Accommodation, Convergence, and Stereopsis in Dyslexic Schoolchildren

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Abstract:
BACKGROUND: Previous studies have shown a correlation between reading problems and binocular function, but few studies have assessed visual skills in dyslexic students, particularly in Iranian Farsi-language students. This study is aimed to determine some of the binocular functions of dyslexic children and compare it with a group of age, sex, and social class-matched control children.

MATERIALS AND METHODS: We conducted a case–control study on 27 dyslexic children and 40 age, sex, and social class-matched control children (all between 7 and 13 years old) in grades one to six. This study was performed at three elementary schools in Tehran, Iran. Monocular and binocular near point of accommodation (NPA) were measured using the subjective push-up method, near point of convergence (NPC) was determined using the standard push-up technique, and stereoacuity was tested with the Titmus stereotypes in all of the children.

RESULTS: Mean NPA of the right eye was 6.90 cm in dyslexic group and 5.98 cm in the control group (P = 0.003). Mean NPA of the left eye in dyslexic children was 7.32 cm and in the control group was 6.23 cm (P = 0.003). Mean binocular NPA was 6.66 cm in dyslexic and 6 cm in the control group (P = 0.049). However, mean NPC (P = 0.33) and mean stereoacuity (P = 0.785) did not differ significantly between the dyslexic and control groups.

CONCLUSION: Our findings showed a reduced monocular and binocular NPA in dyslexic children so that this function should be assessed by an optometric clinician in children with dyslexia.

Keywords: Accommodation, binocular vision, convergence, dyslexia, stereopsis

Introduction

Learning disorders comprise a diverse group of disabilities. Children with these disorders have at least average intelligence but have problems processing information or generating output.¹ Learning disorders can affect neurocognitive processes and may reveal as a defective ability to read, write, spell, listen, speak and reason, solve mathematical problems, and concentrate or organize information as well.¹ Recent studies have suggested that nearly 20% of the population has some grade of a learning disability.² Dyslexia is the most common learning disability so that approximately 80% of people with learning disability have dyslexia.²

Dyslexia is explained as a deficiency in reading skills, despite sufficient intelligence, course of study, education, and sociocultural status.³ According to the British Dyslexia Association, dyslexia is a “Combination of abilities and difficulties that affect the learning process in one or more of reading, spelling, and writing.”³

In a general manner, dyslexia is a neurobiological disorder with the genetic source.³ Other studies have also demonstrated the major theories for the reasons of dyslexia. These theories are the auditory processing deficit hypothesis, the visual processing deficit hypothesis,
the motor control deficit hypothesis, the cerebellar
dysfunction hypothesis, the phonological processing
deficit hypothesis, and the general sensorimotor
processing deficit hypothesis.\textsuperscript{[3]} Associations between
visual abnormalities and dyslexia have been found by
many researchers.\textsuperscript{[4]} Studies have been described that
up to 10\%–12\% of children in the English-speaking
country endure this disorder. The prevalence of
dyslexia is nearly 5\%–20\% of school-aged children in
the United States.\textsuperscript{[1,7]}

Researches show that dyslexic children are at a higher
risk for asthenopic symptoms and visual function
anomalies than their peers without this disability.
Dyslexia is significantly related to different feature of
visual functions containing refractive error and binocular
vision condition.\textsuperscript{[9]}

Reading is a complex motor skill, and it needs various
types of eye movements and adequate accommodation.
Visual dysfunctions do not create reading disabilities,
but visual dysfunctions can contribute to their reading
disability. It is necessary to investigate the real cause when
a child is not making suitable improvement in reading skill.
Binocular dysfunctions are often remarked when children
change the learning-to-read level to the reading-to-learn
level, which happens around third to fourth grade. There
are different opinions about various aspects of vision and
binocular vision, in particular, such as visual acuity (VA),
refractive error, strabismus, accommodation, convergence,
and stereopsis, affect dyslexia.\textsuperscript{[9]}

Prior finding suggests no statistical significant difference
in refractive error between dyslexics and control group
children.\textsuperscript{[9–11]}

Previous studies have shown relationship between
reading difficulties and accommodative function. Any
accommodative dysfunction could lead to work-related
problems among schoolchildren. Accommodative
function has generally received less consideration than
binocular abilities and ocular motilities in dyslexic
children. Clinical accommodation testing is often not the
primary function tested in an examination.\textsuperscript{[12]}

Some researches have explained, there is significant
correlation between reading difficulties and low amplitude
of accommodation and accommodative facility.\textsuperscript{[12]}

Evan \textit{et al.} reported correlation between reduced
amplitude of accommodation and dyslexia.\textsuperscript{[13]} Several
studies show that common reason for dyslexic children
at fourth grade is low amplitude of accommodation.\textsuperscript{[14]}
On the other hand, Latvala \textit{et al.} did not observed
reduced amplitude of accommodation in children with
reading problems.\textsuperscript{[11]} Furthermore, in other research, lag
of accommodation and facility of accommodation were
similar between dyslexic children and control group.\textsuperscript{[13]}

Fusional ability can also be tested by evaluating near point
of convergence (NPC). Normal NPC should have a value
between 4 and 16 cm, measured from the corneal plane.
According to Rowe study, a normal NPC is consider
6 cm.\textsuperscript{[15]} Based on the study by Latvala \textit{et al.}, they found a
statistical significant difference in convergence near point,
which was found to be ≥8 cm in the dyslexic group.\textsuperscript{[11]}

Furthermore, Kapoula \textit{et al.} found that dyslexic children
have a remote NPC and a reduced fusional divergence
range at both distance and near.\textsuperscript{[16]}

VA, stereopsis, and control of eye movements at near vision
associated with accommodation ability in children. While
some researches showed normal range of accommodation
in dyslexic children,\textsuperscript{[10]} other studies documented
significantly reduced monocular and binocular amplitude
of accommodation in these children.\textsuperscript{[13]} Ygge \textit{et al.} reported
that there are no difference between stereopsis of dyslexic
group and control group.\textsuperscript{[10]}

The relationship between binocular vision and
accommodative function with dyslexia remains a
source of controversy. Majority of researches have been
performed in English-language schoolchildren, but in this
article, the binocular abilities such as, accommodation,
convergence, and stereopsis in dyslexic and non-dyslexic
Iranian primary-school-age children with Farsi-language
were analyzed. The aim of this study was to determine
the ability of binocular vision and its relationship with
reading difficulties in Iranian schoolchildren.

\textbf{Materials and Methods}

A case–control study was performed in 2016 at
learning disabilities rehabilitation center (number 3)
and two public elementary schools in Tehran, Iran.
In this rehabilitation center, only elementary dyslexic
students had been registered. These students were not
multilingual school children. Twenty-seven children
with previous diagnosis of dyslexia were chosen
randomly. The diagnosis was based on evaluation by
Specialist Psychology of Exceptional Children using the
following criteria: intelligence coefficient compatible
with normality, using Wechsler Intelligence Scale for
Children, Stanford–Binet Test, aged between 7 and
13 years. Control group were 40 children age-matched,
classified as normal readers with appropriate reading
and academic level were selected randomly from public
schools in the same area.

The exclusion criteria were auditory deficiency,
significant neurological disease (epilepsy, head injury),
eye disorders such as strabismus, amblyopia, VA <10/10, ametropia, use of medication that interferes with cognitive process, and the students who were unable to perform proper examination after three attempts. The research was approved by the Committee of Ethics on Research of Shahid Beheshti University of Medical Sciences, Tehran, Iran. All of the parents gave their consent for their children participate in the study.

The measurements of refractive errors, VA, strabismus, convergence and accommodative function, and stereopsis were performed for all participants in both groups.

Distance VA was assessed for each eye separately using the Snellen chart at 6 m.

Refraction was performed with a streak retinoscope (Heine).

The near point of accommodation (NPA) was evaluated for each student both monocularly and binocularly using the subjective push-up method. For monocularly test, the student was asked to fixate and focus on the 20/30 line with the right eye. The letters were moved toward the nose along the rule until the student reported the first blur. This was repeated 3 times by the same examiner, the average distance from the student recorded as the NPA. The technique was repeated for the left eye, and then, binocular NPA were examined.

NPC was evaluated by the standard push-up technique using an accommodative target (single 20/30 letter). For the test, a ruler was held at the center of the forehead, and the target was moved toward the child at 1–2 cm. The NPC was recorded in centimeters as the average of three measurements, in which either the examiner observed one eye deviate or the student reported diplopia.

Stereoacuity was examined using the Titmus stereo test. The student wore polarized filters during the test. The polarized target plate was presented and aligned perpendicular to the participant’s face at a distance of 40 cm. The target plate includes stereo fly (3600 s of arc), animals (100, 200, 400 s of arc), and circles (maximum 40 s of arc).

Statistical analysis was performed using SPSS software version 18.00 (Chicago, USA). Normality of data distribution was assessed using the Kolmogorov–Smirnov test. Normally distributed variables were analyzed using a two-sided one sample t-test and Chi-square test.

Results

Measurements were performed on 27 children with dyslexia, mean age 8.85 ± 1.51. The sample group contained 19 boys (70.4%) and 8 girls (29.6%). The nondyslexic group was 40 children, mean age 9.02 ± 1.34 with 31 boys (77.5%) and 9 girls (22.5%). No statistical difference in mean age two groups could be found (P = 0.625). The mean age for both groups has shown in Table 1. The number of boys and girls has presented in Table 2.

There was a statistically significantly lower NPA both monocularly and binocularly in the dyslexic group. The mean NPA of the right eye for the dyslexic group was 6.90 ± 1.23 cm, and 5.98 ± 1.15 cm for the control group. There was statistically difference between two groups (P = 0.003) Table 3.

The mean NPA of the left eye for the dyslexic group was 7.32 ± 1.68 cm, and 6.23 ± 1.20 cm for the control group. There was statistically difference between two groups (P = 0.003) Table 4.

The mean NPA binocularly for the dyslexic group was 6.66 ± 1.21 cm, and 6.00 ± 1.38 cm for the control group. There was statistically difference between two groups (P = 0.049) Table 5.

The mean NPC for the dyslexic group was 5.25 ± 1.36 cm and 4.95 ± 1.17 cm for the control group. This difference was not statistically significant (P = 0.33) Table 6.

Mean stereoacuity failed to differ significantly in the study and control groups (P = 0.785). Stereocuity in 14.8% of dyslexic group and 12.5% of control group was worse than 60 s of arc.

Discussion

Visual problems are not the cause of learning disorders, but these difficulties have been identified to interfere with the learning process. Visual skills contain NPC, accommodative amplitude, accommodative facility, control of binocular vergence, eye movement, and fusional reserve are necessary in learning activities, reading performance, reading comprehension, and transcribing. Rare studies have assessed visual skills in Iranian Farsi-language students. Therefore, in the present study, the purpose was to investigate the NPA, NPC, and stereopsis in Farsi-language dyslexic children to see if there are any indications of association with dyslexia.

Several studies have reported that the prevalence of reading disability in boys is more than girls. According to our study, the prevalence of dyslexia in boys was more as well [Table 2].

In this study, the values of NPA monocularly and binocularly were statistically significantly more in dyslexic group [Tables 3-5]. Motsch and Muhlendyck found the same
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Evans et al. have also shown amplitude of accommodation in dyslexic group (n = 39) was so lower than control group (n = 43). In the study by Wahlberg-Ramsay et al., a statistical difference between dyslexic (n = 63) and control group (n = 60) have been found in the amplitude of accommodation. They concluded that monocular amplitude of accommodation (P = 0.025) and binocular amplitude of accommodation (P = 0.013) in dyslexic students have reduced. Regarding Palomo-Alvarez and Puell study, students with reading difficulties have more reduced amplitude of accommodation both monocularly and binocularly comparing control group. Dusek et al. demonstrated differences in visual status between a large group of children with reading difficulties (n = 825) and a clinical control group (n = 328) in terms of VA, ocular posture, accommodation, reading speed, and convergence.

The result of our study differs from the results of Ygge et al., who found that there was no statistical difference in the amplitude of accommodation between dyslexic and control group. Latvala et al. have also reported that dyslexic children and control group did not differ significantly from each other in accommodation.

When looking at the NPC, the present study has provided no statistically difference comparing dyslexic and controls [Table 6]. Both groups have a normal NPC as represented by Rowe. Nevertheless, this result differs from the result of Latvala et al., who found that most of dyslexic patients have NPC ≥8 cm, and there was a significant difference between two groups. They reported dyslexic students have convergence insufficiency (CI) type of exodeviation. The results of this study are also contrary to the results of Kapoula et al. who also reported that dyslexic children had a more remote NPC. In the study by Dusek et al., one of the most significant findings was the high ratio of children with reading difficulties who displayed CI.

At this study, the values of stereoaucity in both groups was similar, and there was no statistical difference between dyslexic patients and controls as determined by another researches. The goal of optometric intervention is to improve visual function and alleviate associated signs and symptoms. Therefore, dyslexic children should be evaluated by an optometrist who provides diagnostic and management services in this area.

Conclusion

The present study surveyed accommodation, convergence, and stereopsis in dyslexic and nondyslexic Farsi students. Our findings showed that when comparing dyslexic and control students, monocular

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**Table 1: Mean and standard deviation of age in dyslexic and control groups**

| Groups       | n (%)  | Mean (year)±SD | P   |
|--------------|--------|----------------|-----|
| Dyslexic     | 27 (40.3) | 8.85±1.51     | 0.625 |
| Control      | 40 (59.7) | 9.02±1.34     |     |

SD: Standard deviation

**Table 2: Number of girls and boys in the two groups**

| Sex     | Group       | Total, n (%) |
|---------|-------------|--------------|
| Boys    | Control     | 31 (77.5)    |
| Girls   | Control     | 9 (22.5)     |
| Total   | Control     | 40 (74.6)    |

**Table 3: Mean and standard deviation of monocular near point of accommodation for the right eye in the two groups**

| NPA (OD) | n    | Mean (cm)±SD | P    |
|----------|------|--------------|------|
| Dyslexic | 27   | 6.9037±1.23646 | 0.003 |
| Control  | 40   | 5.9800±1.15741 |      |

NPA (OD): Near point of accommodation of the right eye, SD: Standard deviation

**Table 4: Mean and standard deviation of monocular near point of accommodation for the left eye in the two groups**

| NPA (OS) | n    | Mean (cm)±SD | P    |
|----------|------|--------------|------|
| Dyslexic | 27   | 7.3296±1.68587 | 0.003 |
| Control  | 40   | 6.2375±1.20057 |      |

NPA (OS): Near point of accommodation of the left eye, SD: Standard deviation

**Table 5: Mean and standard deviation of binocular near point of accommodation in the two groups**

| NPA (OU) | n    | Mean (cm)±SD | P    |
|----------|------|--------------|------|
| Dyslexic | 27   | 6.6630±1.21058 | 0.049 |
| Control  | 40   | 6.0050±1.38304 |      |

NPA (OU): Binocular near point of accommodation, SD: Standard deviation

**Table 6: Mean and standard deviation of near point of convergence in the two groups**

| NPC       | n    | Mean (cm)±SD | P    |
|-----------|------|--------------|------|
| Dyslexic  | 27   | 5.2593±1.36615 | 0.33 |
| Control   | 40   | 4.9525±1.17495 |      |

NPC: Near point of convergence, SD: Standard deviation

Results in their study on dyslexic children between 9 and 10 years old. They reported that the most common reason for reading difficulties is reduced accommodation. In addition, several researches found significant correlation between reduced accommodation and reading difficulties. It has been reported that accommodative insufficiency (AI) influences reading performance. It seems AI is a common cause of asthenopia in students between the ages of 8 and 15. The subjective reading improvement in children with AI subjected to treatment, including plus lens corrections and accommodative training, may be related to symptomatic relief and increased concentration.
and binocular NPA were reduced in the dyslexic group; however, there was no statistical difference in NPC and stereopsis in both the groups.

Visual screening for schoolchildren is essential, but most eye tests have been focused on evaluating reduced VA caused by refractive errors. In general, optometrists do not examine visual parameters related to binocularity such as accommodative and oculomotor tests. Therefore, the evaluation of these parameters is important because there is a high incidence of such problems in schoolchildren and impression on visual comfort and academic efficiency. Thus, checking accommodative function and special vision training in dyslexic children is beneficial. Although our findings suggest that dyslexic children show a lower NPA both monocularly and binocularly statistically significant, more studies need to be done for clinically applications of these tests. Furthermore, more studies should be performed to investigate the effects of accommodative treatments in dyslexic students to determine whether these kinds of therapies improve reading performance. In fact, accommodative optometric vision therapy may produce true physiological alterations in the accommodative system, but there is considerable ongoing controversy surrounding the role of vision therapy in the treatment of dyslexia and many challenges still need to be overcome to define an effective treatment.

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Conflicts of interest
There are no conflicts of interest.

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