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Handwriting Performance of Children with Attention Deficit Hyperactivity Disorder: The Role of Visual-Motor Integration

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Abstract

Background

Poor performance in motor skills is common among children with Attention Deficit Hyperactivity Disorder (ADHD). However, difficulties of children with ADHD in handwriting and its underlying mechanism have rarely been studied. We aimed to investigate the handwriting performance of children with ADHD by considering the role of Visual-Motor Integration (VMI) as a possible underlying mechanism.

Materials and Methods: The present study used a comparative-correlational method, which was carried out in 2019 in Gorgan, Iran. Twenty-four children with ADHD and 24 healthy children of primary-school-age performed the Persian Handwriting Assessment Tool (PHAT). Children copied words on a paper sheet in which words were printed on top of the paper, and they had to copy words as accurately as possible. In the dictation part, the experimenter read a text aloud, and children had to write words on a paper sheet as accurately as possible. Legibility (including word formation, size, space, alignment, and text slant), as well as the speed of handwriting, were evaluated in both copying and dictation parts. The Beery test was used to measure VMI.

Results: Results showed that children with ADHD were weaker in word-formation compared to healthy children. However, they had the same performances as healthy children in terms of word size, space, alignment, and text slant. The speed of handwriting was not significantly different between healthy and ADHD groups. ADHD children showed significantly lower scores in VMI compared to healthy children ($p = 0.004$).

Conclusion

Children with ADHD had weaker handwriting legibility compared to healthy children, which is mainly due to word-formation. Moreover, VMI might act as a possible underlying mechanism affecting poor handwriting in ADHD children.

Key Words: Attention Deficit Hyperactivity Disorder, Handwriting, Visual-Motor Integration.

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1- INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is a disorder caused by neurological, genetic, and environmental factors that appear in childhood and may persist until adulthood (1-3). According to the previous studies, children with ADHD show cognitive difficulties such as inattentiveness, impulsiveness, hyperactivity (4), academic difficulties (5), abnormal information processing (3), or problems with cognitive-motor skills (2). One of the most impaired motor skills, which is scarcely studied among ADHD children, is handwriting (2, 4). Handwriting, which is the focus of the present study, is a complex and important skill. It consists of a combination of different components and requires the integration of psychological, biophysical, and neurological processes that are acquired over time, as well as linguistic processes that interact in the maintenance and processing of verbal materials that should be converted to writing (4, 6-7).

Despite modern computer tools for writing, handwriting is still a prerequisite for many classroom activities at school. In this regard, it has been shown that handwriting skill is an important predictor of academic performance (5). An individual must retrieve relevant content and, at the same time, maintain an inherent state of this content among the sentences and paragraphs in the absence of feedback from the audience in writing. Furthermore, an individual must retrieve appropriate words, spellings, and combinations and then put the words in the form of a proper motor program and create visible output on paper to write a sentence. To this end, an individual must access content and words from his long-term memory and use them when involving in necessary psychological processing for the production of coherent text. This will require a high level of sustained attention (7). If a student is suffering from problems to maintain sustained attention, it will likely affect writing processes and performances, e.g., handwriting (7). Children with attention deficit hyperactivity disorder are likely to have difficulties in creating correct image processing that is a prerequisite for reading and writing an alphabetic system (2). In handwriting, some components could be investigated. Two important components are legibility and speed. Legibility is very important for the main function of writing (e.g., keeping and transferring knowledge). Speed is also important since it affects classroom and school activities (i.e., taking notes or writing, spelling, academic performance). Therefore, having good handwriting is important for children, specifically those with attention disorders (4). The speed of writing grows over the elementary school, and the development of alphabetical letters that are crucial for the legibility is continued during elementary and secondary school (8). Hence, the acquisition of automated processes is very important for writing graphical signs as quickly and accurately as without the need for conscious attention. Some research examined the relationship between ADHD and handwriting difficulties (2, 4, 7, 9-12).

Although previous has studies investigated handwriting in individuals with different learning disabilities (13), legibility in individuals with ADHD has rarely been studied. Nevertheless, some research showed that children with ADHD generally have poorer handwriting compared to healthy children (2, 4, 7, 9-12). However, legibility components such as formation, size, alignment, space, and slant have not been precisely examined, and it is not clear that which components of legibility are poor in children with ADHD. In this regard, children with ADHD were weaker in size component compared to healthy children, mainly due to attention deficit disabilities in children with ADHD (14). Besides, children with ADHD wrote words larger compared to

healthy children (15). However, numerous studies are needed to identify handwriting difficulties in children with ADHD with an emphasis on legibility. Moreover, the speed of writing in children with ADHD has been rarely investigated. Besides, the results of previous studies on the speed of writing in children with ADHD are controversial. For instance, it has been shown that children with ADHD write slower compared to healthy children (6). Moreover, the speed of writing in children with ADHD is faster compared to healthy children (11). Furthermore, no significant difference has been found between children with ADHD and healthy children in the speed of writing (16). Moreover, VMI contributes significantly to the quality and speed of handwriting (4, 17-21). It is defined as the ability to copy geometric shapes (22) and includes effective and efficient coordination between eyes and hands (e.g., eye-hand coordination), by which children can copy, draw, or write. Efficient VMI could occur when foundations of visual-motor skills are well developed (18).

Children with a well-developed VMI may have appropriate handwriting as well as other school skills (18, 23). Given the importance of VMI in handwriting, it may play a significant role in the handwriting of ADHD children. Given that handwriting legibility components have not been investigated as well as existing contradictory results for writing speed, it seems necessary to investigate legibility and speed of writing in children with ADHD. Therefore, the purpose of the present study was to investigate handwriting difficulties in children with ADHD with considering the role of VMI as a possible underlying mechanism. It was predicted that: 1) children with ADHD would show poor handwriting compared to healthy children, and 2) ADHD children would show lower scores on VMI compared to healthy children.

2- MATERIALS AND METHODS

The present study used a cross-sectional comparative-correlational method, which was performed in 2019 in Gorgan, Iran.

2-1. Study design and population

Participants included 24 girls and boys with symptoms of ADHD from special schools and 24 healthy children from regular schools who were matched based on age, sex, and class with those children with ADHD. The sample size included 24 students for each group according to GPower software with an effect size of 80%, a test power of 0.8, and a significant level of 0.05. Means and standard deviations of the age of children were 8.02± 0.75 and 8.15±0.64 years old for ADHD and healthy children, respectively. The Research Ethical Committee of the university approved the protocol (Code: IR.IAU.AK.REC.1398.012). Parents gave written informed consent.

2-2. Measuring tools

2-2-1. Handwriting tool*:* The handwriting task was adopted from the Persian Handwriting Assessment Tool (PHAT) (24). This tool evaluates writing performance in second and third grades students of primary school. The authors examined the validity of this instrument and reported internal consistency of 0.84-0.99 for all legibility dimensions (24). PHAT included demographic and handwriting parts. The demographic part contained information such as class, gender, hand-dominant, using eye-glass, and hearing-aid. The handwriting part included copying and dictation items. In copying items, children were asked to copy words on a sheet of paper as accurately as possible. Legibility dimensions, including formation, size, space, alignment, and text slant, were assessed for written words. All legibility components (except size) were assessed by

a five-point Likert scale ranging from very poor to very good. The size was assessed by a five-point Likert scale ranging from very small to very big. Children copied words on a paper sheet in which words were printed on top of the paper, and the child had to copy words as accurately as possible. While copying, a time in which the child took to copy text was measured by a chronometer in seconds and considered as the speed of writing. In the dictation item, the experimenter read a text aloud, and children had to write words on a paper sheet as accurately as possible. Two independent judges blinded to children's status or performance conditions assessed legibility of handwriting performances by using an evaluation form designed specifically for this test (24). Inter-rater reliability for two reviewers was $r > .70$. Data from the first reviewer was used for further analysis.

2-2-2. VMI (3rd ed): We used the VMI test (22) designed for children ranging from 2 to 15 year-old. This test consisted of 24 geometric forms, in which the child had to draw a form exactly like the one presented in the test booklet. Each was scored from 1 to 4 points for a total of 50 points. Scores are calculated by adding the scores of forms that are copied successfully until the child fails to copy three consecutive forms correctly. Scores of this test ranged from zero to 50 points. Higher points indicate better VMI ability. The validity and reliability of this test were positively assessed, and its Cronbach coefficient was reported as $r > .90$ (22).

2-3. Ethical considerations

This protocol study has been approved by the Research Ethics Committee of Islamic Azad University, Aliabad Katoul Branch (Code: IR/IAU/AK/REC/1398/012).

2-4. Data Analysis

Descriptive statistics, including mean and standard deviation, were used to describe variables. An independent t-test was used to compare handwriting performance and VMI between ADHD and healthy children. Linear regression was used to measure the perdition of handwriting performance by VMI. The Kolmogorov-Smirnov test measured the normality of data. The significance level was set at $p < 0.05$.

3- RESULTS

In this section, we will first present demographic data of ADHD and healthy children. Afterward, the results of the copying and dictation parts are presented. Finally, the results of VMI and its prediction on handwriting performance are presented. The demographic data of children are presented in **Table.1**. Results showed that all children were from the second grade of primary school. Seventeen boys and seven girls participated in each group. Most of the children were right-handed and used no eye-glass or hearing-aid. Moreover, results of normality tests showed that data were normally distributed.

Table-1: Demographic data of ADHD and healthy children, n=48.

Groups	ADHD	Healthy
Class	2th Grade	2th Grade
Number	24	24
Age (years)	8.02	8.15
Gender (boy/girl)	17/7	17/7
Hand-dominant (right/left)	23/1	22/2
Eye-glass (yes/no)	22/2	21/3
Hearing-aid (yes/no)	0/24	0/24

ADHD: Attention deficit hyperactivity disorder.

3-1. Copying

Means, standard deviations, and results of comparing all handwriting components of copying in ADHD and healthy children are presented in **Table.2**. Results showed that children with ADHD received lower legibility scores compared to healthy children, which was statistically significant (p = 0.001). Besides, children with ADHD had weaker scores compared to healthy children in word-formation. This difference was statistically significant (p=0.000). However, children with ADHD received scores between good to very good in space, alignment, and slant components, in which the results showed no significant difference between these children and healthy children (p > 0.05). In the size component, children with ADHD also received scores in the normal size; however, there was still no significant difference between these children and healthy children (p > 0.05). In the speed component, both children with and without ADHD wrote the text with a relatively similar average time. Moreover, there was no significant difference between the two groups (p > 0.05).

Table-2: Results of copying in healthy (n=24), and ADHD children (n=24).

Legibility	Groups	Ranged	Mean ± SD	Comparison
Formation	ADHD	1-5	3.10 ± .19	t = - 9.31, sig = .000
	Healthy	1-5	3.69 ± .23	
Space	ADHD	1-5	3.79 ± .12	t = - 1.52, sig = .135
	Healthy	1-5	3.83 ± .07	
Alignment	ADHD	1-5	4.04 ± .21	t = 1.07, sig = .290
	Healthy	1-5	3.99 ± .09	
Size	ADHD	1-5	3.01 ± .08	t = .86, sig = .393
	Healthy	1-5	2.99 ± .08	
Slant	ADHD	1-5	4.33 ± .48	t = - .58, sig = .561
	Healthy	1-5	4.41 ± .50	
Legibility	ADHD	5-25	18.28 ± .52	t = - 3.74, sig = .001
	Healthy	5-25	18.93 ± .66	
Speed	ADHD	> 1 s	82.25 ± 21.35	t = - .08, sig = .934
	Healthy	> 1 s	82.83 ± 26.61	

ADHD: Attention deficit hyperactivity disorder, SD: Standard deviation.

3-2. Dictation

Means, standard deviations, and results of comparing all handwriting components of dictation in ADHD and healthy children are presented in **Table. 3**. Results showed that children with ADHD had a lower legibility score compared to healthy children. This difference was statistically significant (p = 0.000). Children with ADHD had lower scores compared to healthy children in word-formation. The results of the t-test showed a significant difference between the two groups (p = 0.000). However, children with ADHD received a score between good to very good in terms of space, alignment, and slant components, in which the results revealed no significant differences between groups (p > 0.05). In the size component, children with ADHD also received scores in the appropriate range, which again, the results did not show a significant difference between the two groups (p > 0.05).

3-3. VMI (3rd ed)

Results revealed that healthy children showed significantly higher scores (31.46±4.96) compared to ADHD children (27.12±4.77) in VMI (**Figure.1**). Results of t-test showed a significant difference between healthy and ADHD children in VMI, t = -3.05, df = 46, p = 0.004.

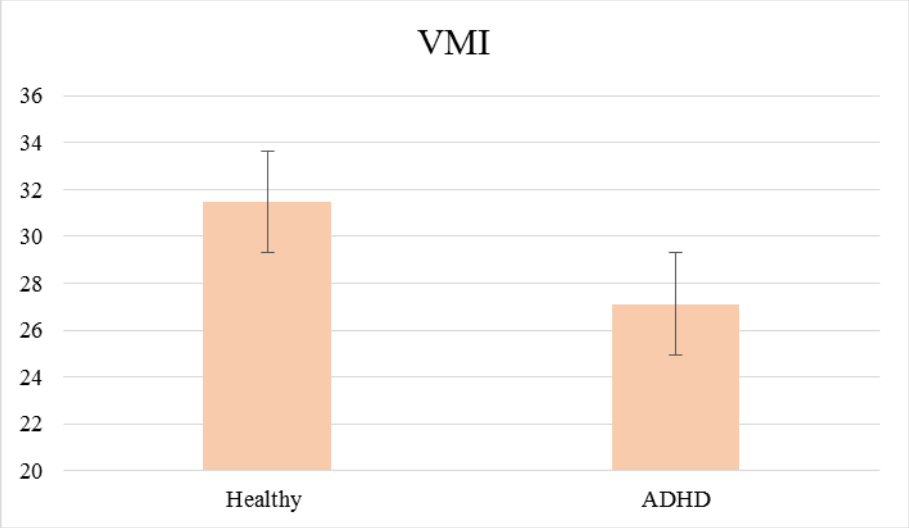

Fig.1: VMI scores of healthy and ADHD children, n=48.

ADHD: Attention deficit hyperactivity disorder, VMI: Visual-Motor Integration.

3-4. Linear Regression Analyses

Results of regression test are presented in **Table.4**. In copying, results showed that VMI significantly predicted word formation, F (1, 46) = 9.51, p=0.003, adjusted R^2=0.153, β= 0.414. Furthermore, in dictation, results demonstrated that VMI significantly predicted word formation, F (1, 46) = 5.43, p= 0.024, Adjusted R^2 =0.086, β=0.325. No other significant predictions were observed between VMI and handwriting performance.

Table-4: Results of regression tests between VMI and handwriting.

	Variable	*F* (1, 46)	*P-value*	Adjusted R^2	β
VMI	Word formation Copying	9.51	.003	.153	.414
	Word formation dictation	5.43	.024	.086	.325

4- DISCUSSION

The purpose of the present study was to investigate the handwriting difficulties of children with ADHD, with emphasis on legibility components as well as the speed of writing. It was predicted that: 1) children with ADHD would show poor handwriting compared to healthy children, and 2) ADHD children would show lower scores on VMI compared to healthy children. Regarding the first hypothesis, the results showed that children with

ADHD received lower legibility scores in both copying and dictation. Investigating the legibility components showed no significant differences between children with and without ADHD in terms of space, alignment, slant, and size components in both the copying and the dictation. However, children with ADHD showed significantly lower scores compared to healthy children in terms of word formation in both copying and dictation. The results of this study were consistent with the results of previous studies that found that children with ADHD had a weaker performance in handwriting compared to healthy children (2, 4, 7, 9-12), and supported our first hypothesis. However, the results of this study concerning the word size component did not match the results of previous studies (14-15), which found that children with ADHD write the words larger compared to healthy children.

Notably, the results of the present study showed that the more unsatisfactory performance of children with ADHD in handwriting legibility compared to healthy children was mainly related to the word-formation component. In this regard, word-formation and word-size components are the most significant components of handwriting legibility (8). A written sample may be readable even if the text slant or the space between the words is weak, but if the word size and especially the word-formation were weak, the legibility of the words and the text would be problematic. Therefore, the weakness of children with ADHD rather than healthy children in the word-formation component could be considered as the most important factor affecting their weakness in handwriting legibility. Besides, the results of this study showed that there was no significant difference between healthy and ADHD children in writing speed. These results are consistent with previous studies (16), which found no significant difference between children with and without ADHD in terms of writing speed. However, the results are not consistent with some previous studies showing that children with ADHD have slower or faster writing speed compared to healthy children (6, 11). Writing speed is also an important component of handwriting performance (8). A child at school should adapt himself to the needs of the class, including copying (writing) lesson concepts presented on the blackboard, noting teacher's lessons, and dictation. The performance of children in all these items is related to the speed of writing. According to the results of this study, the speed of writing of children with ADHD in copying was not different from that of healthy children, which might indicate that children with ADHD have no difficulty in writing speed.

The results of this study demonstrated that healthy children had higher VMI scores compared to ADHD children. These results are consistent with those of previous studies (25-26), which found that ADHD children compared to healthy children have low VMI scores and support our second hypothesis. Moreover, the results of regression analyses showed that VMI significantly predicted word-formation. VMI has been examined in the present study as a possible mechanism underlying the poor handwriting performance of ADHD children.

Based on previous research, VMI contributes significantly to the quality of handwriting (18-21). According to the results of the present study, it might be possible that VMI act as an underlying mechanism for poor handwriting in ADHD children. Among the limitations of this study, we assessed handwriting by using a qualitative method (rating by two judges). Using digital devices for handwriting and a quantitative assessment may result in a clearer picture of handwriting performance.

5- CONCLUSION

The present study showed that children with ADHD have weaker handwriting legibility rather than healthy children, which is mainly due to word-formation. According to the results of this study, VMI might act as a possible underlying mechanism affecting poor handwriting in children with ADHD. Moreover, the speed of writing between children with and without ADHD did not differ, which was added to the controversy results of previous research. Therefore, it is hard to make a clear conclusion about the speed of writing in children with ADHD. Further studies should focus on the speed of writing in free-writing and taking-notes to clarify the writing speeds of children with ADHD. The results of the present study have some educational considerations.

Given that poor handwriting performance of children with ADHD is mainly related to word-formation, teachers of special schools and, more specifically, teachers of first and second grades could optimize handwriting performance of ADHD children with focusing especially on teaching word-formation to ADHD children. Additionally, some educational interventions and conditions such as the focus of attention strategies or autonomy supports might be applied by teachers to improve hardwiring difficulties in ADHD children. Finally, given the importance of VMI on handwriting performance in ADHD children, we suggest that to improve the quality of handwriting, interventions for ADHD children in a class should focus on the improvement of VMI.

6- CONFLICT OF INTEREST: None.

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