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Relation of Executive Function Problems with Severity of ADHD Symptoms

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Abstract

Background: Attention Deficit Hyperactivity Disorder (ADHD) affects 7.2% of school-aged children. Affected children have been reported to show a range of executive function (EF) problems. This study investigated problems in different aspects of executive function and their relationships with the severity of attention deficit (AD) and hyperactivity symptoms (HS) in primary school children with ADHD.

Methods: In this cross-sectional study, 104 children with ADHD were recruited from schools based on the Vanderbilt test, which was administered by teachers for those who seemed to be inattentive or overactive in class. The executive function of participants was measured by BRIEF-2 and the prevalence of clinical deficits in different executive function domains and components was calculated. Additionally, correlations between EF scores and each of the "AD" and "HS" scores were examined using the Pearson correlation test.

Results: Among the 9 executive function components measured by BRIEF-2, clinical deficits in "Initiation" (44%), "Working memory" (42%) and "Shifting" (41%) were most commonly seen, while clinical deficits in the "Plan/Organize" function were least common (10.1%) in children with ADHD. Each of the "Cognitive", "Emotional" and "Behavioral" regulation index scores fell within the clinical-deficit range for approximately 31.7% to 35.6% of children with ADHD. The "Self-monitor" (r=0.334) and "Emotion control" (r=0.527) problems were correlated only with hyperactivity severity, whereas "Initiation" (r=0.416) and "Working memory" (r=0.528) problems were only correlated with AD symptom severity.

Conclusion: Children with ADHD form a heterogeneous group in terms of the type of executive-function problem. The severity of each group of "Attention deficit" and "Hyperactivity" symptoms is correlated to problems in different types of executive-function.

Key Words: ADHD, Executive functions, Emotion, Initiation, Organization.

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1- INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is the most common neurodevelopmental disorder in childhood (1, 2). Worldwide, the prevalence rate of the disorder is 7.2% among 2 to 17 year old children (3, 4). Symptoms of ADHD usually appear at preschool age, but it is often diagnosed during school ages and can still be seen in adolescence and adulthood years. ADHD affects the individual's ability to focus, organize, plan, and think before acting (5).

Several studies have found executive function (EF) developmental delay in school-aged children with ADHD (6, 7). It is proposed that reduced blood flow in the prefrontal and frontal regions of the brain impairs executive function, including attention, working memory, response inhibition, and planning (8). Although there is no single definition for executive function, Diamond names inhibition (inhibitory control, self-control, behavioral inhibition), response control (selective attention and cognitive inhibition), working memory (verbal and nonverbal), and cognitive flexibility (shifting) as the main components of executive function (9), while Wollrich formulated it in three domains of Behavior regulation (inhibit, self-monitor), Emotion-regulation (shift, emotional control), and Cognitive-regulation (initiate, working memory, plan/organize, task-monitor and organization of materials) (10). Executive function development is important for building basic life skills and school performance during childhood. Interventions focused on executive function can reduce learning problems and behavioral problems in children (9, 11) and predict health, economics, and delinquency outcomes in adulthood (12).

A number of researchers have examined the relationship between executive functioning and attention deficit and hyperactivity among children. However, most of those studies have been conducted in clinics (13, 14) and compare differences in executive function between children with and without ADHD. Given the continuum of severity of ADHD, most children with less severe symptoms are not recognized by mental health services (15) and would be overlooked in studies that recruit participants from clinics (16). However, children with milder forms of ADHD may benefit from interventions to prevent increases in the severity of their symptoms (17). Studies have shown that children and young adults with subclinical ADHD also experience problems with executive functioning (18). The heterogeneity of executive function among children with ADHD syndrome has been mentioned before (19). There are few studies researchers tried to determine which type of executive function deficits are associated with each group of inattention and hyperactivity symptoms. Neely et al., who studied 115 six to eight years old children, found that working memory (measured by digit span backward) and reasoning (measured by the matrix reasoning test) were correlated with inattention but not hyperactivity symptoms. However, none of the hyperactivity or inattention symptoms were related to the response inhibition as measured by the Walk-Don't-Walk test (20).

The present study aims to provide a clearer picture of executive function and its different domains (indexes) and components (clinical factors) among 6 to 11 year old children with ADHD, and to determine potential relationships between deficits in the three executive function domains and severity of attention deficit and hyperactivity symptoms in those children.

2- MATERIALS AND METHODS

This study was a cross-sectional study that was approved by the ethics committee (IR.USWR.REC.1402.219).

2-1. Sampling and Sample Size

To determine the correlation between executive function domains and ADHD symptoms, a correlation coefficient of 0.2 with a 95% confidence interval of width 0.4 (0.0-0.4) was set. The minimum required sample size for running parametric (Pearson) and non-parametric (Spearman) tests was calculated to be 91 (21). Taking into account a sample loss rate of 10%, the sample size was determined to be 100 children with ADHD.

The teachers of 42 1st to 4th grade classes in 3 primary schools were informed about the study and invited to participate. They all agreed and were provided with the Vanderbilt questionnaire. They were asked to fill in the questionnaire for students who seemed inattentive and/or overactive at school. The teachers filled in the questionnaire for 170 students, of which 104 had ADHD symptoms severe enough to fulfill the ADHD syndrome based on DSM IV-TR criteria (i.e., they had 6 out of 9 hyperactivity and/or inattention symptoms, based on the teacher filled Vanderbilt questionnaire) and were included in the study. Of these 104 students, 90 (86.5%) were boys with an average age of 8.0±0.84.

2-2. Measurements

2-2-1. Vanderbilt Questionnaire

The Vanderbilt Questionnaire was utilize to measure the severity of attention deficit and hyperactivity symptoms. This questionnaire was developed (22) and standardized (10) by Wollrich et al. It is intended to be completed by teachers and/or parents of children. The Questionnaire consists of 55 items. Eighteen items are used to evaluate the presence and severity of attention deficit and hyperactivity symptoms based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) criteria for preschool and elementary school children. This section of the questionnaire is identical to the SNAP-IV and the CADDARA test. Each item is rate on 5-point scales: never = 0, sometimes = 1, often = 2, and very often = 3. To meet the criteria for ADHD, the child must score a 2 or 3 on more than 6 items of attention deficit symptoms, hyperactivity symptoms or both. The total severity score for each hyperactivity and attention deficit symptom can range from 0-27, with higher scores show more severe symptoms. The Persian version of the questionnaire was validated in 2012. The internal consistency of this questionnaire based on Cronbach's alpha is reported to be 0.90 for attention deficit hyperactivity disorder (23).

2-2-2. Behavioral Rating Inventory of Executive Function 2 (BRIEF-2)

The Behavioral Rating Inventory of Executive Function 2 (BRIEF-2) was adapted from the original BRIEF in 2015 by Gioia et al (24). and has been widely used to assess the executive function of children with ADHD. It takes about 15 minutes to complete the inventory and has two forms for parents and teachers. It consists of 63 questions, with a Likert scale of 1 (“never”) to 3 (“always”). The inventory measures the executive function of children and adolescents age 5 to 18 years based on their behaviors at school or home. Using the BRIEF-2 inventory, the total score (Global Executive Composite), three Indexes (Behavior Regulation Index, Emotional Regulation Index and Cognitive Regulation Index) and 9 factor scores (Inhibit, Self-monitoring, Shift, Emotional Control, Initiate, Working-Memory, Plan/Organize, Task-Monitor, and Material Organization) can be calculated for each child. The raw scores should then be converted to t-scores based on gender

(girls and boys) and age groups (5-7 years, 8-10 years, 11-13 years, and 14- 18 years) according to the related T tables provided along with the inventory. The T scores are categorized into four ranges: normal (0-59), mild elevation (60-64), potentially of clinical importance (65-69), and clinical deficit (70 and above). The Persian version of this inventory was validated by Parhoon, et al. in 2021 (25).

2-3. Data Analysis

The Kolmogorov Smirnov test was used to check if the variables were normally distributed. As the Vanderbilt and BRIEF-2 scores of the participants were not normally distributed, Pearson'Rho was calculated to examine the correlation between the 'Executive Composite', 'Index' and 'Clinical-Factor' scores with the severity of each attention deficit and hyperactivity symptom. SPSS v25 software was used for data analyses, and a p-value of less than 0.05 was considered significant.

3- RESULTS

A total of 104 children with ADHD symptoms were included in the study. Table 1, shows the prevalence of receiving any type of intervention with-in 6 months of the study among participants.

As can be seen in table 1, only 17 students out of 104 had received any kind of therapy or medication within six months of the study.

Table 2, shows type of ADHD and severity of attention deficit and inattentiveness symptoms among participants.

As can be seen in table 2, the relative prevalence of inattentive type of ADHD was more than twice as the hyperactive type (44.23% vs. 20.19%) and the combined form of ADHD were reported in about a third of primary-school-aged children by their teachers.

Table-1. Prevalence of receiving any type of medicine or therapy within six months of the study among participants.

Medicine or therapy	Number of participants (%)
Medicine	4 (3.8)
Individual Psychology	9 (8.7)
Medicine and Individual Psychology	3 (2.9)
Group Psychology	0
Occupational therapy	0
Speech therapy	1 (1.0)
Neurofeedback and biofeedback	0
Parental biofeedback and education	0
No medicine or therapy	87 (83.6)
Total	104(100)

Table-2. Type and severity of attention deficit and hyperactivity symptoms among primary-school children with ADHD Symptoms.

ADHD Type	Number	%
ADHD-IN	46	44.23
ADHD-H	21	20.19
ADHD	37	35.57
Total	104	100
Severity of Symptoms	Mean*	Standard Deviation
Attention Deficit symptoms**	17.94	4.971
Hyperactivity Symptoms**	14.64	6.960
Hyperactivity and Attention Deficit symptoms severity†	32.59	9.006

*Calculated in the whole group of 104 children with Attention Deficit Hyperactivity symptoms

**From 0-27 scoring scale. Higher scores indicate more sever condition

† From 0-54 scoring scale. Higher scores indicate more sever condition

Table-3. Relative Prevalence of executive function deficits among primary school-aged children with ADHD.

Index/Scale	Normal (0-59)		Mild t score elevation (60-64)		Potentially of Clinical Importance (65-69)		Clinical Deficit (70 and more)		Score Mean±SD
	N	%	N	%	N	%	N	%	
Inhibit	31	29.8	11	10.6	32	30.8	30	28.8	64.8±10.73
Self-Monitor	45	43.3	25	24	10	9.6	24	23.1	62.4±9.43
Behavior Regulation Index (BRI)	26	25.0	24	23.1	17	16.3	37	35.6	64.8±9.92
Shift	30	28.8	11	10.6	22	21.2	41	39.4	66.4±12.22
Emotional Control	45	43.3	16	15.4	16	15.4	27	26.0	59.8±12.65
Emotional Regulation Index (ERI)	35	33.7	8	7.7	27	26.0	34	32.7	63.7±12.10
Initiate	24	23.1	26	25	10	9.6	44	42.3	65.0±10.13
Working Memory	23	22.1	15	14.4	24	23.1	42	40.4	67.0±9.48
Plan/Organize	36	34.6	20	19.2	37	35.6	11	10.6	61.6±7.72
Task-Monitor	30	28.8	17	16.3	35	33.7	22	21.2	64.0±7.76
Organization of Materials	48	46.2	27	26.0	9	8.7	20	19.2	58.8±10.17
Cognitive Regulation Index (CRI)	30	28.8	20	19.2	21	20.2	33	31.7	64.0±8.18
Global Executive Composite (GEC)	27	26.0	10	9.6	17	16.3	50	48.1	67.65±9.42

Table 3 displays the relative prevalence of clinical deficits in the global executive function composite as well as behavior regulation, emotional regulation and cognitive regulation indexes and each of the nine executive factors in children with ADHD included in the study.

Additionally, table 3 reveals that, approximately half of children with ADHD (48.1%) had Global Executive Composite scores in the clinical deficit range and about a third of children with ADHD (31.7% to 35.6%) had Cognitive, Emotional or Behavioral scores in the clinical deficit range.

Also, as can be seen in table 3, among different executive functions, the most prevalent clinical deficits observed were deficits in Initiate (42.3%) followed by working memory (40.4%) and shift (39.4%). Conversely, clinical deficits in Plan/Organize were less prevalent in primary-school-aged children with a prevalence rate of 10.6%.

Table 4 shows problem in the Self-monitor and Emotion control subscales of executive function correlate only with the severity of hyperactivity symptoms, while problems in Initiate and Working memory subscales of executive function correlate only with inattentiveness symptoms of ADHD. The other subscales of executive function correlate with the severity of both hyperactivity and inattentive symptoms. Additionally, the highest correlation coefficient for attention deficit symptoms goes to Task-monitor(r=0.570) and Working Memory(r=0.528), and for hyperactivity symptoms goes to Inhibition (r=0.649) and Emotion Control (r=0.527)

The relationship between attention deficit, hyperactivity symptoms and executive function t scores in the subgroup of 87 children who did not receive any therapy within 6 months of the study did not notably differ from the whole group of 104 children.

Table-4. Correlation between different Executive Function scores and severity of Attention Deficit and Hyperactivity Symptoms

Index/Factor	AD Score		HS Score	
	Correlation Coefficient†	Sig. (2-tailed)	Correlation Coefficient†	Sig. (2-tailed)
Inhibit	0.209*	0.033	0.649**	<0.001
Self-Monitor	0.165	0.095 (NS)	0.334**	0.001
Behavior Regulation Index (BRI)	0.196*	0.046	0.555**	<0.001
Shift	0.258**	0.008	0.323**	0.001
Emotional Control	-0.067	0.500 (NS)	0.527**	<0.001
Emotional Regulation Index (ERI)	0.056	0.576 (NS)	0.493**	<0.001
Initiate	0.416**	<0.001	0.188	0.057 (NS)
Working Memory	0.528**	<0.001	0.057	0.259(NS)
Plan/Organize	0.331**	0.001	0.364**	<0.001
Task-Monitor	0.570**	<0.001	0.282**	0.004
Organization of Materials	0.291**	0.003	0.473**	<0.001
Cognitive Regulation Index (CRI)	0.514**	<0.001	0.353**	<0.001
Global Executive Composite (GEC)	0.434**	<0.001	0.529**	<0.001

*P value <0.05
**P value < 0.01
†Spearman correlation coefficients are shown in whole table

4- DISCUSSION

School-aged children with ADHD face a wide range of executive function deficits. The present study showed that the 'Global Executive Function Composite' has a stronger correlation with hyperactivity than attention deficit symptoms. Additionally, different strengths of correlation between hyperactivity and attention deficit symptoms exist with various issues in different executive function components.

There are few studies that focus separately on the correlations of executive function components and each group of hyperactivity and inattention symptoms in ADHD. Ceruti C. and Marco G. (2025) examined the association between ADHD symptoms and EF impairments in 1068 students aged between 7-14 years old, studying in 2 nd to 8 th grade who did not have intellectual disability (Raven's score above 20). They were not selected based on any neurodevelopmental disorder. Researchers used Conners 3 Rating Scales to assess ADHD symptoms and the Executive Function Questionnaire (EFQU) to assess EF impairments. Based on the teacher rated Conners 3 and EFQU questionnaires (total EF scores with 3 subscales of self-regulation, self-organization, material management), and by calculating the Spearman coefficient, results showed relationships between inattention symptoms and cognitive self-regulation (-0.79), inattention with self-control (-0.63), hyperactivity symptoms and self-control (-0.70), and finally both inattention (-0.66) and hyperactivity symptoms (-0.58) with material management.

Bethan et al. (2017) and Michael et al. (2019) also found this heterogeneity in the working memory deficits of children with ADHD. It is important to note that executive function includes the working memory function. The correlations of problems in different EF components with attention deficit and hyperactivity

symptoms in children with ADHD will be discussed in more detail.

5-1. Behavioral Regulation

According to the BRIEF-2 inventory, the Behavioral Regulation Index is composed of two factors: ‘inhibition’ and ‘shifting’.

Inhibition

The present study indicated that the ‘inhibition’ t score is related to both hyperactivity and attention deficit, but the relationship was stronger with hyperactivity symptoms, which is in line with the Barkley model (26). However, Gambin and Swiecicka, who measured ‘stop signal reaction time’ to examine the executive inhibition deficit, reported that the inhibition deficit examined by ‘stop signal reaction time’ measurement was correlated with inattention but not hyperactivity symptom severity (27).

The relationship between hyperactivity and inhibition in pre school children had been previously mentioned in the study of Berlin and Bohlin (28). They demonstrated that hyperactivity and conduct problems were correlated with the inhibition deficit. Further analysis show that when they treated hyperactivity as a confounder, the correlation between conduct problems and inhibition was no longer significant.

Self-Monitor

The present study shows that 23.1% of children with ADHD symptoms had Self-monitor t scores in the clinical deficit range. The Self-monitor t scores were correlated with hyperactivity but not attention deficit scores.

The usefulness of self-monitoring skills training courses for children with ADHD has been mentioned in several studies. Alsalamah systematically reviewed 9 articles and dissertations on this topic conducted between 2000 and 2016 (29). She found that on-task behavior and academic outcomes of most children with ADHD improved following those training courses. However, we could not find articles that precisely measure self-monitoring problems in children with ADHD or examine its relationship with the severity of ADHD symptoms.

5-2. Emotional Regulation

According to the BRIEF-2 inventory, the Emotion Regulation domain (index) is composed of ‘shifting’ and ‘emotional control’ components.

Shifting

In the present study, about two-fifths of the participants had clinical deficits in shifting. There was a significant correlation between the shifting deficit and both attention deficit and hyperactivity symptoms. Willcutt et al. reported a shifting deficit in children with ADHD (30). Irwin et al. who examined reaction times of children with and without ADHD during “shift” and “non-shift” trials”, attributed deficits in performing shifting tasks to problems in performing prerequisite tasks for shifting such as inhibition (31).

Emotional Control

In the present study, emotional control scores were correlated with hyperactivity but not with the attention deficit symptom scores. Groves et al. had similar findings. They studied 145, children aged 8-13 years, of which 49 had ADHD, 53 had ADHD and common comorbidities, 21 had other clinical diagnoses but not ADHD, and 22 were neurotypical children without ADHD. Emotion regulation was measured by BRIEF and ADHD symptoms were measured by parent and teacher scores from the Behavior Assessment Scale for Children (BASC-3). They also demonstrated that HS symptom scores were correlated with emotion regulation, but AD symptom scores were not

significantly related to emotion regulation (32).

5-3. Cognitive Regulation

Cognitive regulation, the process of controlling cognitive activities, is composed of the Initiate, Working Memory, Plan/Organize, Task-Monitor, and Organization of materials components as measured by BRIEF-2. In the present study, around a third of participants had a clinical deficit in Cognitive Regulation, and Cognitive Regulation t scores were correlated with both attention deficit and hyperactivity symptom scores, although the relationship with AD scores was stronger than with HS.

Initiation

There is scarce evidence about the relationship between initiation problems and the severity of Attention Deficit and Hyperactivity symptoms. In the present study, about two fifths of participants had a clinical deficit in initiation. Initiation deficit was correlated with AD scores, but there was no correlation between Initiation scores and HD scores. This finding is in line with the results of the study of Niermann & Scheres in adults with ADHD. They studied the relationship between delays in activities that have to be completed before a deadline and the severity of ADHD symptoms in adults. Participants were 54 pre-graduate students with a self-reported questionnaire on ADHD symptoms. The correlation was only present with AD but not Hyperactivity scores (33).

Working Memory

The present study shows, that only about one-fifth of participants had working memory t scores in the clinical deficit range. The working memory t score was correlated to AD but not HS scores. Deficits in the working memory of children with ADHD have been mentioned in many studies before. Similar to the findings of the present study, in the study of Groves et al. who measured working memory using computerized working memory tests in 8-13 years old children, working memory scores were correlated with teacher reported attention deficit, but not hyperactivity scores (32). In contrast, in the Kofler et al. study, the working memory t scores were related to both AD and HS t scores (34). However, in Kofler's study, only two out of 81 participants had the Hyperactive type of ADHD; others were affected with Combined (n=62) or Inattentive (n=17) type of the disorder, so the present study can better examine the presence of a relationship between HD severity and working memory function.

Plan /Organize

In the present study, about one-tenth of participants had a clinical deficit in plan/organize; and plan/organize function was correlated with both AD and HS symptoms. Some studies compare Plan/Organize function among people with and without ADHD. Different results have been seen at different ages. In earlier developmental stages, (3 to 5.5 years old children) Sonuga-Barke et al. found no correlation between planning (measured by the Tower London test) and the presence of ADHD (35). But Boyer et.al's study on planning and social skills of adolescents with ADHD, which included 150 adolescents with ADHD and 34 typically developed control, using the parental rating BRIEF, showed scores of Plan/Organize were similarly correlated with Inattentive (ADD) and combined form of ADHD (36).

Task-Monitor

In the present study, about one-fifth of participants had clinical deficits in the task-monitor. Task-monitor scores were correlated with both AD and HS symptom scores. We could not find reports on measurement of Task-monitor function in children with ADHD and its relation to

AD and HS symptoms. However, successful monitoring of tasks relayed on sustained attention and self-regulation so these relationships are not surprising.

Organization material

In the present study, about one-fifth of participants had clinical deficit in organization material. Organization material problems were correlated with both AD and HS symptoms. Similarly, in the study of Jarratt et al. on 9-15 years old children with (42 students) and without (26 students) ADHD, with BRIEF inventory, and Behavior Assessment System for Children (BASC), hyperactivity was shown to be correlated with organizing materials (37).

It is noteworthy to say BASC measures hyperactivity as well as some other externalizing problems and internalizing problems, behavioral symptoms and adaptive skills. However, the study of Kofler et al. who studied organizational skills problems in ADHD, using path analysis, showed that attention problems, but not hyperactivity, have a direct relation with organizational problems (38). The relationship between hyperactivity and organization of material should be studied more precisely in further studies.

Also, the possible role of demographic, social and spiritual factors in the relationship between attention deficit symptoms, hyperactivity symptoms and executive function problems has not been examined in this research, and should be addressed in future studies.

5- CONCLUSION

School-aged children with ADHD syndrome are highly heterogeneous in terms of executive function disturbances, with a wide range of severity present in most of them. However, about a quarter of these children, have a global executive score within the normal range. The severity of most executive functions has a relationship to the severity of both hyperactivity and attention deficit symptoms' severity. The most prevalent executive function deficits in ADHD children are in working memory and initiate, interestingly, the severity of deficits in these two functions does not show a relationship with the severity of hyperactivity symptoms. On the other hand, self-monitoring and emotional control deficits showed no relationship with attention deficit symptom severity. Based on the results of the present study, assessing global executive function along with its domains and components in children with ADHD syndrome, could help in developing intervention that best fits the unique health needs of each child with ADHD.

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