Ametropia, Preschoolers' Cognitive Abilities, and Effects of Spectacle Correction

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Objectives: To examine cognitive abilities of low-income preschoolers with uncorrected ametropia and effects of spectacle correction.

Methods: Baseline and 6-week data from a longitudinal controlled study were analyzed. Subjects were 70 preschoolers (mean age, 4.6 years; 60.0% were female; and 85.7% were Latino), including 35 children with previously uncorrected ametropia and 35 emmetropic control subjects. Ametropia was defined as bilateral hyperopia of 4.00 diopters (D) or more in children aged 3 to 5 years, astigmatism of 2.00 D or more in children aged 3 years and 1.50 D or more in children aged 4 and 5 years, or a combination of both. Emmetropia was defined as 2.00 sphere diopters or less and 1.00 cylinder diopter or less in both eyes. Ametropes were assessed before and 6 weeks after correction and compared with control subjects. Primary and secondary outcome measures were Beery-Buktenica Developmental Test of Visual-Motor Integration and Wechsler Preschool and Primary Scale of Intelligence–Revised scores, respectively.

Results: At baseline, uncorrected ametropes scored significantly lower on the Beery-Buktenica Developmental Test of Visual-Motor Integration ($P = .005$) and the Wechsler Preschool and Primary Scale of Intelligence–Revised performance scale ($P = .01$). After 6 weeks of correction, the ametropic group significantly improved on the Beery-Buktenica Developmental Test of Visual-Motor Integration compared with emmetropic control subjects ($P = .02$).

Conclusions: Preschoolers with uncorrected ametropia had significant reduction in visual-motor function. Wearing spectacles for 6 weeks improved Beery-Buktenica Developmental Test of Visual-Motor Integration scores to emmetropic levels.

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ALTHOUGH THERE HAVE BEEN studies examining the relationship of refractive errors and academic performance in elementary school children,[1-5] few have looked at ametropia and cognitive abilities in younger children. In elementary school children, one study[1] found no relation between refractive errors and scores on tests of academic achievement and reading, whereas others[2-7] found associations between lower academic achievement scores and hyperopia of 1.25 to 3.00 diopters (D) but not myopia. Younger children (aged 9 months to 5.5 years) with hyperopia of 3.50 D or greater in at least 1 axis were found to have modest but consistent reductions in scores on the Movement Assessment Battery for Children involving visual-motor function.[8,9]

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We conducted a study to add to previous research in preschool children[8,9] and to determine the relevance for clinical practice in the care of preschool children by assessing the cognitive abilities of ametropic children aged 3 to 5 years with a battery of widely used tests that are standardized, age-normed, normalized developmental measures of cognitive abilities and are predictive of academic achievement.[10,11] Scores on tests performed by children before and 6 weeks after wearing optical correction were compared with those of control subjects assessed at comparable times.

METHODS

The protocol for this longitudinal controlled study was approved by the University of California, San Diego Human Research Protections Program Institutional Review Board as well as the Human Subjects Research Committees of the San Diego Unified School District and the Neighborhood House Association Head Start. Written informed parental consent was obtained.

The study was designed to determine the cognitive abilities of ametropic children before and 6 weeks after wearing corrective lenses in comparison with those of group-matched emmetropic control subjects assessed at the comparable times. The main comparison was between the change on cognitive test scores in the ametropic group before and 6 weeks after wearing optical correction and that in the emmetropic control group.

PARTICIPANTS

Participants in this study were recruited from children seen sequentially on the mobile eye clinic of the University of California, San Diego that serves preschool children attending Head Start (federally funded) and the San Diego Unified School District (state funded). Children in both programs are required to be from low-income families. The curriculum is determined by the preschool administration and is similarly standardized with structured classroom activities. Both programs often use the same facilities. The 70 subjects were enrolled between January 21, 2003, and May 24, 2006. Inclusion criteria for the ametropic group were uncorrected bilateral hyperopia of 4.00 D or more in children aged 3 to 5 years, astigmatism of 2.00 D or more in children aged 3 years and 1.50 D or more in children aged 4 to 5 years, or a combination of both. Inclusion criteria for emmetropes were bilateral refractive error of 2.00 sphere diopters or less and 1.00 cylinder diopter or less in both eyes. All of the subjects also met the following criteria: (1) had no other eye abnormalities (eg, did not have strabismus, amblyopia [defined as a 2-line visual acuity difference between eyes], cataract, or glaucoma and did not previously wear glasses); (2) had no developmental problems, eg, autism, hearing loss, cerebral palsy, or mental retardation on preschool health records; (3) were aged 3, 4, or 5 years; and (4) used English or Spanish as the primary language.

Overall, there were 81 eligible children. Of these, 5 had parents who declined and 6 moved. Nonparticipants were not significantly different from participants in demographic and vision characteristics ($P > .05$). The sample comprised 35 subjects with previously uncorrected ametropia and 35 emmetropic subjects.

PROCEDURES AND MEASURES

Refraction, Prescription of Glasses, and Compliance

Eye examinations were performed by optometrists in the department's mobile eye clinic. Cycloplegia was induced with a combination of phenylephrine hydrochloride (1.6%), tropicamide (0.167%), and cyclopentolate hydrochloride (1.3%).[12] After waiting a minimum of 30 minutes, all of the children received retinoscopy under cycloplegia and most had autorefraction (Nikon Retinomax K-plus 2; Nikon, Melville, New York) and manifest refraction. The lowest value of refractive error on any test was used to meet study criteria. Visual acuity was assessed before correction prior to cycloplegia and after correction under cycloplegia at near using the Allen Preschool Vision Test and at far using B-VAT PC version 2.3 software (Medtronic Solan, Jacksonville, Florida).

When glasses were prescribed, full astigmatic errors were corrected and hyperopic refractive errors were undercorrected by 1.50 D to 2.50 D or by 3.00 D if the hyperopic component was 7.00 D or more.[13,14] Children's compliance to wearing glasses was monitored 3 weeks after receiving glasses using a questionnaire completed by parents. Compliance was assessed on the basis of answers to the question "Does your child wear his/her glasses?" on a scale of always, most of the time, sometimes, and never. A child reported as wearing glasses at least most of the time was considered compliant.

Tests of Cognitive Abilities and Behavior

Bilingual English- and Spanish-speaking psychometrists performed developmental assessments at 2 points at the child's preschool or home in accordance with standard highly structured methods.[10,11,15] Baseline assessments were conducted an average of 2 weeks after the eye examination. At the end of developmental testing, the prescribed glasses were then given to the child. The second assessment was performed 6 weeks after wearing corrective lenses for ametropic children and at a comparable interval for control subjects.

The Beery-Buktenica Developmental Test of Visual-Motor Integration[10] (VMI) is a nonverbal, standardized, age-normed test of visual-motor integration widely used in assessment of visual perception and eye-hand coordination in children aged 3 to 7 years. The child is required to copy 18 large geometric figures in a sequence of increasing difficulty (eg, from drawing lines, to closed figures [eg, circles and squares], to embedded figures [eg, 3 overlapping circles], to joined figures [eg, a square touching a circle]). The child must satisfy all of the criteria exactly as specified in the manual to receive a score of 1 point. Possible scores range from 45 to 155, with higher scores indicating higher performance. The VMI has been found to be free of cultural biases and to be predictive of school achievement, especially in children from low socioeconomic groups.[10]

The Wechsler Preschool and Primary Scale of Intelligence–Revised[11] (WPPSI-R) is a widely used standardized developmental test of cognitive abilities in children aged 3 to 7 years. It is age normed, ie, raw scores are transformed into equivalent scaled scores on the basis of norms defined for each age range. This allows for comparison of children's scores at different ages and times. Possible scores range from 41 to 160, with higher scores indicating higher cognitive abilities (mean [SD] standardized score, 100 [15]). Credit is given for each item only when the child's answer matches the correct answers listed in the WPPSI-R manual. The WPPSI-R full scale comprises verbal and performance scales (**Table 1**). The verbal scale contains information, comprehension, arithmetic, vocabulary, similarities, and sentences subtests that are free from sensorimotor demand. Performance scale subtests are object assembly, geometric design, block design, mazes, picture completion, and animal pegs. Some degree of eye-hand coordination is required for performance scale subtests except for picture completion, a 28-item subtest for which only vision is required to identify the missing component in a picture. Each WPPSI-R subtest has a mean (SD) scaled score of 10 (3).[11] Performance on the WPPSI-R is strongly correlated with intellectual abilities as measured by other tests and academic achievement, especially reading abilities.[11] The WPPSI-R has been successfully translated into Spanish for research in investigations in Latin America.[15] For this study, the WPPSI-R was translated by a Spanish-speaking clinical psychologist (Brian Lee Ford, PhD) experienced in working with the study population.

Both the VMI and the WPPSI-R use materials (ie, geometric figures, images, and objects) that are large, high contrast, and/or brightly colored.

The Child Behavior Checklist 1.5-5 English/Spanish[16] (CBCL) is completed by parents and is widely used in clinical research to assess behavioral problems. Referral to a mental health professional is recommended at a standard score of 65.

Demographic and family health information came from standard medical questionnaires completed by parents.

Table 1. Description of the Performance and Verbal Subtests of the Wechsler Preschool and Primary Scale of Intelligence–Revised[a]

Test or Subtest	Description
WPPSI-R performance scale	Six subtests involving visual-motor integration skills, spatial analysis, visual perception, and planning.
Object assembly	Fit the pieces of a puzzle together to form a meaningful whole within time limits.
Geometric design	Draw a geometric figure, eg, a square, from a printed model.
Block design	Analyze and reproduce within time limits patterns made from flat, red and white blocks.
Mazes	Solve pencil-and-paper mazes of increasing difficulty under time constraints.
Picture completion	Identify a missing part in pictures of common objects or events.
Animal pegs	Place pegs of the correct colors in holes below a series of pictured animals.
WPPSI-R verbal scale	Six subtests involving verbal abilities.
Information	Demonstrate knowledge about events or objects in the environment.
Comprehension	Express in words understanding of the reasons for actions and the consequences of events.
Arithmetic	Demonstrate understanding of basic quantitative concepts, eg, counting blocks and solving word problems.
Vocabulary	Provide verbal definitions for orally presented words.
Similarities	Demonstrate an understanding of similarity.
Sentences	Repeat verbatim a sentence read aloud by the experimenter.

Abbreviation: WPPSI-R, Wechsler Preschool and Primary Scale of Intelligence–Revised.
[a] Credit is given for each item only when the child's answer matches the correct answers that are listed in the WPPSI-R manual.

Table 2. Demographic and Health Characteristics of Corrected Ametropic and Emmetropic Groups

Characteristic	Ametropic Group (n=35)	Emmetropic Group (n=35)	*P* Value
Age, y			
Mean (SD)	4.6 (0.6)	4.7 (0.5)	.31
Median (range)	4.7 (3.1-5.8)	4.8 (3.1-6.0)	
Sex, No. (%)			
Female	22 (62.9)	20 (57.1)	.81
Male	13 (37.1)	12 (42.9)	
Ethnicity, No. (%)			
Hispanic	29 (82.9)	31 (88.6)	.73
Other	6 (17.1)	4 (11.4)	
Primary language, No. (%)			
English	15 (42.9)	19 (54.3)	.47
Spanish	20 (57.15.9)	16 (45.7)	
Current health problems, No. (%)			
No	33 (94.3)	31 (88.6)	.67
Yes	2 (5.7)	4 (11.4)	
Birth weight, kg			
Mean (SD)	3.0 (0.6)	3.3 (0.5)	.09
Median (range)	3.1 (1.4-4.2)	3.3 (2.2-4.4)	
Parents at home, No. (%)			
Mother	30 (85.7)	32 (91.4)	.71
Father	25 (71.4)	21 (60.0)	.45
Both	20 (57.1)	18 (51.4)	.81
Mother's education, No. (%)			
$<$ High school	16 (45.7)	13 (37.1)	.63
$\geq$ High school	19 (54.3)	22 (62.9)	
Father's education, No. (%)			
$<$ High school	12 (34.3)	16 (45.7)	.46
$\geq$ High school	23 (65.7)	19 (54.3)	
Range of household income, No. (%)			
$0-$25 000	25 (71.4)	23 (65.7)	.80
$25 000-$45 000	10 (28.5)	12 (34.3)	
No. of children at home, No. (%)			
$\leq$ 2	16 (45.7)	21 (60.0)	.34
$\geq$ 3	19 (54.3)	14 (40.0)	

STATISTICAL ANALYSES

Statistical analyses were conducted using Statistica for Windows version 6.1 statistical software (Statsoft, Tulsa, Oklahoma). Demographic and health characteristics listed in **Table 2** were considered as potential confounding variables and were assessed as possible covariates. Continuous variables were compared using 2-sample *t* tests or using Wilcoxon rank sum tests if normality and homogeneity of variance assumptions were not met. Discrete variables were compared using χ^2 analysis and Fisher exact test. If differences between groups were detected and factors were found to be associated with the outcome variables, confounders were included as covariates in an analysis of covariance model.

The VMI score was the primary outcome measure. Secondary outcome measures were the WPPSI-R and CBCL scores. A general linear model was applied on each outcome measure to allow for inclusion of covariates in the analysis. If no significant covariate was found, repeated-measures analyses of variance (ANOVAs) were performed on overall standardized test scores of outcome measures with 1 within-subject factor, time (2 levels: baseline and reassessment), and 1 between-subject factor, group (2 levels: ametropia with correction vs emmetropia). The time × group interaction was used to compare slopes or change in scores between ametropic and emmetropic groups. Group × subtests multivariate ANOVAs on subtests of the WPPSI-R performance and verbal scales were performed. If assumptions of normality and homogeneity of variances were not met for each variable, a nonparametric test, ie, Mann-Whitney rank sum test, was performed on the difference scores. Comparisons with normed values were performed with 1-sample *t* tests.

Associations between ophthalmic measures and developmental outcome variables, ie, VMI, WPPSI-R, and CBCL scores, were examined using Pearson *r* or using Spearman ρ if assumption of normality was not met. Analyses were reported only on visual acuity before correction prior to cycloplegia at far distance because only this measure detected a difference between ametropes and emmetropes. Refractive errors were transformed based on a Fourier analysis into a power vector representation of spherocylinders to provide 1 value for statistical analyses that captures interactions between the 3 components of refractive error.[17-20] The statistical significance level was set at $P = .05$. With the sample size of 70 subjects, the power was 0.61 to detect the observed effect size of 0.55, a standardized difference of 6 points on the primary outcome measure, ie, the VMI score.

RESULTS

DESCRIPTIVE ANALYSES

The sample comprised 70 (35 ametropic and 35 emmetropic) low-income children enrolled in Head Start and pub-

Table 3. Comparison of Clinical Characteristics of Ametropic vs Emmetropic Groups

Clinical Characteristic	Ametropic Group (n=35)	Emmetropic Group (n=35)
Right eye		
Refractive error, mean (SD)	+4.05−1.94×1 (+2.81−1.42×10)	+1.23−0.13×145 (+0.74−0.34×38)
Spherical equivalents		
Mean (SD)	3.10 (2.10)	1.20 (0.57)
Median (range)	3.50 (−1.00 to 8.25)	1.13 (0.25 to 2.75)
Spherocylindrical power vector		
Mean (SD)	3.57 (1.60)	1.20 (0.60)
Median (range)	4.60 (1.00 to 8.27)	1.20 (0.35 to 2.75)
LogMAR visual acuity		
Mean (SD)	0.50 (0.25)	0.20 (0.09)
Median (range)	0.50 (0.00 to 1.00)	0.18 (0.00 to 0.30)
Left eye		
Refractive error, mean (SD)	+4.19−2.12×179 (+2.96−1.56×9)	1.28−0.09×126 (+0.83−0.45×41)
Spherical equivalents		
Mean (SD)	3.10 (2.20)	1.24 (0.60)
Median (range)	3.00 (−1.25 to 7.50)	1.14 (0.00 to 2.50)
Spherocylindrical power vector		
Mean (SD)	3.70 (1.60)	1.20 (0.60)
Median (range)	3.20 (1.25 to 7.50)	1.10 (0.00 to 2.53)
LogMAR visual acuity		
Mean (SD)	0.54 (0.28)	0.18 (0.11)
Median (range)	0.54 (0.00 to 1.00)	0.18 (0.00 to 0.30)

Abbreviation: LogMAR, logarithm of the minimum angle of resolution.

lic preschool (Table 2). The mean age was 4.6 years; 60.0% were female; and 85.7% were Latino. There were no differences between the ametropic and emmetropic groups in demographic or medical characteristics (Fisher exact test, 2-tailed $P > .05$). No demographic or medical characteristics were associated with outcome variables ($P > .05$). Therefore, no covariate was included in the ANOVA model. Other factors not reported in Table 2, ie, prematurity, marital status of parents, place of testing, family mental health history, and interval were balanced between the 2 groups and not associated with test scores ($P \geq .63$).

Comparisons between the clinical characteristics of the ametropic and emmetopic groups and among the subtypes of refractive errors in the ametropic group revealed differences between groups and among subtypes as shown in **Table 3** and **Table 4**.

Values from cycloplegic retinoscopy and autorefraction were highly correlated (Spearman $\rho \geq 0.71$; $P < .001$). Correlations were highly significant ($P \leq .001$) between the amount of refractive error expressed in sphere and cylinder diopters, the power vector representation of spherocylinders, and the visual acuity at far distance before correction prior to cycloplegia expressed in logarithm of the minimum angle of resolution in the best eye (ie, the eye with the lowest amount of refractive error).

At baseline and 6-week reassessment, there were significant correlations between scores on the VMI and WPPSI-R full scale as well as the WPPSI-R performance scale ($r_{70} \geq 0.51$; $P < .001$ for the entire sample). Scores on the VMI were moderately correlated with results on WPPSI-R verbal scale at baseline ($r_{70} = 0.28$; $P = .02$) but not at 6-week reassessment ($r_{70} = 0.19$; $P = .11$).

The 35 ametropic children had worn their glasses always or most of the time for the 6-week period. Five children broke or lost their glasses and subsequently had them replaced within 1 week.

PRIMARY ANALYSES

At baseline before optical correction, children with ametropia scored significantly lower on the VMI ($P = .005$; mean difference score, 8.6; 95% confidence interval, 6.2-11.0) (**Table 5**). The mean score of the ametropic group on the VMI was significantly lower than the norm value ($P = .009$), whereas the mean score of the emmetropic group was not ($P = .19$). There was no correlation between scores on the VMI and visual acuity tested at near and far prior to cycloplegia and correction ($P \geq .44$).

After wearing glasses for 6 weeks, there was a significant interaction on the VMI ($P = .02$), showing that the ametropic group improved by a mean of 6.0 points (95% confidence interval, 4.2-7.8) from baseline to 6-week reassessment compared with 0.0 points for the emmetropic group and reached the level of performance of the emmetropic control group (Table 5). There was a weak correlation between change scores on the VMI and the amount of refractive error expressed in sphere diopters and spherocylindrical power vectors of the best eye (Spearman $\rho_{70} = 0.24$, $P = .06$; and Spearman $\rho_{70} = 0.27$, $P = .04$, respectively). There was no correlation with visual acuity at near or far distance ($P \geq .33$).

SECONDARY ANALYSES

At baseline, children with ametropia also scored significantly lower on the WPPSI-R performance scale ($P = .01$; mean difference score, 7.0; 95% confidence interval, 4.9-

Table 4. Clinical Characteristics by Refractive Condition

Clinical Characteristic	Subjects With Compound Hyperopia and Astigmatism (n=23)	Subjects With Hyperopia (n=5)	Subjects With Mixed Hyperopia and Astigmatism (n=7)
Right eye			
Refractive error, mean (SD)	+4.60−1.96×1 (+2.23−1.27×1)	+4.90−0.13×170 (+1.17−0.23×14)	+1.66−3.17×2 (+1.31−1.10×5)
Spherical equivalents			
Mean (SD)	3.60 (1.60)	4.90 (1.06)	0.07 (0.76)
Median (range)	3.75 (1.13 to 8.25)	5.00 (3.75 to 6.50)	0.00 (−1.00 to 1.00)
Spherocylindrical power vector			
Mean (SD)	3.80 (1.50)	4.90 (1.06)	1.76 (0.45)
Median (range)	3.80 (2.10 to 8.30)	5.00 (3.75 to 6.50)	1.80 (1.00 to 2.20)
LogMAR visual acuity			
Mean (SD)	0.55 (0.27)	0.30 (0.11)	0.45 (0.15)
Median (range)	0.54 (0.00 to 1.00)	0.30 (0.20 to 0.40)	0.48 (0.20 to 0.70)
Left eye			
Refractive error, mean (SD)	+4.74−2.28×178 (+2.14−1.23×10)	+5.40−0.20×177 (+1.50−0.20×1)	+1.73−3.55×2 (+1.50−1.60×9)
Spherical equivalents			
Mean (SD)	3.60 (1.53)	5.30 (1.37)	−0.04 (0.73)
Median (range)	3.38 (1.63 to 7.38)	4.60 (4.13 to 7.50)	0.00 (−1.25 to 0.75)
Spherocylindrical power vector			
Mean (SD)	3.90 (1.45)	5.30 (1.40)	1.97 (0.56)
Median (range)	3.50 (2.10 to 7.40)	4.60 (4.10 to 7.50)	1.90 (1.00 to 2.90)
LogMAR visual acuity			
Mean (SD)	0.59 (0.29)	0.30 (0.13)	0.53 (0.25)
Median (range)	0.54 (0.00 to 1.00)	0.30 (0.20 to 0.50)	0.54 (0.20 to 1.00)

Abbreviation: LogMAR, logarithm of the minimum angle of resolution.

Table 5. Scores on Outcome Variables for Ametropic and Emmetropic Groups at Baseline and 6 Weeks

	Mean (SD) Score			
	Baseline Assessment		6-wk Assessment	
Variable	Ametropic Group Before Correction (n=35)	Emmetropic Group (n=35)	Ametropic Group After Correction (n=35)	Emmetropic Group (n=35)
VMI[a]	94.1 (13.7)	102.7 (11.0)	100.1 (12.0)	102.7 (10.7)
WPPSI-R				
Full scale	89.9 (9.2)	92.4 (7.5)	95.1 (9.9)	96.4 (9.2)
Performance scale	99.3 (11.9)	106.3 (10.2)	107.0 (13.4)	111.4 (11.4)
Object assembly	9.2 (3.0)	10.9 (2.7)	11.2 (3.4)	11.7 (3.0)
Geometric design	9.2 (2.6)	9.9 (1.7)	9.5 (2.5)	9.6 (2.2)
Block design	9.9 (2.6)	11.0 (2.1)	11.3 (2.3)	11.8 (2.6)
Mazes	9.5 (2.3)	9.8 (2.5)	10.0 (2.5)	11.4 (2.6)
Picture completion	12.3 (2.9)	13.1 (2.2)	13.1 (2.5)	13.9 (2.0)
Animal pegs	8.9 (3.4)	11.2 (2.4)	10.7 (2.6)	11.7 (2.1)
Verbal Scale	83.7 (9.6)	82.5 (8.2)	86.3 (9.6)	84.7 (11.9)
Information	6.6 (2.4)	6.5 (1.9)	7.2 (2.6)	6.9 (2.5)
Comprehension	6.6 (2.4)	6.5 (2.0)	7.6 (2.0)	6.5 (2.6)
Arithmetic	8.3 (1.7)	8.1 (2.4)	8.6 (2.0)	8.3 (2.6)
Vocabulary	7.0 (2.8)	6.5 (2.0)	7.3 (2.6)	7.8 (3.0)
Similarities	7.9 (2.1)	7.9 (1.7)	8.0 (2.1)	8.2 (2.1)
Sentences	5.0 (2.8)	5.8 (2.3)	5.8 (3.1)	6.1 (2.5)
CBCL	48.6 (10.3)	48.6 (11.6)	47.3 (9.6)	47.2 (12.1)

Abbreviations: CBCL, Child Behavior Checklist 1.5-5 English/Spanish; VMI, Beery-Buktenica Developmental Test of Visual-Motor Integration; WPPSI-R, Wechsler Preschool and Primary Scale of Intelligence–Revised.

[a] $P = .02$.

9.1). A group × subtests multivariate ANOVA comparing the scores of the ametropic group with those of emmetropic control subjects on the WPPSI-R performance scale subtests as the repeated-measure variable yielded a main effect of status ($F_{1,68}=10.3$, $P=.002$), indicating that the ametropic group scored significantly lower on the subtests than the emmetropic control subjects (mean [SD] scores, 9.8 [2.8] vs 11.0 [2.3], respectively). The mean subtest scores of the ametropic group were below norm values, whereas those of the control subjects were not (Table 5).

A main effect of subtest ($F_{5,330}=18.7$; $P<.001$) showed that both the ametropic and emmetropic groups had similar scores on the 1 subtest in which only vision but not eye-hand coordination was involved, ie, picture completion. Scores on this subtest for both groups were above the norm value (Table 5).

There was no difference between the ametropic and control groups on the WPPSI-R verbal scale ($P = .56$) or its subtests ($P = .39$) (Table 5).

After wearing optical correction for 6 weeks, the ametropic group improved on the WPPSI-R performance scale, bringing their scores to the baseline level of the control group (Table 5), but the amount of change between groups did not reach statistical significance ($P = .17$). Across performance scale subtests, a multivariate ANOVA revealed a trending difference ($P = .10$), indicating that the ametropic group improved more than the emmetropic group (mean [SD] scores, 6.5 [5.9] vs 4.3 [5.3], respectively). Repeated-measures ANOVAs on the WPPSI-R verbal scale and multivariate ANOVAs on its subtests revealed no significant differences in change scores between the ametropic and emmetropic groups ($P \geq .95$) (Table 5).

Correlational analyses revealed no association between change on the VMI score and change on the WPPSI-R performance and verbal scale scores in the ametropic or emmetropic groups ($P \geq .11$). However, for children who performed under the norm value (ie, VMI score < 100) at baseline, there was a correlation between change on the VMI and verbal scale scores for the corrected ametropic group ($r_{22} = 0.42$; $P = .05$) but not for the control group ($r_{14} = 0.009$; $P = .98$). This suggests that improvement in visual-motor coordination scores after wearing corrective lenses may be associated with some improvement in scores on verbal abilities in children who performed below the norm value on the VMI.

There were no differences at baseline and at 6 weeks after wearing corrective lenses between the ametropic and emmetropic groups on the CBCL ($P = .96$). Average standard scores were in the normal range for both groups at both times[16] (Table 5).

COMMENT

The baseline results showed that low-income preschool children with uncorrected ametropia as defined in this study had significantly reduced scores on standardized tests involving visual-motor integration skills when compared with group-matched emmetropic control subjects. Specifically, these alterations were found on the VMI and most of the WPPSI-R performance subtests requiring eye-hand coordination. The reduction of scores on the WPPSI-R performance scale in the ametropic group accounted for their lower scores on the full scale of the WPPSI-R.

Because our subjects were tested using the VMI and the WPPSI-R, which are widely used, normalized, standardized measures with strong psychometric properties, it is possible to compare cognitive alterations of the children with ametropia with other conditions that affect young children's cognitive abilities. Reduced test scores in the ametropic group are comparable to those found in studies of preschool-aged children affected by nutritional deficiencies,[15] high blood lead concentrations,[21,22] and low birth weight and prematurity.[23-25] Furthermore, because reduced scores on the VMI and the WPPSI-R found in this study are at levels that have been shown to predict lower levels of academic achievement,[10,11,15,26-28] ametropia may be a risk factor for academic difficulties.

Since this study was limited to low-income children in standardized structured preschool programs, economic status and type of preschool instruction did not confound the findings. It is not known whether these findings would apply to all populations of preschool children affected by ametropia.

There are at least 3 possible explanations for reduced baseline performance in visual-motor integration skills of the preschoolers with ametropia. The first is that without spectacle correction, the children may not see testing materials. This possibility is unlikely because the tests use large, high-contrast materials. Moreover, the ametropic group did as well as the control group on the subtest that required only vision and no eye-hand coordination, ie, picture completion. A second possible explanation is that ametropia may be a risk factor for a neural alteration not yet understood.[8,9] Finally, ametropia may make near tasks uncomfortable, interfering with development of visual-motor coordination skills in these preschoolers.[29]

Our study also showed that after wearing glasses for 6 weeks, the ametropic group improved on the VMI to the level of the emmetropic control subjects, with the differences in scores between the ametropic and emmetropic groups no longer being statistically significant. Although the sample size was small, the magnitude of this change demonstrated that wearing glasses for 6 weeks improved the ametropic group to the VMI norm level. The ametropic group also improved on the WPPSI-R performance scale, but the amount of change did not reach statistical significance. Whereas VMI assesses only visual-motor skills, the WPPSI-R performance scale comprises measures that include not only visual-motor coordination but also spatial analysis and planning skills. Consequently, the WPPSI-R performance scale may not be as sensitive as the VMI to changes in visual-motor integration.

Improvement on visual-motor scores in the corrected ametropic group disagrees with the findings by Atkinson et al,[8,9] who reported that children with glasses[30] did not show significantly better scores on the Movement Assessment Battery for Children at ages 3.5 or 5.5 years. However, their study was not designed to investigate change after refractive correction in young children. Instead, they compared, post hoc, children with glasses with children with uncorrected refractive errors. Furthermore, their measures did not include the VMI, which is widely used in clinical and research settings to assess alterations in visual-motor function.

The improvement on the VMI in preschool children with ametropia following refractive correction for 6 weeks is similar to the time observed for improvement in anisometropic amblyopia with refractive correction in children aged 4 to 7 years.[31,32] Further research, now under way with the study population used here, also may show continued improvement over a longer period.

Our study also suggested a possibility that poorer visual-motor integration scores may be associated with lower verbal scores, which may be improved by wearing glasses. This could be clarified with a larger sample and/or a longer period of observation.

These results from this relatively small sample of low-income preschoolers with ametropia suggested that early identification and correction should optimize cognitive development and learning, at least in the studied sample.

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