Article ▸ A Literature Review of Refractive Error and Its Potential Effect on Reading Attainment in the Early Years of School

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ABSTRACT

This paper is a review of the literature surrounding the potential impact of undiagnosed and untreated refractive vision problems on reading development in the early years of primary school. Despite pre-school screening programmes, it is still possible for children to enter school with undiagnosed or uncorrected refractive vision problems. This paper generally discusses correlations between refractive errors and poor reading development. However, the relationships reported remain complex. Myopia is noted to correlate to high reading ability in some studies, but a correlation does not necessarily imply causation. Previous research in the field and deficiencies in the current literature base are discussed. Recommendations for the nature of research that explores whether refractive error is the cause of poor reading development for some children in school are suggested.

Keywords: academic performance, children, reading, refractive error

Introduction

Recent data suggests that a majority of children achieve success in Scottish schools. However, about one in five children leave school with only basic levels of literacy.[1] Despite the best efforts of all involved (teachers, psychologists, special education specialists), these children fail to develop literacy levels to the expected levels.[2] The Royal National Institute of Blind People (RNIB) estimates that as many as one in five children in UK schools may have an undiagnosed vision problem.[3] Previous research identified that British children who had mild hypermetropia were likely to be reading at a level significantly below their intelligence level.[4] There is a correlation between visual perception anomalies and reading ability in primary school students as well.[5,6] It is also suggested that young students with myopia perform better in reading tests than their peers.[4] Therefore, studies evaluating myopia and reading are less common. With hyperopia, the visual system tires quickly when reading a book or working on a computer screen. In the early years of school, print size gets smaller and problems can be exacerbated.[3] 'Close reading work' is the method most often used as a preferred pedagogy in teaching young students to read in the early years of school (i.e. use of reading books, flashcards, computers, and 'jotters').[7] Therefore, it is hyperopia that is of primary interest to researchers examining the link between refractive errors and reading development.

It is not known whether poor vision (from refractive error) or accommodative stress (from uncorrected hypermetopia) is a factor in problems learning to read, however. This raises the question as to how many of the children failing to develop satisfactory literacy levels in school do so because of undetected or untreated refractive problems, in particular hypermetropia. The aim of this review is to identify current literature on refractive vision problems and reading development.

Methods

A broad literature search was carried out in an attempt to locate as many studies as possible that dealt with undiagnosed refractive vision problems and their effect on reading development. Different combinations of key words were used for searches (for example, undetected vision problems and schools). Results were narrowed by subject area (for example, reading achievement, refractive error). Inclusion criteria were that the articles dealt with refractive vision problems in school or pre-school populations and academic/reading development. Articles from any published or unpublished source that met the inclusion standards were included. The search included the years 1970 to 2011. References were sought from 1970 onwards as this has become standard practice in reviewing in the field of educational literature.[8]

Electronic searches were made of the following educational databases:

- Journal Storage (JSTOR)
- Education Resources Information Center (ERIC)
- Elton B. Stephens Company (EBSCO)
- American Psychological Association Article Database (Psych INFO)
- Dissertation Abstracts
- Web of Knowledge

Table 1: Refractive vision anomalies and reading development

Study	Focus	Findings
Orfield[14]	A study in Mather School, Boston looking at undetected visual problems.	50% of students had a visual problem that could affect their ability to learn to read. The study concluded that it was important to test students for near vision problems as well as distance vision during screenings
Atkinson, et al.[12]	Undetected vision problems were reported for a sample of 1096 six- to nine- month old infants.	13% were found to have a significant refractive error.
Johnson & Zaba[15]	Vision tests and literacy levels measured in juvenile offender and graduate students.	16% of juvenile offenders had near vision refractive problems that could affect reading ability.
Kavale[5]	Meta-analysis of 161 studies on reading ability and visual errors.	Visual problems in up to eight visual skills (but not visual acuity) were correlated to poor reading ability.
Krumholtz[16]	Test of relationship between visual error (farsightedness) and reading ability in three public schools in New York City.	Hypermetropia was found to be associated with lower levels of reading. Twenty-five students were given vision correction (predominantly prescription eyeglasses). Of this sample, 21 (84%) gained over 20 percentage points in their achievement test percentile rank.
Simmons[6]	Review of why poor vision may prevent reading development.	Vision anomalies lead to issues of failing to learn to decode letters into sounds, because the vision anomaly prevents discrimination of letter patterns at near point.
Kulp[17]	Correlations between visual acuity and reading test score in a sample of 53 first-grade students in Cleveland, Ohio.	Significant correlation between visual acuity and reading test score on the Stanford Reading test.
Vaughn, et al.[18]	A study of 91 third-, fifth-, and seventh-grade students in Charleston, Arkansas, looking at relationship between reading development and visual errors.	Significant inverse correlations were found between academic performance on Stanford Reading Tests and vision symptoms. The worse vision the symptoms, the lower the academic performance.
Grisham, et al.[19]	A study of 78 first- and second-year college students looking at relationship between reading development and visual errors.	A significant correlation was found between reduced reading speed and visual dysfunction. Vision symptoms were reported to reduce reading speed and performance.
Snowdon & Stewart-Brown[20]	A review of vision problems and reading attainment.	Negative correlations were found between exotropia at near, vertical phorias, and reading attainment.
Stewart-Brown & Snowdon[21]	A study of 15,000 United Kingdom children looking at relationship between reading development and visual errors.	Those who failed near vision tests were significantly likely to be reading at a level below that which their intelligence level indicated.
Rosner & Rosner[22]	A study of 782 first- through fifth-grade students looking at relationship between reading development and visual errors.	Significantly lower reading achievement test scores among hyperopic students.
Goldstand, et al.[23]	A study that compared 46 proficient readers and 25 non-proficient readers from seventh grade in Jerusalem looking at relationship between reading development and visual errors.	Non-proficient readers had lower reading scores and poorer vision screening scores.
Dusek, et al.[24]	A study of 825 students with reading difficulties and 325 control students with no difficulties aged 6-14 years old in Austria looking at relationship between reading development and visual errors.	Students with slower reading speeds were more likely to have refractive errors and difficulties with binocular vision.
Maples[25]	A study of 1329 students from Iowa looking at relationship between reading development and visual errors.	Regression analysis indicated that visual factors were a more significant predictor of student performance than race or socio-economic status.
Williams, et al.[26]	A study of 1298 eight-year-old children in Wales, looking at relationship between reading development and visual errors.	Students with new diagnoses of hypermetropia and refractive errors between +1.25D and +3D scored significantly lower on national assessments in literacy.
Orlansky, et al. [27]	A study of a sample of 176 three- to five-year-old students in Pennsylvania looking at the relationship between academic development and visual errors.	Significant correlations between untreated astigmatism of >0.5D and lower scores on Work Sampling System tests by students.

Websites of the UK Government and RNIB were searched. In addition to looking for studies by key terms and subject area, searches were conducted in specific journals. The journals selected for specific searching were those that were identified in initial searches in the databases described above as having published a significant number of articles that may have been of interest to the research team. These detailed searches were deemed necessary in case key-word meta-tags had not been identified via the database searches. The tables of contents of the following journals were searched:

- *British Educational Research Journal*
- *Optometry*
- *Optometry & Vision Science*
- *Journal of Behavioral Optometry*
- *Journal of Learning Disabilities*

Seventy-two articles were identified and forty articles were selected for inclusion. One of the limitations of the current research literature identified was that all of the randomized controlled studies limited findings to medical outcomes.[9,10] A number of studies that were identified in the literature search, but that were not subsequently selected for use in the review, included data of this nature.

Results/Discussion

Vision problems in school-aged and pre-school populations

Vision problems are reported to be widespread amongst school age populations in both the United States and the UK.[3,11] RNIB estimates that there are about one in five children in the UK who have a vision problem.[3] Similar issues are found in the United States where it is reported that one in five children has a vision problem. These vision problems are reported to be disproportionately high amongst students from low-income families.[11] This group of students represent an important sub-group in schools. The majority may not have vision problems severe enough to warrant further investigation or the establishment of a record of additional support needs. In a study of 1096 six- to nine-month-old infants in Cambridge, UK, about 13% were found to have a significant refractive error, defined as hypermetropic (>+3-5D, but not exceeding 1D between eyes), myopic (>-3D, but not exceeding 1D between eyes), or anisometropic (over 1D difference between each eye).[12] Refractive errors in early childhood are not necessarily linked to undiagnosed vision problems when children are older. However, the study does demonstrate that even at an early age, a certain percentage of children have significant refractive error. Vision problems which do not correct/lessen during growth and development and which remain undocumented and untreated may impact academic performance in schools.

Accommodation

One of the considerations in testing children's vision is accommodation. It can be used to negate the effects of hypermetropia. It is often assumed that children accommodate readily and therefore, mild degrees of hypermetropia do not require correction. This was not found to be the case in a recent publication.[13] In this study, a photorefractor in a laboratory setting was used to collect binocular accommodation data from participants viewing a detailed picture target moving between 33 cm and 2 m. Thirty-eight typically developing infants were studied between six and 26 weeks of age and were compared with cross-sectional data from children five to nine years of age with clinically significant hypermetropia (n=15), corrected fully accommodative strabismus (n=14), and 27 age-matched controls. The study concluded that hypermetropic children referred for treatment for reduced distance visual acuity are not likely to accommodate habitually to overcome residual hypermetropia due to under-correction. It should be noted that this study would probably require verification in a larger scale trial before changes to existing practice were recommended.

Refractive vision anomalies and reading development

A synopsis of the focus and findings of studies in this section is presented in Table 1.[14-27] The act of reading requires the coordination of a number of visual activities, including: a focused image on the retina (refraction and accommodation), a disease-free retina and optic nerve (for visual acuity), efficient eye movement along the line of print (saccades), good convergence (if binocular), two integrated images in the brain (fusion), and minimal effort required for fusion. Subsequently, the information needs to be processed (visual cortex), and the process of reading needs to be learned through repetition, language, and assimilation. There is knowledge that this learning process is often handicapped by an inability to deconstruct and reconstruct phonemes. Many of these latter activities are far removed from the visual system both conceptually and anatomically. The review will limit itself to refractive vision errors.

A study involving children at the Mather School in Boston reported that 50% of students had a visual problem that could affect their ability to learn to read. The study concluded that it was important to test students for near vision problems as well as distance vision during screenings.[14] Other studies have reported smaller percentages of subjects with abnormal refractive error. A study of 50 juvenile offenders and 54 graduate students in New York State reported that whilst no graduate students had near vision problems, 16% of juvenile offenders had near vision refractive problems that could affect reading ability.[15] However, this data is from a small sample and multiple tests were used. Therefore, results should be treated with caution and the benefit of extrapolating results beyond this sample may be limited.

It is reported that there is a strong correlation between vision anomalies and reading problems in school-age students. Hypermetropia and anisometropia have been identified as possible vision anomalies that could lead to poor reading.

However, a causal relationship between vision anomalies and poor reading has not been established in the current literature.[6] Recent studies have reported significant correlations between untreated astigmatism of >0.5D and lower scores on Work Sampling System tests in a sample of 176 three- to five-year-old students in Pennsylvania.[27] A meta-analysis of 161 studies reported that visual potential problems in up to eight visual skills (but not visual acuity) were correlated with poor reading ability. However, when corrected for Intelligence Quotient (IQ), visual memory, visual discrimination, and visual motor integration were associated with poor reading. This finding presents a degree of debate, as two of these three areas are not related to visual acuity.[5] Hypermetropia in students at three public schools in New York City was found to be associated with lower levels of reading. These students tended to be located in the bottom quartile of reading ability. In this study, 25 students were given vision correction (predominantly prescription eyeglasses) and 21 (84%) gained over 20 percentage points in their achievement test percentile rank.[16]

The American Optometric Association recognises that undetected vision problems will make it difficult for individuals to perform to their full academic potential.[28] It is reported that vision anomalies lead to issues of failing to learn to decode letters into sounds. This is principally because the vision anomaly prevents discrimination of letter patterns at near point.[6] Use of the Beery Developmental Test of Visual Motor Integration (Beery VMI) (which included a section on visual acuity) found a significant correlation between visual acuity and reading test score measured with the Stanford Reading test (a widely used standardised test that assesses vocabulary, comprehension, and scanning skills) in a sample of 53 first-grade students in Cleveland, Ohio. However, two issues present themselves when interpreting data from this study. Firstly, this effect was correlational and not causative. Secondly, it is difficult to extract the relative correlational weight that visual acuity had on reading score. The Beery VMI provides data on three aspects of visual-motor integration as three sub-scales. These sub-scales are Visual-Motor Integration, Visual Perception, and Motor Coordination. Study data from the Beery VMI was presented as a composite score. Correlations between individual sub-scales and reading test scores were not presented. This made the relative contribution of each sub-scale to the overall correlation with reading score difficult to interpret.[17]

In a study of 91 third-, fifth- and seventh-grade students in Charleston, Arkansas, significant negative correlations were found between academic performance on Stanford Reading Tests and vision symptoms. An increase in vision symptoms correlated with lowered academic performance. The relationship was strongest for third-grade students.[18]

These relationships have been identified in older students. In a sample of 78 first- and second-year graduate students (mean age 25.13 years), it was reported that there was a significant correlation between reduced reading speed and visual dysfunction. Vision symptoms were associated with reduced reading speed and performance within the sample. However, although statistically significant, the correlation was weak.[19]

In a review of vision problems and reading attainment, negative correlations were found between exotropia at near, vertical phorias, and reading attainment.[20] However, the authors also conclude that there is no clear evidence that pre-school children benefit from the correction of minor refractive errors that are common in childhood. There is evidence that such children often make choices not to wear glasses. They recommend the need for future research, to include the use of properly designed randomized controlled trials, to allow for the benefits and costs of interventions to be systematically established. In a study of 15,000 UK children, it was reported that those who failed near vision tests were significantly likely to be reading at a level below that which their intelligence level dictated.[21]

A study of 782 first- through fifth-grade students in Iowa found significantly lower reading achievement test scores among those with uncorrected hyperopia whose refractive error exceeded +1.25 D.[22] A study that compared 46 proficient readers and 25 non-proficient readers in the seventh grade in Jerusalem reported that non-proficient readers had lower reading scores and poorer vision screening scores. Sixty-eight percent of students had an identified vision problem. It was concluded that vision difficulties should be considered as a contributory factor in students with academic difficulties.[23] A study in Austria of 825 students with reading difficulties and 325 control students with no difficulties, aged 6-14 years, reported that students with slower reading speeds were more likely to have refractive errors and difficulties with binocular vision. It was concluded that children with poor reading have higher proportions of visual function anomalies.[24] In a study of vision and academic performance in 1329 students from Iowa, correlations were found between vision problems and student attainment. Regression analysis indicated that visual factors were a more significant predictor of student performance than race or socio-economic status. Whilst only from one context and with a limited sample size, this study does raise questions regarding the significant role that vision issues can play in academic performance.[25] A study of 1298 eight-year-old children served by the Rhondda Cynon Taff Community Paediatric Service, Wales, reported that students with new diagnoses of hypermetropia between +1.25D and +3D scored significantly lower on national assessments in literacy (SATS) than comparison groups with no vision problems. Thirty percent of this sample had been referred to educational psychology services to investigate their delay in development.[26]

However, the studies reporting correlations between reading performance and visual problems have not established cause and effect. Whilst it might appear that this relationship implies causality, this is not necessarily the case. These

Table 2: Screening, diagnosis, and treatment

Study	Focus	Findings
Scottish Government[30]	A study examining the benefits of pre-school screening for students in Scotland.	Unless parents followed up on the results of screening and took their child to an optometrist, there was no benefit to the screening process.
Preslan & Novak[31]	A study examining whether pre-school screening led to follow-up treatment for 285 students in Baltimore.	Only 30% and 20% of students were in compliance with prescribed treatments one and two years, respectively, after the screening.
ABT Associates[32]	A study examining whether pre-school screening led to follow-up treatment for students in the USA.	Screening led to a 144% increase in successful treatment for amblyopia
Feldman, et al.[33]	A study examining whether pre-school screening led to follow-up treatment for 763 screened and 743 non-screened kindergarten children in Halton County, Ontario.	Screened students showed significantly fewer vision problems and significantly less moderately decreased visual acuity (≤ 20/50) than the unscreened population. Fifty-three percent more screened students were wearing glasses
Kemper, et al.[34]	A study examining whether pre-school screening led to follow-up treatment for 2229 children screened during the 2000-2001 school year in Michigan.	Twenty-five percent of those identified with a visual problem had a follow-up treatment.
Kimel[35]	A study of 175 parents of kindergarten through fifth-grade students in Rockford Public School District in Michigan examined the reasons why a diagnosis may not result in treatment of vision problems.	Parents reported that they did not have time to take children to an eye care provider due to both parents working, did not believe the result of the test, and did not see vision treatment as a priority.
Marshall, et al.[36]	A study to see whether screening glasses provision was correlated to enhanced reading performance.	Provision of reading glasses and vision therapy correlated with improvements in teacher grades, percentiles, and grade equivalents on standardized tests in reading and mathematics for a school-age population of low socio-economic status (85% free school meals).

relationships may be relational and directional, but not causal. The lack of certainty regarding the value of screening and prescribing spectacles to school students with low refractive errors makes it ideal for study via a randomised controlled trial. The lack of controlled studies that investigate refractive error and reading was recently noted in a review of reading and vision.[29] A similar call to arms was made by Ethan and Basch.[11]

Screening, diagnosis, and treatment

A synopsis of the focus and findings of studies in this section is presented in Table 2.[30-36] The reasons why students do not have refractive errors diagnosed and treated may be complex. This review has been confined to examining eye health screening programmes in one part of the UK—Scotland—due to the fact that it is the domicile of two of the authors of the review and both authors sit on the Scottish Parliament Cross-party Advisory Committee on Visual Impairment and Blindness. In Scotland, pre-school vision testing is offered to all children. This is normally undertaken by orthoptists.[37] Vision screening may also take place at a single point in secondary school (although this is not consistent throughout Scotland). Orthoptic assessments are available on demand to all children being assessed for learning difficulties.[38] If a child fails the vision screening, a letter is sent home advising the parent or guardian to seek an appointment with an optometrist. There is no process of follow-up to ascertain whether children are subsequently taken for further tests or receive a prescription.[39] This is the point at which it is possible for refractive vision problems to go untreated. Without parental involvement, treatment will not be provided even to children in whom refractive errors have been identified. This was confirmed in research undertaken by the Scottish Government.[40] Subsequent follow-up of children who had received a vision screening indicated that unless parents followed up on the results of the screening and took their child to an optometrist, there was no benefit to the screening process. It is recommended that children with visual acuity of less than 20/30 or who have greater than a two-line difference on tests within the passing range (Snellen letters, Tumbling E, Allen figures, LEA symbols), i.e. 10/12.5 & 10/20 or 20/25 & 20/40, should be referred.[40] In the UK, poor acuity is defined as a best-corrected acuity of 6/12 (20/40) or worse on crowded letters or 6/9 (20/30) or worse on single letters at age four.[41]

Vision screening in schools has been reported to be effective in some contexts at identifying vision problems.[42] There is debate in the literature as to how effective such screening programmes are at identifying vision problems.[43] In addition, subsequent follow-up treatment is reported to be inconsistent. In a sample of 285 students in the Baltimore primary school system who were screened for vision problems, it was reported that only 30% and 20% of students were in compliance with prescribed treatments at one and two years, respectively, after the screening.[31] A review of vision screenings by the National Health Service (NHS) reported that screenings did not result in effective treatment for ambylopia.[21] However, a US report claimed that a 144% increase in successful treatment for amblyopia could be attained through the use of vision screening programmes. This was concluded after financial models were run to determine the estimated cost of treatment

of undetected amblyopia as compared to the estimated cost of universal vision screening programmes.[32]

Screenings are reported to increase the number of students who wear glasses and can help prevent worsening of vision problems one year post-screening. In a sample of 763 screened and 743 non-screened kindergarten children in Halton County, Ontario, it was reported that screened students showed significantly fewer vision problems and a lower rate of visual acuity of 20/50 or worse than the unscreened population. It was also reported that 53% more screened students were wearing glasses.[33] In a sample of 2229 children screened during the 2000-2001 school year in Michigan, it was found that only 25% of those identified with a visual problem had a follow-up treatment.[34] A study of 175 parents of kindergarten through fifth-grade students in the Rockford Public School District in Michigan examined the reasons why a diagnosis may not result in the treatment of vision problems. Questionnaires returned from parents of students who had been identified as having a vision problem by a school screening programme and who did not receive follow-up treatment established the following reasons for lack of treatment for their children: 1) not enough time to take children to an eye care provider due to both parents working, 2) not believing the test results, 3) not seeing vision treatment as a priority. Eighty-five percent of students who did not receive follow-up treatment were in receipt of free school meals, and nearly two-thirds would have received free eye-care through the Medicaid insurance health plan.[35] A review of screening studies within the NHS found that the benefits of such screening programmes on correction of small refractive problems were debateable due to the fact that no randomized controlled trial has been undertaken and previous studies were methodologically weak in design relying on survey and observation.[44] It has been reported that an intervention of reading glasses and vision therapy correlated with improvements in teacher grades, percentiles, and grade equivalents on standardized tests in reading and mathematics for a low socio-economic status (85% free school meals) school-age population. However, correlational data does not demonstrate cause and effect. The lack of a cluster-randomized design leaves question marks over the generalizability of such findings.[36]

Conclusion

In conclusion, many studies examine the role of testing and treating specific parts of the visual system and the optometric and ophthalmic outcome of such activities. Smaller numbers of studies attempt to link eye health to academic data. In these studies, academic outcomes are often a secondary focus of the research. In the studies that looked at academic outcomes, a large number reported a correlation between refractive (particularly undetected and untreated) vision errors and lower levels of reading. However, very few published studies have looked beyond these correlational effects and tried to establish cause and effect on reading attainment outcomes in the early school years. This pattern was noted by previous researchers, but little has changed in the intervening years. This is mainly due to the fact that academic outcomes were not necessarily considered as outcome variables in those studies conducting experimental designs on treatment of refractive errors. This means that there is a lack of evidence of causation between refractive errors and poor reading.

Despite the lack of evidence of causation, the literature review does raise the question as to how many children who are failing to read in UK schools may be doing so because of poor vision that could be treatable. It is not possible to answer this question given the current evidence base. What is required is a robust randomized controlled trial that would establish causation between refractive errors and reading development. If causation was established, then the lack of treatment compliance in current screening programmes in Scotland may be an area where policy and practice may also need review. Such a study may have implications wider afield, as it may cause many countries to review their current practices with respect to vision screening and treatment for young school-aged students.

Even for treatment, where few would debate that there are well-established benefits, the link between screening/diagnosis/treatment can be tenuous for the majority of children of school age. This is an issue where education for parents regarding eye health or vision care and appropriate examination of vision and binocular status may be important. It is now essential that health authorities, orthoptists, ophthalmologists, and both commercial/health authority providers of optometry services address these issues, and that policy and business practices target these groups to improve eye health outcomes for children.

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