Optical Treatment Reduces Amblyopia in Astigmatic Children Who Receive Spectacles Before Kindergarten

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Objective: To examine the effect of spectacle correction of astigmatism during preschool on best-corrected recognition visual acuity (VA), grating VA, and meridional amblyopia (difference between acuity for vertical versus horizontal gratings) once the children reach kindergarten.

Design: Comparative case series.

Participants: Seventy-three astigmatic (right eye ≥1.50 diopters [D] cylinder) Native American (Tohono O’odham) children 5 to 7 years of age. All had with-the-rule astigmatism. In 28 children, the astigmatism was simple myopic, compound myopic, or mixed (M/MA), and in 45 children, it was simple or compound hyperopic (HA).

Intervention: Thirty-nine children (Treated Group) had spectacle correction of refractive error, prescribed for full-time wear, in preschool (0.8–2.4 years before testing). Thirty-four children (Untreated Group) had no prior correction.

Main Outcome Measure: Comparison of Treated versus Untreated Groups for mean best-corrected right-eye recognition VA, measured with the Early Treatment Diabetic Retinopathy Study (ETDRS) chart and the Lea Symbols chart, for grating VA, measured with modified Teller acuity card stimuli, and for meridional amblyopia, based on grating acuity results.

Results: Mean ETDRS VA was significantly better in the Treated Group (20/37) than in the Untreated Group (20/48; \( P<0.003 \)), but the difference between mean Lea Symbols VA in the Treated Group (20/33) and in the Untreated Group (20/38) was not significant. No significant Treated versus Untreated Group differences were found for either vertical or horizontal grating acuity. Meridional amblyopia differed between the M/MA group, which showed better acuity for vertical than for horizontal gratings, and the HA group, which showed better acuity for horizontal than for vertical gratings. However, in neither the M/MA group nor the HA group was there a significant difference in magnitude of meridional amblyopia in the Treated versus the Untreated Group.

Conclusions: Spectacle correction during the preschool years results in a significant improvement in best-corrected letter recognition acuity in astigmatic children by the time they reach kindergarten. However, grating acuity was not improved and magnitude of meridional amblyopia was not reduced in children who had received early spectacle correction.

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cycloplegic refraction, or to the absence of an untreated group, to compare the results of children who had received spectacle correction.5

In the present study, we revisit the question of whether or not astigmatism-related amblyopia can be successfully treated in preschool children. In contrast with our previous study,3 duration of spectacle wear was relatively long (average, 1.8 years), best-corrected VA was measured with spectacles rather than in trial frames after cycloplegic refraction, and an untreated group of children were also tested. The overall goal of the study was to determine whether spectacle correction at age 3 to 5 years would reduce astigmatism-related amblyopia once children reach kindergarten.

Methods

Subjects

Subjects were 73 children, 5 to 7 years of age, who were kindergarten students in schools on the Tohono O’odham reservation in southern Arizona, and who were enrolled in a large study of optical treatment of astigmatism-related amblyopia. All subjects included in the present study had ≥1.50 D of with-the-rule astigmatism (plus cylinder axis ≥70° and ≤110°) in the right eye, but no significant anisometropia (≥1.50 D difference in spherical equivalent between eyes), and no ocular abnormalities (other than high refractive error), based on the study eye examination described.

Although all subjects were enrolled in a larger prospective study of optical treatment of astigmatism-related amblyopia, the data presented here are not prospective analyses, but rather a comparative case series in which we compare best-corrected visual performance in kindergarten in the astigmatic children who enrolled in the larger study in preschool and received optical correction for astigmatism (Treated Group) to the best-corrected visual performance in kindergarten in the astigmatic children who enrolled in the larger study in kindergarten and had not received any previous optical correction for astigmatism (Untreated Group).

Thirty-four astigmatic subjects (Treated Group) were enrolled in the larger study of optical treatment of astigmatism-related amblyopia when they were preschoolers (prekindergarten), during the 2005/2006 or 2006/2007 academic year. All were participants in the Tohono O’odham Head Start program. A questionnaire completed by parents at enrollment indicated that the children had never worn spectacles. These children were not enrolled in the study of optical treatment of astigmatism-related amblyopia during the prekindergarten years because (1) they were participants in Head Start before the 2005/2006 academic year when the study began, (2) their parents chose not to enroll them in the study, or (3) they were not attending Head Start at the time of year when study enrollment occurred. Of these 34 children, 13 had attended Head Start, 10 had not attended Head Start, and Head Start status was unknown for 11. Although fewer of the children in the Untreated Group had been enrolled in Head Start before kindergarten, they were similar to children in the Treated Group in ethnicity, and it is likely that they were of similar socioeconomic status because children in the 2 groups lived in the same communities and attended the same schools.

The research followed the tenets of the Declaration of Helsinki, was the Health Insurance Portability and Accountability Act of 1996 (HIPAA) 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

Eye Examinations. Eye examinations were conducted when the children were in kindergarten and included assessment of distance VA at 4 m with Early Treatment Diabetic Retinopathy Study (ETDRS) logMAR charts (Precision Vision, Inc., LaSalle, IL),11 assessment of eye alignment using the cover–uncover test at distance and near, measurement of refractive error at least 40 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.12,13 The Retinomax K+ autorefractor (Nikon, Inc., Melville, NY, now manufactured by Righton Manufacturing Co., Tokyo, Japan) was used to measure cycloplegic refractive error. The autorefractor reading was placed in a phoropter and an experienced retinoscopist (JMM) determined by retinoscopy whether there was residual with or against motion. If there was residual motion, the retinoscopist adjusted the phoroptor to eliminate the motion and recorded the result as the final estimate of refractive error.13

Vision Testing Session. At an average of 6.9 weeks (standard deviation [SD] 4.7) after the study eye examination, children were fitted with new spectacles. The spectacles contained full correction for astigmatism and myopia, as measured at the eye examination, but correction for hyperopia was reduced by one third or by 1.00 D, whichever was greater.14

Immediately after spectacles were fitted, children had best-corrected right eye VA tested with the Lea Symbols logMAR distance VA chart14 (Precision Vision, Inc., right and left eyes VA tested with the ETDRS logMAR distance VA charts,13 and right eye grating VA tested with horizontal and vertical gratings.12 Order of testing of recognition versus grating acuity was determined randomly, with the constraint that half of the children had grating acuity tested first and half had recognition acuity tested first, but assessment of Lea Symbols recognition acuity always preceded testing of ETDRS recognition acuity. During monocular testing, the fellow eye was occluded with 5-cm wide adhesive paper tape (3M Micropore, Minneapolis, MN).

Testing of Best-Corrected Recognition Acuity with the Lea Symbols Chart. Best-corrected, monocular VA was measured in the right eye at a distance of 3 m, using a 62– × 65-cm Lea
Symbols logMAR chart, mounted in an illuminator cabinet (Precision Vision, Inc.). The child was asked to identify, by naming or by matching to symbols on a lap card, the optotypes on each line (house, circle, square, heart), beginning with the top line (20/200). The tester used a pointed object positioned under the optotype to indicate the optotype that the child should identify. When the child had identified 3 optotypes on a line correctly, the tester indicated that the child should proceed to the next line. Acuity was scored as the smallest optotype size at which the child correctly identified 3 optotypes.

Testing of Best-Corrected Recognition Acuity with ETDRS Charts. Best-corrected VA was measured, first in the right eye, then in the left eye, at a distance of 4 m, using 62- × 65-cm ETDRS logMAR charts, mounted in an illuminator cabinet (Precision Vision, Inc.). The child was asked to identify all 5 optotypes (letters) on each line, beginning with the top line (20/200), and to continue until he or she could no longer identify any letter on a line. The tester used a pointer positioned under the letter to indicate the letter that the child should identify. Children could name the letter or match the letter by pointing to the correct letter on a lap card that contained the 10 letters that appear on the chart. Acuity was scored as the smallest letter size on which the child correctly identified at least 3 out of the 5 letters on the line.

Testing of Best-Corrected Resolution Acuity with Horizontal and Vertical Gratings. Horizontal and vertical grating acuity stimuli were constructed using unmounted Teller Acuity Cards II (Stereo Optical Co., Inc., Chicago, IL), and were assembled into a test book with gratings organized from lowest to highest spatial frequency, as described previously. The test book contained four 3-alternative forced-choice stimulus sets for each spatial frequency for each orientation. Each of the 3-alternative forced-choice stimulus sets was composed of three 5.6-cm (2.1°) diameter circular apertures, behind one of which was a grating, and behind 2 of which were uniform gray stimuli that had been cut from the same unmounted Teller Acuity Cards II card as the grating. Spatial frequencies ranged from 38 to 0.86 cy/cm (99.5–2.3 cy/deg at the 1.5 m test distance), in approximately half-octave steps. At each spatial frequency, horizontal and vertical gratings were presented sequentially, with order of presentation constant across all spatial frequencies for all children tested at a school. Order of orientation was counterbalanced across schools.

During testing, the child was seated with his or her eyes 1.5 m from the grating stimuli. The child’s task was to identify which of the circles (number 1, 2, or 3) contained the grating. Grating acuity for each stimulus orientation was scored as the highest spatial frequency at which a subject could correctly locate the grating on at least 3 of 4 trials.

Data Analysis
Threshold acuity scores were transformed to log values for data analysis. We used t tests to compare results in the Treated Group versus the Untreated Group for best-corrected right eye Lea Symbols acuity and best-corrected right eye ETDRS acuity.

For grating acuity analyses, subjects were further classified by type of astigmatism: myopic or mixed astigmatism (M/MA; in plus cylinder notation, sphere <0) or hyperopic astigmatism (HA; in plus cylinder notation, sphere >0). This was done because previous research has indicated that the meridional amblyopia shown by astigmatic individuals is typically related to the grating orientation for which they experienced greatest optical blur during early development. Thus, predictions regarding grating acuity depend on the individual type of astigmatism. Specifically, because subjects included in the present study had with-the-rule astigmatism (i.e., plus cylinder axis near 90°), those in the MMA group would be expected to have experienced greater blur for horizontal than for vertical stimuli, and therefore show best-corrected acuity that was worse for horizontal than for vertical stimuli. In contrast, individuals in the HA group would be expected to have experienced greater blur for vertical than for horizontal stimuli, and therefore show best-corrected acuity that was worse for vertical than for horizontal stimuli. Grating acuity scores were transformed to log values, and analysis of variance was used to evaluate the effects of treatment (Treated vs Untreated) and astigmatism type (M/MA vs HA) on acuity for vertical and horizontal stimuli, and on the difference between vertical and horizontal grating acuity (meridional amblyopia).

A subanalysis of VA results that included only data from children who were Head Start participants was conducted. Because all children in the Treated Group had participated in Head Start, but only about one third (13/34) of those in the Untreated Group were known to have participated, we were concerned VA differences between groups might have been related to a better educational status among children in the Treated Group than among children in the Untreated Group.

Results

Subjects
The mean age of subjects on the day of VA testing in the Treated Group was 6.1 years (SD, 0.3), which was not significantly different from the mean age of 6.0 years (SD, 0.3) of subjects in the Untreated Group (P=0.05). The mean age at which subjects in the Treated Group received their first spectacles was 4.3 years (SD, 0.6; range 3.3–5.2). Average duration of spectacle wear was 1.8 years (SD, 0.5; range, 0.8–2.4).

The mean amount of right eye astigmatism in the Treated Group was 2.85 D (SD, 1.10; range, 1.50–5.25), which was not significantly different from the mean amount of right eye astigmatism of 2.72 D (SD, 1.00; range, 1.50–5.00) in the Untreated Group. There was no significant difference between the proportion of children in the Treated Group with M/MA (n = 12; 30.8%) and HA (n = 27; 69.2%) astigmatism and the proportion of children in the Untreated Group with M/MA (n = 16; 47.1%) and HA (n = 18; 52.9%) astigmatism.

Best-Corrected Recognition Acuity
Results for recognition acuity are plotted in Figure 1. Mean best-corrected Lea Symbols VA was 0.22 logMAR (20/33; SD, 0.17) in the Treated Group, which was not significantly different from the mean Lea Symbols VA of 0.28 logMAR (20/38; SD, 0.16) in the Untreated Group (Figure 1). Mean best-corrected ETDRS VA was 0.26 logMAR (20/36; SD, 0.14) in the Treated Group, which was significantly better than the mean ETDRS VA of 0.38 logMAR (20/48; SD, 0.16) in the Untreated Group (t(71) = 3.36; P<0.001).

Subanalysis of Recognition Acuity Results for Kindergarten Children Who Participated in Head Start. In kindergarten, the mean amount of astigmatism in Head Start participants in the Treated Group (2.85 SD, 1.10 D; n = 39) was not significantly different from that in the Untreated Group (2.31 SD, 0.67 D; n = 13). However, as was found for the comparison of all children in both groups, the difference in ETDRS VA in kindergarten for Head Start participants in the Treated vs the Untreated Groups was significant: the mean ETDRS VA of the 39 children (all Head Start participants) in the Treated Group of 0.26 logMAR (20/36; SD, 0.14) was significantly better than the mean ETDRS VA of the 13 Head Start participants in the Untreated Group of 0.41 logMAR (20/51; SD, 0.17; t(50) = 3.00; P<0.004). Mean Lea Symbols VA did not differ between the Treated and Untreated Head Start
participants (0.22 SD, 0.17 logMAR [20/33] vs 0.31 SD, 0.18 logMAR [20/41]).

Best-Corrected Grating Acuity

Grating acuity results are plotted in Figure 2. Mean best-corrected VA for vertical stimuli was better for the Treated Group than for the Untreated Group (21.65 cy/deg [SD 0.46 octave] vs 20.01 cy/deg [SD 0.44 octave]), but this difference did not reach statistical significance ($P<0.10$).

There was a significant effect of astigmatism type: mean best-corrected acuity for vertical stimuli was significantly better for the M/MA group (24.71 cy/deg [SD 0.37 octave]) than for the HA group (18.79 cy/deg [SD 0.43 octave]; $F[1,69] = 18.84$; $P<0.001$). The interaction between treatment group and astigmatism type was not statistically significant.

Mean best-corrected acuity for horizontal stimuli did not differ significantly across treatment group (20.03 cy/deg [SD 0.47 octave] for the Treated Group vs 19.04 cy/deg [SD 0.46 octave] for the Untreated Group), nor did it differ by astigmatism type (19.04 cy/deg [SD 0.46 octave] for the M/MA group vs 19.74 cy/deg [SD 0.46 octave] for the HA group). The interaction between treatment group and astigmatism type was not statistically significant.

Meridional Amblyopia

Results for meridional amblyopia are plotted in Figure 3. There was no significant difference in amount of meridional amblyopia (difference in acuity for vertical and horizontal stimuli) for subjects in the Treated Group compared with subjects in the Untreated Group, nor was there an interaction between treatment group and astigmatism type (i.e., the effect of treatment did not vary by astigmatism type). However, there was a significant effect of astigmatism type on meridional amblyopia ($F[1,69] = 21.18$; $P<0.001$), reflecting the tendency for children in the M/MA group to have better acuity for vertical gratings, and children in the HA group to have slightly better acuity for horizontal gratings.

Discussion

The results of the present comparative case series indicate that 5- to 7-year-old astigmatic children who had been provided with spectacles before entry into kindergarten showed significantly better best-corrected recognition (letter) VA than did astigmatic children of the same age who had not received spectacles before kindergarten (Figure 1). This result was obtained with the ETDRS VA chart, which meets the standards set by the Committee on Vision for assessment of VA in adults, and is consistent with previous reports of a reduction in strabismic and anisometropic amblyopia after extended spectacle correction.

It is also
consistent with a previous report indicating a significant reduction in amblyopia after a 1-year duration of spectacle correction in 3- to 9-year-old children with bilateral hyperopic and/or astigmatic refractive amblyopia. However, the mean acuity after 1 year of spectacle correction in that study (0.11 logMAR; 20/25) was better than that of children treated for an average of 1.8 years in the present study (0.26 logMAR; 20/37), perhaps because of the excellent compliance with spectacle wear (75%–100% of waking hours) of subjects in the previous report.

Recognition acuity results obtained with the Lea Symbols chart, the optotypes for which are 4 symbols (heart, house, circle, square) rather than the 10 letters used in the ETDRS chart, also showed better acuity in the group of children who had previous spectacle wear than in the previously uncorrected children. However, the difference (20/33 vs 20/38) was only 0.5 logMAR line and was not significant, in contrast with the significant, 1.2 logMAR line difference (20/37 vs 20/48) found with the ETDRS chart. In a recent comparison of Lea Symbols and ETDRS acuity, we found that, on average, Lea Symbols acuity was 0.5 line better than ETDRS acuity, and the difference between the 2 acuity measures increased as acuity worsened (Invest Ophthalmol Vis Sci 2007 48:E-Abstract 5510). That is, the Lea Symbols acuity score overestimated the ETDRS acuity score by a greater amount in children with poor acuity than in children with good acuity. This is consistent with the present study’s finding of a smaller difference between mean acuities of the Treated versus Untreated Groups where children were tested with the Lea Symbols chart than when they were tested with the ETDRS chart.

The finding of significantly better ETDRS recognition acuity after an extended period of optical correction is in agreement with our results for older astigmatic children, who showed a significant improvement in ETDRS acuity when tested after 6 weeks of spectacle correction. Furthermore, the finding of no significant improvement in Lea Symbols acuity after an extended period of optical correction is in agreement with our previous results from 3- to 5-year-old children in this population. Previously, we had speculated that the failure to find an effect of treatment in the younger children was due to variability introduced by the fact that the younger children in the previous study were tested while they were cyclopeged and wearing trial frames. However, the results of the present study, in which children were tested noncyclopeged and while wearing their own spectacles, suggest that differences in the sensitivity of the ETDRS chart and the Lea Symbols chart to detect acuity deficits, rather than increased variability, may have produced the seemingly inconsistent pattern of results from older versus younger children in prior studies.

Grating Acuity Results

Grating acuity results were analyzed for 2 subgroups of children: (1) those whose astigmatism was myopic or mixed (M/MA), who would be expected to have experienced more blur for horizontal than for vertical stimuli, and (2) those whose astigmatism was hyperopic (HA), who would be expected to have experienced more blur for vertical than for horizontal stimuli. Results (Figure 2) indicated that subjects in the M/MA group had substantially better best-corrected acuity for vertical gratings than for horizontal gratings, and that subjects in the HA group had slightly, but not significantly, better acuity for horizontal than for vertical stimuli. Thus, in agreement with previous results from younger and older astigmatic children in this population, children in the M/MA group showed evidence of meridional amblyopia, whereas those in the HA group showed minimal evidence for meridional amblyopia. However, previous studies found reduced grating acuity for both vertical and horizontal stimuli in HA groups of children, relative to a nonastigmatic control group. No difference was found in grating acuity between the Treated Group and the Untreated Group. The failure to find an effect of treatment on grating acuity differs from results reported previously in older children in this population.

Similarly, no difference was found in meridional amblyopia between the Treated Group and the Untreated Group. The failure to find a reduction in meridional amblyopia after treatment in the present study is consistent with results from both younger and older astigmatic children in this population. However, the results are not consistent with reports, based on a small number of astigmatic adults, indicating that correction of astigmatism before the age of 7 years prevents the development of meridional amblyopia. Perhaps longer duration or more attention to compliance with spectacle wear than occurred in the present study is required to eliminate meridional amblyopia.

Strengths and Limitations

This study has both strengths and limitations. The first strength is that subjects in the Treated and Untreated Groups were similar in age and in amount of astigmatism. Although fewer children in the Untreated Group than in the Treated Group had participated in Head Start, a subanalysis of data from only children who had been Head Start participants showed that the difference in ETDRS VA results was still present. This suggests that differences in educational status between the Treated and Untreated Groups did not produce the better ETDRS VA that was shown by children in the Treated Group. Thus, age, amount of astigmatism, and educational status were unlikely to have played a role in the differences found between groups in recognition acuity (Figure 1). A second strength is that all subjects were tested according to a standardized protocol, in spectacles that were determined by the same protocol and were dispensed at the time of testing.

A limitation of the study is the lack of any reliable compliance measure for spectacle-wearing of children in the Treated Group. Because all children were study participants at the time their spectacles were dispensed in preschool, we know how their correction was determined and exactly when they first received spectacles. But we do not know the
consistency with which they wore the spectacles in the 0.8 to 2.4 years between the initial dispensing of spectacles and the tests of VA conducted when they reached kindergarten. If some children in the Treated Group had poor compliance with spectacle wear, it could have resulted in less-than-maximal reduction in amblyopia before kindergarten. Thus, the results of the study reflect effectiveness of prescribing and providing spectacles to preschool children with astigmatism (i.e., success in actual clinical practice), rather than efficacy (i.e., success resulting from full compliance with spectacle wear). However, children in the Treated Group were able to get replacement spectacles quickly if their spectacles became lost or broken. Thus, these children may have worn their spectacles more consistently than the typical clinic patient, for whom securing replacement spectacles requires parental action and payment. However, it would be of interest to have an objective monitoring system, such as that used for occlusion therapy in the Monitored Occlusion Treatment for Amblyopia Study,\textsuperscript{27} to determine whether amount of time during the day that spectacles were worn was related to the magnitude of improvement that occurred in best-corrected VA over the treatment interval.

A second limitation is that, because subjects were classified according to type of astigmatism (M/MA vs HA) for the analyses of grating acuity and meridional amblyopia, sample size for these analyses was smaller than the sample size used for analyses of recognition acuity results. Therefore, although treated subjects showed better acuity for both vertical and horizontal gratings than the untreated subjects (Figure 2), the relatively small sample size may have limited the power to detect a significant effect of treatment for grating acuity measures.

A third limitation is that testing of children in the Untreated Group typically occurred a year before testing of children in the Treated Group. This is because some of the children in the Untreated Group were participants in Head Start during the academic year (2004/2005) that preceded initiation of the present study’s eye examinations of Head Start participants.

A fourth limitation is that we do not know the refractive errors of children in the Untreated Group when they were in preschool, that is, whether their refractive errors before kindergarten were similar to those of children in the Treated Group. Although children in the Treated and Untreated Groups had equivalent amounts of astigmatism in kindergarten, they may have differed in the amount of astigmatism that was present when they were in preschool. An alternative study design would have been to conduct a trial in which children who enrolled in the study during preschool were randomly assigned to have their refractive error corrected or not corrected. However, we did not feel that failing to provide spectacle correction to young children with high refractive error is an ethical option, because there is ample evidence to suggest that amblyopia has already developed by the time children with high astigmatism reach preschool.

In conclusion, the results of the present study indicate that young astigmatic children benefit if they receive spectacle correction before entry into kindergarten. Average best-corrected letter recognition acuity in the group of children who received spectacles before kindergarten was better than 20/40, whereas astigmatic children who did not receive spectacles until they reached kindergarten showed clear evidence of amblyopia, with an average best-corrected letter recognition acuity of approximately 20/50. Thus, the present results support the implementation of refractive error screening programs for preschool children who are members of populations in which there is a high prevalence of astigmatism.

Previous research has shown that astigmatism-related amblyopia is already present in many astigmatic children by the time they reach the preschool years.\textsuperscript{5} Although the present study suggests that optical treatment during preschool years results in a reduction in amblyopia by the time children reach kindergarten, future studies are needed to examine the effects of optical correction before the preschool years, preferably before the development of amblyopia, to determine if there is an additional benefit of even earlier optical correction. It would also be of interest to determine whether the difference in average letter recognition acuity between children in the Treated and Untreated Groups is eliminated by the time they reach first grade, after the Untreated Group had had approximately a year of spectacle wear.

References


Footnotes and Financial Disclosures

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