



Executive Functions among Traumatic Injury Patients: Comparison of Normal Individuals and those with Attention Deficit Hyperactivity Disorder

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► ABSTRACT

Objectives: To describe the executive function of patients with traumatic injury admitted to Rajaei hospital, Shiraz, Iran and to compare the executive function between normal individuals and those with Attention Deficit Hyperactivity Disorder (ADHD).

Methods: This was a case control study being performed during a 6-month period during spring and summer of 2013 in Shiraz level I trauma center. We included all patients admitted during the study period with impression of traumatic injury with or without adult ADHD. The patients' demographic factors were assessed through self-report questionnaire and executive functions by Wisconsin Card Sort Test (WCST) and Tower of London (TOL). Results were compared between normal individuals and those with ADHD.

Results: Among 60 patients evaluated during the study period, with impression of traumatic injury, 29 fulfilled adult ADHD criteria and 31 were normal. The mean age of ADHD patients was 27.16 ± 5.6 years and that of normal individuals was 26 ± 3.4 years ($p=0.330$). There were no significant differences between two study groups regarding IQ ($p=0.191$) and education ($p=0.396$). Patients with ADHD had significantly poorer mean in executive functions in different parts of the test scoring system when compared to normal individuals.

Conclusion: ADHD patients with traumatic injury had poor executive function compared to normal individuals. This might lead to poor inhibition, shifting and problem solving in this population.

Keywords: Traumatic injury; Attention Deficit Hyperactivity Disorder (ADHD); Executive dysfunction; Wisconsin Card Sort Test (WCST); Tower of London (TOL).

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Introduction

In a general perspective, executive functions (EFs) are often defined as the directive capacities of

the human brain [1]. EFs are a set of interrelated control processes involved in the selection, initiation, execution and monitoring of cognition, emotion and behavior as well as aspects of motor and sensory

functioning [2]. Frontal lobe of the brain is mainly known as the anatomic reference of the EFs [3]; although damage to the frontal lobes can result in significant dysfunction of various EFs, this complex higher order processes are not solely a product of frontal activity. The frontal lobes are interconnected through numerous neuroanatomical pathways, with other cortical and subcortical regions of the brain [3]. To prove this diversity, it is much better to emphasize the pathological situations from which executive dysfunction can arise. Schizophrenia [4], obsession-compulsion disorder [5] and attention deficit/hyperactivity disorder (ADHD) [6] are those psychiatric problems giving rise to executive dysfunction. ADHD is a neurodevelopmental problem [7] with childhood onset which might persist in adulthood [8]. Although adult ADHD patients have different types of deficit especially in neuropsychological function like EF, academic, occupational and social function, diagnostic criteria of adult ADHD are challenging [9]. Clinical manifestations of ADHD are based on spectrum, so a great diversity exists in terms of presence and level of symptoms. Research evidence suggests that ADHD consists of more than inattentiveness and hyperactivity, so the symptoms of EF must be involved in the definition of the disorder [10]. Hervey, Epstein and Curry [11] and Gallagher & Blader [12] reported that executive dysfunctions are common among adults with ADHD. Considering the critical role of EF in normal functions such as self-activation, self-regulation, self-realization, self-determination, self-generation and trans-self integration [13], the deficits of EF are very likely to be associated with functional impairment in the functions of adult life including working [14], being part of family member, keeping appointment and driving safe [15]. Some studies based on accident and ADHD reported that individuals with ADHD have poor driving history than the other psychiatric disorders [16]. Barkely et al., [17] claimed that two neuropsychological functions have been impaired in ADHD drivers, the first of which involves attention, so they can't endure over extended periods of time and the second is modulate attention between multiple tasks while driving.

According to the EF theory which mainly describes ADHD neuropsychological deficits and the fact that this disorder is highly accused to be an unsafe behavior, the goal of the present study is to compare executive dysfunction between patients who had a history of trauma with and without ADHD.

Materials and Methods

Study Population

This was a case control study being conducted using convenience sampling from inpatients who referred to Shahid Rajaee Hospital, the unique center of trauma in Shiraz, affiliated to Shiraz University of Medical Sciences (SUMS). Two groups

of participants were enrolled in this research: (1) ADHD: 31 adults clinically diagnosed with ADHD and trauma in comorbid. The psychiatrist and the psychologist engaged in the study evaluated the new cases that referred during spring and summer 2013, using a structured interview for ADHD, and (2) Clinical Control Group: 29 adults evaluated at the same clinic but not diagnosed with ADHD; they had a recent history of trauma. Both the ADHD and clinical control adults were recruited from consecutive referrals to the hospital with inclusion criteria such as IQ of at least 80 on Ravan Progressive Matrix Test, no evidence of deafness, blindness, no obvious brain damage or neurological injury approved by Brain CT scan or brain MRI, no epilepsy, a chronic and serious medical condition that affects the cognitive process, and past history of mental retardation and severe mental disorders. The present study was approved by the Ethics Committee of Shiraz University of Medical Sciences before it was implemented. Written informed consent was obtained from all subjects to participate in the study, and they were free to withdraw at any time, and also were ensured of the confidentiality of the data. The intuitional review board (IRB) approval was also achieved before the study.

Study Protocol

Participant evaluated by the standard test, such as Wisconsin Card Sort Test (WCST) and Tower of London (TOL) and demographic factors were also evaluated by pencil-paper self-report questioner. Wisconsin Card Sort Test consists of 128 response cards and 4 stimulus cards. The test assesses the abstraction ability and the ability to use shifting cognitive strategies in response to changing environmental contingencies, as a part of EF [18]. The test is based on 64 cards. The shapes on the cards are different in color (red, green, blue or yellow), form (circles, stars, squares or crosses) and number (1, 2, 3, and 4). During the administration of the test, four stimulus cards with the following characteristics are placed in front of the subject: one red triangle, two green stars, three yellow crosses, and four blue circles. The subjects must sort the cards according to color, form, and number. The participant decides whether the cards are to be matched by color, form or number. He/she is not told how to match the cards; however, he/she is told whether a particular match is right or wrong. Participants try different rules to find a correct method for sorting the cards. During the course of the test, the matching rules are changed once the subject has made a specified number (10 cards) of consecutive sorts according to the initial "correct" principle (usually color) [19]. In this study, the test is scored in terms of the number of categories, number of errors before finding the first category rule, perseverative errors and sum of errors. If a subject responds correctly to color (form or number) for 10 consecutive times, he/she achieves

one category. It means a category is the number of runs of 10 correct responses. Perseveration is the uncontrollable repetition of a particular response, despite the absence of a stimulus. Perseverative errors are the number of errors where the participants have used the same rule for their choice as the previous choice. Sum of errors is the total number of errors.

Tower of London was developed to assess higher order problem-solving capacity, specifically executive planning ability. The TOL consists of a board with three pegs differing in length and three balls (blue, red, and green). Two such boards are used: one with the balls arranged in a start position and one with the balls arranged in a goal position. For each TOL problem, the balls of the start position have to be transferred into the goal position, under three restrictions: (a) The balls have to be moved one at a time; (b) they cannot be placed outside the pegs; and (c) a maximum of three balls are allowed to be placed on the tallest peg, a maximum of two on the middle peg and a maximum of one on the shortest peg [20]. In this study, the following quantitative data are extracted from the TOL, (1) the total correct score, which is the total number of problems that are solved, (2) calculating three time scores, such as the initiation time, execution time, and total time.

Statistical Analysis

The collected data were analyzed in Statistical Package for Social Sciences (SPSS Inc., Illinois, USA), version 16. Descriptive statistics (mean±SD) and mean comparison test for independent groups (independent sample t-test) were used for data analysis. A *p* value less than 0.05 was considered statistically significant.

Results

Baseline Characteristics

60 male patients admitted to Shahid Rajaei

Hospital with impression of trauma due to crash or accident over 6 months were evaluated find ADHD and non-ADHD patients who have trauma. 31 of these patients fulfilled ADHD criteria, with a mean age of 27.16±5.6 years, and 29 stayed in non-ADHD group, with a mean age of 26±3.4 years, so there was no significant difference between groups (*p*=0.330). Most of the participants had education about high school, besides there was no significant difference between educational distributions in the groups. The participants were homogeneous based on their IQ and there was no significant difference between them. A summary of the demographic factors of both groups is shown in Table 1.

Pattern of Executive Dysfunctions

Comparison of executive dysfunction between normal and adult ADHD patients showed that although both groups were matched according to their demographic factors and IQ, their functions in some of the EFs were significantly different. In WCST, although ADHD patients had no significant difference in the number of errors before finding the first category rule, the normal group had significantly better functions in the number of categories in the length of the procedure of testing. Perseverative errors and other types of error (sum of errors) were seen in ADHD group. Table 2 compares the EF between two study groups. In TOL, 4 types of the error extracted from the test, in all of these four scores ADHD patients showed significantly poor function as compared to those without ADHD. ADHD group always used much more than the non-ADHD. Table 3 shows these differences in details.

Discussion

The main aim of the present study was to evaluate executive dysfunction among traumatic patients admitted in Shahid Rajaei Hospital. All the

Table 1. Baseline characteristics of the 60 traumatic patients with and without ADHD.

	ADHD (n=31)	Normal (n=29)	<i>p</i> value
Age (years)	26.00±3.4	27.16±5.6	0.330
IQ	102.48±9.02	99.38±9.05	0.191
Education			
Primary and Guidance school (%)	8 (27.6%)	7 (22.6%)	
High school (%)	20 (48.3%)	14 (64.5%)	0.396
College (%)	7 (24.1%)	4 (12.9%)	

Table 2. Mean differences between traumatic patients with and without ADHD in WCST scoring system.

Scoring system of WCST	ADHD (n=31)	Normal (n=29)	<i>p</i> value
Number of categorizing in correct	2.58±1.31	4.72±1.43	0.001
Number of errors before find the first category rule	15.58±13.57	14.82±12.25	0.823
Perseverative errors	8.64±4.6	3.58±3.22	0.001
Sum of errors	29.80±7.58	17.86±6.8	0.001
Time	491.74±13.57	405.27±12.25	0.039
Number of categorizing in correct	2.58±1.31	4.72±1.43	0.001

Table 3. Mean differences between traumatic patients with and without ADHD in TOL scoring system

Scoring system of TOL	ADHD (n=31)	Normal (n=29)	p value
Total correct score	25.64±5.241	29.37±4.20	0.004
Initiation time	286.64±139.39	201.93±89.08	0.007
Execution time	434.77±265.42	300.48±188.39	0.029
Total time	722.70±382.59	502.27±259.67	0.012
Total correct score	25.64±5.241	29.37±4.20	0.004
Initiation time	286.64±139.39	201.93±89.08	0.007

participants who were visited during the time of the present research were divided into two groups of traumatic injury patients with and without adult ADHD and the executive dysfunction was evaluated among them. EF is a multifaceted neuropsychological construct consisting of a set of higher-order neurocognitive processes that allow higher organisms to make choices and engage in purposeful, goal-directed, and future-oriented behavior [21,22]. This neuropsychological construct has its roots in neuroanatomy, especially the prefrontal lobe, which can be divided into three main convexities: (a) the dorsolateral PFC, often described as the substrate of working memory; (b) the superomedial PFC (which also includes the anterior cingulate gyrus), often described as the substrate for sustained attention, response selection, and motivation; and (c) the ventral (or inferior) PFC (which can be divided into orbitofrontal and ventromedial), often described as the substrate for inhibition, social appropriateness, and sensitivity to rewards and punishment [23]. These cognitive processes are necessary in every daily activity and if they are impaired, they might cause severe problem, i.e. moth will be drawn to a light bulb time and time again, no matter if it burns its wings each time. In contrast, as humans, we possess the most highly evolved EF of all species, which allows us the latitude of considering options and selecting a specific response to any given stimulus based on situational contexts, previously acquired knowledge, and long-term goals. In clinical neuropsychology, a patient with EF deficits is typically someone who has suffered some type of a brain injury or is afflicted with a neurodevelopmental or neurodegenerative illness. Typical examples would be individuals who have suffered a stroke in the frontal lobes and/or the related brain circuitry, victims of motor vehicle accidents, or patients with vascular, frontotemporal, or Parkinson's dementia. Among such individuals, EF deficits, especially if severe, can be extremely devastating. Among neurodevelopmental disorders, ADHD is a common disorder, which occurs in several accidents due to their neuropsychological deficits which are documented before [16,17].

The exact nature of the processes that fall under the umbrella of EF is still not well understood, and consequently, there is no universally accepted definition, so in the present study EF means shifting from one category to another, which needs inhibition

of the previous information process; also it means planning which needs preplanning and finally it means problem solving.

Our results showed that ADHD patients as compared to non-ADHD had significantly poor function.

In WCST, although the patient in both groups (without) ADHD) comprehended the order and found the first rule equally, the ADHD group significantly showed perseverative error, in terms of EF; it means that they couldn't inhibit the previous processing and shift in another category so it may be related to ventral (or inferior) PFC deficit [23]. ADHD patients consumed more time than non-ADHD, so they might be affected by distracters more than non-ADHD.

In TOL, the ADHD group compared to the non-ADHD had significantly more time prior to starting the task, in EF term, mean preplanning time, and also they need more time to do the task, it means, although they consumed much time before starting, the solution or execution the task was time consuming, too. It can be concluded that ADHD group had poor problem solving.

These results further support our earlier contention that EF tests should not be viewed as the only standard of evidence for establishing the presence of EF deficits, particularly in ADHD as prior research has stated or implied [11,15,24-27]. As reported elsewhere [28], EF deficits are present in the vast majority of adults with ADHD (89%–98%) when ratings of EF in daily life activities are used. Thus, it is necessary to set up EF evaluation in trauma related center to pick up the patients who suffer from executive dysfunction to reduced next trauma.

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