

Neurocognitive Profile of Children with Attention Deficit Hyperactivity Disorders (ADHD): A comparison between subtypes

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Objective: The aim of this study was to examine the differences between ADHD subtypes in executive function tasks compared to themselves and normal controls.

Method: In this study, 45 school aged children with Attention Deficit Hyperactivity Disorder (ADHD) and 30 normal children who were matched based on age and IQ score in Wechsler Intelligence Scale for Children-Revised (WISC-R) were compared in terms of executive function. We used Wisconsin Sorting Card Test to assess executive function in both groups. We also used children's scores in Children Symptom Inventory-4 (CSI-4) for diagnosing ADHD and specifying ADHD subtypes. Data were entered in SPSS-17 and analyzed by T-test and ANOVA static tests to clarify the differences between ADHD and controls and between ADHD subtypes. Scheffe's test was also used to identify which groups were different from one another. The mean and standard divisions (SD) were used for descriptive analysis.

Results: ADHD subtypes are significantly different in terms of perseverative responses ($p \leq 0/01$) and perseverative errors ($p \leq 0/001$). Based on Scheffe's test, Attention Deficit Hyperactivity Disorders-Hyperactive type (ADHD-H) is not that different from Attention Deficit Hyperactivity Disorders-Inattention type (ADHD-I) and Attention Deficit Hyperactivity Disorders-Combined type (ADHD-C), but there are significant responses and perseverative differences between ADHD-I and ADHD-C in terms of perseverative errors. ADHD-C shows more perseverative responses and perseverative errors than ADHD-I.

Conclusion: The findings of this study revealed that executive function patterns are different in children with ADHD compared to normal children. In this study it was also found that ADHD subtypes are also different in terms of perseveration and response inhibition domains; ADHD-C has more deficits in these domains.

Keywords: ADHD, Subtypes, Executive Function, Wechsler Intelligence Scale for Children-Revised (WISC-R).

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According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), attention deficit and hyperactivity disorder (ADHD) is defined as a neuro-developmental disorder that is characterized by impairment in the levels of attention, disorganization and/or hyperactivity-impulsivity and it occurs in about 5% of children and about 2.5% of adult population (1, 2). In this group of children, inattention and disorganization characteristics are involved in inability to maintain tasks, seeming not to listen and losing things, and the hyperactivity-impulsivity characteristic involves in over activity, fidgeting, inability to stay seated, disrupting other's activities and inability to wait more than what is expected for their age (1). Moreover, in childhood, there are overlaps between ADHD and other disorders like oppositional defiant disorder and conduct disorder (1, 3, and 4). In

adulthood, ADHD leads to impairments in social, academic and occupational functions (1, 4-6).

It has been suggested that there are deficits in underlying cognitive processes related to attention, organization and hyperactivity-impulsivity in children with ADHD (1, 7). One of the most accepted explanations of characteristics of children with ADHD is the deficit in executive function (EF) domain which is assumed to be facilitated by the frontal lobes and is defined as neuro-cognitive processes that maintain an appropriate problem solving ability to achieve future goals (8-10). Executive function domains that are assumed to be related to ADHD symptoms are response inhibition or working memory or overall weakness in executive control (7, 8, 10-12). As noted in Willcutt et al., this explanatory theory is based on the observation that reveals damages to the prefrontal lob may lead to distraction, hyperactivity or impulsivity along with deficits on EF tests (13). As defined in DSM-5,

ADHD is divided to three subtypes: predominantly hyperactive/impulsive (ADHD-H), predominantly inattentive (ADHD-I) and combined (ADHD-C) (1). According to the previous studies, these three subtypes are distinguished from one another based on inattention symptoms, related features, motor function, demographic variables and reaction to stimulant medications (14-21). Some authors proposed that not only there are differences between children with ADHD and typically developing children in executive functions domains, but also these differences are observed between ADHD subgroups (mostly between inattentive and combined) to some extent, mostly on amount of response inhibition (18, 22-25).

Based on Barkley's model, ADHD-C subtype is related to deficits in executive functions, but there is no executive function deficit for ADHD-I subtype (7). This model is supported by subsequent studies, in which executive dysfunction is observed in ADHD-C subtype but not in ADHD-I subtype (26, 27).

In some studies it has been shown that the ADHD-C subtype groups have impairments in planning and cognitive flexibility domains in comparison with ADHD-I (28), but this finding has not been repeated in later studies (29). It is also found that there are more weaknesses in the ADHD-C subtype in comparison to the ADHD-I subtype in response inhibition domain and verbal fluency (29, 30).

In another study, discrepancy in executive functions of children with ADHD was investigated based on subtypes and gender. This study showed that the ADHD-C subtype had differences in cognitive flexibility and inhibition in comparison to normal controls, but there were no differences between ADHD-I subtype and controls. Moreover, two ADHD subtypes did not show any differences (27). Other studies on this subject revealed no significant differences between the ADHD subtypes in the executive function domain (31-33).

Given these inconsistent findings, there is a necessity for more investigation on this issue. Therefore, the present study was designed to examine the differences between the ADHD subtypes in executive function task in comparison with themselves and with the normal group.

Material and Methods

Participants

The study population was all the 6 to 9 year- old students from the districts of one and two in Yazd, an old and big city located in the center of Iran.

For the study group, 56 students were selected from Imam Hussein Counseling Center (Counseling Center of Educational Organization of Yazd Province) who were referred by their school staff and had received ADHD diagnosis by a child psychiatrist based on DSM-IV-TR criteria and had no comorbid disorders.

After that, the entire study group and their parents (mother or father) were interviewed by a clinical psychologist. The Child Symptom Inventory-4 (CSI-4) was filled out by parents to be used for the diagnosis and differentiation between the ADHD subtypes. Of the participants, 19 were diagnosed with ADHD-H, 15 with ADHD-I and 22 with ADHD-C.

In the ADHD-C group, 7 participants and in the ADHD-H group 4 were excluded. Finally, 45 students (15 students in each ADHD subtype groups) were remained as the study group.

The control group consisted of 30 students who were selected from the above mentioned population by stratified random sampling method. In the control group, none had a history of psychiatric disorders or developmental delay based on their parents' report.

Exclusion criteria was wearing glasses, color blindness, physical or psychological disorder and using psychiatric medicines. Students who were diagnosed with ADHD in the past and were under treatment with medicine were excluded from the study due to the medicines' effect on attention.

In the current study, all the students (from both sexes) with all ADHD subtypes were participated as the study group.

All cases in the study and the control group were matched based on age, sex and IQ level.

Instruments

In the current study four tools of Structured Interview, Wechsler Intelligence Scale for Children-Revised (WISC-R) and Child Symptom Inventory-4 (CSI-4) were used. Wisconsin Card Sorting Test (WCST) was used for neuropsychological evaluation. All evaluations were performed in individual sessions.

Child Symptom Inventory-4 (CSI-4) is a screening tool for the symptoms of behavioral and emotional disorders in children based on the diagnostic criteria of DSM-IV. This inventory has a parent checklist and a teacher checklist. The parent report checklist contains 97 items to screen 15 behavioral and emotional disorders including AD/HD, Oppositional Defiant Disorder, Conduct Disorder, Generalized Anxiety Disorder, Social Phobia, Separation Anxiety Disorder, Obsessive-Compulsive Disorder, Specific Phobia, Major Depressive Disorder, Dysthymic Disorder, Schizophrenia, Pervasive Developmental Disorder, Asperger's Disorder and Tics Disorder.

There are two methods to score CSI-4: criterion-related and norm-based. In the criterion-related method the score of zero was given to items which were rated as never and seldom, and the score of one was given to the items which were rated as sometimes and often. The final score for each subscale was obtained by adding the scores of the items related to the given subscale.

In the present study, we only used the AD/HD subscale. This subscale consists of 18 items, in which items 1-9 are used for ADHD-I and items 10-18 for ADHD-H. The total ADHD score can be obtained by

adding the scores of 1-18 items. The cutoff point for diagnosing ADHD based on the CSI-4 is 6 for both the mainly attention deficit and the mainly hyperactive-impulsive types.

The test-retest reliability of the parent checklist in an Iranian sample was reported as 0.90. Furthermore, in another study, Cronbach's alpha of 0.92 and a sensitivity of 0.94 were reported for this inventory(11).

Wechsler Intelligence Scale for Children-Revised (WISC-R) is a well-known scale for assessing the IQ in children aged between 6-16 years. WISC-R gives two different scores for verbal and performance IQ and a total IQ scores. Each scale consists of 6 subscales. Moderate internal consistency for total IQ, verbal IQ and performance IQ were reported as 0.96, 0.95 and 0.91 by Wechsler, respectively(34). In the present study we used total IQ score to match the participants.

Wisconsin Card Sorting Test (WCST-64) is a neuropsychological test for assessing problem solving, sorting, abstract thinking, ability to maintain concepts and cognitive flexibility skills which are related to performances of the frontal lobe. In this test, a set of 64 cards including 1-4 shapes in forms of red triangle, green star, yellow cross and blue circle are given to the participants, and then they should place the cards based on their perception of the pattern used by the examiner. The pattern is a red triangle, green star, yellow cross and a blue circle. For example, if the principle is color, the true placement is that the red card regardless of the shape or number should be placed under the triangle and the examiner determines if the placement is correct or not. After that, the subject completes a round of ten placements correctly, and the examiner will then change the principle. The test will continue until the subject finishes the placement of ten cards for six times and place 64 cards in one category(35).

Data Analysis:

Data were entered in SPSS-17 and analyzed by T-test and ANOVA static tests to clarify the differences between ADHD and normal group and between ADHD subtypes. Scheffe's test was also used to identify which groups were different. The mean and standard deviations (SD) were used for descriptive analysis.

Results

The study group consisted of 45 school aged children; of whom, 27 were male and 18 were female. In the control group, there were 30 school aged children, of whom 18 were male and 12 were female. Other characteristics of the two groups (age, IQ, ADHD subtype frequency) are presented in Table 1.

Data analysis showed that ADHD and normal group were significantly different in terms of perseverative

responses, perseverative errors and total errors on WSCT (Tables 2 and 3)

As shown in Table 4, ADHD subtypes were significantly different in terms of perseverative responses ($p \leq 0/01$) and perseverative errors ($p \leq 0/001$). Based on Scheffe's test, ADHD-H was not different from ADHD-I and ADHD-C but there were significant differences between ADHD-I and ADHD-C in terms of perseverative responses and perseverative errors. ADHD-C showed more perseverative responses and perseverative errors than ADHD-I.

Discussion

The aim of the present study was to investigate the differences between ADHD subtypes in terms of executive function profile. Previous studies showed inconsistent findings in this regard.

In an extended study, Houghton et al. investigated the executive function in 94 children with ADHD (without any co-morbid disorder) in terms of subtype and gender using five tests of the Wisconsin Card Sorting Test, the Stroop Color-Word Test, the Matching Familiar Figures Test, the Trail Making Test, and the Tower of London. They found that children with both types of ADHD (ADHD-I and ADHD-C) differed from normal children in terms of perseveration and response inhibition, but this difference was significant in ADHD-C, only (27). The lack of any co-morbidity in children with ADHD showed that the impairments in executive function were obviously found in ADHD, particularly in the ADHD-C, so providing support for Barkley's theory of ADHD (27). Consistent with this finding, in another study, Klorman et al. found that children with ADHD-C revealed more non-perseverative errors in WCST and solved fewer puzzles and also violated more rules on the Tower of Hanoi (TOH) than ADHD-I, but they were not different based on perseverative errors in WCST(28). Also, Lawrence et al. explored executive function in children with ADHD using WCST, Stroop and Zoo measures. Their finding revealed that children with ADHD were only different in set-shifting on WCST (perseverative responses and errors) (10).

In this respect, we found that children with ADHD significantly differed from normal children in terms of total errors, perseverative errors and perseverative responses ($p \leq 0.01$). Also, we found that ADHD subtypes operated differently in the executive function domain ($p \leq 0.01$); children with ADHD predominantly combined type showed more perseverative responses and perseverative errors than children with ADHD predominantly inattentive type.

Some researchers suggest that the two primary subtypes of ADHD share similar neuropsychological weaknesses in inhibitory control, but there are subtype differences in response to success and failure that are contributed to a child's ultimate level of performance (36).

Table 1: demographic variables of control and study groups

Group	N	Mean of age	Sex		Total IQ
			Male	Female	
Control	30	7.8	18	12	108.9
ADHD-I*	15	6.9	9	6	104.5
Study ADHD-H**	13	7.5	8	5	106.6
ADHD-C***	17	8.1	10	7	101.2

* Attention Deficit Hyperactivity Disorders-Inattention type

** Attention Deficit Hyperactivity Disorders-Hyperactive type

*** Attention Deficit Hyperactivity Disorders-Combined type

Table 2: mean and SD scores of the normal group and ADHD in Wisconsin Card Sorting Test

Percentiles	Normal group		ADHD	
	Mean	SD	Mean	SD
Total errors	19.18	12.69	28.71	14.22
Perseverative responses	13.92	10.61	23.17	15.22
Perseverative errors	17.78	11.32	26.89	11.75
Non-perseverative errors	5.97	7.08	9.24	11.63

Table 3: comparison between normal group and ADHD on the Wisconsin Card Sorting Test

Percentiles	T	P
Total errors	3.4	0.002 **
Perseverative responses	2.8	0.007*
Perseverative errors	3.04	0.004**
Non-perseverative errors	1.28	n.s.***

*p≤ 0.01

**p≤ 0.005

*** non-significant

Table 4: comparison of total errors, perseverative responses, perseverative errors and non-perseverative errors of subtypes of ADHD on WCST using ANOVA

Source of variance		Sum of squares	Mean squares	df	f	p-value
Total errors	Between groups	57.127	28.563	2	2.541	n.s.***
	Within groups	81.100	1.930	42		
	Total	138.227		44		
Perseverative responses	Between groups	2954.086	1477.043	2	4.981	0.002*
	Within groups	18253.500	434.607	42		
	Total	21507.586		44		
Perseverative errors	Between groups	10705.79	5352.895	2	18.372	0.001**
	Within groups	14436.4	343.723	42		
	Total	25142.19		44		
Non-perseverative errors	Between groups	65.772	32.886	2	3.186	n.s.***
	Within groups	78.941	1.879	42		
	Total	144.713		44		

*p≤0.01

**p≤0.001

*** non-significant

Unlike the Barkley's behavioral inhibition theory, Song and Hakoda found that both types of ADHD (ADHD-I and ADHD-C) showed deficits in the inhibition domain (24). Also, Li et al. found noticeable cognitive impairments such as poor response inhibition, impaired working memory, dysfunction of planning and set-shifting in children with ADHD, but there were no significant differences between the two subtypes of ADHD in their study (12).

Limitations

This study suffers from some limitations. The first and most notable limitation of our study was that we only

used one test to assess the executive function; and the second limitation was that we did not directly evaluate the control group for psychiatric disorder and only relied on the parental report.

Conclusion: Our findings revealed that executive function patterns are different in children with ADHD compared to normal children. Our study also confirmed that ADHD subtypes are different in terms of perseveration and response inhibition domains; ADHD-C type showed more deficits in perseveration and response inhibition.

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