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ORIGINAL ARTICLE

Screening for Myopia and Refractive Errors Using LogMAR Visual Acuity by Optometrists and a Simplified Visual Acuity Chart by Nurses

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ABSTRACT: *Purpose.* To compare the sensitivity and specificity of a widespread method of screening for refractive errors in Singapore schoolchildren using a simplified acuity screening chart with a more rigorous method using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart. A secondary aim is to estimate the best cutoff values for the detection of refractive errors using these two methods. *Methods.* This is a population-based study, involving 1779 schoolchildren from three schools in Singapore. Logarithm of the minimum angle of resolution (logMAR) visual acuity was recorded using a modified Bailey-Lovie chart by trained optometrists, and visual acuity measurement was also undertaken using a simplified 7-line visual acuity screening chart by school health nurses. The main outcome measures were the receiver-operating characteristics (ROC's) of logMAR and the simplified screening visual acuity to detect myopia or any refractive errors. The difference between measurements, simplified screening visual acuity − logMAR visual acuity, was calculated. *Results.* The optimal threshold using the simplified screening visual acuity chart for the detection of myopia or any refractive error was 6/12 or worse. Using logMAR visual acuity, the most efficient threshold for the detection of myopia was 0.26, but this was 0.18 for the detection of any refractive error. The area under the ROC curves was significantly greater in the case of the logMAR visual acuity measurement compared with the simplified screening visual acuity measurement for the detection of myopia or any refractive errors. The 95% limits of agreement for the two methods (simplified screening − logMAR acuity) was −0.219 to +0.339. *Conclusions.* Bearing in mind that the visual acuity measurements were performed by two different groups of professionals, visual acuity screening using the ETDRS method appears to be more accurate than the simplified charts for the detection of myopia or any refractive errors in children. (Optom Vis Sci 2004;81:684–691)

Key Words: epidemiology, human, clinical study, cross-sectional study, refractive errors, myopia, visual acuity

Refractive errors (e.g., myopia, hyperopia, and astigmatism) are important vision disorders requiring screening in children[1–3] and adults.[4–9] Although screening using a visual acuity chart is the most practical method to detect refractive errors, the methods and thresholds of screening have not been universally accepted.[10, 11] Early detection of refractive errors in children allows timely intervention in the form of spectacle correction.

For the purpose of screening elementary schoolchildren, two types of visual acuity charts have been most commonly used. The first type, the non-logarithm of the minimum angle of resolution (MAR) type of visual acuity chart,[12, 13] uses lines of English alphabets, with no universally accepted number of letters per line or standardized number of lines per chart, and has acuity values recorded as a Snellen notation (a fraction) or as a decimal.[14] The second type, from the Early Treatment Diabetic Retinopathy Study (ETDRS),[15] is a letter-counting type of visual acuity chart, which not only has a standardized number of lines and letters per line but also is able to discriminate finer levels of visual acuity and document minimum resolution acuity in a logarithmic scale (log-

MAR), which facilitates algebraic operations for compiling statistics. Despite the shortcomings of using the non-logMAR visual acuity chart[13, 16] and the advantages[17, 18] of the second type of visual acuity chart, screening traditionally has been performed in many studies using simplified visual acuity charts based on Snellen fractions. Various studies using a "Snellen" chart for screening in children have been reported in the U.S.,[19] Western Australia,[20] Denmark,[21] Oman,[22] and England[2] using an equivalent of "6/12 or worse" criterion without previous justification of this threshold. For methodological reasons discussed elsewhere,[23] these previous studies were also unable to determine the actual sensitivity and specificity of screening. In contrast, in many scientific studies, especially clinical trials,[15, 24, 25] in which visual acuity and its changes were important endpoints, visual acuity has been measured using an ETDRS type chart and documented in logMAR format. The optimal logMAR visual acuity threshold for screening referral recently has been reported.[23]

In Singapore, a multilingual society with a high rate of English literacy, simple 7-line visual acuity charts with English alphabets have been used for many years to screen for eye problems in schools. Children with visual acuity of "6/12 or worse" are referred for further assessment. The accuracy of screening using the non-logMAR type chart compared with the ETDRS chart has not yet been evaluated in a large study involving schoolchildren.

The objective of this study was to compare the sensitivity and specificity of a method of screening using a simple 7-line acuity chart with a more exacting method using the ETDRS chart for the purpose of screening for refractive errors in Singapore schoolchildren. As a secondary objective, the study aimed to estimate the best cutoff values for the detection of refractive errors.

PATIENTS AND METHODS

Subjects

The cross-sectional results of an ongoing longitudinal observational study that commenced in 1999, the Singapore Cohort Study of the Risk Factors of Myopia (SCORM),[26–28] are reported. Schoolchildren aged 8 to 11 years attending three Singapore schools (an eastern school, N = 241 or 15.9% of total school population; a northern school, N = 376 or 24.8% of the total school population; and a western school, N = 902 or 59.4% of the total school population) were recruited for this study. The ethics committee of the Singapore Eye Research Institute approved this study, and all the procedures adhered to the Declaration of Helsinki. Informed written consent was obtained from parents of the children who chose to participate.

Subjects with established serious medical conditions (e.g., cardiovascular disorders) detected before the commencement of the study or with known allergy to eye drops were excluded. Of the initial sample size of 1779 children, 260 were excluded or dropped out. The proportion of children who reported myopia before the school eye examination was similar between participants (27.3%) and nonparticipants (26.8%). One thousand five hundred nineteen schoolchildren (51.0% boys) with a mean age of 9.68 years (SD, 1.15) were recruited; 84.5% of the study participants were Chinese, 8.0% were Malays, and 7.6% were Asian Indians.

Measurement

Visual acuity was performed monocularly in each eye without optical aids. Although habitual visual acuity with pre-existing glasses also was measured, these data were not used for this report. The testers were not masked as to whether the children wore glasses.

LogMAR visual acuity was recorded using a nonilluminated ETDRS chart with Sloan letters (distance visual acuity test, 2nd ed. catalogue no. C105, Lighthouse Inc, New York, NY) with room lighting at a distance of 4 m at eye level. Optometrists and optometric students trained in the use of this chart carried out the tests in a suitable room within the compound of the schools. This chart is designed to be used at 4 m; it has 5 letters per line; and the acuity that can be measured on it ranges from logMAR 1.10 to logMAR −0.30. Chart 1 was used to measure the visual acuity of the right eyes, whereas chart 2 was used for the left eyes. The testing procedure and scoring were formulated based on the ETDRS-Fast Procedure;[18] the unique feature of this procedure is that when the subject is far from the threshold, the number of stimulus presentations is greatly reduced. The reproducibility and other details of the ETDRS-Fast Procedure have been published.[18] This method reduces testing time and yet retains the accuracy of the standard test procedure.[18] The standardized steps of the testing and the termination rule were strictly adhered to. These have been published in detail elsewhere, along with a scoring example.[23] In brief, for any line of the chart, each letter read correctly would reduce the logMAR score by 0.02 from the identifying logMAR level of the row above, although our scoring also included the increase of the visual acuity by 0.02 for any letter misread in the row(s) above.

After instillation of 0.5% proparacaine, cycloplegia was accomplished with 3 drops of topical 1% cyclopentolate in each eye, each drop at 5-minute intervals. Cycloplegic measurements were performed 30 minutes after the last drop instillation. Autorefraction was performed using a Canon RK-5 autorefractor (Canon, Tochigiken, Japan). The mean of five refractive errors was calculated, expressing all the refractive errors as negative cylinders whenever a cylinder was measured.[29]

Visual acuity recorded using the "simplified screening chart" was performed for the same subjects within a 4-month period from the aforementioned assessment. All the subjects used a simplified screening visual acuity chart with the same design. The testing environments were identical to that described previously. Visual acuity of the right eye was measured before that of the left eye. Unlike the case of the ETDRS charts, the same chart was used for the right and left eyes. School health service nurses rather than optometrists performed the testing.

The simplified screening visual acuity chart used has seven possible values corresponding to these notations: 6/6, 6/9, 6/12, 6/18, 6/24, 6/36, and 6/60. The uncorrected monocular visual acuity for each eye was tested from the top of the chart, corresponding to the 6/60 line, to the bottom of the chart, corresponding to the 6/6 line. In this article, the chart used will be referred to as the "screening chart" for simplicity. If the subject could read all the letters on the 6/6 line, the testing would stop, and the acuity was recorded as 6/6. If the subject could not read the 6/60 line, the acuity was recorded as "worse than 6/60." If the subject could only read some but not all the letters of a line, the acuity was recorded as the line above.

Definitions

Cycloplegic autorefraction as performed in our study is a well-established, standard method of evaluation for the presence of refractive errors.[30] Myopia in this study was defined as a spherical equivalent (sphere + cylinder/2) of at least −0.5 D. Hyperopia was defined as a spherical equivalent of at least +3.0 D. Astigmatism was defined as a cylinder of at least 1.0 D. A common definition of myopia of −0.5 D or worse was adopted, although we are aware that definitions of myopia vary from study to study.[31]

In the subsequent analyses, we defined myopia in at least one eye as the condition to be screened, and we also used a combined category of any refractive errors in at least one eye because in a real screening scenario in schools one would wish to detect any significant refractive error using one referral threshold.

The proportion of children testing positive for any refractive error (i.e., having myopia, hyperopia, and/or astigmatism in at least one eye) was 70.1%. Eight hundred seventy-six (57.7%) children had myopia; 514 (33.9%) children had astigmatism; and 102 (6.7%) children had hyperopia in at least one eye. Fig. 1 shows the frequency distribution of the logMAR (bottom) visual acuities and a bar chart of the visual acuities (top) from a simplified screening chart.

Three hundred ninety-one (25.7%) subjects had myopia and astigmatism; 35 (2.3%) subjects had hyperopia and astigmatism; and 2 (0.013%) subjects had hyperopia in one eye and myopia in the other. One (0.066%) subject had myopia, hyperopia, and astigmatism.

Data Analysis

The sensitivity and specificity of using the visual acuity thresholds from the simplified chart to detect myopia and any refractive error were calculated. Similarly, the sensitivity and specificity for the logMAR visual acuity thresholds were calculated.

Receiver-operating characteristic (ROC) curves were constructed for the visual acuity referral thresholds using the logMAR values and the Snellen equivalent values (excluding the acuities

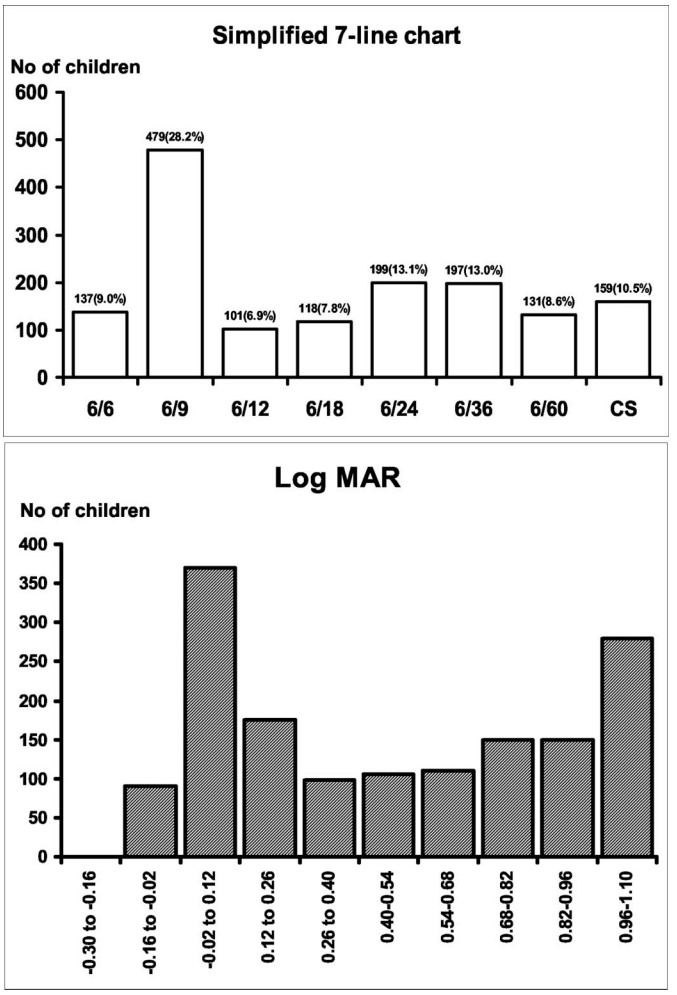

FIGURE 1.
Bar chart of simplified screening visual acuity (top) and histogram of logMAR visual acuity (bottom). logMAR, logarithm of the minimum angle of resolution.

TABLE 1.
Screening accuracy for thresholds in the simplified visual acuity test[a]

Cut-offs	Sensitivity	Specificity	Efficiency	κ (SE)[b]	κ (SP)	PPV	NPV
			In Predicting Myopia				
≥ 6/9	99.2	20.1	65.7	91.1	12.2	62.9	94.9
≥ 6/12	91.0	83.5	87.8	77.7	72.2	88.3	87.2
≥ 6/18	84.0	89.7	86.4	66.1	80.5	91.8	80.4
≥ 6/24	74.9	95.3	83.5	54.2	89.7	95.6	73.6
≥ 6/36	54.8	98.9	73.5	33.4	96.6	98.6	61.6
≥ 6/60	32.8	99.5	61.0	16.9	97.6	99.0	52.0
			In Predicting Any Refractive Errors				
≥ 6/9	98.8	24.0	73.3	86.6	16.5	71.6	91.2
≥ 6/12	85.9	91.7	87.9	65.2	86.0	95.2	77.1
≥ 6/18	77.8	95.6	83.9	53.0	91.6	97.1	69.0
≥ 6/24	67.5	98.1	77.9	40.8	95.7	98.5	60.9
≥ 6/36	48.5	99.6	65.9	24.1	98.8	99.6	50.0
≥ 6/60	28.9	99.8	53.0	12.1	99.0	99.7	42.0

[a] Figures are in %.
[b] κ (SE), kappa sensitivity; κ (SP), kappa specificity; PPV, positive predictive value; NPV, negative predictive value.

worse than 6/60). Area-under-the-curve analyses then were performed to evaluate the accuracy of the two methods of visual acuity charts to detect myopia and any refractive errors. The efficiency values and χ^2 statistics were calculated for each point along the ROC curve. Efficiency is defined as proportion of true positives and true negatives among the total number of subjects evaluated. The best compromise threshold for the detection of myopia and any refractive errors was determined using the optimal point criterion.[32] The predictive values of a "positive test" (failing the threshold) and a "negative test" (passing the threshold) were calculated for the best compromise thresholds using the two methods of measuring visual acuity.

The simplified screening visual acuity charts used in this study, unlike the ETDRS charts, do not have letters controlled for equal legibility at equal sizes and instead have a different number of letters on different lines. This precluded fine distinctions of individual visual acuity measurements for thresholds at the top of the acuity chart. Nevertheless, we attempted a comparison because many clinicians will be interested in the difference between the two methods of visual acuity assessment. For the purpose of comparing the difference between the individual logMAR and simplified visual acuity chart readings, the simplified visual acuity readings were converted to a two-decimal place format using the formula: $\log_{10}$ (1/Snellen fraction). Because the range of the logMAR chart exceeded that of the simplified screening chart, only logMAR values of 0.00 (corresponding to Snellen fraction 6/6) to logMAR values of 1.00 (corresponding to Snellen fraction 6/60) were used in these analyses. Spearman correlation coefficients and 95% confidence intervals (CIs) were calculated to compare visual acuity measurements from the two methods.

RESULTS

Tables 1 and 2 shows the screening efficacies of thresholds in the simplified screening visual acuity test and on the logMAR visual acuity test, respectively. As expected, there was an inverse relationship between sensitivity and specificity, and any adopted threshold must be a compromise between sensitivity and specificity. The highest efficiency corresponded to a cutoff point of 6/12 or worse acuity on the simplified visual acuity screening chart (for the detection of myopia or any refractive error). Using logMAR visual acuity, the most efficient threshold was 0.26 logMAR for the detection of myopia and 0.18 logMAR for the detection of any refractive error.

Table 3 compares the screening accuracy between the logMAR visual acuity and the simplified screening charts using the best

TABLE 2.
Screening accuracy corresponding to the thresholds in the logMAR visual acuity test[a]

Cut-offs	Sensitivity	Specificity	Efficiency	κ (SE)[b]	κ (SP)	PPV	NPV
In Predicting Myopia							
0.16	96.5	73.7	86.6	89.5	60.3	82.9	94.0
0.18	95.9	77.3	87.9	88.4	64.7	84.8	93.4
0.20	95.1	80.4	88.7	86.8	68.6	86.5	92.5
0.22	93.4	85.1	89.8	83.7	74.9	89.2	90.7
0.24	92.3	86.8	89.9	81.6	77.3	90.2	89.5
0.26	91.8	87.5	89.9	80.5	78.4	90.7	88.9
0.28	90.7	88.6	89.8	78.6	79.9	91.3	87.8
0.30	90.2	89.1	89.7	77.7	80.5	91.6	87.3
0.32	88.9	90.8	89.7	75.6	83.2	92.7	86.1
0.34	88.4	91.3	89.7	74.8	83.9	93.1	85.7
0.36	87.5	91.6	89.3	73.2	84.3	93.2	84.7
0.38	86.4	92.1	88.9	71.4	84.9	93.5	83.7
0.40	85.3	92.5	88.4	69.5	85.6	93.8	82.6
In Predicting Any Refractive Errors							
0.16	93.2	84.5	90.2	79.9	76.6	91.9	86.9
0.18	91.9	87.4	90.3	77.2	80.5	93.2	85.1
0.20	90.2	89.6	90.0	73.9	83.3	94.2	83.0
0.22	87.9	93.6	89.9	70.0	89.3	96.3	80.4
0.24	86.2	94.4	89.1	67.0	90.4	96.7	78.5
0.26	85.3	94.6	88.5	65.4	90.6	96.7	77.4
0.28	84.0	95.2	87.9	63.1	91.4	97.0	75.9
0.30	83.3	95.2	87.4	61.9	91.4	97.0	75.1
0.32	81.6	96.3	86.7	59.5	93.3	97.7	73.6
0.34	81.0	96.5	86.4	58.6	93.6	97.8	73.0
0.36	80.0	96.5	85.7	57.0	93.5	97.7	71.9
0.38	79.0	97.1	85.3	55.8	94.5	98.1	71.1
0.40	77.8	97.3	84.6	54.0	94.8	98.2	70.0

[a] Figures are in %.
[b] κ (SE), kappa sensitivity; κ (SP), kappa specificity; PPV, positive predictive value; NPV, negative predictive value.

TABLE 3.
Comparing the screening accuracy between logMAR (using thresholds of 0.26 and 0.18) and simplified visual acuity screening (using 6/12 as the threshold)[a]

VA Test	In Predicting Myopia				
	Threshold	Sensitivity	Specificity	PPV[b]	NPV
LogMAR	0.26	91.7 (89.7–93.4)	87.5 (84.8–89.9)	90.7 (88.5–92.4)	88.9 (86.2–91.1)
Snellen	6/12	91.0 (88.9–92.7)	83.5 (80.4–86.2)	88.3 (86.0–90.2)	87.2 (84.3–89.6)
	In Predicting Any Refractive Errors				
LogMAR	0.18	91.9 (90.0–93.4)	87.4 (84.3–90.0)	93.2 (91.5–94.6)	85.1 (81.8–87.9)
Snellen	6/12	85.9 (83.6–87.9)	91.7 (89.0–93.8)	95.2 (93.6–96.4)	77.1 (73.6–80.2)

[a] Figures are in % with 95% confidence itnervals in the parentheses.
[b] PPV, positive predictive value; NPV, negative predictive value.

compromise thresholds discovered previously. In the case of the logMAR visual acuity, there is a clear trend for superior screening accuracy for the prediction of myopia and any refractive error.

Figs. 2 and 3 show the ROC for the prediction of myopia and any refractive errors, respectively. The best threshold corresponded to the point on the curve closest to the ideal point of (100%, 100%). This essentially confirmed the interpretation of the most optimal threshold as the most efficient threshold in Tables 1 and 2. For the case of myopia detection, the area under the curve was 0.93 (95% CI, 0.91 to 0.94) and 0.96 (95% CI, 0.95 to 0.97). The difference was statistically significant ($p < 0.001$). For the case of detecting any refractive errors, the area under the curve was 0.92 (95% CI, 0.91 to 0.94) and 0.96 (95% CI, 0.95 to 0.97) for the simplified screening and logMAR visual acuities, respectively. These areas were also significantly different ($p < 0.001$). The larger area under the curves for the logMAR visual acuity essentially suggests a more efficient screening tool for any possible thresholds.

The Spearman correlation coefficient between the logMAR and the simplified screening visual acuities was 0.865 (95% CI, 0.851 to 0.878; $p < 0.01$).

The 95% limits of agreement for the two methods (simplified screening acuity − logMAR acuity) was −0.219 to +0.339. The mean difference (simplified screening acuity − logMAR acuity) was 0.060 (95% CI, 0.050 to 0.070). Throughout this range of visual acuities, the difference between the two methods was not related to the magnitude of the visual acuity measurements.

DISCUSSION

The two main findings in this study were the optimal referral thresholds for the two methods of measurement of visual acuity and the greater relative accuracy of the logMAR visual acuity measurement by optometrists to correctly predict cases of myopia and any refractive errors in children.

Bearing in mind that different types of professionals were used for the visual acuity measurements, this study showed that the optimal threshold level for using the visual acuity chart to screen for myopia is similar between the ETDRS and the simplified screening charts. In the case of the prediction of any refractive errors, the optimal threshold for referring cases on the logMAR visual acuity appears to be lower than the case for the simplified acuity charts. Nevertheless, it would appear from the data that the intuitive threshold of 6/12 used in screening seems to be the optimal level.

The determination of the optimal threshold in this study assumes the sensitivity and specificity of screening to be equally important. In populations with different prevalences of myopia and refractive errors, this assumption may not be valid. In populations with low prevalences of myopia, for example, it may be preferable to adopt a more specific test that may result in fewer false-positive referrals.

The ROC curve for the ETDRS chart was higher than the simplified visual acuity screening chart. This implied that for any threshold on the simplified chart as used by nurses, there would exist a superior threshold using the logMAR chart by optometrists in terms of sensitivity and specificity for the detection of refractive errors. This superior accuracy of the logMAR has never been demonstrated in any previous study. For given levels of sensitivity, the specificity values of the ETDRS method were superior. Referring to Tables 1 and 2, at the 91% sensitivity level, the specificity is about 88% for the ETDRS and 83.5% for the method using the simplified screening chart. Although the superiority of the ETDRS method is clear, economic considerations will dictate whether this level of benefit warrants a switch in real screening scenarios.

Camparini et al.[18] have shown that a fast ETDRS threshold testing method to measure logMAR visual acuity is valid compared with the full threshold testing method. In this article, we have taken this one step further to show that in a school population, which is a common target for screening for refractive errors, the logMAR visual acuity test, using this fast threshold algorithm, performed superiorly by optometrists compared with the current standard of visual acuity screening as performed by school nurses.

What are the possible reasons for this relative superiority in the case of screening with logMAR visual acuity measurement by optometrists? Besides the issues of standardized letter sizes and spacing, this study used the line-by-line scoring with the simplified screening visual acuity chart, a common practice with this type of visual acuity chart. In contrast, letter-by-letter scoring was performed using the ETDRS charts. Letter-by-letter scoring has been shown to result in improved test-retest variability than is permitted by line-by-line scoring.[17, 33, 34] In this particular study, the testing of the children was performed by different testers for the two

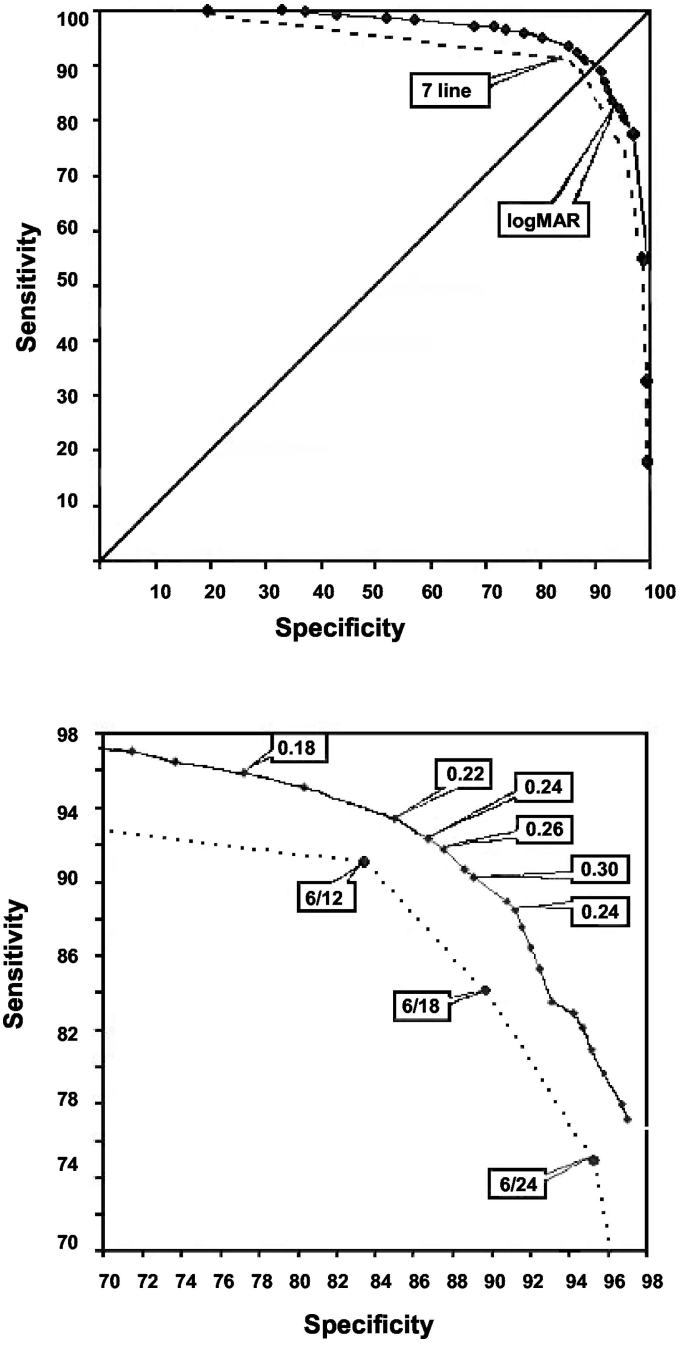

FIGURE 2.

ROC curve of logMAR and simplified 7-line screening VA's in predicting myopia (top). Magnified portion of ROC curve (bottom). ROC, receiver-operating characteristic; logMAR, logarithm of the minimum angle of resolution; VA, visual acuity.

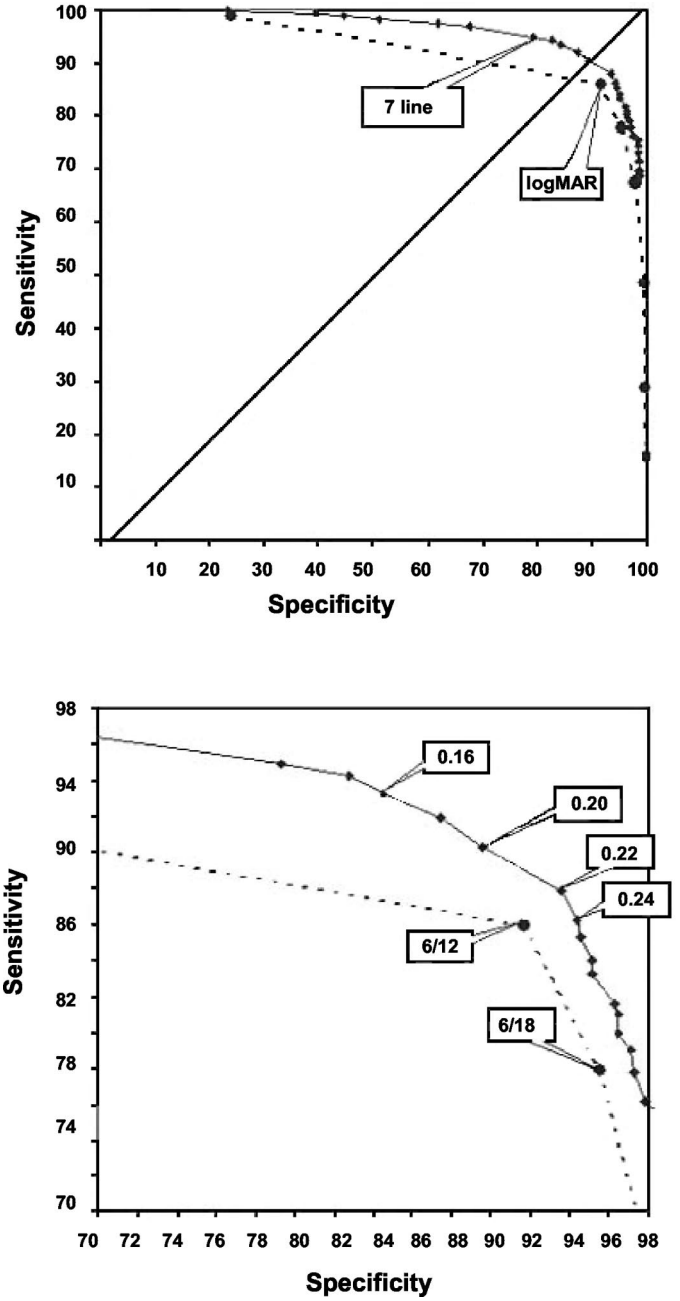

FIGURE 3.

ROC curve of logMAR and simplified 7-line screening VA's in predicting any refractive errors (top). Magnified portion of ROC curve (bottom). ROC, receiver-operating characteristic; logMAR, logarithm of the minimum angle of resolution; VA, visual acuity.

different types of visual acuity charts. It may be that optometrists could perform the testing procedure more rigorously than nurses. In the case of the simplified screening visual acuity charts, there is a possibility of some children artificially obtaining better than real visual acuity in the left eyes from the effect of memorizing the letters while reading with the right eyes.

The mean difference between the logMAR visual acuity compared with the simplified screening acuity was significantly different from zero. This suggests that visual acuities measured on the simplified charts have a tendency to be worse. A systematic difference exists despite the presence of a good correlation, which measures degree of association but not agreement.

The strengths of this study include a large sample size drawn from a population, uniformity of assessment, and objectivity of autorefraction. The use of cycloplegia excluded pseudomyopia or accommodative spasm.

Economic and logistic considerations, important in screening tests, have not been considered in this article.[35] Initial impression of the testing indicated that the time required for measuring visual

acuities with the logMAR method was slightly longer than that for the simplified screening acuity charts (unpublished data).

The study sample was not randomly selected from the school population of Singapore. The method of sampling was an issue in this study. The sensitivity and specificity profile may change with differing disease prevalences in different schools. Berkson's fallacy[36] dictates that in a sample obtained from high-risk and low-risk populations, a biased sensitivity estimate is obtained in the high-risk population and a biased specificity estimate is obtained in the low-risk population. These limitations of the study make it more difficult to generalize our findings to other populations.

A further limitation of the study is the time interval between the two methods of visual acuity assessment; in a period of up to 4 months, it is possible that some of the subjects may have had progression of their refractive errors (in particular, myopia). The direction of bias introduced is uncertain. To evaluate the possible effect of bias, the adjusted scores (κ) for sensitivity and specificity also were calculated (columns 5 and 6 in Tables 1 and 2). The result, once again, favors the logMAR visual acuity measurement.

For now, we conclude that the advantage of using the ETDRS method for screening for refractive errors is at least of statistical significance. This advantage may be related to the nature of the visual acuity chart or to the different background of the screeners. Should the cost-effectiveness of screening be equivalent for the two methods of determining visual acuity, the logMAR method of screening is preferred for detection of myopia or any refractive errors in a population like Singapore, where there is a relatively high prevalence of refractive errors, particularly myopia.

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REFERENCES

1. Blum HL, Peters HB, Bettman JW. Vision Screening for Elementary Schools: The Orinda Study. Berkeley: University of California Press, 1959.
2. Stewart-Brown S, Butler N. Visual acuity in a national sample of 10 year old children. J Epidemiol Community Health 1985;39:107–12.
3. Yang YF, Cole MD. Visual acuity testing in schools: what needs to be done. BMJ 1996;313:1053.
4. Hawkins BS. Reliability of visual acuity measurements and screening under field conditions. Ophthalmic Epidemiol 1995;2:99–106.
5. Leibowitz HM, Krueger DE, Maunder LR, Milton RC, Kini MM, Kahn HA, Nickerson RJ, Pool J, Colton TL, Ganley JP, Loewenstein JI, Dawber TR. The Framingham Eye Study monograph: an ophthalmological and epidemiological study of cataract, glaucoma, diabetic retinopathy, macular degeneration, and visual acuity in a general population of 2631 adults, 1973–1975. Surv Ophthalmol 1980;24: 335–610.
6. Ederer F, Krueger DE, Mowery RL, Connett J, Wentworth D. Lessons from the visual acuity impairment survey pilot study. Am J Public Health 1986;76:160–5.
7. Stone DH, Shannon DJ. Screening for impaired visual acuity in middle age in general practice. BMJ 1978;2:859–61.
8. Ottar WL. The ABCs of visual acuity assessment. Insight 1997;22: 81–7.
9. van der Pols JC, Bates CJ, McGraw PV, Thompson JR, Reacher M, Prentice A, Finch S. Visual acuity measurements in a national sample of British elderly people. Br J Ophthalmol 2000;84:165–70.
10. Brant JC, Nowotny M. Testing of visual acuity in young children: an evaluation of some commonly used methods. Dev Med Child Neurol 1976;18:568–76.
11. Myrowitz E. A public health perspective on vision screening. Am J Optom Physiol Opt 1984;61:359–60.
12. Bennett AG. Ophthalmic test types. A review of previous work and discussions on some controversial questions. Br J Physiol Opt 1965; 22:238–71.
13. Langrova H, Hejcmanova D, Peregrin J [How should visual acuity be measured?]. Cesk Slov Oftalmol 1996;52:158–63.
14. Oshima S. [Visual acuity testing—basis and clinical application]. Nippon Ganka Gakkai Zasshi 1987;91:27–47.
15. Early Treatment Diabetic Retinopathy Study Group. Photocoagulation for diabetic macular edema. Early Treatment Diabetic Retinopathy Study report number 1. Arch Ophthalmol 1985;103:1796–806.
16. Hirsch MJ, Wick RE. Vision of Children, an Optometric Symposium. Philadelphia: Chilton Books, 1963:333–59.
17. Bailey IL, Bullimore MA, Raasch TW, Taylor HR. Clinical grading and the effects of scaling. Invest Ophthalmol Vis Sci 1991;32: 422–32.
18. Camparini M, Cassinari P, Ferrigno L, Macaluso C. ETDRS-fast: implementing psychophysical adaptive methods to standardized visual acuity measurement with ETDRS charts. Invest Ophthalmol Vis Sci 2001;42:1226–31.
19. Bailey RN. Assessing the predictive ability of the test-positive findings of an elementary school vision screening. Optom Vis Sci 1998;75: 682–91.
20. Bremner MH. Visual acuity in the primary school child aged four to twelve years: a review of amblyopia treatment in this age group at Princess Margaret Hospital. Aust J Ophthalmol 1984;12:395–9.
21. Jensen H, Goldschmidt E. Visual acuity in Danish school children. Acta Ophthalmol (Copenh) 1986;64:187–91.
22. Lithander J, Al Kindi H, Tonjum AM. Loss of visual acuity due to eye injuries among 6292 school children in the Sultanate of Oman. Acta Ophthalmol Scand 1999;77:697–9.
23. Tong L, Saw SM, Tan D, Chia KS, Chan WY, Carkeet A, Chua WH, Hong CY. Sensitivity and specificity of visual acuity screening for refractive errors in school children. Optom Vis Sci 2002;79:650–7.
24. Macular Photocoagulation Study Group. Argon laser photocoagulation for senile macular degeneration. Results of a randomized clinical trial. Arch Ophthalmol 1982;100:912–8.
25. Central Vein Occlusion Study Group. Natural history and clinical management of central retinal vein occlusion. Arch Ophthalmol 1997;115:486–91.
26. Saw SM, Hong CY, Chia KS, Stone RA, Tan D. Nearwork and myopia in young children. Lancet 2001;357:390.
27. Saw SM, Chua WH, Hong CY, Wu HM, Chan WY, Chia KS, Stone RA, Tan D. Nearwork in early-onset myopia. Invest Ophthalmol Vis Sci 2002;43:332–9.
28. Saw SM, Zhang MZ, Hong RZ, Fu ZF, Pang MH, Tan DT. Nearwork activity, night-lights, and myopia in the Singapore-China study. Arch Ophthalmol 2002;120:620–7.
29. Thibos LN, Wheeler W, Horner D. Power vectors: an application of Fourier analysis to the description and statistical analysis of refractive error. Optom Vis Sci 1997;74:367–75.
30. Zadnik K, Mutti DO, Adams AJ. The repeatability of measurement of the ocular components. Invest Ophthalmol Vis Sci 1992;33: 2325–33.
31. Zadnik K, Mutti DO. Let's define myopia: a need for consensus? In: Myopia 2000: Proceedings of the VIII International Conference on Myopia, July 7–9, Boston, Massachusetts. Boston: New England College of Optometry, 2000:320–4.
32. Kraemer HC. Evaluating Medical Tests: Objective and Quantitative Guidelines. Newbury Park, CA: Sage Publications, 1992:63–94.

33. Vanden Bosch ME, Wall M. Visual acuity scored by the letter-by-letter or probit methods has lower retest variability than the line assignment method. Eye 1997;11:411–7.
34. Brown B, Lovie-Kitchin J. Repeated visual acuity measurement: establishing the patient's own criterion for change. Optom Vis Sci 1993;70:45–53.
35. McNeil BJ, Varady PD, Burrows BA, Adelstein SJ. Measures of clinical efficacy. Cost-effectiveness calculations in the diagnosis and treatment of hypertensive renovascular disease. N Engl J Med 1975;293:216–21.
36. Berkson J. Limitations of the application of four-fold table analysis to hospital data. Biometrics Bull 1946;2:47–53.

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