

The Association Between Refraction, Ocular Biometry, and a Child's Behavior Assessed by Conners' Parental Rating Scale

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Purpose: To examine the association between refraction, ocular biometry and a child's behavioral disorder using the Conners' Parent Rating Scale.

Materials and Methods: This cohort study recruited 139 children aged 6–9 years old. Their legal guardians completed the Conners' Parent Rating Scale [the revised-long version (CPRS-R-L)], and the individual responses were entered into the software scoring program, resulting in 14 scores for behavioral disorders. Cycloplegic refraction and ocular biometry were performed. Correlation analyses among the 14 behavioral scores, refraction, and biometry were performed. The analyses were performed for three refractive groups: hyperopia, emmetropia, and myopia.

Results: Children (N = 93) with mean age of 7.2 ± 1.2 y were included. Spherical equivalent (SE) of the refractive groups were $+3.46 \pm 1.71$ diopters (D), 0.61 ± 0.41 D and -1.76 ± 2.15 D ($p < 0.0001$). The CPRS-R-L subscale scores positively correlated with sphere, SE, and negatively correlated with cylinder. With the exception of oppositional behavioral subscale that had higher than mean score, 13 CPRS-R-L scores fell within the normal range, regardless of refraction. CPRS-R-L subscale scores negatively correlated with axial length. Axial length shorter than 22.5 mm had CPRS-R-L 95th percentile, some of which surpassed the normal range score of CPRS-R-L, and indicate the presence of ADHD concerns.

Conclusion: Refraction, astigmatism, and axial length were associated with Conners' behavioral subscales and warrant additional studies to clarify any cause–effect relationship.

Keywords: hyperopia, ADHD, Conners' parental rating scale, a child's behavior, ocular biometry

Introduction

Childhood behavioral disorders, including ADHD, result in learning difficulties. Studying the link between refraction and disruptive behavioral patterns is challenging. Tools used to examine a child's behavioral development should be developmentally sensitive and account for age-appropriate variation. Several studies have examined the link between refractive error and ADHD, a chronic condition that affects children and includes a combination of persistent problems such as difficulty sustaining attention, hyperactivity, and impulsive behavior.^{1–3} Aghai et al,⁴ reported a high rate of behavioral disorders in hyperopic and hyperopia-astigmatic children. Their study used the Rutter questionnaire, a screening tool that has been designed to detect behavioral disorders other than ADHD. Mezer and Wagnanski-Jaffe,³ evaluated ocular features in children with ADHD and reported significant ametropia, particularly astigmatism, in most cases. Additionally, binocular function difficulties and convergence insufficiency have also been found to be associated with ADHD.^{5,6} Contrary to this, Fabian et al⁷ reported that hyperopia and astigmatism were not more common in the ADHD group; thus, they concluded that it could not be a major factor contributing to disabilities associated with ADHD in children. Therefore, the contribution of refractive error to behavioral disorders and ADHD remains controversial. Studies examining the association between ocular biometry and children's behavior are scarce.

The revised Conners' Rating Scale (CRS-R) is used to assess ADHD and other behavioral problems in children.⁸ Conners' Parent Rating Scale (CPRS) was developed as a comprehensive checklist for acquiring parental reports on childhood behavioral problems.⁹ The revised-long version CPRS (CPRS-R-L), answered by parents, consists of 80 items and includes 14 index scores related directly to ADHD scores. The other half was related to comorbid behavioral problems.

The objectives of this study were to examine the correlation between refraction, ocular biometry and CPRS-R:L index scores related to ADHD and its comorbid behavioral problems in children ages 6–9.

Materials and Methods

This retrospective cohort study was designed to correlate refraction and ocular biometry, to behavior evaluated by CPRS-R-L in children aged 6–9 years who were referred to the pediatric ophthalmology clinic for refractive error follow-up or suspected refractive error. The study was approved by Ziv Medical Center Ethics Committee in 2020 and was performed in accordance with the tenets of the Declaration of Helsinki of the World Medical Association. Written informed consent was obtained from all participants' legal guardians. Individuals with a history of ocular surgery or other abnormalities that compromise visual function, such as cataracts, glaucoma, retinitis pigmentosa, retinal detachment, or strabismus, were excluded. Data of age at first prescription glasses was documented, and we excluded ametropic children who wore glasses for less than six months. The subjects included were in regular education classes and accompanied by their legal guardians who completed the CPRS-R-L.

Refraction and Examination

Cycloplegia was induced with 1 drop of cyclopentolate 1.0% and 1 drop of Tropicamide 1% administered twice, 10 minutes apart. Cycloplegic refraction was performed using an autorefractor (KR-8800, Topcon Corp). Before dilation, the anterior segment was examined using a slit lamp. After pupil dilation, fundus examination was performed by a trained ophthalmologist using a 90.0 D lens (Volk Optical, Inc) to exclude other eye diseases. We defined the groups according to their SE accordingly: hyperopic ($SE > +1D$), emmetropic ($+1.0D$ to $-0.5D$) and myopic ($< -0.5D$).

Ocular Biometry

Optical biometric measurements using the Lenstar LS900 were obtained by a trained examiner. All measurements were performed before pupil dilation, in a semi-dark room. Lenstar LS900 measurements for the corneal curvature, central corneal thickness (CCT), anterior chamber diameter (ACD), white-to-white (WTW) diameter, lens thickness and axial length were extracted from the device using a spreadsheet file.

We divided the children into three axial length groups for analysis based on T score results. The inverse correlation between axial length and T score pointed to an intersection between axial length of >22.5 mm and T score of 60 (which is considered a normal value); Axial length >22.5 mm defined as relatively long axial length group (N:34). The short (<21.5 mm; N: 27) and medium (21.5–22.5 mm; N: 32) axial length groups were determined by approximately halving the remaining number of participants.

Conners' Parent Rating Scale

Parents were asked to rate the paper-and-pencil form of the CPRS-R-L, with an 80 item-pool using 4-point Likert scales (ranging from 0 (not at all true) to 3 (very much true). An evaluator input the individual responses to the software scoring program, resulting in 14 raw T-scores. CPRS-R-L converts the raw scores to 14 behavioral subclasses, reflecting what is typical or atypical for that age category (6–9 years in our study) and gender. The behavioral subclasses included oppositional, cognitive problems/inattention, hyperactivity, anxious/shy, perfectionism, social problems, psychosomatic, and ADHD subscales (ADHD index, Conners' global index [CGI], restless-impulsive, CGI emotional lability, DSM-inattentive, DSM-hyperactive/impulsive, and DSM total). T-scores are presented in Table 1. Percentiles are reported for a normalized standard theoretical distribution as well as from normative data. T-scores falling below 60, generally indicate typical or absent ADHD concerns for the child's age and gender. Average scores (40–59 score = 16th–83rd

Table 1 T Score Levels and Percentile of CPRS-R-L

T-score	Percentile	Guideline
70+	98+	Very Elevated Score
65–69	93–97	Elevated Score
60–64	84–92	High Average Score (scores here and above are more concerning for potential ADHD)
40–59	16–83	Average score
<40	16	Low score

percentile) are in the white band, borderline scores are slightly atypical, and are colored pink. The atypical scores and markedly atypical scores (above the 98th percentile) gradually reached a red tone.

Statistical Analysis

We determined the minimum sample size of 90 based on an effect size of 0.25–0.3, significance of 0.05 and power level of 0.80. The estimated low effect size evolved from a pilot data. Results are presented as the mean \pm standard deviation (SD). The right eye was used for data collection and analysis. Kendall's tau rank correlation analysis was used to assess the correlation between refraction (sphere, SE, and cylinder) and biometry parameters, and the T-scores of the subclasses. Data analysis was performed on refraction groups: hyperopic, emmetropic, myopic, and axial length. Analyses were performed using SPSS (version 23.0; IBM Corp., Armonk, NY, USA).

Results

We examined 139 children and included 93 children, excluding those who were noncompliant with completing the Conners' questionnaire ($N = 26$) or performing ocular biometry ($N = 13$). Seven children with ocular pathologies were excluded from this study. Children's age was 7.23 ± 1.21 years (6–9) and did not significantly correlate with the CRSP-R-L score, verifying that the CRSP-R-L score was independent of age at this specific age (6–9 years) category.

The correlations between CPRS-R-L, refraction and ocular biometry are presented in Table 2. The CPRS-R-L subscale scores positively correlated with sphere, SE, and negatively correlated with cylinder. Corneal curvature, corneal thickness, WTW diameter, ACD, and lens thickness did not correlate with CPRS-R-L. Axial length was the only biometric that

Table 2 Correlations Between CPRS-R-L, Refraction and Ocular Biometry

	Sphere	P value	Cylinder	P value	SE	P value	AL	P value
Cognitive	0.16*	0.05	-0.19*	0.04	0.14	0.08	-0.21*	0.01
Hyperactivity	0.15	0.08	-0.15	0.10	0.13	0.10	-0.2*	0.02
Anxious	0.25**	0.01	-0.24**	0.01	0.23**	0.01	-0.22**	0.01
ADHD index	0.16	0.06	-0.14	0.12	0.14	0.08	-0.22**	0.01
Impulsive	0.20*	0.02	-0.16	0.08	0.18*	0.04	-0.25**	0.01
Emotion	0.19*	0.03	-0.18	0.06	0.18*	0.04	-0.24**	0.01
General	0.19*	0.02	-0.18	0.05	0.17*	0.04	-0.26**	0.01
DSM inattentive	0.14	0.09	-0.22*	0.01	0.11	0.17	-0.21**	0.01
DSM hyperactive	0.12	0.15	-0.10	0.25	0.11	0.18	-0.18*	0.03
DSM total	0.13	0.12	-0.17	0.06	0.11	0.17	-0.19*	0.02

Note: * $p < 0.05$; ** $p < 0.01$.

Abbreviations: SE, spherical equivalent; AL, axial length.

correlated with CPRS-R-L and the only biometric parameter presented in Table 2. While the sphere showed a significant positive correlation with the CPRS-R-L in the five subscales, SE had only four positive correlations. A significantly weak inverse correlation was found between axial length and CPRS-R-L subscales; the shorter the axial length, the higher the CPRS-R-L for cognitive problems/inattention, hyperactivity, anxious-shy, impulsive, emotional instability, and ADHD.

The hyperopic, emmetropic, and myopic groups had similar mean age (Table 3). The refractive groups differed significantly in sphere, SE, ACD, and axial length ($p < 0.05$). Children underwent follow-up examinations for hyperopic and myopic refractive errors at least 6 months after their vision prescription was given. The time from first prescription glasses for the hyperopic and myopic participants was 3.68 ± 1.31 and 1.11 ± 1.13 years, respectively.

Figure 1 depicts the CPRS-R-L for hyperopic, emmetropic, and myopic children. With the exception of the oppositional subscale score for the hyperopic group, most T-scores fell within the normal range of 40–59, regardless of their refraction. Hyperopic children had oppositional subscale scores greater than 83% (63.07 ± 16.32), which is considered borderline for children age 6–9 years. Total ADHD scores were 56.26 ± 13.27 , 52.5 ± 10.51 , 48.6 ± 6.32 for the hyperopic, emmetropic, and myopic groups, respectively, with statistically non-significant differences/tendency for significance (One-way ANOVA; $p=0.14$).

Based on CPRS-R-L scores, we divided the children into three axial length groups for further analysis depicted in Figure 2 (short, medium, and relatively long axial length groups, <21.5 mm (N:27), 21.5 – 22.5 mm (N:32), >22.5 mm (N:34), respectively). The CPRS-R-L of the axial length groups significantly differed in cognitive, hyperactivity, ADHD index, impulsivity, emotion, DSM general, DSM hyperactivity, and DSM total scores (One-Way ANOVA; $P = 0.08, 0.03, 0.03, 0.001, 0.03, 0.02, \text{ and } 0.03$, respectively). Except for the oppositional behavior, the CPRS-R-L of the relatively long axial length group (> 22.5 mm) was < 60 , which was within the normal range. CPRS-R-L of the short and medium axial length groups, in part, surpass the normal T score range in most ADHD subscales.

Table 3 Demographic, Refraction and Biometry

	Hyperopia N: 42	Emmetropia N:20	Myopia N:31	P value One-way ANOVA
Age (years)	7.18±1.05	7.20±1.24	7.59±1.3	0.40
Gender F (%)	46	45	53	
Age of prescription glasses (years)	3.37±1.13		6.61±1.08	
Duration of glasses (years)	3.68±1.31		1.11±1.13	
Sphere (D)	+3.89±1.89	1.04±0.05	-1.73±2.07	<0.001
Cylinder (D)	-0.90±1.0	-1.01±0.99	-0.09±0.88	0.079
Axis	120.36±65.76	65.76±73.67	10.53±31.04	0.519
SE (D)	+3.46±1.71	+0.61±0.41	-1.76±2.15	<0.001
Keratometry 1 (D)	42.68±1.77	43.48±1.74	42.90±1.62	0.25
Keratometry 2 (D)	43.96±1.73	44.73±1.78	43.70±1.44	0.18
CCT (μm)	556.71±41.62	551.53±36.11	542.20±34.38	0.56
WTW (mm)	12.27±0.61	12.35±0.55	12.39±0.47	0.76
ACD (mm)	3.07±0.28	3.14±0.28	3.40±0.31	0.03
Lens thickness (mm)	3.43±0.12	3.42±0.13	3.33±0.12	0.09
Axial Length (mm)	21.80±0.77	22.69±0.91	24.24±0.73	<0.001

Note: Duration of glasses: the time from first prescription glasses until start of study.

Abbreviation: F, female.

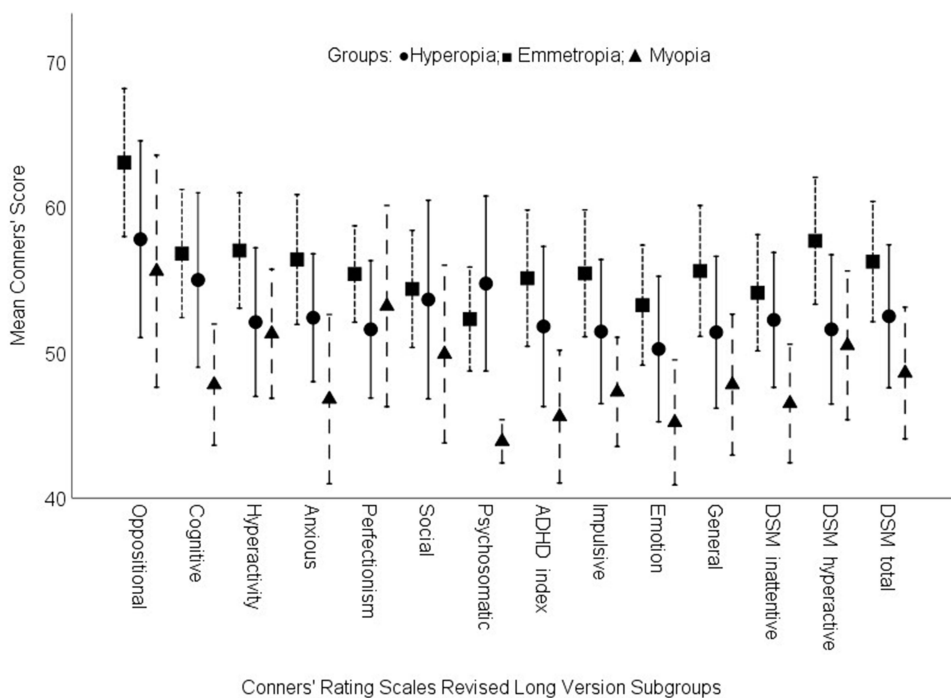


Figure 1 Refraction Groups and CPRS-R-L. Figure 1 depicts the CPRS-R-L for the hyperopic, emmetropic and myopic children at each behavioral subtype. Most subtype scores fall within normal range. Error bars: 95% confidence interval.

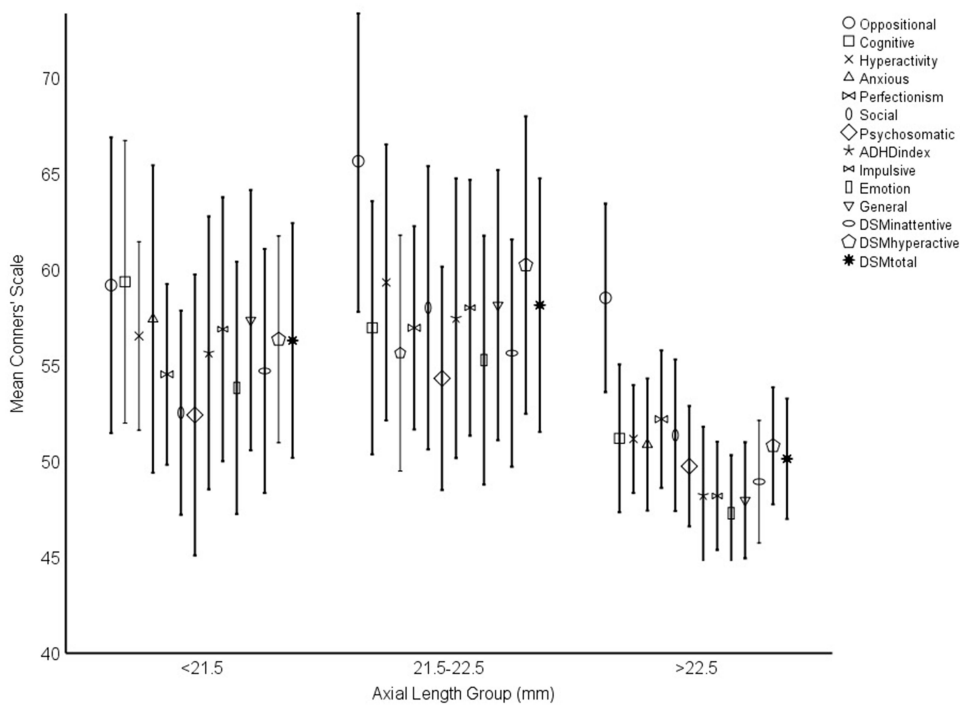


Figure 2 CPRS-R-L and Axial Length Subgroups. Error bars: 95% confidence interval, Conner's score: CPRS-R-L.

Discussion

In our study, the association between refraction, ocular biometry, and behavioral disorders in children was evaluated using the CPRS-R-L. We showed that in children between the ages of 6–9, refraction, astigmatism, and axial length were significantly associated with CPRS-R-L score. The more hyperopic the child is, the higher the CPRS-R-L, which includes

cognitive problems/inattention, anxiety, impulsivity, emotion, and general ADHD. The shorter the eye, the higher were the CPRS-R:L subscale scores for cognitive problems/inattention, hyperactivity, anxious-shy, impulsive, emotional instability, and ADHD. This study supports the link between hyperopia and hyperactive, inattentive children.

The Conners' Rating Scale (CRS) began in 1960 as an untitled collection of informal questions given to parents to document the multiple problematic behaviors of children who brought them to the Harriet Lane Home clinics associated with the Johns Hopkins Hospital in the USA. In 1973, the first version of a psychometric scale, including 93 items, was established, possessing strong and lasting cross-cultural robustness for identifying "hyperkinetic" children.^{10,11} Conners' (1997) revision of the CPRS consists of an 80 item long form.⁸ Factor analysis produced seven behavioral subscales: (1) oppositional, (2) cognitive problems, (3) hyperactivity, (4) anxiety-shy, (5) perfectionism, (6) social problems, and (7) psychosomatic. The CPRS-R:L also contains the Conners' Global Index (CGI), also known as the impulsive-hyperactive scale, and DSM-IV symptom subscale. Factor analytic studies by Parker et al described two distinct factors of CGI that are now considered subscales of the CGI: (1) emotional lability and (2) restlessness/impulsivity.¹² Lastly, the CPRS-R:L assists in the diagnosis of ADHD with its ADHD DSM-IV symptom scale, composed of two subscales meant to distinguish between ADD with and without hyperactivity: (1) DSM-IV Inattentive and (2) DSM-IV hyperactive/impulsive. The Conners' rating scale analysis was dependent on age. In our study, CPRS-R:L was analyzed for the age range of 6–9 years, where learning and reading skills were challenged by behavioral disruption.

CPRS-R:L has a scale from 38 to 90, with a T-score higher than 60, representing a risk for the specific behavioral subscale. CPRS-R:L does not distinguish between normative individual differences and clinically significant behaviors. The CPRS-R:L should be further assessed by teachers and neurologists to diagnose ADHD and efforts for intervention and prevention.¹³ In our study, the SE was linked to CPRS-R:L in the inattention, hyperactivity, anxiousness, and impulsiveness subclasses. As most T-scores were below 60, we used the CPRS-R:L as the sole tool for documenting a suspected disruption of behaviors. Further studies are needed to assess the clinical relevance of these differences.

Refractive error, as a part of visual function, is a critical component of a child's development and can reflect dependent cognitive functions. Hyperopia is associated with learning difficulties, late developmental milestones in reading ability,¹⁴ and slow reading speed.¹⁵ Moreover, children with uncorrected moderate hyperopia performed significantly worse on early literacy tests than did age-matched controls.¹⁶ Previous study showed that impaired reading performance could be artificially induced by simulated bilateral hyperopia, suggesting that refractive error correction can reverse this learning disability.¹⁷ In our study, even with correction of refractive error for at least six months, refraction was still associated with behavioral subscales and did not completely lower inattention, hyperactivity, anxiousness, and impulsiveness. Thus, refractive correction may not resolve the learning difficulties.

In general, the correction of hyperopia, particularly in young children, is not straightforward, since most hyperopic refractive errors do not produce symptoms experienced by the child, and the goals of treatment for hyperopia are to improve binocular function and reduce patient symptoms.¹⁸ Further studies assessing the CPRS-R:L scores before correcting ametropic and after prescribing glasses might provide an additional insight to the importance of wearing glasses on the child's behavior.

In our study, axial length was associated with most ADHD scores. The association between the behavioral subscales and ocular structure supports a more complex long-lasting relationship between ocular shape, brain structure, and function, rather than dependence on glasses. It has been hypothesized that there may be a link between axial length of the eyeball and cerebral development in children with myopia.¹⁹ Brain structural changes noted in children diagnosed with ADHD showed small intracranial volumes and subcortical brain structures relative to controls.²⁰ Moreover, ADHD symptoms have been associated with functional abnormalities in the left subgyral white matter of the frontal lobe, right medial frontal gyrus, right cingulate, and the frontal lobe.²¹ Further studies should be performed to evaluate the link between ocular and brain structures in children with ADHD and their related behaviors.

The limitations of our study include: First, the use of the Conners' Parental Score, a subjective questionnaire that could be biased by overprotective parents rating a child's behavioral disruption as lower than expected. The CPRS-R:L suggests that the diagnosis of clinically significant behaviors should be confirmed by neurological examination. Second,

the study had a high dropout rate of 33%. It is explained by low compliance when completing long questionnaire, and especially when any participants' legal guardians that had not fully completed the CPRS-R:L was excluded. Third, selection bias as our participants were recruited from a tertiary eye clinic with presumably complex disorders necessitating treatment.

In conclusion, the complexity of the relationships between refraction, astigmatism, axial length, and Conners' behavioral subscale scores warrant additional studies to clarify any cause–effect relationship.

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Disclosure

The authors report no conflicts of interest in this work.

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