Prevalence of Astigmatism in Native American Infants and Children

Erin M. Harvey*, Velma Dobson†, Candice E. Clifford-Donaldson‡, Tina K. Green§, Dawn H. Messer¶, and Joseph M. Miller**

ABSTRACT

Purpose. To describe the prevalence of high astigmatism in infants and young children who are members of a Native American tribe with a high prevalence of astigmatism.

Methods. SureSight autorefraction measurements were obtained for 1461 Tohono O’odham children aged 6 months to 8 years.

Results. The prevalence of astigmatism >2.00 diopters was 30% in Tohono O’odham children during infancy (6 months to <1 year of age) and was 23 to 29% at ages 2 to 7 years. However, prevalence dipped to 14% in children 1 to <2 years of age. At all ages, axis of astigmatism was with-the-rule (plus cylinder axis 90° ± 30°) in at least 94% of cases.

Conclusions. As in non-Native American populations, Tohono O’odham infants show a high prevalence of astigmatism, which decreases in the second year of life. However, the prevalence of high astigmatism in Tohono O’odham children increases by age 2 to <3 years to a level near that seen in infancy and remains at that level until at least age 8 years. Longitudinal data are needed to determine whether the increase in high astigmatism after infancy occurs in infants who had astigmatism as infants or is due to the development of high astigmatism in children who did not show astigmatism during infancy.

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Key Words: astigmatism, prevalence, infants, children, Native American

Previous research in white and Asian populations has indicated that there is a high prevalence of astigmatism in infancy,1–14 with as many as 50 to 65% of infants having astigmatism ≥1.00 diopter (D) during the first year of life.1–3,7–9 However, longitudinal studies have shown that in these populations, the amount of astigmatism decreases significantly after the first year of life,4,5,7,8,10,11,15–17 resulting in a prevalence of astigmatism ≥1.00 D that is generally reported to be <10% in elementary schoolchildren.18–25

A high prevalence of astigmatism has been documented among preschool- and school-age members of several Native American tribes,24–31 including the Tohono O’odham of southern Arizona.32–35 However, because there have been no reports concerning the prevalence of astigmatism in children younger than 3 years, it is not known whether, as in other populations, the prevalence of astigmatism in these Native American populations is higher in infancy than after the first year of life.

The purpose of this study is to provide cross-sectional data on the prevalence of high astigmatism in Tohono O’odham infants and young children. At all ages, measurements were made with the Welch-Allyn SureSight autorefractor, a hand-held instrument that has been shown to be useful in assessing refractive error in infants36 and young children.37–47 Recently, we have shown that SureSight measurements overestimate the magnitude of astigmatism in young children but that the instrument’s measurements can be used effectively to categorize astigmatism as ≤2.00 D or >2.00 D.48

METHODS

Subjects

Subjects were 1502 children aged 6 months to 8 years who were recruited through Women, Infants and Children (WIC) clinics.
Apparatus
Each child was tested with the SureSight autorefractor (software version 2.16 and 2.20, Welch Allyn Medical Products, Skaneateles Falls, NY), which is based on a Shack-Hartmann wavefront analyzer and has a working distance of 35 cm. The fixation stimulus is a circle of eight flashing green light-emitting diodes (LEDs) around a red central light. The SureSight takes five to eight measurements of the eye, after which it displays a reading for sphere, cylinder, and axis, along with a confidence rating from 1 to 9, indicating the reliability of the reading. The SureSight provides cylinder values up to 3.00 D, and displays a value of 9.99 for cylinder values >3.00 D, along with axis values. In addition, when high astigmatism is present, the SureSight sometimes takes a measurement (as indicated by the auditory cue provided by the instrument) but then turns off without reporting the value.48

Procedures
Testing was conducted in a dimly lit room, away from any windows that allowed sunlight to enter the room, as recommended by the SureSight’s manufacturer. Subjects sat either on a parent’s lap or on a chair facing the tester, who attempted to make three SureSight measurements of the child’s right eye (RE).

Data Analysis
For each child, the median cylinder value for all right eye SureSight measurements obtained was determined using vector methods. That is, measurements were transformed into J0 and J45 components,49 the median J0 and median J45 were determined, and the median J0 and J45 were transformed back into clinical notation to obtain median cylinder and axis estimates. If the SureSight measurements were out of range (9.99) and an axis value was given, the simple median of all axis measurements was used. If the SureSight measurements were out of range (instrument turned off after measurement), and no axis value was provided, axis was estimated by one of the following methods: (a) For children younger than 3 years, an overrefraction with the SureSight while the child wore cross-cylinder glasses that corrected 3.75 D of astigmatism, plus cylinder axis 90° was attempted, and if this method did not yield an estimate of axis, an axis measurement obtained with cycloplegic retinoscopy on a later day was used, if available, (b) For children aged 3 years and older, an axis measurement from cycloplegic Retinomax K+ autorefractor measurements of astigmatism obtained the same day was used.

A previous comparison of non-cycloplegic SureSight vs. cycloplegic Retinomax K+ autorefractor measurements of astigmatism in Tohono O’odham children indicated that the SureSight could be used to accurately categorize low vs. high astigmatism in most instances.48 The study indicated that when a dioptric value SureSight measurement was obtained (0.00 to 3.00 D), ≤2.00 D of astigmatism was present per the Retinomax K+ 97.4% of the time, and when an out of range SureSight result was obtained (value of 9.99 for cylinder), >2.00 D of astigmatism was present 86.6% of the time per the Retinomax K+. Therefore, in this study, astigmatism was categorized as ≤2.00 D if the median SureSight cylinder value was ≤3.00 D, >2.00 D if the SureSight displayed a value of 9.99 for cylinder, or if the instrument turned off without displaying a value after measuring refractive error in a cooperative child. Axis was categorized as with-the-rule (WTR) if plus cylinder axis was ≥60° and ≤120°, against-the-rule (ATR) if plus cylinder axis was ≤30° or ≥150°, and oblique if plus cylinder axis was >30° and <60° or >120° and <150°.

RESULTS
Subjects
Data from 41 of the 1502 children were excluded from analysis: 27 due to presence of ocular abnormalities and 14 because of SureSight estimates of astigmatism were not obtained (one due to experimenter recording error, two because of the instrument was not functioning on the test day, and 11 because of the child did not cooperate for measurements). Lack of cooperation occurred in one child in the 6 months to <1 year age range, five in the 1 to <2 years age range, four in the 2 to <3 years age range, and one in the 3 to <4 years age range. The mean age of the final sample of 1,461 children was 3.11 years (SD 2.17, range 0.50 to 7.97 years).

Prevalence of Astigmatism
Fig. 1 shows the percentage of children who had astigmatism >2.00 D in each age group, based on the SureSight measurements. Chi-square analysis indicated a significant difference across age in prevalence of astigmatism >2.00 D [χ²(7) = 24.52, p < 0.001], and pairwise χ² analyses showed a significant difference between prevalence of astigmatism >2.00 D in the 1 to <2 years age group, when compared with all other age groups (p values <0.05 before Bonferroni correction, with only the comparisons with the <1 year vs. 4 to <5 years age group comparison significant after correction). Test for trend (a consistent increase or decrease) across age yielded no significant effect (Gamma = −0.004).

Axis of Astigmatism
In all cases of astigmatism ≤2.00 D, axis of astigmatism was determined from the vector median of the SureSight measure-
creases after the first year of life and remains low. This is in contrast to data from white children, which shows a different pattern of prevalence. For cases of astigmatism >2.00 D, axis was determined from the median SureSight measurement in 310 children (86.6%), from SureSight overrefraction in nine children (2.5%), from cycloplegic Retinomax K+ autorefraction in 28 children (7.8%), and from cycloplegic retinoscopy in 6 children (1.7%). In five children, axis could not be determined.

Axis of astigmatism in the 358 children with high astigmatism, based on SureSight measurements, was WTR for all but two children, one of whom had ATR astigmatism and one of whom was found to have no astigmatism on cycloplegic retinoscopy. For the low astigmatism group, astigmatism was also overwhelmingly WTR (979/1103, 88.8%).

**DISCUSSION**

The results of this study indicate that prevalence of high astigmatism in Tohono O’odham children decreases from infancy (6 months to <1 year of age) to the second postnatal year (1 to <2 years) and then increases subsequently to levels similar to that seen in infancy. As shown in Table 1, the decrease in astigmatism that occurs after the first year of life is similar to the pattern of prevalence reported in a number of studies of white and Asian children of these ages.\(^6\,9\,11\,13\,14\) However, in Tohono O’odham children, the prevalence of astigmatism increases by age 2 to <3 years to nearly the level seen in infancy and remains there at least through age 7 years (Fig. 1 and Table 1). This is in contrast to data from white and Asian populations in which prevalence of astigmatism decreases after the first year of life and remains low.\(^6\,12\,14\)

We are currently collecting longitudinal data, which will indicate whether individual infants show a decrease in magnitude of astigmatism during the second year of life, followed by an increase in magnitude of astigmatism in subsequent years, or whether the pattern of prevalence is due to two different populations of infants, one that has high astigmatism in infancy that decreases and another that does not develop high astigmatism until after the second year of life.

Although it would be of interest to compare prevalence rates from this study with those of the previous studies shown in Table 1, this is difficult, because most previous studies used ≥1.00 D or >1.00 D as the criterion for presence of astigmatism, whereas limitations of the SureSight autorefractor\(^48\) meant that we could only quantify the prevalence of astigmatism >2.00 D. However, in a previous article, we did report a prevalence of astigmatism ≥2.00 of 22% in 3- to 5-year-old Tohono O’odham children. This value is similar to the prevalence values of 24 to 28% for astigmatism >2.00 D in Tohono O’odham children of the same age in this study.

It has been suggested that the high prevalence values found in studies of infants might be inflated by poor fixation on the part of infants, resulting in off-axis astigmatism that is ATR.\(^57\) Such off-axis astigmatism could have resulted in an underestimation of the prevalence of high WTR astigmatism in children in the 1 to <2 years age group, which was the age group with which we had most difficulty maintaining the subject’s attention and was also the age group with the lowest prevalence of astigmatism. For children aged 3 years and older, it is unlikely that off-axis astigmatism played a major role, because the prevalence values obtained (23 to 29%) were consistent with previously reported prevalence values of 32% for astigmatism ≥1.50 D\(^34\) and 22% for astigmatism ≥2.00 D\(^34\) for 3- to 5-year-old Tohono O’odham children tested with the Retinomax autorefractor, which is held approximately 5 cm from the eye, as opposed to the much greater distance (35 cm) of the SureSight.

In the children with high astigmatism, axis was WTR in 98%. This value is in agreement with previous reports of 92%\(^34\) and 99%\(^58\) WTR astigmatism in 3- to 5-year-old Tohono O’odham children. It is also consistent with reports of a high prevalence of WTR astigmatism among members of the Navajo,\(^30,31,59–61\) Sioux,\(^62\) and Zuni\(^30\) tribes.

This study has both strengths and limitations. Strengths include a large sample size, a community based rather than a clinic-based sample, and the use of the same instrument across the entire age range tested. A potential limitation is that data are based on all SureSight readings, regardless of whether the confidence rating for the reading met or did not meet the manufacturer’s recommended value of 6 or greater. This might seem to suggest that inaccurate data were included. However, data from a large group of 3- to 7-year-old Tohono O’odham children\(^48\) and data from a large group of children in Head Start\(^63\) have indicated no difference in the accuracy of SureSight measurements of astigmatism for low (<6) vs. high (≥6) confidence ratings. Another potential limitation is that the sample of children recruited through WIC clinics and Head Start may not be representative of the population as a whole, because both programs enroll only children whose families have incomes below a specified level. However, it is unlikely that this could account for the change in prevalence between the 6 months to <1 year group and the 1 to <2 years group, or the change in prevalence between the 1 to <2 years group and the 2 to <3 years group, because these children were all recruited through WIC clinics. The third potential limitation is that the study that compared SureSight and Retinomax K+ measures of astigmatism, on which the categorization of astigmatism as ≤2.00 D or >2.00 D in this study is based, was conducted on children aged 3 to 7 years. We assume that the categorization is valid for

**FIGURE 1.**

Prevalence of right eye astigmatism >2.00 diopters (D) for each age group. Total number of children in each age group was 353, 255, 155, 167, 211, 111, 147, and 62 for the 0.5 to <1, 1 to <2, 2 to <3, 3 to <4, 4 to <5, 5 to <6, 6 to <7, and 7 to <8-year-old age groups, respectively.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Percentage with astigmatism &gt;2.00 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1</td>
<td>30.3%</td>
</tr>
<tr>
<td>1.0–2</td>
<td>23.9%</td>
</tr>
<tr>
<td>2.0–3</td>
<td>24.0%</td>
</tr>
<tr>
<td>3.0–4</td>
<td>26.5%</td>
</tr>
<tr>
<td>4.0–5</td>
<td>27.9%</td>
</tr>
<tr>
<td>5.0–6</td>
<td>23.1%</td>
</tr>
<tr>
<td>6.0–7</td>
<td>29.0%</td>
</tr>
<tr>
<td>7.0–8</td>
<td>20.0%</td>
</tr>
</tbody>
</table>
TABLE 1.
Proportion of children with astigmatism ≥1.00 diopter (D) of the total sample size (in parentheses) for all studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Ethnicity</th>
<th>Technique</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 mo to &lt;1 yr</td>
</tr>
<tr>
<td>Santonastaso</td>
<td>Primarily white</td>
<td>Non-cyclo and</td>
<td>43% (33)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cyclo ret</td>
<td></td>
</tr>
<tr>
<td>Howland et al.</td>
<td>Primarily white</td>
<td>Non-cyclo</td>
<td>~40% (26)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>photoref</td>
<td></td>
</tr>
<tr>
<td>Mohindra et al.</td>
<td>Primarily white</td>
<td>Non-cyclo near</td>
<td>~39% (31)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ret</td>
<td></td>
</tr>
<tr>
<td>Fulton et al.</td>
<td>Primarily white</td>
<td>Cyclo ret</td>
<td>24% (70)</td>
</tr>
<tr>
<td>Mohindra and Held</td>
<td>Primarily white</td>
<td>Non-cyclo near</td>
<td>45% (50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ret</td>
<td></td>
</tr>
<tr>
<td>Goviaard et al.</td>
<td>Primarily white</td>
<td>Non-cyclo near</td>
<td>42% (81)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ret</td>
<td></td>
</tr>
<tr>
<td>Howland and Sayles</td>
<td>Primarily white</td>
<td>Non-cyclo</td>
<td>65% (171)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>photoref</td>
<td></td>
</tr>
<tr>
<td>Ehrlich et al.</td>
<td>Primarily white</td>
<td>Cyclo ret</td>
<td>35% (254)</td>
</tr>
<tr>
<td>Montes-Mico</td>
<td>Asian</td>
<td>Cyclo ret</td>
<td>~20% (96)</td>
</tr>
<tr>
<td>Mayer et al.</td>
<td>Primarily white</td>
<td>Cyclo ret</td>
<td>33% (97)</td>
</tr>
<tr>
<td>Pennie et al.</td>
<td>Primarily white</td>
<td>Cyclo ret</td>
<td>24% (33)</td>
</tr>
<tr>
<td>Mutti et al.</td>
<td>Primarily white</td>
<td>Cyclo ret</td>
<td>14% (24)</td>
</tr>
<tr>
<td>Lipener et al.</td>
<td>Not given—Brazilian</td>
<td>Cyclo ret</td>
<td>26% (66)</td>
</tr>
<tr>
<td>Woodruf</td>
<td>Primarily white</td>
<td>Non-cyclo ret</td>
<td>—</td>
</tr>
<tr>
<td>Ingrum et al.</td>
<td>Primarily white</td>
<td>Cyclo ret</td>
<td>30% (148)</td>
</tr>
<tr>
<td>Fan et al.</td>
<td>Asian</td>
<td>Cyclo autoref</td>
<td>—</td>
</tr>
<tr>
<td>Shankar and Bobich</td>
<td>Primarily white</td>
<td>Non-cyclo ret</td>
<td>—</td>
</tr>
<tr>
<td>Dobson et al.</td>
<td>Tohono O’odham</td>
<td>Cyclo autoref</td>
<td>—</td>
</tr>
<tr>
<td>Coleman et al.</td>
<td>Primarily white</td>
<td>Non-cyclo ret</td>
<td>—</td>
</tr>
<tr>
<td>Grönund et al.</td>
<td>Primarily white</td>
<td>Cyclo autoref</td>
<td>—</td>
</tr>
<tr>
<td>Hirsch</td>
<td>Primarily white</td>
<td>Non-cyclo ret</td>
<td>—</td>
</tr>
<tr>
<td>Woodruf</td>
<td>Primarily white</td>
<td>Non-cyclo ret</td>
<td>—</td>
</tr>
<tr>
<td>Lam and Goh</td>
<td>Asian</td>
<td>Subjective ref</td>
<td>—</td>
</tr>
<tr>
<td>Yamashita et al.</td>
<td>Asian</td>
<td>Cyclo autoref</td>
<td>—</td>
</tr>
<tr>
<td>Zhang et al.</td>
<td>Asian</td>
<td>Cyclo autoref</td>
<td>—</td>
</tr>
<tr>
<td>Huynh et al.</td>
<td>White and Asian</td>
<td>Cyclo autoref</td>
<td>—</td>
</tr>
<tr>
<td>Present study</td>
<td>Tohono O’odham</td>
<td>Non-cyclo</td>
<td>30.2% (158)</td>
</tr>
</tbody>
</table>

In this study, however, values represent the proportion of children with astigmatism ≥2.00 D because of limitations in measurements provided by the SureSight autorefractor.48

48From Banks 1980.
49≥0.75 D.
50>1.00 D.
510–1 yr.
52≥1.25 D.
53Ages not given—grades K, 1, and 2.
54Ages not given—grade 1.
55≥2.00 D.

Cyclo, cycloplegic; ret, retinoscopy; ref, refraction.

younger children also but do not have data to verify this. A final potential limitation is that we could only examine prevalence of astigmatism >2.00 D because of limitations inherent in the SureSight. We do not know whether the same pattern of prevalence would have been seen if we could have used another cutoff, e.g., ≥1.00 D.

In conclusion, the results of this study indicate that the prevalence of high astigmatism (>2.00 D) is approximately 30% in Tohono O’odham children during infancy (6 months to <1 year of age) and is nearly this high at ages 2 to 7 years. However, there is a dip in prevalence of high astigmatism to approximately 14% in children 1 to <2 years of age. Only longitudinal data from individual infants will reveal whether children who have high astigmatism in infancy show a decrease in magnitude of astigmatism during the second year of life, followed by an increase in high astigmatism as they get older. Alternatively, longitudinal data may indicate that the group of children with high astigmatism during infancy show a decrease in amount of astigmatism, as is seen in white and Asian populations,4,5,7,8,10,11,15–17 and a second group of children, who did not have high astigmatism during infancy, develop an increase in astigmatism as they age past 2 years. Additional work is also needed to determine whether the observed changes in prevalence
of refractive astigmatism are accompanied by changes in keratometric (anterior corneal) astigmatism.

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Erin M. Harvey
Department of Ophthalmology and Vision Science
The University of Arizona
655 N. Alvernon Way, Suite 108
Tucson, Arizona 85711
e-mail: emharvey@u.arizona.edu