working days. The teachers sent information to the parents of children who showed positive screening results (those failing to get 4 out of 5 letters in the middle line of at least two charts).

Clinical procedures followed by the optometrist

Children who failed in the teacher's screening and/or validation by the optometrist were brought to a vision centre that was located at an easily accessible place for all the schools, where eye examinations were carried out by the optometrist and an ophthalmologist. Eye examinations included history, clinical ocular examination and vision testing using an illiterate 'E' chart. The simplified logMAR chart was used by the optometrist to evaluate the efficacy of the teachers screening results. The testing proceeded 30–45 minutes later for children, where an informed consent was available from parents/legal guardians, for the instillation of homatropine (two drops with an interval of 5 minutes) for fundus and cycloplegic retinoscopy.

Children without their parents' agreement and/or those afraid of eye drops were examined without cycloplegia. Optometrist and ophthalmologist documented the findings, and their clinical judgement regarding further diagnostic procedures, treatment and follow-up at the base hospital (Sankara Nethralaya) were established. If positive, the reason for referral was stated. Reasons included cataract, corneal pathology, retinal pathology, amblyopia, strabismus, high refractive errors and/or nystagmus.

Myopia and hyperopia was defined as a spherical refractive error of ≤|-0.50 D| and ≥ 2 dioptres sphere (D), respectively. A cylindrical power of ≤|-0.50 D| was considered as astigmatism. Children who had refractive error ≥|-1 D| and > 3.50 D sphere or astigmatism of ≥|-1.5 D| were given refractive correction. Children were transported back to their respective schools after completion of the examination with the help of a social worker. Children who were referred for the ocular pathologies underwent appropriate treatments.

Refractive error treatment

Spectacles were dispensed on a separate day to the children who required them. Awareness and the importance of spectacle wear were conveyed by a team that included an optometrist, an ophthalmologist and a social worker.

Data collection and analysis

The data collected were checked for accuracy and completeness on the field before data entry. The data collected were analysed using SPSS (version 15.0) and Instat (version 3.0) of GraphPad. Descriptive statistics was employed to report the means, ranges, proportions and their 95% confidences intervals (CI). A 5% level of significance was used for all statistical analysis. The degree of agreement was quantified by kappa (reproducibility of VA screening done by the teachers). The following values of the screening were estimated: (1) the ability of the teachers to fail the children with VA deficits (sensitivity), (2) the ability of the teachers to pass the children with normal visual acuities (specificity), (3) the proportion of children who failed in the teachers screening despite their VA being better than the cut off (false positives), (4) the proportion of children who pass in the teachers training despite their VA being below the cut off (false negatives), (5) the probability of having VA below cut off (poor – given that these children fail in the teachers screening [positive predictive]) and (6) the probability of having VA above cut off (better – given that the children pass in the teachers screening [negative predictive]).

Results

A total of 10 354 school children between 5 and 14 years of age were included in the study, of whom 5488 (53%) were girls and 4866 (47%) were boys. Of these, 1300 were screened by the optometrist. This population was taken into consideration for validating the simplified logMAR chart and the teacher's ability to screen appropriately. The mean age of children sampled for validation was 8.6 years (range, 9–14 years).

Simplified logMAR versus Standard logMAR

The sensitivity and the specificity of the simplified logMAR chart when compared to the standard logMAR chart were found to be 95% and 98%, respectively. The positive likelihood ratio for the simplified logMAR chart was 95%/1 – 98% = 0.97. Kappa value was 0.97.

Validity of teachers screening

The agreement between the teachers and optometrist was calculated. The weighted kappa value was 0.59. Table 2 shows the screening efficiency of the teachers.

The screening efficiency of the teachers, with respect to gender of the children was calculated and the false-positive rate between boys and girls was found to be 2.08% and 2.21%, respectively. However, the false-negative rate was 1.04% and 2.07%, respectively.

Sensitivity and specificity findings, when the children were categorized into those between the age group of 5–9 years and those in the age group of 10–14 years, are shown in Table 3. False-positive rate and false-negative rate were 1.86% and 1.51% in the 5- to 9-year group and were 2.61% and 1.68%, respectively, in the 10- to 14-year group. The correlation coefficient (R^2) between the age of the children and the

TABLE 2: Screening efficacy of teachers: validity parameters.

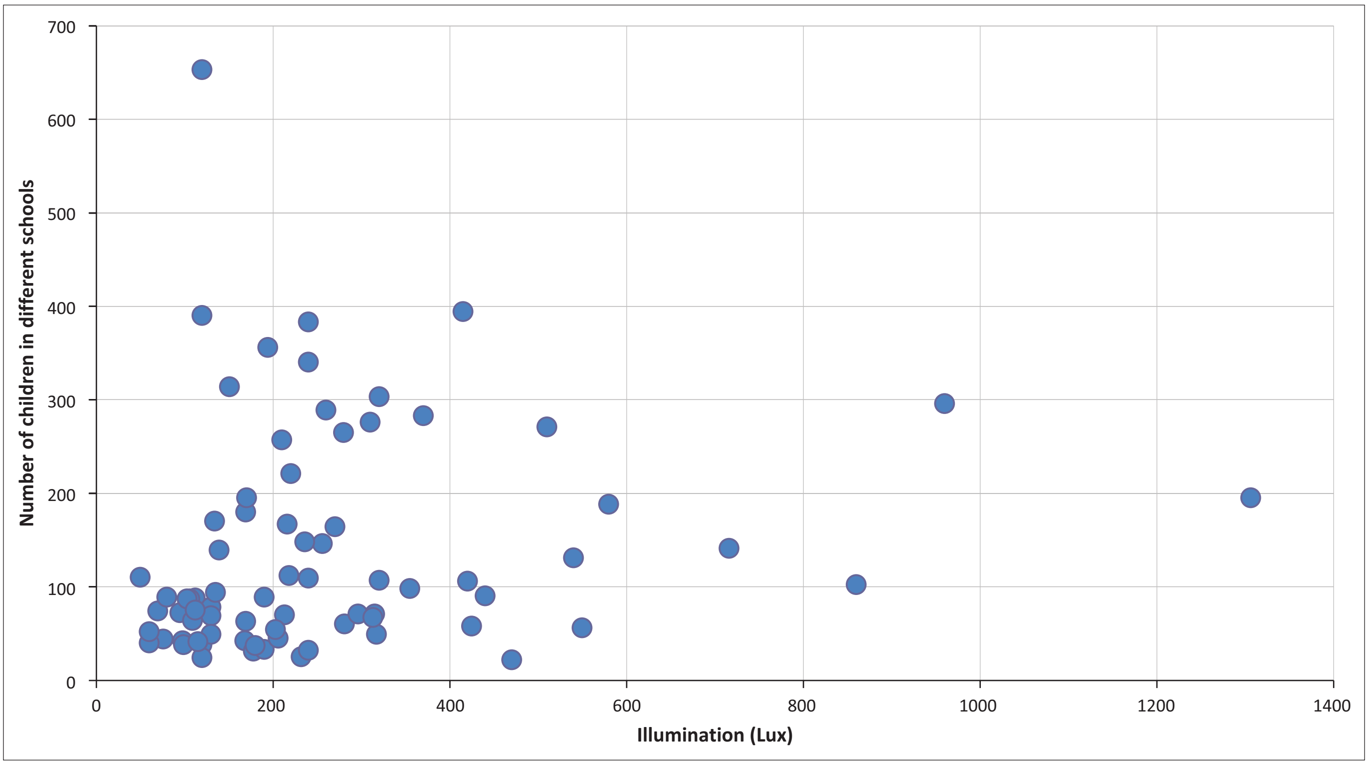
Validity measure	%	95% Confidence interval
Sensitivity	66.63	52.73–77.02
Specificity	98.33	97.49–98.95
Positive predictive value	58.33	46.13–69.81
Negative predictive value	98.33	97.49–98.95

False-positive rate = 2.15%, false-negative rate = 1.58%.

TABLE 3: Screening efficacy of the teachers: validity by age of children.

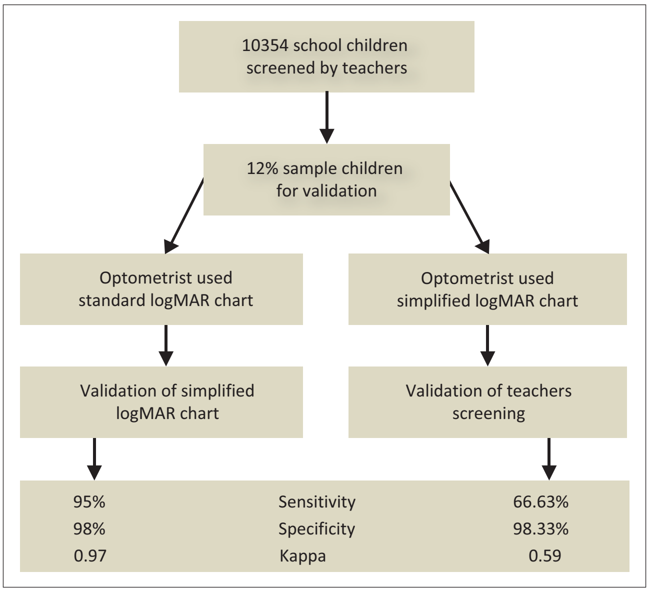
Validity measure	Primary[a]	95% Confidence interval	Middle[b]	95% Confidence interval
Sensitivity	62.9	44.93–78.52	69	49.18–84.73
Specificity	98.1	96.87–98.89	97.2	95.40–98.48
Positive predictive value	57.9	40.78–73.70	58.8	40.72–75.33
Negative predictive value	98.4	97.31–99.16	98.2	96.62–99.18

[a], 5–9 years; [b], 10–14 years.



Source: Authors' own creation

FIGURE 3: Illumination levels in the different schools set-ups.



Source: Authors' own creation

FIGURE 4: Validation of screening process.

agreement between the teacher and optometrist was found to be 0.20 in the pass group and 0.06 in the failed group.

Testing standards

A digital lux metre was used to measure the illumination levels, and the measurement was obtained by the optometrist who did the validation. When the illumination was taken into consideration in the various schools, 13% of the population was found to have been screened under standard illumination, which should be greater or equal to 480 lux, whereas 87% of the population had found to be tested under substandard illumination levels ranging from 50 to 470 lux (Figure 3).

The illumination levels did not dramatically impact on the results because actual acuity scores were not considered in this study and the study focused more on the reliability of the score based on the test methods.

Validation of screening

In the 10 354 children who were screened in total, 425 children were found to have some form of visual and/or ocular defect picked up either by the teacher or by the optometrist. Teachers used the simplified logMAR chart to screen the children and the optometrist used the simplified logMAR chart to study the efficacy of teachers screening. The average time took for the teachers to screen was 5 (±6) days. Of the 425 children, 45% were boys (or male children) and 55% were girls. Only 75% of the children underwent comprehensive eye examination at the vision centre, of whom 57% were found to have real visual or ocular defects and the rest of the children were found to be normal (Figure 4). Twenty-five percent (25%) of the children did not present for a comprehensive eye examination despite failing the school-based vision screening.

Discussion and recommendations

The WHO has recommended that a cost-effective vision-screening tool have minimum 80% sensitivity and specificity.[21] The sensitivity and specificity (95%) of our simplified logMAR chart is in accordance with the WHO standards, which validates its reliability and usability as a screening tool. It should be noted that although the results for the simplified logMAR chart (95%) were 3% lower than the standard logMAR chart (98%), the simplified logMAR chart is proved in this study to be more acceptable in vision-screening programmes because it is less time consuming.

Limburg et al.[23] studied the accuracy of screening with teachers in the year 1995. According to his study, 43% of the children failed the screening conducted by teachers and were found to have an ocular problem/s. However, in this study, we found that 57% of the children who underwent VA screening and were failed by the teachers conducting the screening had some form of ocular or visual deficits. The 57% sensitivity result (ability to identify the children with VA deficits) recorded for the teachers could be improved by providing repeated training on vision screening to the teachers. It should be noted that the teachers were not failing the students when their VA was good (specificity is more than 80%). This could be the main cost-effective factor in using the simplified logMAR chart. If the teachers inaccurately fail the students in the screening, it will lead to excessive referrals, and excessive referrals could affect the cost-effectiveness of a screening programme.

The predictive value of the positive test was almost 58% in our study as compared to 45% in the study by Limburg et al.[23] The improved outcome shown in our study could be because of the improved design of the simplified logMAR chart used in our study compared to the tumbling 'E' cards used by Limburg et al.[23]

The sensitivity and specificity were 71% and 94%, respectively, in the study by Limburg et al.[23] and 69% and 99%, respectively, in the study by Khandekar et al.[24] wherein the screening was conducted by school nurses. However, in our study there was 66% sensitivity and 98% specificity. This difference in sensitivity could be because of the large sample size in the study by Khandekar et al.[24] The high specificity in our study shows that teachers can be used effectively in screening school children to identify precisely those children who do not have vision problems. The higher false-positive rate when teachers were used than when school nurses were used could be because of the fact that teachers have less healthcare awareness than school nurses.

The age of the children did not have any influence on the screening results, which is evident from the coefficient of determination (R^2). Although there was only moderate agreement between the optometrist and teachers ($k = 0.59$), this was not influenced by the age of the children, which is apparent from the R^2 value. The decreased influence because of age could be because of the simple fact that the children were guided and comforted by their respective class teachers when the vision-screening programme was conducted.

The testing done by the optometrist was usually during the prelunch session but those by the teachers were done throughout the day. The moderate agreement between the optometrist and the teachers might have been influenced by this factor, namely the time of the day during which the screening was done. However, this difficulty was not sensed before conducting the training programme for school teachers for having instructed them to conduct screening only during the first part of the day. The cooperation of the school children and most probably their academic performance might have been influential on the moderate agreement between optometrist and teachers; however, this was not considered in this study.

The sensitivity of the vision screening was significantly higher for boys than for girls, in contrast to the study by Khandekar et al.[24] where the performance of girl children was better than the boys. The varied result could be a result of studying a rural population in this study, where girls get less exposure to proper education.

The false-positive rate in the study by Khandekar et al.[24] was 0.76%, and in this study it was 2.15%. This increased rate might have been because of the stringent criterion that was followed in this study as opposed to the lenient criterion followed in their study. The illumination levels followed during screening could not be controlled as the facilities in different schools varied in their own way. The illumination also had no major impact. This suggests that screening in a different school set up might not have any influence on the outcome, which in turn will create a cost-effective scenario and hence large-scale training programmes, facilitating VA screenings in schools. In this study, 89 teachers had screened 10 354 children on an average span of just 15 days. When huge numbers of school children can be screened in short periods of time, implementing regular school screening by teachers seem to no longer be a mammoth task. However, future testing using the simplified logMAR charts needs to consider that illumination should be controlled and remain constant for all testing as a larger illumination was noted in this study between 50 and 480 lux. Furthermore, the time when testing is done should also remain constant.

The ministry of health and family welfare have started to look in these terms; however, schools should also come forward to take this programme a step ahead and make VA screenings a routine programme for school children during every academic year.

Children who failed during the vision screening were brought to the vision centre for comprehensive evaluation by a social worker in collaboration with the school teachers and the parents. But only 75% of the children were able to come for the comprehensive evaluation at the vision centre, which is located in a place that is accessible to all schools that were covered in this study. The reasons for the failure of 25% of the children presenting for a comprehensive eye examination could be because of a lack of vision care awareness amongst the parents and their cooperation with the social worker and school teachers. This demands the need for vision care awareness amongst the parents. It should be noted that this study did not determine the prevalence of ocular defects amongst children who failed during the screening, as the primary aim was to study the efficacy of the simplified logMAR algorithm method of testing. It is therefore suggested that further studies consider determining the prevalence of eye conditions in these groups.

The study demonstrates the need for vision screening to be conducted in schools regularly by trained teachers to prevent school dropouts because of uncorrected refractive error and, on the large scale, to prevent blindness because of uncorrected refractive errors in the future citizens of India. The study confirms that using a simplified logMAR chart is efficient in screening programmes and is less time consuming than standard logMAR chart acuity measurements. Considering that the standard logMAR chart has been found to be more accurate than the Snellen chart acuity measurements,[20,22,23,24,25] it can be deduced that the simplified logMAR chart can be a reliable alternative to the logMAR chart and possibly replace the use of Snellen charts in vision-screening programmes. However, further research and comparative studies need to be conducted to verify this assumption.

Based on the findings from the study, the authors suggest that further screening programmes make use of internally illuminated vision-screening charts to avoid increased false-positive rates as well as to standardize the method of screening. Furthermore, future vision-screening studies should screen children preferably during the morning hours to enhance the children's cooperation. The cost-effectiveness of such future studies should be considered to employ this on a mass scale. Future studies can take into consideration the academic performance of the child as well as the child's performance during vision screening to predict the nature of school dropouts, which would be a larger step in a developing country like India. In addition, the benefit of spectacles as a treatment option should be studied by means of a follow-up evaluation at the end of any vision-screening programme. Large-scale vision-screening programmes at schools should be conducted on a regular basis, and this in turn should be recommended to and by the government. The authors further suggest that the sample needs to be validated regularly by an optometrist for every vision-screening programme employed by the government which involves a mass population.

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Competing interests

The authors declare that they have no competing interests which may have inappropriately influenced them in writing this article.

Authors' contributions

N.M. was the project leader and was responsible for the research design, implementation and data write-up, M.S. conducted the data analysis and contributed to the data interpretation and write-up, J.J. was responsible for data interpretation and manuscript writing, and T.S.S. was the Masters project supervisor and contributed to the overall study design, methodology, data analysis, manuscript writing and review.

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