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# Comparison of Executive Functions of Working Memory, Cognitive Flexibility and Inhibition Skills in Patients with Traumatic Brain Injury and Healthy People

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**ABSTRACT**:
The purpose of this research is to compare the executive functions of working memory, cognitive flexibility and inhibition skills in patients with traumatic brain injury and healthy people. In this causal-comparative study, 15 patients with traumatic brain injury with an age range of 20 to 60 years who were hospitalized in the past 3 months to a year as the experimental group and 15 healthy people from the normal community of Rasht city as companions Referees to specialized centers with an age range of 30 to 60 years were voluntarily selected as a control group by purposive sampling. The results showed that the patients performed weaker in two active memory tests, Wechsler's forward and backward digit span test in both visual and auditory sections, as well as the N-BACK test, and showed a significant difference in active memory performance compared to the healthy group. They gave. The difference between the two groups in the number of classes obtained, survival and response time in the cognitive flexibility test, Wisconsin test, is statistically significant, and this shows the significant superiority of the healthy group in cognitive flexibility compared to the sick group. Also, the findings of this research show that in the evaluation of inhibitory control with the go/no test, no significant difference was observed in the number of errors in this test between the two groups, but in the response time, the patient group showed a statistically significant difference compared to the control group.

***Keywords: Traumatic brain injury, Working memory, Inhibitory control, Cognitive flexibility, Traumatic brain injury***

## INTRODUCTION:

Traumatic brain injury (TBI) is the leading cause of death and disability in people under the age of 45, usually resulting from motor vehicle accidents, falls, contact sports, or assault. TBI often results in persistent cognitive impairment and psychiatric symptoms, including memory deficits, anxiety, and depression, which have a negative impact on quality of life and the rehabilitation process (Bombardier et al., 2010; Ponsford et al., 2018; Graham and Sharpe, 2019). Considering the significant heterogeneity in clinical manifestations and neuropathology in TBI patients, it is challenging to predict the risk of concomitant psychiatric disorders and cognitive impairment (Fazel et al., 2014). Previous studies showed that the severity of TBI is not related to neuropsychological outcome (Alavi et al., 2016; Singh et al., 2019). Meanwhile, previous findings were inconsistent for the relationship between injury location and cognitive function and psychiatric complaints (Khalaf5 et al., 2019). Evaluation of executive functions is worth investigating because executive functions include a wide set of cognitive functions that are required for dependent and self-directed behavior (Lee, 2008, p. 37). When EFs are significantly impaired, individuals may lose their ability to respond in adaptive ways, fail to regulate or control their emotions and behavior, lose social skills, or may cause other problems (Kapp et al., 2018, p. 379). One of the important issues of working with EFs is that the term "executive functioning" can cover many cognitive abilities, and the range it covers in its definition has met with very little agreement (Kani et al., 2007, p.379). In other words, it is an umbrella term that is conceptualized differently depending on the researcher. What is agreed upon is that impairment of executive functions often leads to problems that can affect all aspects of behavior (Johan et al., 2021, 380-379; Zhang, 2009, p. 37). Although TBI is heterogeneous in terms of cause and injury severity, it still shows a distinct pattern of anatomical damage. Trauma usually results in contusions involving the basal and polar regions of the frontal and temporal lobes. In addition to focal brain injuries, diffuse axonal injuries (DAI) occur after TBI, often affecting frontal and temporal white matter, corpus callosum, and brainstem. Traditionally, cognitive deficits and psychiatric disorders following TBI have been associated with damage to the medial temporal and prefrontal lobes, yet the location and extent of these lesions often cannot fully explain the patient's impairments. During the acute and subacute stages of

TBI, secondary injuries including inflammation, apoptosis, excitotoxicity, and long-term hypoperfusion lead to progressive and widespread white matter atrophy (WM1) and gray matter volume reduction (GM2) in large areas of the cortex and The subcortical areas of the brain become over time. These abnormalities in parietal and occipital lobes and subcortical areas including basal ganglia and thalamus are closely related to post-traumatic cognitive functions and psychiatric symptoms. Due to the inherent heterogeneity of study design, segmentation, and analysis in previous studies, the topographical distribution of morphometric changes and their clinical relevance to posttraumatic psychiatric symptoms and memory function are inconsistent (Wood et al., 2017).

One of the components of executive function that is important in social adaptation is cognitive flexibility. Cognitive flexibility is the ability to change cognitive cues in order to adapt to changing environmental stimuli (Grotz, Corbett and Solomon 2009). Some studies (Zelazo et al., 2020) have defined cognitive flexibility as a person's assessment of the controllability of the situation, which changes in different situations. Weak cognitive flexibility shows itself in the form of stagnation, stereotyped behaviors and problems in regulating and adjusting motor actions (quoted from Uzonov and Makoy, 1994). New theories look at flexibility as a multidimensional structure that includes fundamental variables such as temperament, personality and specific skills such as problem solving skills. These skills allow a person to adapt favorably to traumatic or traumatic life events. Therefore, although the first wave of research in the field of resilience was more focused on understanding the characteristics of resilient people, the second wave was on understanding the processes through which people could successfully adapt to stress and traumatic events.

Working memory is defined as a limited capacity and at the same time a stable and flexible system in the service of cognition, which is responsible for the temporary accumulation and processing of information at the same time (Graham Hitch4, 2018). It is obvious that the short-term retention of sensory stimuli in active memory is the foundation for the human cognitive system, and this important function is challenged in case of damage to the sensitive frontal, parietal and temporal regions of the brain (Christophel 5, 2018). Balan (2021) stated that the episodic buffer is an independent component of working memory with short-term storage capacity, a type of backup storage that is able to support the retrieval of series and the integration of visual, auditory and other types of information in space and time. This section deals with filling in the gaps in the general visual, audio storage and turning them into an episode. A study conducted by Alvi et al. (2004) assessed episodic buffer function using two spoken sentence recall tasks. Their final model included the episodic buffer, the central operator, and the components of the phonological loop. However, they did not assess visuospatial functions. Therefore, there is no structural evaluation of Ahmed's (2017) three-component working memory model in the research literature.

Response inhibition, as the ability to stop or refrain from a current response (Cheno et al., 2019), is one of the important components of executive function in behavioral self-regulation (Diamond et al., 2013).

The efforts of researchers in identifying different dimensions of complications on the one hand and the progress of diagnostic facilities such as: brain imaging, non-imaging biomarkers and neuropathology related to brain damage caused by trauma, over the past 15 years, have required doctors and policy makers to change their views in especially the complications of TBI and has caused brain damage caused by trauma to be recognized as a common disorder with significant effects on public health. These developments have led to the revision of the guidelines for the management of this injury in civilians, military personnel and athletes, hence, there is still a need to focus on clarifying the dimensions of this injury and its long-term effects for clinical management in emergency departments. and remains community-based health care (Lizma et al., 2010).

Therefore, considering the wide range of cognitive complications following brain damage on the lives of patients, it is necessary to put their cognitive rehabilitation on the agenda, along with medical interventions and psychological evaluation of patients, in order to reduce disorders and treatment costs. Delayed complications, some of which have been clarified during research, have been prevented. Based on this, the aim of this research is to compare the executive functions of working memory, cognitive flexibility and inhibition skills in patients with traumatic brain injury and healthy people.

## METHOD:

The current research is a causal-comparative type of research. The statistical population of the present study included patients suffering from TBI in Rasht in 1401, who were referred to specialized centers in Rasht due to this condition. From the above society, a sample of 15 people was selected based on the entry and exit criteria using the purposeful sampling method. Inclusion criteria included experience of traumatic brain injury at least 3 months and at most one year before conducting the research, age range from 20 to 60 years, alertness and motor and physical ability to conduct the research, right of superiority, voluntary consent to conduct the research. Exclusion criteria were simultaneous suffering from other brain diseases such as epilepsy or tumor, history of diabetes and metabolic syndromes, mental retardation, severe physical and motor disability, receiving cognitive rehabilitation services in the last 6 months. Also, in order to compare patients with normal people, 15 people from the normal community of Rasht were selected voluntarily to participate in the research from among the companions who referred to specialized centers. From all the participants of the normal group, the GHQ (general health) test was first taken to ensure the absence of psychological problems in the clients. None of the subjects in the normal group had a history of concussion, epilepsy or any other type of brain or psychiatric disease. All the normal group was right superior and their age range was 30 to 60 years and they had minimum education.

## **<u>Tools</u>:**

### Wisconsin Card Sorting Test (WCST):

This test was developed by Berg and Grant (Burns, 2003) to evaluate mental ability and the ability to change cognitive strategies in response to changing environmental possibilities. This test is considered to be a measure of executive functions in which strategic planning, organized search, the ability to use environmental feedback to change cognitive cues, goal-oriented behavior, and the ability to moderate impulsive responses are required.

In this research, cognitive flexibility is measured by the Wisconsin Card Sorting Test (WCST; Heaton et al., 1981). In this test, the examinee is presented with a set of 64 cards on which there are one to four symbols in the form of a triangle, star, plus, and circle in the four colors of red, green, yellow, and blue. Four cards consisting of "a red triangle, two green stars, three plus yellow and four blue circles" are used as the main cards. The examinee's task is to place other cards under the main cards based on the principle that governs the four main cards. After each answer, the subject receives correct or incorrect feedback. The desired pattern is for the four main cards in the order of color, shape and number, which is repeated twice. After the subject gives a sufficient number of correct answers in a row, the target pattern changes, but the subject is not aware of the pattern change and must discover it himself. The two main indicators that show the subject's performance are "the number of floors obtained" and "the number of errors of staying in place". The Wisconsin test is sensitive to lesions of the dorsolateral prefrontal cortex (DLPFC). Menoli (2021) mentioned the validity of this test to measure cognitive deficits following brain injuries above 0.86. The reliability of this test is also reported as 0.83 based on the agreement coefficient of evaluators in McDonald's study (2021). Naderi (1373) mentioned this test in the Iranian population with a retest method of 0.85.

### N-Back test

The N-back task is a cognitive performance task related to executive actions (EF). This task was introduced for the first time in 1958 by Kirchner. The general process of the task is that a sequence of stimuli is presented to the subject step by step, and the subject must check whether the currently presented stimulus is consistent with the stimulus n steps before it or not. This experiment is performed with different values of n, and increasing the value of n increases the difficulty of the assignment. In this way, in the 1-Back task (n=1), the last presented stimulus will be compared with the previous stimulus, and in the 3-Back task (n=3), the last presented stimulus will be compared with the previous three stimuli. Since this task includes both the maintenance of cognitive information and its manipulation, it is known to be very suitable for measuring working memory and has been widely used in this field in recent years (Chen et al., 2008). Studies indicate that different types of this task can be used well in laboratory studies of working memory and other cognitive actions such as fluid intelligence (Chu et al., 2005), for example, Dikman et al. (2007) report the validity of this The test is very acceptable as an indicator of working memory performance, although the convergent validity is not very favorable when this task is used to compare individual differences in working memory capacity and performance. The validity and reliability coefficients in the range between 0.54 and 0.84 showed the high validity of this test. In various studies, various applications in the field of working memory have been recorded for the n-back test: examining the level of brain arousal during working memory activity; Investigating individual differences in working memory or measuring working memory performance in special groups such as brain injury patients, substance abusers, sufferers of disorders such as depression, schizophrenia, ADHD, etc. When performing the n-back task, executive actions such as attention control and allocation, decision making, planning, peripheral information processing, etc. are involved. In the field of working memory, when performing this task, the greatest amount of involvement is created in the performance of the central processor system.

### Wechsler Working Memory Scale (WMS)

There are different methods to assess working memory (active, short-term). But one of the most common ones is measuring the memory capacity of numbers. Numerical memory span measurement is one of the subtests of the Wechsler IQ test (children and adults). This test is performed in two parts "forward repetition of digits and reverse repetition of digits" separately in two auditory and visual parts. Even if the subject has scored zero in the forward repetition of digits section, the reverse repetition of digits section is still performed. In this test, there are a total of 7 double chain groups. For each chain, there are two sets of numbers that are shown in two times (attempts) in the auditory part of the reader or in the visual part of the test. After both presentations, if the subject is successful in one of them, the degree of difficulty is increased by one, in other words, one is added to the chain of numbers. that this process takes place for the reverse repetition of figures (Khodadadi et al., 2020). In Iran, in the research of Mohaghegh Ardabili University, the reliability of the subtests was calculated using the binomial method above 0.70, and in Qureshi's research at Allameh Tabatabai University, the reliability of the subtests was calculated The mystery of the sight and width of the figures has been obtained with the method of Landaher's coefficient of 0.75 and the validity of the criteria between 0.60 and 0.72.

**Go/NoGo Test**

Inhibitory control is a broad concept and has various forms of inhibition in the fields of perception, attention, cognition and movement. The go/no-go (move/stop) task has been widely used to investigate inhibition of motor inhibition (Mussell et al., 2010). Imaging studies suggest that the frontal region, particularly the right inferior prefrontal gyrus, is responsible for response inhibition (Chamber, 2006). Studies of structural magnetic resonance imaging (Ozega et al., 2018), functional magnetic resonance imaging and electroencephalography (Okada et al., 2006) provide strong evidence of a link between deficits in the right frontal region (especially in the prefrontal) and impaired inhibitory control. have provided. This test includes two categories of stimuli. Subjects must respond to a group of these stimuli (Go) and refrain from responding to another group (No Go). Go/noGo tests are divided into easy and complex categories. In the easy category, the No Go trigger is always fixed. In the complex category, the No Go stimulus is variable and changes during the test, and the correct answer requires working memory performance. In these tests, the type of stimulus can be changed according to the study objectives, from letters to simple colored shapes. The number of stimuli also varies from 48 to 1260 in different studies. The duration of stimulus presentation can vary from 200 to 1100 milliseconds and the interval between two presentations can vary from 800 milliseconds to 12 seconds. The above criteria are determined by the target and the study group (Divan, 2018). The present test is simple and the total number of stimuli can be from 40 to 200, each of which is revealed on the screen for 0.2 to 3 seconds. The interval between two presentations can be from 1 to 5 seconds. In addition, the color of the stimuli can also be changed. In all cases, go stimuli make up 70% of the total stimuli. Therefore, the bias of the subject is towards Go response. A lack of appropriate inhibition or a commit error means a response when the No Go stimulus is presented. The internal reliability coefficients obtained for this test are reported as 0.72, 1 and 0.87 respectively (Mia, 2004).

After collecting the data in order to evaluate the research question, the obtained information was analyzed using descriptive statistics methods such as average, maximum and minimum, and at the inferential level using analysis of variance.

To evaluate the active memory of the two groups, the N-BACK software test and two Wechsler auditory and visual digit recall software subtests were used. The performance of sick and healthy people in these two tests was compared with one-way analysis of variance in Spss software, which shows the significance of the difference between the averages in the two groups.

**Table 1:** Output of one-way analysis of variance results for comparison of working memory (Wechsler)

| **Variables** | | **SS** | **df** | **$S^2$** | **F** | **Significant** |
|---|---|---|---|---|---|---|
| forward repetition of digits span | Between groups | 53.333 | 1 | 53.333 | 21.918 | 0.000 |
| | Within groups | 68.133 | 28 | 2.433 | | |
| | Total | 121.467 | 29 | | | |
| reverse repetition of digits span | Between groups | 22.533 | 1 | 22.533 | 9.962 | 0.004 |
| | Within groups | 63.333 | 28 | 2.262 | | |
| | Total | 85.867 | 29 | | | |

The results of table (1) show that in the sub-test of listening digit span (a_span) between the two groups, F=21.918 and Sig=0.000. Because the value of Sig<0.05 has been calculated, it is assumed that there is a significant difference in this criterion between the two groups. In comparing the span of visual digits (v_span) between the groups, F=9.962 and Sig=0.004 were calculated, and in this criterion, Sig<0.05, and this subtest rejected the null hypothesis and found a significant difference between the two groups.

**Table 2:** The output of one-way analysis of variance results for the comparison of working memory (N-back)

| **Variables** | | **SS** | **df** | **$S^2$** | **F** | **Significant** |
|---|---|---|---|---|---|---|
| Correct answer | Between groups | 7970.700 | 1 | 7970.700 | 12.048 | 0.002 |
| | Within groups | 18523.600 | 28 | 661.557 | | |
| | Total | 26494.300 | 29 | | | |
| Incorrect answer | Between groups | 28.033 | 1 | 28.033 | 0.242 | 0627 |
| | Within groups | 3245.333 | 28 | 115.905 | | |
| | Total | 3273.367 | 29 | | | |
| The missed answer | Between groups | 9013.333 | 1 | 9013.333 | 14.751 | 0.001 |
| | Within groups | 17109.467 | 28 | 611.052 | | |
| | Total | 26122.800 | 29 | | | |

The results of table (2) show that in the analysis of the number of correct answers (truea) between the two groups, F=12.048 and Sig=0.002<0.05, so there is a significant difference in this measure between the two groups. In the analysis of incorrect answers (errora), the value of F=0.242 and Sig=0.627>0.05. This result shows that there is no significant difference in this measure between the two groups. In the comparison analysis of the number of missing answers (noa) between the two groups, the output of the table shows the value of F=14.751 and Sig=0.001<0.05, which indicates the significance of the difference in this criterion between the two groups.

**Table 3:** The output of one-way analysis of variance for the comparison of cognitive flexibility

| Variables | | SS | df | $S^2$ | F | Significant |
|---|---|---|---|---|---|---|
| Number of classes obtained | Between groups | 38.533 | 1 | 38.533 | 16.685 | 0.000 |
| | Within groups | 64.667 | 28 | 2.310 | | |
| | Total | 103.200 | 29 | | | |
| Number of remaining errors | Between groups | 464.133 | 1 | 464.133 | 16.089 | ٠.٠٠٠ |
| | Within groups | 807.733 | 28 | 28.848 | | |
| | Total | 1271.867 | 29 | | | |
| Test time | Between groups | 287076.544 | 1 | 287076.544 | 23.250 | 0.000 |
| | Within groups | 271637.289 | 22 | 12347.149 | | |
| | Total | 558713.833 | 23 | | | |

In the analysis of this test, according to the contents of table (3), the value of F=16.685 for the variable numcatcom (number of classes obtained), F=16.089 for the variable pererr (number of remaining errors), F=23.250 for the variable timetest (response time) and Sig=0.000<0.05 is reported for all three variables between the two research groups. This evaluation shows that there is a significant difference in the cognitive flexibility of sick people compared to the healthy group.

**Table 4:** The output of one-way analysis of variance for the comparison of inhibition (go/no go)

| Variables | | SS | df | $S^2$ | F | Significant |
|---|---|---|---|---|---|---|
| Lack of proper restraint | Between groups | 4.821 | 1 | 4.821 | 3.022 | 0.093 |
| | Within groups | 44.679 | 28 | 1.596 | | |
| | Total | 49.500 | 29 | | | |
| Missed answer | Between groups | 232.515 | 1 | 232.515 | 3.794 | 0.062 |
| | Within groups | 1716.152 | 28 | 61.291 | | |
| | Total | 1948.667 | 29 | | | |
| response time | Between groups | 48139.315 | 1 | 48139.315 | 10.430 | 0.003 |
| | Within groups | 129237.652 | 28 | 4615.630 | | |
| | Total | 177376.967 | 29 | | | |

The results of Table (4) show the value of F=3.022 and Sig=0.093>0.05 for the commission variable (lack of appropriate inhibition), which indicates that there is no significant difference in this component between the two groups. The value of F=3.794 and Sig=0.062>0.05 in the analysis of the omission variable (missing the correct answer or inhibition) indicates that there is no significant difference in this component between the two groups. In the analysis of the rt variable (response time) of the two groups, the value of F=10.430 and

Sig=0.003<0.05 indicates a significant difference between the two groups.

## DISCUSSION:

The results showed that there is a significant difference in working memory performance of the affected group compared to normal people. The findings of Mulligan's research (2004) show the difference in the performance of subjects in the working memory test. This result is consistent with the findings of previous research (Marsh Koenig1, 2018; Walter Stewart2 et al., 2018), regarding the weakness of active memory in patients compared to the control group. Also, the results of this research confirm the findings of previous researchers such as (McMahan et al., 2014) regarding the persistence of active memory disorders in patients after one year of injury. 2008) and the aforementioned researchers also showed that there is a significant difference between the working memory of patients and healthy people in the subscales of forward auditory memory, reverse auditory memory, total auditory memory, forward visual memory, reverse visual memory, total memory There is visual, auditory and visual perception, with poor performance in the patients' group and excellence in the healthy group.

The results showed that people with traumatic brain injury perform weaker in cognitive flexibility compared to healthy people. The findings of Thomas et al. (2011) in the study "Investigation of cognitive complications following mild traumatic brain injury on the executive function and working memory of brain injury patients" showed a significant difference between the executive function of the TBI patients group and healthy individuals in subscales of classes, survival , there are correct answers, incorrect answers, the number of attempts to complete the first pattern and conceptual level answers. The results of the present study, in line with the findings of Van (2022), show that there is a significant difference in terms of cognitive flexibility between patients and normal people, which indicates that the cognitive flexibility of concussion patients is weaker than that of healthy people, and there are reports of structural abnormalities. frontal lobe in sick people. Also, this research confirms the findings of Bozal et al. (2019) regarding the persistence of executive dysfunction in patients with TBI.

The results of the present study have shown that people with TBI do not have a significant difference with normal people in the number of errors committed or lack of appropriate inhibition, the number of inhibition or loss of the correct response, and inhibition inhibition, which is in line with the findings of Zhu (2022) research in the "Evaluation" research. The cognitive and behavioral inhibition of patients with mild traumatic brain injury" which has shown that there is a significant difference in the number of congruent and incongruent errors, the interference score and the sum of wrong answers between the patient group and normal people, is not consistent, but there is a significant difference in the average response time of both studies. between two groups of subjects. Research results showed that concussion patients performed similarly to controls on the CRT when only "go" responses were required. This result is consistent with a recent report of concussed patients using a selective reaction time task. However, when inhibition/stopping of the initial response/go routine was sometimes necessary (for example, in Switch or Stop conditions), patients had longer response time (RT) than the control group. The results of the present study with The findings of his research and colleagues (2005) are also consistent with regard to the response time component.

### Limitations

One of the limitations of the research is that in order to reduce the interventions, the study sample was assigned only to the male group, but the non-cooperation of this group and the time limit led to the selection of the female group. It is obvious that the findings of the present research, along with the results of similar researches, represent the dimensions of the psychological problems of the affected people and pave the way for interventional researches and creating effective treatments focused on cognitive functions.

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