Convergence Approach to the Incidence of Visual Function Problems by the Type of ADHD in Children

Hyung-Chel Cho[1], Hyo-Lyun Ro[2*]
[1]Doctoral Course, Division of Medical, Graduate School, Kangwon National University
[2]Professor, Division of Physical-therapy, Kangwon National University

ADHD 아동의 유형별 시각 기능의 문제 발생률에 대한 융복합적 접근

조형철[1], 노효련[2*]
[1]강원대학교 대학원 의학과 박사과정, [2]강원대학교 물리치료학과 교수

Abstract The objective of this study is to identify the visual function impairment of children with each type of attention deficit hyperactivity disorder(ADHD). The subjects of this study were 49 children diagnosed with ADHD with visual function out of the normal range. The type of ADHD was investigated using the Korean-ADHD Rating Scale and visual function test. The attention deficit type(69.4%) of ADHD was the most common type among children with ADHD with vision problems. Although their overall naked-eye visual acuity was good, about 50% of the subjects showed problems with visual function. For those with the attention deficit type of ADHD, the myopia-related refractive error was high. For those with the hyperactivity type of ADHD, the astigmatism-related refractive error was higher. For those with vergence function disorder, convergence insufficiency was the most common. As there were differences in the visual impairment characteristics of children with different types of ADHD, it is necessary to approach a child's problem behavior through examination and screening for visual function disorders.

Key Words : Child with ADHD, Convergence, Inattention type, Hyperactivity type, Visual function

요 약 본 연구는 시각적인 장애를 호소하는 ADHD로 진단받은 아동의 유형별 시각 기능의 특징을 확인하고자 하였다. 연구 대상자는 ADHD로 진단받은 아동 49명으로 시각기능이 정상범위에서 벗어난 경우이다. Korean-ADHD Rating Scale을 이용하여 ADHD 유형을 알아보았고 시각기능 검사를 통해 시각 기능의 문제를 알아보았다. 시각의 문제를 가지고 있는 ADHD 아동들은 부주의 유형(69.4%)이 가장 많았으며 시력은 좋지만 시각 기능 문제가 드러난 경우도 50% 정도 되었다. 주의력결핍 유형에서 근시 관련 시각장애, 과잉활동형 유형에서 난시 관련된 시각장애가 높게 나타났다. 버전스 기능 장애에서는 폭주부족이 가장 많았으며 유형별 차이는 나타나지 않았다. ADHD 아동의 유형별 시각장애의 특성은 차이가 나타나므로 시각 기능 장애의 검사와 선별을 통해 아동의 문제행동에 접근하는 것이 필요하다.

주제어 : ADHD 아동, 융복합, 주의력 결핍형, 과잉 활동형, 시각기능,

1. Introduction

Attention deficit hyperactivity disorder(ADHD) children have problems of selective attention (suppressed responses to irrelevant stimuli with responses to relevant stimuli) and sustained attention (maintaining concentration for a long time)[1]. In addition, their overall attention-concentration capacity is insufficient, resulting in low performance in tasks requiring a higher level of attention-concentration ability[1].

Attention-concentration ability is also related to visual function[2]. Vision plays a very import-ant role in everyday life as a sense of receiving and processing about 70% of the information from outside[3]. The prevalence of vision problems is 15.6% in children with ADHD, which is much higher than that (8.3%) in normal children[2]. Frequent visual problems in children with ADHD can lead to problems with color classification and depth perception[4]. The prevalence of ADHD in children with convergence insufficiency (CI) is about three times higher than the prevalence of ADHD in the general US population[4]. Problems with visual function in children with ADHD have been revealed by several studies[5,6]. However, the visual characteristics of each ADHD type are not well-studied yet.

ADHD is classified into three main subtypes, the equal type, hyperactivity type, and the inattention type[7]. The equal type is characterized by impulsivity and hyperactivity as well as inattentiveness and distractibility. The hyperactivity type is the most common type. It is characterized by impulsivity and hyperactivity without inattentiveness or distractibility. The inattention type is characterized by inattentiveness and distractibility without hyperactivity[7]. The ADHD classification is based on behavioral characteristics[8]. Studies on whether there is a difference in visual function by the type of ADHD are insufficient.

Therefore, in this study, the following two hypotheses is establish. First, there will be problems with visual function of each type of ADHD children with visual impairment. Second, there will be problems with visual function characteristic of ADHD children with visual impairment. The aim of this study was to identify the visual function problems of children with each type of ADHD who also had a visual impairment. Whether visual function might affect the behavioral characteristics of children with ADHD was also investigated based on this result.

2. Subjects and Methods

2.1 Subjects

The subjects of this study were 6 to 13-year-old children diagnosed with ADHD. Those with mental retardation (MR) were excluded. All study subjects were evaluated for visual function. Their data were compared with those of normal children and were out of the normal ranges. There were 49 children diagnosed with ADHD (male 44; female 5; average age 8.13±1.01 years) who were not receiving any medication(Table 1). As these children were underage, their data were used after explaining the objective and purpose of this study to their guardians and obtaining consent for use in this study.

2.2 Measurements

2.2.1 Korean-ADHD Rating Scale (K-ARS)

The ADHD Rating Scale-IV is a standard reference checklist for measuring the symptoms of ADHD according to the diagnostic criteria of the DSM-IV[9]. The purpose of the evaluation scale was to collect information on the frequency of problematic behavior from parents or teachers and use them for ADHD diagnosis and treatment in clinical settings. The evaluation scale

consisted of a total of 18 questions and was conducted by parents or teachers. Each question was evaluated on a 4-point scale: at all or not(0 points), sometimes (1 point), often(2 points), and very often(3 points). The odd-numbered items on the scale were configured to respond to attention deficit and the even-numbered items were configured to respond to hyperactivity-impulsive symptoms. The total score of the odd-numbered questions was used to measure attention deficit symptoms while the total score of the even-numbered questions was used to measure hyperactivity-impulsive symptoms. The total score of all questions was used to measure ADHD. According to Kim et al.[10] ADHD can be suspected if the total score of the questions is 19 or higher in the parent's evaluation and 17 or higher in the teacher's evaluation[10]. A school-level screening study in a large city reported that ADHD could be suspected if the parental evaluation score was 18 or higher.[11] The reliability of K-ARS is high as 0.92.[25]

2.2.2 Visual function measurement

A visual function test (VFT) was performed for all subjects. The VFT was performed using the following measurement equipment and tools: the VISUSSCREEN 500 (Carl Zisss Inc., Germany), the Worth 4 Dot (Bernel Inc., USA), a prism bar (Bernel Inc., USA), Polaroid glasses device (Carl Zisss Inc., Germany), polarized glasses (Bernel Inc., USA), a Howell phoria card (Cyclopean Design Inc., Australia), a Titmus fly (Stereo Optical co., Inc., USA), a pencil, red- green filter glasses, and a penlight. The VFT included visual acuity, distance sensory fusion (Worth 4 Dot), distance/near stereo-acuity, distance/near phoria, the alternate prism cover test(ACT), and an assessment of the distance/near vergence range. Before performing the VFT, if the subject had a refraction problem, the test was performed in a state where maximum plus to maximum visual acuity was generated through the test lens

so that the visual function due to the refraction problem was not affected. After sufficient practice was given to the subjects to ensure the reliability of the VFT measurement, the mean value was measured and recorded by performing two or more tests.

2.3 Statistical analysis

All statistical analyses were performed using SPSS 21.0 for Windows to investigate visual problems in the children according to the type of ADHD. Descriptive statistical analysis was performed for the children's general characteris -tics and scores by type of ADHD. The Chi-squared test was performed for the types of ADHD, refraction type, and binocular dysfunction types, non-strabismus, strabismus. Statistical significance was set at $p < 0.05$.

3. Results

3.1 General characteristics of the subjects

The general characteristics of the study subjects are shown in Table 1. There were 44 males with an average age of 8.07 ± 1.59 years and five females with an average age of 8.65 ± 1.66 years. One male had nystagmus. The ADHD score was 29.05 ± 8.37 points for males, 26.00 ± 4.97 points for females, and 28.78 ± 8.13 points for all subjects.

Table 1. General characteristics of the subjects (M±SD)

Gender (n)	Age	ADHD scores		
		Inattention component	Hyperactivity component	Total
M (44)	8.07 ± 1.59	16.56 ± 4.66	12.49 ± 5.11	29.05 ± 8.37
F (5)	8.65 ± 1.66	13.75 ± 2.63	12.25 ± 3.59	26.00 ± 4.97
Total (49)	8.13 ± 1.59	16.31 ± 4.57	12.47 ± 4.96	28.78 ± 8.13

M±SD: Mean±Standard deviation, ADHD: Attention deficit hyperactivity disorder, M: male, F: Female

3.2 Types of ADHD in the children

Regarding the types of ADHD in male children, 32 subjects with an inattention type, nine with an hyperactivity type, and four with a equal type were found are shown in Table 2. The types of ADHD in female children included an inattention type in two subjects, an hyperactivity type in one subject, and a equal type in one subject. Among all subjects of the study, the inattention type (n = 34) was the most common ADHD type, followed by the hyperactivity type (n = 10) and the equal type (n = 5).

Table 2. Types of ADHD   n(%)

Gender	Inattention type	Hyperactivity type	Equal type	Total
M (44)	32 (65.31)	9 (18.37)	4 (8.16)	45 (83.67)
F (5)	2 (4.08)	1 (2.04)	1 (2.04)	4 (8.16)
Total (49)	34 (69.4)	10 (20.4)	5 (10.2)	49 (100.0)

ADHD: Attention deficit hyperactivity disorder, M: male, F: Female

3.3 Types of ADHD and refraction types in the children

The types of ADHD and refraction types were investigated. The results are shown in Table 3. For those with the inattention type of ADHD, myopia with astigmatism was found in seven (14.3%), myopia in six (12.2%), hyperopia in four (8.2%), and hyperopia with astigmatism and astigmatism were each found in one child (2.0%).

For those with the impulsive/ hyperactive type of ADHD, astigmatism in two (4.1%) and myopia with astigmatism in one (2.0%) were found. For those with the equal type of ADHD, myopia in one (2.0%) and hyperopia with astigmatism in one (2.0%) were found. Therefore, in those with the inattention type, the refraction type related to myopia (astigmatism 12.2% and myopia with astigmatism 14.3%) was present in the highest proportion in children with ADHD. For those with the hyperactivity type of ADHD, the refraction type related to astigmatism (2.0% of myopia with astigmatism 4.1% of astigmatism) was present in the highest proportion.

3.4 Types of ADHD and strabismus incidence rate in the children

The types of ADHD and the strabismus incidence rate were investigated. The results are shown in Table 4. In those with the inattention type of ADHD, strabismus was classified as intermittent exotropia in six (12.2%) and esotropia in one (2.0%). For those with the hyperactivity type of ADHD, eight (16.3%) were normal and the strabismus type was intermittent exotropia in two (4.1%). In those with the equal type of ADHD, strabismus did not appear.

Table 4. Types of ADHD in children and the strabismus incidence rate   n(%)

Type	Non-strabismus	IXT	ET	Total
Inattention	27 (55.1)	6 (12.2)	1 (2.0)	34 (69.4)
Hyperactivity	8 (16.3)	2 (4.1)	0 (0.0)	10 (20.4)
Equal	5 (10.2)	0 (0.0)	0 (0.0)	5 (10.2)
Total	40 (81.6)	8 (16.3)	1 (2.0)	49 (100.0)

ADHD: Attention deficit hyperactivity disorder, IXT: Intermittent exotropia; ET: esotropia

Table 3. Types of ADHD and refraction types in the children   n(%)

Type	Normal	Myopia	Myopia with astigmatism	Hyperopia	Hyperopia with astigmatism	Astigmatism	Total
Inattention	15 (30.6)	6 (12.2)	7 (14.3)	4 (8.2)	1 (2.0)	1 (2.0)	34 (69.4)
Hyperactivity	7 (14.3)	0 (0.0)	1 (2.0)	0 (0.0)	0 (0.0)	2 (4.1)	10 (20.4)
Equal	3 (6.1)	1 (2.0)	0 (0.0)	0 (0.0)	1 (2.0)	0 (0.0)	5 (10.2)
Total	25 (51.0)	7 (14.3)	8 (16.3)	4 (8.2)	2 (4.1)	3 (6.1)	49 (100.0)

ADHD: Attention deficit hyperactivity disorder

Table 5. Vergence anomalies   n(%)

ADHD type	Normal	CI	VD	B.Exo	B.Eso	DI	CE	Total
Inattention	7 (14.3)	14 (28.6)	1 (2.0)	9 (18.4)	2 (4.1)	0 (0.0)	1 (2.0)	34 (69.4)
Hyperactivity	2 (4.1)	4 (8.2)	1 (2.0)	2 (4.1)	0 (0.0)	1 (2.0)	0 (0.0)	10 (20.4)
Equal	0 (0.0)	5 (10.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (10.2)
Total	9 (18.4)	23 (46.9)	2 (4.1)	11 (22.4)	2 (4.1)	1 (2.0)	1 (2.0)	49 (100.0)

ADHD: Attention deficit hyperactivity disorder, CI:Convergenc insufficiency, VD: Vertical anomalies, B.Exo: Basic exophoria, B.Eso: Basic esophoria, DI: Divergence insuffciency, CE: Convergence excess

3.5 Types of ADHD and incidence rate of non-strabismic binocular dysfunction in children

The types of ADHD and the incidence rate of non-strabismic binocular dysfunction were investigated. The results are shown in Table 5. In those with the inattention type of ADHD, the non-strabismic binocular dysfunctions (i.e., vergence function disorder) were as follows: CI in fourteen (28.6%), vertical anomalies in one (2.0%), basic exophoria in nine (25%), basic esophoria in two (4.1%), and convergence excess in one (2.0%). For those with the hyperactivity type of ADHD, the results were as follows: CI in four (8.2%), vertical anomalies in one (2.0%), basic exophoria in two (4.1%), basic esophoria in two (4.1%), convergence excess in one (2.0%), and divergence insufficiency in one (2.5%). Regarding the incidence rate of vergence function disorder, CI had the highest rate at 42.5%.

4. Discussion

In this study, we tried to identify the characteristics of visual function by the type of ADHD. Overall, children with ADHD lack attention-concentration abilities due to impaired selective attention and sustained attention capabilities. Selective attention is the ability to suppress responses to irrelevant stimuli and the ability to respond to related stimuli. Sustained attention is the ability to maintain concentration

for a long period[12].

In this study, among the ADHD subtypes, the inattention type was the most common one at 69.4%, followed by the hyperactivity type (20.4%), and the equal type (10.2%). In a study by Byun et al.[13], the equal type was the most

common at 66.7%, followed by the inattention type at 21.0%. In a study by Lahey et al.[14], the equal type was the most common at 66%, followed by the inattention type at 33%, which were different from the results of the present study. Such differences in results might be because this study targeted only cases with visual problems among children diagnosed with ADHD. In contrast, Wolraich et al.[15] reported that the inattention type was the most common, followed by the equal type and the hyperactivity type when evaluated by teachers. Similar to their results, the inattention type was also the most common in the present study. Therefore, it can be inferred that the inattention type has a high prevalence in children with ADHD with visual function problems.

When classifying attention, it is sometimes classified as attention with eye movement (overt attention) and attention without eye movement (covert attention)[1]. Covert attention is an active, spontaneous, and conscious attention mechanism. It is mainly used when actively exploring an environment[16]. Overt attention is an attention mechanism that can be defined as an automatic orienting response triggered by sudden environmental stimuli. It has the

properties of being involuntary, passive, reflexive, and unconscious. Overt attention lasts about 100 to 120 ms after it occurs[17]. Since eye movement and attention are related functions, even among children with ADHD who lack the overall capacity for attention-concentration, if they have visual function problems at the same time, the ADHD behavior characteristics may have higher intensities.

In this study, 51.0% of the children with ADHD with visual impairment had normal refraction, whereas about half of them had abnormal refraction. Therefore, even in children with ADHD who had visual problems, about half of them did not have visual refraction problems (that is, visual acuity problems). Of those with the inattention type of ADHD, there were many myopia-related visual impairments. In those with the hyperactivity type of ADHD, there were many astigmatism-related visual impairments. In the equal type, only one child had myopia. Therefore, there was a difference in the abnormal refraction patterns according to the type of ADHD. Myopia-related refractive disorder had the highest proportion among all children with ADHD. It is more likely to be included in the ADHD category when the vision problems are mild or moderate than when the vision problems are serious[2].

In this study, in children with the inattention type of ADHD, intermittent exotropia accounted for 12.2% and esotropia accounted for 2.0%. However, intermittent exotropia accounted for only 4.1% of the children with the hyperactivity type of ADHD. The incidence of strabismus was 18.3% in all subjects. Although the incidence of strabismus varies between countries and races, it is in the range of 0.3% to 5%[18]. In this study, the incidence of strabismus was 18.3%, which was much higher than the general incidence. In particular, the incidence of exotropia was 16.3%. Although the frequency of esotropia is high in the West, the frequency of exotropia is high in the East, the Middle East, and Africa, including

Korea, with a reported range of 0.3-5%[19]. Therefore, strabismus appears to be one of the major characteristics of visual function disorders in children with ADHD. Strabismus is a patholo -gical condition in which different images are formed on the corresponding retinal points of the two eyes due to misalignment of the two eyes[20]. The cause of strabismus remains unclear. However, the following factors are known to be related to strabismus: 1) refractive anomalies or amblyopia that can hinder the process of integrating visual information into the eyes; 2) central nervous system abnormalities, structural abnormalities of extraocular muscles or nerves; 3) genetic diseases; 4) delayed fetal growth in the womb; and 5) low birth weight or premature birth[21].

In this study, CI was the highest in children with ADHD with visual impairment. In particular, the CI was high at 28.6% in those with the inattention type. Rouse et al[22] also reported that the prevalence of ADHD increased in children with CI, which supports the results of this study. In contrast, children with convergence and accommodation abnormalities may be misdiagnosed as having ADHD because their concentration may be decreased or they have difficulty concentrating while listening to lectures or reading materia[23]. Therefore, it is essential to distinguish the difference between visual impairment and ADHD[24].

This study attempted to understand the characteristics of visual function by the type of ADHD in children. As there were differences in the characteristics of visual impairment according to the type of ADHD in the children, research on the relationship between the characteristics of visual impairment and the behavioral characteris -tics of children with ADHD is needed in the future. The limitation of this study is that the small number of subjects and comparisons without visual impairment with ADHD children have been made.

4. Conclusion

In this study, among children diagnosed with ADHD, we tried to determine the characteristics of their visual function problems according to each type of ADHD. Some meaningful results were drawn and the conclusions based on these findings are as follows.

First, about 50% of the children with ADHD who had visual function problems showed normal levels of naked-eye visual acuity. This aspect confirms that if the visual acuity of a child with ADHD is good, the vision problem should not be considered to be resolved.

First, since about 50% of children with ADHD who have visual function problems do not have vision problems, it is necessary to distinguish between vision problems and vision problems of ADHD children.

Second, in the inattention type of ADHD, visual function problems were common and myopia-related refractive error was the most common.

Third, since the incidence of strabismus in children with ADHD was very high, preparations are needed to reduce the incidence of strabismus from infancy.

Fourth, CI had the highest incidence in those with vergence function disorder, showing no difference between ADHD types. Therefore, there will be a lot of problems that the eyes cannot focus on.

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조 형 철(Hyung-Chel Cho)   [정회원]

· 2018년 2월 : 강원대학교 응급의료재활학과 (이학석사)
· 2018년 9월 ~ 현재 : 강원대학교 의학과 박사과정
· 2003년 5월 ~ 현재 : 한국시지각센터 원장
· 관심분야 : Brain Cognition, Visual Physiology, Vision Therapy
· E-Mail : id2166@hanmail.net

노 효 련(Hyo-Lyun Ro)   [정회원]

· 2002년 8월 : 대구대학교 재활의학과 (이학석사)
· 2008년 2월 : 대구대학교 물리치료학과(이학박사)
· 2010년 3월 ~ 현재 : 강원대학교 물리치료학과 교수
· 관심분야 : 운동치료, 아동 물리치료
· E-Mail : bustryagain@naver.com