Normative Monocular Visual Acuity for Early Treatment Diabetic Retinopathy Study Charts in Emmetropic Children 5 to 12 Years of Age

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Objective: To provide normative data for children tested with Early Treatment Diabetic Retinopathy Study (ETDRS) charts.

Design: Cross-sectional study.

Participants: A total of 252 Native American (Tohono O'odham) children aged 5 to 12 years. On the basis of cycloplegic refraction conducted on the day of testing, all were emmetropic (myopia ≤0.25 diopter [D] spherical equivalent, hyperopia ≤1.00 D spherical equivalent, and astigmatism ≤0.50 D in both eyes).

Methods: Monocular visual acuity was tested at 4 m, using 1 ETDRS chart for the right eye (RE) and another for the left eye (LE).

Main Outcome Measures: Visual acuity was scored as the total number of letters correctly identified, by naming or matching to letters on a lap card, and as the smallest letter size for which the child identified 3 of 5 letters correctly.

Results: Visual acuity results did not differ for the RE versus the LE, so data are reported for the RE only. Mean visual acuity for 5-year-olds (0.16 logarithm of the minimum angle of resolution [logMAR] [20/29]) was significantly worse than for 8-, 9-, 10-, 11-, and 12-year-olds (0.05 logMAR [20/22] or better at each age). The lower 95% prediction limit for determining whether a child has visual acuity within the normal range was 0.38 (20/48) for 5-year-olds and 0.30 (20/40) for 6- to 12-year-olds, which was reduced to 0.32 (20/42) for 5-year-olds and 0.21 (20/32) for 6- to 12-year-olds when recalculated with outlying data points removed. Mean interocular acuity difference did not vary by age, averaging less than 1 logMAR line at each age, with a lower 95% prediction limit of 0.17 log unit (1.7 logMAR lines) across all ages.

Conclusions: For monocular visual acuity based on ETDRS charts to be in the normal range, it must be better than 20/50 for 5-year-olds and better than 20/40 for 6- to 12-year-olds. Normal interocular acuity difference includes values of less than 2 logMAR lines. Normative ETDRS visual acuity values are not as good as norms reported for adults, suggesting that a child's visual acuity results should be compared with norms based on data from children, not with adult norms.

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In 1980, the Committee on Vision of the National Academy of Sciences–National Research Council recommended that visual acuity charts should use logarithmic scaling of the distance between letters on successive lines, logarithmic progression of lines, and the same number of letters on each line of the chart.[1] The Early Treatment Diabetic Retinopathy Study (ETDRS) logarithm of the minimum angle of resolution (logMAR) charts[2] meet these recommendations, and normative data are available for adults.[3–5] However, although ETDRS charts have been used in studies of children as young as 5 years of age,[6–9] only limited normative data are available for children 10 years of age and younger,[8,10–12] and no studies have examined whether norms vary with age in young children.

The purpose of the present study is to provide normative monocular visual acuity data for ETDRS charts for children who are 5 to 12 years of age and to determine whether there is a developmental trend for improvement in normative visual acuity or interocular acuity difference with age.

Materials and Methods

Subjects

Subjects were 252 children between 5 and <13 years of age whose eye examination indicated they had no ocular pathology and whose cycloplegic refraction indicated that they were emmetropic, that is, had ≤0.25 diopter (D) of myopia (spherical equivalent), ≤1.00 D of hyperopia (spherical equivalent), and ≤0.50 D of astigmatism in both eyes. The mean age of the subjects was 9.11 years (standard deviation, 2.16; range, 5.17–12.96 years).

The 252 children who met the inclusion criteria represented 33.5% of 753 children who were participants in a prospective study of astigmatism-related amblyopia that enrolled astigmatic and non-astigmatic children in grades K-2 and 4-6 who attended 1 of 5 elementary schools on the Tohono O'odham Reservation in

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southern Arizona.[7,8,13] Children in grades K-2 were examined during the 2003/2004 academic school year, and children in grades 4-6 were examined during the 2001/2002 academic school year. Data are reported for the first study-related eye examination conducted on each child.

The research followed the tenets of the Declaration of Helsinki, was Health Insurance Portability and Accountability Act compliant, and was approved by the Tohono O'odham Nation and by the institutional review board of the University of Arizona. Parents provided written, informed consent before testing.

Procedures

All children underwent an eye examination that was conducted at their school. Initially, monocular distance visual acuity was assessed at 4 m, using ETDRS logMAR charts (Precision Vision, Inc., La Salle, IL)[2] mounted in a chart illuminator box (Precision Vision, La Salle, IL). An adhesive eye patch of 5-cm–wide adhesive paper tape (3M Micropore, Minneapolis, MN) was placed over the child's left eye (LE), and the visual acuity of the right eye (RE) was tested using ETDRS chart 1 (Precision Vision catalog item no. 2121). Testing began with the top line on the chart (20/200), and the child was asked to name, or to match to letters on a lap card, all letters on each line until they reached a line on which they could not correctly identify any of the 5 letters. Masking of adjacent lines or letters was not allowed, but the tester was permitted to place a pointer beneath a letter to direct the child's attention to the letter. Visual acuity was recorded as the total number of letters correctly identified (letter by letter scoring) and as the smallest letter size at which the child identified at least 3 of the 5 letters correctly (line by line scoring). Testing of the RE was followed by testing of the LE with ETDRS chart 2 (Precision Vision catalog item no. 2122). Visual acuity scores were converted to logMAR values before analyses.

Visual acuity testing was followed by assessment of eye alignment using the cover–uncover test at distance and near, measurement of refractive error 40 to 60 minutes after instillation of 1 drop of proparacaine (0.5%) and 2 drops of cyclopentolate (1%) in each eye, and examination of the external eye and the fundus for abnormalities.[7,14] Cycloplegic refractive error was measured with the Retinomax K+ autorefractor (Nikon, Inc., Melville, NY, now manufactured by Righton Manufacturing Co., Tokyo), followed by verification of autorefractor measurements by an experienced retinoscopist (JMM) and, when possible, by subjective refinement, both under cycloplegia.[14] The final estimate, that is, the estimate confirmed by retinoscopy and, when possible, by subjective refinement, was used for determination of each subject's refractive error.

Data Analysis

The primary analyses were conducted with visual acuity data scored on the basis of the total number of letters identified correctly. By using the following formula, which assigns a value of 0.02 log unit to each letter identified, scores were transformed to logMAR values:

$$logMAR = 1.10 - 0.02T_c$$

where T_c = the total number of letters identified correctly. This letter-by-letter scoring method provides better reliability of scores than does the line-by-line scoring.[15] However, because in clinical settings visual acuity is often scored as the last line on which the patient identifies 3 letters correctly we also provide, in Tables 1 and 2 and Figure 1, data based on this line-by-line scoring method.

Separate repeated-measures analyses of variance were conducted to determine whether there was a difference in acuity across age (separate analyses for RE [tested first] and LE) and in interocular acuity difference across age.

For visual acuity results and interocular acuity difference results, 95% prediction limits[16] were calculated to determine the visual acuity or interocular acuity difference value that would indicate that a newly tested individual's score was within normal limits with 95% probability. A visual acuity score less than the lower 95% prediction limit would indicate a below-normal acuity score, and an interocular acuity difference greater than the lower 95% prediction limit would indicate an abnormally large difference in visual acuity between eyes. The formula used for the 95% prediction limits was as follows:

$$\text{Mean} + t_{\alpha/2}\left(\sqrt{1 + 1/n} \times \text{SD}\right)$$

where $t_{\alpha/2}$ = 2-tailed value for alpha of 0.05 from the Student t distribution, n = number of subjects, and SD = standard deviation.

Table 1. Mean and Standard Deviation of the Logarithm of the Minimum Angle of Resolution Recognition Visual Acuity and Snellen Equivalent for Testing with Early Treatment Diabetic Retinopathy Study Charts in the Present Study

	5 to <6 yrs n = 27	6 to <7 yrs n = 28	7 to <8 yrs n = 35	8 to <9 yrs n = 25	9 to <10 yrs n = 28	10 to <11 yrs n = 50	11 to <12 yrs n = 39	12 to <13 yrs n = 20
Present study (letter by letter scoring*)								
Mean	0.16	0.09	0.06	0.03	−0.01	0.05	0.04	−0.00
SD	0.10	0.08	0.10	0.08	0.08	0.19	0.13	0.18
Snellen equivalent	[20/29]	[20/25]	[20/23]	[20/21]	[20/20]	[20/22]	[20/22]	[20/20]
Present study (line by line scoring†)								
Mean	0.13	0.07	0.04	0.01	−0.05	0.02	0.00	−0.02
SD	0.11	0.08	0.10	0.09	0.08	0.20	0.13	0.19
Snellen equivalent	[20/27]	[20/24]	[20/22]	[20/20]	[20/18]	[20/21]	[20/20]	[20/19]

SD = standard deviation.
Subjects were emmetropic children who had ≤0.25 D of myopia (spherical equivalent), ≤1.00 D of hyperopia (spherical equivalent), and ≤0.50 D cylinder in both eyes.
*Letter by letter scoring based on number of letters correctly identified.
†Line by line scoring based on smallest line on which child identified at least 3 letters correctly.