ORIGINAL ARTICLE

Visual and binocular status in elementary school children with a reading problem

Lisa W. Christian *, Krithika Nandakumar, Patricia K. Hrynchak, Elizabeth L. Irving

School of Optometry and Vision Science, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

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Abstract

Purpose: This descriptive study provides a summary of the binocular anomalies seen in elementary school children identified with reading problems.

Methods: A retrospective chart review of all children identified with reading problems and seen by the University of Waterloo, Optometry Clinic, from September 2012 to June 2013.

Results: Files of 121 children (mean age 8.6 years, range 6–14 years) were reviewed. No significant refractive error was found in 81% of children. Five and 8 children were identified as strabismic at distance and near respectively. Phoria test revealed 90% and 65% of patients had normal distance and near phoria. Near point of convergencia (NPC) was <5 cm in 68% of children, and 77% had stereoacuity of ≤40 seconds of arc. More than 50% of the children had normal fusional vergence ranges except for near positive fusional vergence (base out) break (46%). Tests for accommodation showed 91% of children were normal for binocular facility, and approximately 70% of children had an expected accuracy of accommodation.

Conclusion: Findings indicate that some children with an identified reading problem also present with abnormal binocular test results compared to published normal values. Further investigation should be performed to investigate the relationship between binocular vision function and reading performance.

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PALABRAS CLAVE
Visión binocular; Dificultad lectora; Pediatría; Visión y aprendizaje

Estado visual y binocular en niños de primaria con dificultades lectoras

Resumen

Objetivo: Este estudio descriptivo aporta un resumen de las anomalías binoculares observadas en niños de primaria en los que se identificaron problemas de lectura.

* Corresponding author at: School of Optometry and Vision Science, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1.

E-mail address: lisa.christian@uwwaterloo.ca (L.W. Christian).

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Introduction

Reading is a multifactorial process that is influenced by psychological, physiological, environmental, sociological and linguistic factors. From an optometrist’s perspective, a decrease in reading ability may be associated with poor visual acuity, unstable binocular vision, or ocular disease. It is therefore important that people with poor reading comprehension receive a comprehensive oculo-visual assessment.

A thorough case history is one of the critical components of an oculo-visual assessment. More so than with adults, the case history from a younger population may be inconclusive or unreliable. Younger children may be unaware of their visual problems, or are unable to describe their associated symptoms. In these cases, observations from parents and teachers such as eye rubbing, close working distance, or avoidance of near work, provide additional information.

In cases where the patient is wearing their full refractive correction and shows no signs of ocular disease, but describes symptoms of asthenopia, an investigation of the binocular vision system is of particular importance. Literature has shown an association between poor reading performance and binocular vision disorders. These disorders include poor pursuits, abnormal convergence, low amplitude of accommodation, accommodative infacility, poor fusional vergence reserves, and abnormal fixation disparity. In Ontario, Canada, children who read below their expected grade may be eligible for an Individual Education Plan (IEP) provided by their local school board. An IEP is a special education plan designed to modify the curriculum for a particular student in order to assist the student in achieving his or her learning goals.

The current manuscript investigates the prevalence of visual and binocular vision anomalies in a cohort of school children who have an IEP for reading (ReIPE).
Table 1 Visual and binocular vision tests used in assessing students identified with reading difficulties.

<table>
<thead>
<tr>
<th>Visual function</th>
<th>Tests administered</th>
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<tr>
<td>Distance (6m) visual acuity (VA)</td>
<td>Kay pictures or Snellen chart</td>
</tr>
<tr>
<td>Near (0.4m) visual acuity</td>
<td>Kay pictures or Lighthouse Continuous Text Card for Children</td>
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<td>Distance and Near Strabismus</td>
<td>Alternating cover test</td>
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<tr>
<td>Saccades</td>
<td>Direct observation, alternating fixation between 2 targets</td>
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<td>Stereocuacity</td>
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<td>Near Fusion</td>
<td>Worth four dot</td>
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<td>Accommodative of Amplitude (AoA)</td>
<td>Push-down amplitude</td>
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<td>Near Point of Convergence (NPC)</td>
<td>Push-up technique with accommodative target ±2.00D flippers</td>
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<td>Monocular and Binocular Accommodative Facility (MF, BF)</td>
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<td>Accommodative Response (Dynamic Retinoscopy)</td>
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<td>Refractive Error</td>
<td>Static retinoscopy with lens bars</td>
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</table>
| Distance and near Positive (PFV) and Negative Fusional Vergence (NFV) | Prisms bars | 1% cyclopentolate was performed. For those children who required a new or updated spectacle correction, the binocular vision assessment was performed again 4-6 weeks later with the appropriate spectacle prescription, and these results were used for analysis. All oculomotor, binocular vision and accommodative results were calculated using the mean result, and classified according to normative data described by Scheiman and Wick12 (Table 2).

Results

The age range of patients was 6–14 years (mean age: 8.6 ± 2.3 years) and included 121 children (49 females, 72 males). The mean and standard deviation (SD) for all findings are shown in Table 3 and used as a comparison to the normative data in Table 2. However, as analyzed with both the Komgorov–Smirnov and the Shapiro–Wilk tests, the data were not normally distributed (p < 0.01) for any tests except for distance positive fusional vergence break and recovery, and near positive and negative fusional vergence recovery.

Visual Acuity and Refractive Error

One hundred and nine (90%) children were able to reliably respond to at least one type of visual acuity chart. In all the children who were assessed, 13% (n = 16) had a previous spectacle correction. The mean LogMAR distance VA in the right (OD) and left (OS) eyes were 0.04 ± 0.11 and 0.03 ± 0.11 respectively, and the binocular VA was 0.00 ± 0.08 in this group.

Near LogMAR VA was assessed in 88% of children, and the mean binocular LogMAR VA was 0.03 ± 0.20. A dry static retinoscopy was done on all 121 patients using lens bars, and a cycloplegic retinoscopy was performed on 25,
followed by a subjective refraction (when possible). A total of 23 (19%) of children were prescribed a new or updated spectacle correction.

In our cohort, the overall prevalence of myopia was 7%, hyperopia was 12%, and emmetropia was 81%.

**Oculomotor, Binocular Vision, and Accommodative Assessments**

All tests were attempted on the ReIPE group; however, due to inattention or poor comprehension of test instructions, not all tests yielded usable results. This section describes the results of all the oculomotor, binocular vision, and accommodative assessments in the ReIPE group, that could be accurately performed.

**Ocular motility**

The results of ocular motility testing were available for 104 children. Results showed one patient had an overacting right superior oblique muscle, and 103 patients had unrestricted motility. The results of saccadic function were available for 64 children of whom 62 had accurate saccades, with one child demonstrating an undershoot, and one with an overshoot of the saccadic endpoint.

**Ocular alignment**

Ocular alignment showed 96% of children were non-strabismic at distance, and 94% were non-strabismic at near. A summary of all findings is shown in Tables 5a and 5b.
expected findings in Table 3. Results showed that 65% of the children were within the expected limits for NPC break.

Stereoaucity
Stereoaucity was measured in 108 patients. Our results found 77% of children had a stereoaucity that was ≤40s of arc.13

Accuracy of accommodation
Accuracy of accommodation was assessed in 46 children, and a lag of 0.50 ± 0.25 D was used as a norm for within expected values from Scheiman and Wick.12 Seventy one percent and 73% fell within the expected values for OD and OS respectively.

Accommodative facility
Facility was measured in 57 children. Binocular facility found 91% fell within the expected clinical findings of at least 5 cpm. For monocular facility, 77% and 81% of patients fell within the expected finding for OD and OS respectively.

Amplitude of accommodation
AoA was measured in 107 children, using the push down method. To provide a direct comparison against Hoffstetter’s minimum amplitude equation of 15 D – age/4,14 AoA values were converted from push down to push up. Since push down values are lower than push up values,15-18 +1.82 D was added to the AoA value obtained for each patient based on the study by Antona et al.18 The AoA values are shown in Fig. 3.

Discussion
This retrospective study looked at the prevalence of visual and binocular vision anomalies in children identified with a reading problem by their educators. The prevalence of refractive error was examined, and 19% of children were identified as either myopic (≤−0.50 D) or hyperopic (≥+1.00 D) using the criterion by Czepita et al.10 and Kleinstein et al.11 As expected based on the age range of this study (6-14 years), hyperopia was more frequent than myopia, however, frequency values vary depending upon the

Figure 2 Distance and near positive (PFV BO) and negative fusional vergences (NFV BI) in comparison with normative values.

Fusional vergence testing
Distance and near positive (BO) and negative fusional vergences (BI) were measured in 65 and 66 children respective to direction. The results were compared with the expected findings as described in Table 2.12 The percentage of children who had lower than the expected norms are shown in Fig. 2.

As seen in Fig. 2, more than half of the children had fusional vergences within norms, except for PFV (BO) break where 46% fell within the expected clinical findings.

Near point of convergence
NPC was assessed in 86 patients. The mean NPC break was calculated to be 4.86 ± 4.27 cm, and compared with the

Figure 1 Distance and near phoria in the RelEP group.
examining found in Nevertheless, found who The Visual age convergence than as on overall study accommodative didn’t which average, in the children didn’t spend as much time doing near work and more time on distance related tasks or playing outdoors.

Results for ocular alignment showed 35% of the children had a near phoria that fell outside normative values as defined by Scheiman and Wick (exophoria > esophoria). Fusional vergence results showed less than half (46%) of the children had findings that were within the expected norms for near BO break, and nearly half (41%) had poorer than expected results for distance BO break. These findings are consistent with previous studies by Simons and Grisham, Park and Burri, and Palomo-Alvarez and Puell, all of whom reported evidence of reduced fusional vergences associated with poor reading performance. This suggests that a decrease in a child’s fusional vergence could cause difficulty in maintaining binocularity for performing tasks such as reading. In addition to poor fusional vergence, the reduced NPC results in 32.5% of children is also consistent with previous studies showing abnormal results in tests for convergence in children with reduced reading efficiency.

A cross-sectional study by Kulp and Schmidt found accommodative facility and stereaoacuity were the best predictors of reading performance in children aged 5–7 years. Other studies have also had similar findings where stereaoacuity has been shown to be reduced in children with a reading disability and accommodative anomalies (specifically accommodative infacility) are often seen in children with learning disorders. While the results in this study showed approximately 25% of children had stereaoacuity below expected age, 10% of the children also did not meet expected normative values for BF well below the published failure rates of 83–87%. The most obvious reason is that the cut-off for failure was based on the expected clinical findings published by Scheiman and Wick (Table 2), which is below the value used in prior studies. When converting the BF failure rate from 5 cpm to the cutoff rate of 15 cpm used in other studies the results change dramatically from 9% to 95% of children failing binocular facility. When analyzing other accommodative data, the average AoA in this group was close to the Donder’s age expected values in the 8–10-year-olds but was variable after 10 years. This could be due to the fact that older works by Donders, and the Hoffstetter’s formula used the push-up method to calculate AoA. Nevertheless, the values obtained for 10–14-year-olds were similar to those reported by Leon et al. who cited an average amplitude of 12.5 D in comparison to 12.7 D in the ReIPE group.

In the current retrospective study, 81% of patients did not require a spectacle prescription. Tests for oculomotor, binocular vision, and accommodation showed a range of patients that did not meet published clinical norms; 19% (OS MF) and 23% (OD MF) to 35% (NPC) of those tested for that function. Further investigation should be done to study the association between reading problems and binocular vision anomalies; however, of the patients that were able to perform the diagnostic test, this study does show a moderate percentage of the patient population with an identified reading problem also have an inadequate binocular vision system.

It is therefore important for the optometrist to provide a binocular vision assessment in all children, especially those who have been identified with reading problems. From the findings in this study, it is recommended that tests for binocular vision and accommodative status such as NPC, accommodative facility, AoA and fusional ranges, be included in a comprehensive eye examination for school age children identified with a reading problem to ensure proper diagnosis and management.

**Limitations of the study**

The results in this study are based on 5 schools in Waterloo Region and are not reflective of all children enrolled in the school board with an IEP for reading. For future studies, all children from different schools should be used. Results should be compared to a control group (age-matched children with no previously identified reading problem) with the same tests performed in each group. Ideally, randomized controlled trials should be done to determine if children treated for binocular vision conditions improve significantly in their reading ability, and level of reading should be quantified. In addition, due to age or level of understanding, all binocular tests could not be performed on all children and eye movements were measured by direct observation only.
Thus, future studies should also include a larger cohort of children and incorporate additional tests for saccadic eye movements, such as an eye tracker.

Conclusion

The results in this study show that children with an IEP for reading also present with abnormal binocular and/or accommodative test results. To thoroughly investigate the binocular vision system, we recommend that tests of accommodation, binocular vision, and oculomotor function should be performed on all children, especially those with identified reading problems. Future studies will further investigate the relationship between reading performance scores, reading ability and binocular vision function.

Conflicts of interest

The authors have no conflicts of interest to declare.

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References