Use of Visual Acuity to Screen for Significant Refractive Errors in Adolescents

Is It Reliable?

Jody Fay Leone, BAppSci(Orth)Hons; Paul Mitchell, MD, PhD, FRANZCO; Ian George Morgan, PhD; Annette Kifley, MBBS, MAppStat; Kathryn Ailsa Rose, PhD

Objective: To detect significant refractive error in a population-based random cluster sample of 12-year-old schoolchildren by using sensitivity and specificity of uncorrected visual acuity (VA).

Methods: The Sydney Myopia Study randomly selected 21 secondary schools stratified by socioeconomic status. All year 7 students (mean age, 12.7 years) were invited to participate. We tested VA monocularly, unaided at 2.44 m, using a retroilluminated logMAR chart. Cycloplegic autorefraction (induced with instillation of cyclopentolate hydrochloride, 1%) was used to define clinically significant refractive error as a spherical equivalent of −1.00 diopters (D) or less for myopia; at least +2.00 D for hyperopia; and −1.00 D or less cylinder power for astigmatism.

Results: Data for both eyes were pooled for a total of 4497 observations. The sensitivity and specificity for all clinically significant refractive errors at the best VA cutoff level of 53 letters (6/9) were 72.2% and 93.3%, respectively. Myopia had the highest sensitivity and specificity of any of the refractive errors for detection using VA (97.8% and 97.1%, respectively, for a 45-letter VA cutoff [6/9]). The best VA cutoffs for hyperopia and astigmatism were 57 (6/6) and 55 (6/6) letters, respectively, with sensitivities of 69.2% and 77.4%, respectively, and specificities of 58.1% and 75.4%, respectively.

Conclusions: In this adolescent group, a VA cutoff of 6/9.5 or less detects myopic refractive error reliably. However, there is no reliable VA cutoff for clinically significant hyperopia or astigmatism. Improved VA screening methods are required to improve detection of these conditions. Even so, with the methods described herein, the prevalence of uncorrected VA may provide a reasonably accurate estimate of the prevalence of myopia.
Methods

Forming part of the Sydney Childhood Eye Survey, the Sydney Myopia Study was a school-based, cross-sectional survey of refraction and eye health of 2 age cohorts in 4118 Sydney schoolchildren. Detailed study methods have been described elsewhere. To obtain the older sample, 21 high schools across metropolitan Sydney were randomly selected using a stratified cluster sampling design; the stratification was by socioeconomic status. Two thousand three hundred fifty-three year 7 students (mean age, 12.7 years; range, 11.1-14.4 years) were examined, with a response rate of 75.3%. We excluded from the analysis 99 children (4.2%) with ocular pathology, amblyopia, and/or strabismus and 11 eyes with missing or incomplete data. Study approval was obtained from the Human Research Ethics Committee at the University of Sydney and from the Department of Education and Training in New South Wales, the Catholic Education Office, and private schools. The study adhered to the tenets of the Declaration of Helsinki. Informed written consent from at least 1 parent and verbal assent from each child were obtained before examination.

VA Determination

As a part of a comprehensive eye examination, uncorrected VA was measured monocularly with the use of a logMAR chart that was retroilluminated with automatic calibration to 85 candela/m² (C-SV1000: VectorVision, Dayton, Ohio) and read at 2.44 m. For each eye, VA was calculated as the number of letters read correctly from 0 (<6/60) to 70 (6/3). The procedure for the vision test was based on a staircase method to establish threshold. Threshold was confirmed by asking the child to read all the letters on the line that contained the last letter correctly read. If 4 or more letters were correctly identified on that line, then the child was asked to read the letters on the lines below until 2 or more errors were made on a line. This determined the final VA. Pointing to individual letters was avoided to prevent interference with crowding. If no letters could be read at 2.44 m, the distance to the chart was reduced to 1.22 m, giving the following 3 additional VA levels: 6/120, 6/96, and 6/76 (recorded as a raw number of letters read as −15, −10, or −5, respectively). If no letters could be identified on the chart at that distance, the VA was assessed as counting fingers at 38 cm and a VA value was recorded as −16 letters read. No child had a VA of less than counting fingers.

Cycloplegic autorefraction and keratometry were performed on all children (RK-F1 Auto Ref-Keratometer; Canon, Tokyo, Japan). Cycloglegia and dilation were induced using 1 drop each of cyclopentolate hydrochloride, 1%, and tropicamide, 1%, after instilling tetracaine hydrochloride, 1%. A second cycle of cyclopenolate and tropicamide instillation was repeated after 5 minutes. Full cycloplegia was considered obtained when the pupil was fixed and the diameter was at least 6.0 mm with no response to light or an accommodative target. Clinically significant refractive error was defined as a spherical equivalent of −1.00 diopters (D) or less for myopia and +2.00 D or more for hyperopia. Astigmatism was defined as −1.00 D or less of cylinder (DC) power, whether it occurred in isolation or in combination with myopia or hyperopia.

Statistical Analysis

Analyses were performed using pooled data from both eyes (SAS software, version 9.1; SAS Institute Inc, Cary, North Carolina). Sensitivity and specificity values and receiver operating characteristic curves were examined for a comprehensive range of VA cutoff points. The best cutoff points were taken as the point closest to the top left corner on the receiver operating characteristics curve. This cutoff point reflected the best overall discriminative ability of VA testing to distinguish between children with and without clinically significant refractive errors, based on a trade-off between sensitivity and specificity. Correlation in VA between eyes was calculated using the Spearman rank correlation coefficients. Correlation in VA with clinically significant myopia and hyperopia (spherical equivalent) was calculated using Pearson correlation coefficients. We described mean uncorrected VA for spherical refractive error with various astigmatic cutoff points for each eye with 95% confidence intervals and compared findings between eyes using the paired t test. We compared VA across subgroups for astigmatism severity within categories of spherical error by using analysis of variance; results given for the pooled data were confirmed in analyses for each eye separately.

Results

Data from both eyes were pooled for a total of 4497 observations. The average VA was 54 letters (6/6.2) and was slightly but significantly lower in girls (53.07 letters) than in boys (53.18 letters) (P < .001). Mean uncorrected VA was 53.97 (95% confidence interval, 53.48-54.47) letters in the right eyes and 54.19 (53.71-54.67) letters in the left eyes. Although this difference of less than 1 letter between eyes was statistically significant (P = .04), it would not be considered clinically significant. The distribution of VA was negatively skewed in the right and left eyes, but the VA between the 2 eyes was well correlated (Spearman rank correlation, 0.72). Of the sample of eyes, 289 (6.4%) were significantly myopic (−1.00 D or less), 244 (5.4%) were significantly hyperopic (+2.00 D or more), and 184 (4.1%) were significantly astigmatic (−1.00 D or less).

All Refractive Errors

The relationship between uncorrected VA and refractive error was quite complex (Figure 1) and appeared to vary considerably depending on the underlying spherical component. Visual acuity had only a moderate ability to detect all clinically significant refractive errors (Figure 2A and Table 1). For the detection of any significant refractive error, the sensitivity and specificity were 72.2% and 93.3%, respectively, for the best VA cutoff of 53 letters (6/6.2).

Myopia

Clinically significant myopia had the greatest sensitivity and specificity for detection by VA (97.8% and 97.1%, respectively, for a VA cutoff of 45 letters [6/9.5]) of any of the refractive errors (Figure 2B and Table 1). The relationship between increasing spherical equivalent myopia (−1.00 D or less) and decreasing VA was quite strong (Pearson correlation, 0.85; R² = 0.73).

Hyperopia

The VA cutoff for hyperopia was 57 letters (6/6.2) with low sensitivity (69.2%) and specificity (58.1%) (Figure 2C and Table 1). The relationship between spherical equivalent hyperopia (+2.00 D or more) and VA was not strong (Pearson correlation, −0.28; R² = 0.08.).
ASTIGMATISM

The best VA cutoff for clinically significant astigmatism was 55 letters (6/6), with sensitivity of 77.4% and specificity of 75.4% (Figure 2D and Table 1). In Figure 1, the relationship of VA and astigmatism has been plotted as 4 categories of severity of astigmatism. Although every −0.5 D of astigmatism caused a statistically significant reduction in VA (P < .001), a reduction in VA of 5 letters or more (equivalent to 1 line) occurred only when astigmatism was −1.00 D or less.

The impact of astigmatism independent of the sphere power was examined to quantify its effect on VA within each spherical refractive error group (Table 2). For eyes with no significant spherical refractive error (greater than −1.00 to less than +2.00 D), moderate (−1.00 to more than −1.50 DC) and high (−1.50 DC or less) levels of astigmatism significantly affected mean VA (P < .001) when compared with the reference group (0 to more than −1.00 DC). For significant hyperopia, a similar trend was noted only with a higher level of astigmatism (−1.50 DC or less) (P < .001). However, for clinically significant myopia, mean VA was not affected by any level of significant astigmatism.

Visual acuity was generally poor at detecting any clinically significant refractive error in this group of adolescent Australian schoolchildren. In contrast, VA of 6/9.5 or less had high sensitivity and specificity for myopia of −1.00 D or less. With a threshold VA set at 6/9.5 or less, almost all cases (97%) of myopia will be reliably detected and referred with high specificity. Our results suggest a slightly higher sensitivity than a previous study in the area,15 which found they would reliably refer most children with myopia (87.6%) on the basis of reduced VA (=0.28 equal to =6/12 + 1). The difference in these findings is probably related to the lower cutoff of −0.50 D or less for myopia in their study, which will tend to lower sensitivity and specificity for detection.

However, the low sensitivity of VA testing for detecting hyperopia and astigmatism with the best VA cutoff means that many children with clinically significant levels of hyperopia and astigmatism would not be referred for treatment. The best VA thresholds for detecting clinically significant hyperopia and astigmatism were 57 and 55 letters or less, respectively, which equates to normal VA of 6/6 or less, making the use of these thresholds quite meaningless. On occasion, even children with very high levels of hyperopia achieved near-normal levels of VA. If these VA values were used to identify children with hyperopic and astigmatic refractive errors, the level of overreferral would be unacceptably high.

Little systematic research has been performed on VA screening for significant hyperopia. The SCORM study of younger children (aged 7-9 years) in a population with a higher proportion of myopia and a correspondingly small proportion of children with hyperopia also reported low rates of detecting hyperopia.15 It could be argued that, because a significant number of children with hyperopia can achieve near-normal VA on testing, it is not important to detect them. However, previous research has shown that educational attainment may be reduced in children with hyperopia7-12 and that children with uncorrected hyperopia read fewer books than children with corrected hyperopia or no refractive error.16 This implies that accommodative effort may be maintained for the brief duration of VA testing but cannot be sustained for longer-term tasks such as reading books. It has been suggested that a +4.00
A lens utilized as a fogging technique could be used for screening for hyperopia. The basis of this test is to convert low to moderate hyperopia in these subjects, who normally overcome their refractive error by accommodation, into functional myopia, leading to lowered VA, whereas those with high amounts of hyperopia will be able to view letters on the VA chart and be referred. Further systematic testing of this approach in a population-based setting in comparison with the results of cycloplegic refraction is required to establish the reliability of this noninvasive method for improving the detection of hyperopia in children during screening.

The observation of only moderate sensitivity and specificity for the detection of astigmatism has been reported in other studies. In the case of astigmatism associated with myopia, the spherical myopic refractive error will reduce VA to a level at which children will be referred for fuller assessment. Because increasing levels of myopia produce significant visual impairment, the additional levels of astigmatism do not seem to further affect the VA. Using the referral value of 6/9.5 or less (the same as that for myopia) will lead to referral of some children with astigmatism of −1.00 D or less, but most will be missed. Because their level of astigmatism has not significantly reduced their level of VA, this may not be particularly important in a screening context. However, whether uncorrected astigmatism has a detrimental effect on the performance of visual tasks needs more investigation. If greater precision on levels of astigmatism is required, then screening with noncycloplegic refraction may accurately detect astigmatism.

For screening and referral purposes, a criterion of 6/9.5 or less will provide high sensitivity and specificity for the detection of any clinically significant refractive error. B, The ROC curve of myopia (spherical equivalent [SE], −1.00 dioptr [D] or less). C, The ROC curve of hyperopia (SE, +2.00 D or more). D, ROC curve of astigmatism (−1.00 D of cylinder power or less).

**Figure 2.** Receiver operating characteristic (ROC) curves of visual findings in the study sample of schoolchildren. A, The ROC curve of any clinically significant refractive error. B, The ROC curve of myopia (spherical equivalent [SE], −1.00 diopter [D] or less). C, The ROC curve of hyperopia (SE, +2.00 D or more). D, ROC curve of astigmatism (−1.00 D of cylinder power or less).
The sensitivity and specificity for predicting the presence of significant refractive error from LogMAR visual acuity (VA) in either eye are shown in Table 1. The table presents the sensitivity and specificity for each level of VA, with data stratified by level of astigmatism.

Table 1. Sensitivity and Specificity for Predicting the Presence of Significant Refractive Error From LogMAR Visual Acuity (VA) in Either Eye

<table>
<thead>
<tr>
<th>Astigmatism Level</th>
<th>Nonsignificant Spherical Error</th>
<th>Hyperopia</th>
<th>Myopia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Patients</td>
<td>VA, Mean No. of Letters (95% CI)</td>
<td>P Value</td>
</tr>
<tr>
<td>0 to more than −1.0 DC</td>
<td>3848</td>
<td>57 (57.15-57.43)</td>
<td>.001</td>
</tr>
<tr>
<td>−1.0 to more than −1.5 DC</td>
<td>126</td>
<td>52 (50.37-52.92)</td>
<td>.001</td>
</tr>
<tr>
<td>−1.50 DC or less</td>
<td>42</td>
<td>40 (38.92-42.79)</td>
<td>.001</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; DC, diopters of cylinder power; VA, visual acuity.

Table 2. Mean Uncorrected VA vs Cycloplegic Spherical Error, Stratified by Level of Astigmatism

referral of children with clinically significant levels of myopia and will provide high specificity for the referral of children with clinically significant hyperopia or astigmatism, although the sensitivity of referral will be low in these cases.

This combination of high sensitivity for myopia coupled with low sensitivity for hyperopia and astigmatism means that previous attempts to estimate the prevalence of myopia from VA data may have considerable validity. Based on 3 plausible assumptions, the prevalence of visual impairment has been used as a proxy measure of myopia in some analyses of data from the British Birth Cohort series.20,21 These assumptions are that, in children, the prevalence of refractive errors is high compared with other causes of visual impairment, that myopia is the major refractive error causing visual impairment in children, and that only myopia will be increasing in prevalence with age throughout childhood. The validity of these assumptions and the validity of the prediction of the prevalence of myopia can only be tested with data sets that include systematic measures of both VA and cycloplegic refraction, but most of the assumptions have been confirmed. Data sets with non-cycloplegic refractions are not suitable for this purpose because of the well-documented overestimation of myopia and underestimation of hyperopia that occur without cycloplegia.22 Our results demonstrate that, for the detection of myopia and changes in prevalence, data on uncorrected VA can be used with some accuracy. In addition, VA was reduced linearly with increasing severity of myopic refractive error. Thus, rigorously measured VA has the potential to provide a reasonably accurate estimate of the prevalence, and, with lesser precision, the severity of myopia in study cohorts, particularly if uncorrected VA is measured by logMAR charts and reported as number of letters rather than number of lines read. This approach may therefore be useful for analyzing changes in myopia in historical data sets in which uncorrected VA was determined but measurements of cycloplegic refractions were not performed.

In conclusion, findings from this large population-based study of 12-year-old children show that lower-than-normal VA is predominantly associated with myopia and that a VA referral criterion of 6/9.5 or less can reliably detect myopia. We have also shown that lower-than-normal VA may be used as a proxy measure for myopia severity with considerable accuracy. However, a similar VA referral criterion cannot be recommended for the detection of clinically significant astigmatism and hyperopia. Further research on detecting these forms of refractive error more reliably during screening is required.

Submitted for Publication: August 3, 2009; final revision received November 29, 2009; accepted January 8, 2010.
Correspondence: Jody Fay Leone, BAppSci(Orth) Hons, Discipline of Orthoptics, Faculty of Health Sciences, University of Sydney Cumberland Campus, PO Box 170, Lidcombe NSW 1825, Australia (jmaj7969@uni.sydney.edu.au).

Author Contributions: Dr Rose had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Financial Disclosure: None reported.

Funding/Support: This study was supported by grant 253732 from the National Health and Medical Research Council of Australia and the Vision Co-operative Research Centre; grant CEO561903 from the Australian Research Council (Dr Morgan); and National Health and Medical Research Council Biomedical (Dora Lush) postgraduate research scholarship 57173 (Ms Leone).

Role of the Sponsors: The sponsoring institutions had no role in the design and conduct of the study; in the collection, management, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript.

REFERENCES