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Research Paper

Psychometric Properties of the Persian Version of the Frontal Assessment Battery in Patients With Traumatic Brain Injury

Ramin Banimahdi[1], Seyed Majid Akhavan Hejazi[2], Seyed Ali Hosseini[3], Nazila Akbarfahimi[3*], Mohsen Vahedi[4]

1. School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa, Ottawa, Canada.
2. Brain and Spinal Cord Injuries Ward, Rofeideh Rehabilitation Hospital, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.
3. Department of Occupational Therapy, School of Rehabilitation Sciences, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.
4. Department of Biostatistics and Epidemiology, School of Rehabilitation Sciences, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.

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ABSTRACT

Background and Objectives: This study aimed to assess the reliability and validity of the Persian frontal assessment battery (P-FAB) in individuals with traumatic brain injury (TBI).

Methods: This cross-sectional and prospective study included 65 patients with TBI (PwTBI) and 65 healthy participants. Concurrent validity was evaluated through comparative analysis with the mini-mental state examination (MMSE), the Wisconsin card sorting test (WCST), and the Stroop color and word test (SCWT). Discriminant validity was analyzed by comparing mean FAB scores between TBI patients and healthy participants. Reliability was assessed through internal consistency, test re-test reliability, and inter-judge reliability. Data were processed using SPSS software, version 22.

Results: FAB scores exhibited no significant relationship with age, gender, or educational background. Significant correlations were identified between FAB scores and those from the MMSE ($r=0.791$, $P<0.001$) as well as various measures of executive function (EF). This included the number of categories achieved in the WCST ($r=0.745$, $P<0.001$) and perseverative errors ($r=0.307$, $P<0.05$) in addition to all items of the Stroop test ($P<0.001$), with exception of the interference score ($P>0.05$). The FAB demonstrated good internal consistency (Cronbach's α: 0.863) and strong test re-test ($r=0.882$, 95% confidence interval (CI)=0.77–0.95) and inter-rater reliability ($r=0.994$, 95% confidence interval (CI)=0.77–0.95). A FAB cutoff score 15 yielded optimal sensitivity (0.93) and specificity (0.90) for differentiating TBI patients from healthy controls.

Conclusion: The P-FAB is a valid, reliable, and effective tool for assessing executive dysfunction in PwTBI.

Keywords: Traumatic brain injury (TBI), Frontal assessment battery (FAB), Validity, Reliability, Cut-off

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*** Corresponding Author:**
Nazila Akbarfahimi, Associate Professor.
Address: *Department of Occupational Therapy, School of Rehabilitation Sciences, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.*
Tel: *+98 (21) 22180019*
E-mail: *na.akbarfahimi@uswr.ac.ir*

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What is "already known" in this topic:

The frontal assessment battery (FAB) has been proven to be a valid and reliable measure to evaluate the existence and extent of executive dysfunction across various conditions.While the FAB is clinically useful, its validity and reliability remain untested in patients with traumatic brain injury (PwTBI), despite the frequent occurrence of executive dysfunction following moderate to severe TBI.

What this article adds:

This research demonstrated that the P-FAB provides adequate validity and reliability to evaluate frontal lobe functions and executive dysfunction in PwTBI, effectively distinguishing them from healthy participants. We recommend the P-FAB as a rapid, convenient assessment tool for TBI screening.

Introduction

Traumatic brain injury (TBI) is characterized by physical damage to brain tissue, resulting in either transient or enduring changes in brain function [1]. Neuropsychiatric outcomes experienced after TBI include a wide array of physical, cognitive, emotional, behavioural, and psychosocial difficulties [2]. Approximately 65% of individuals with moderate to severe TBI endure continuing cognitive deficits, particularly affecting memory, information processing, and executive function (EF) [3]. Executive dysfunction often emerges as a result of neurological injury to the frontal lobe, basal ganglia, thalamus, cerebellum, and the associated white matter pathways, which collectively constitute the fronto-subcortical circuits [4].

EF encompasses complex cognitive processes essential for planning, goal-oriented behaviour, social judgment, empathy and the anticipation of behavioural outcomes [5]. Deficits in these functions, especially in executive domains, can lead to significant impairments in occupational performance, social relationships, recreational activities, and daily living tasks. Such deficits also impose considerable economic burdens on patients, their families, and society [6]. These observations underscore the need for effective diagnostic tools to assess cognitive capacity and determine both the existence and seriousness of executive dysfunction.

Although the mini-mental state examination (MMSE) and the Montreal cognitive assessment (MoCA) evaluate cognitive impairments, both of them lack sufficient sensitivity to detect dysfunction specifically within the frontal lobes as screening tests [7, 8]. Traditional assessments, such as the MMSE, are more attuned to memory and language deficits and may miss early signs of executive dysfunction [9]. Moreover, research indicates that the MoCA can be time-intensive to administer and may be challenging for patients suffering from motor or speech deficits [8].

The frontal assessment battery (FAB) was developed as a functional tool to evaluate the existence and extent of executive dysfunction. It is easy to administer, requiring less than 10 minutes, and is well-received by patients [9]. Studies have shown that FAB scores correlate with various neuropsychological assessments of EF, including the Mattis dementia rating scale, Wisconsin card sorting test (WCST), and trail-making test [9, 10], as well as regional cerebral blood flow in the left callosomarginal and precentral regions, as measured by single-photon emission computed tomography [11].

The FAB has been proven to be a valid and reliable measure across various conditions, including, frontotemporal dementia [12], Huntington's disease [13], Parkinson's disease [14] and Alzheimer's disease [15]. It has also been translated and validated in several languages, showing strong reliability metrics, such as Korean [16], Japanese [12], Chinese [17], German [18] and Italian [19]. In the Persian adaptation of the FAB, translated by Asaadi et al., it was applied to 49 individuals with Parkinson's disease, achieving inter-rater reliability of 0.90 (confidence interval [CI]=0.77%, 0.95%). A linguistic adaptation was also made to the lexical fluency subtest by replacing the letter "S" with "B" to suit the phonetic characteristics of Farsi because "S" can lead to confusion among less-educated individuals due to phonetic variations [20].

While the FAB is clinically useful, its validity and reliability remain untested in patients with TBI (PwTBI), despite the frequent occurrence of executive dysfunction following moderate to severe TBI [6]. Consequently, our

study was conducted to evaluate the reliability and validity of the FAB in individuals with TBI. Additionally, we sought to determine an optimal cut-off score for the FAB to effectively identify between PwTBI and healthy controls. We hypothesized that the FAB will be a valid and reliable tool for screening executive dysfunction in PwTBI.

Materials and Methods

This was a cross-sectional and descriptive-analytical study that received ethics approval from the University of Social Welfare and Rehabilitation Sciences ethics board. Sixty-five PwTBI (55 men, 10 women), aged 18 and 60, were recruited through University-affiliated rehabilitation centers in Tehran City, Iran. The inclusion criteria for TBI patients included a neurologist-confirmed TBI diagnosis, a cognitive functioning level of at least 6 on the Rancho Los Amigos scale, indicating goal-directed behaviour and consistent ability to follow simple directions [21], literacy and normal visual and auditory abilities. The exclusion criteria included patients with additional neurological disease (e.g. multiple sclerosis) or mental illness (e.g. schizophrenia). Table 1 presents the demographic and clinical profiles of the PwTBI.

A comparison group of 65 healthy participants was matched to the TBI group by age and sex. The inclusion criteria for healthy controls included the absence of any history of neurological or psychiatric disorders, hearing impairments, or visual disabilities. Participants were selected via convenience sampling, with stratified sampling overseen by the study investigator. Exclusion from the study occurred if participants withdrew consent or experienced seizures during testing. Exclusion decisions were made in consultation with a neurologist.

Measures of EF

The Persian frontal assessment battery (P-FAB) included six subtests, conceptualization (recognizing similarities between objects), lexical fluency (number of words beginning with "B" provided in 60 seconds), motor programming (fist-palm-edge motor sequence), sensitivity to interference (performing tasks that require responding in opposition to the given signal), inhibitory control (go/no-go paradigm) and environmental autonomy (inhibition of grasping behaviour). Scores for each subtest range from 0 to 3, with lower scores reflecting more severe executive dysfunction and a total maximum score of 18 [9]. The P-FAB has demonstrated high intra-judge reliability in individuals with Parkinson's disease (r=0.9) [20].

The WCST is a widely employed neuropsychological assessment for EF, measuring abilities in concept formation, planning, cognitive flexibility, visuospatial working memory, deductive reasoning, problem-solving, and set-shifting [22]. The Heaton's 64-card version of the WCST was used in this study [23, 24]. Among the Iranian population, the WCST has shown strong test re-test reliability, with a coefficient of 0.85 [25].

The Stroop colour and word test (SCWT) is a well-established neuropsychological tool used to evaluate processing speed (colour and word naming), cognitive flexibility (switching conditions) and inhibition of cognitive interference, known as the Stroop effect, where processing one feature of a stimulus interferes with simultaneous processing of another [26]. Among the Iranian population, this test demonstrated a test re-test reliability coefficient of 0.71 [27].

Procedures

An experienced occupational therapist conducted interviews with all participants (both patients and healthy controls), explaining the study's purpose and procedures. Eligible participants provided written informed consent. Each participant was assessed using demographic data collection, the MMSE, WCST, Stroop test and the P-FAB. The study comprised three phases, reliability testing (including test re-test and inter-judge reliability), validity assessment (concurrent and discriminant), and identifying an optimal threshold score for the total FAB to differentiate PwTBI from healthy controls.

For inter-judge reliability, two raters independently scored 20 patients simultaneously. Test re-test reliability was estimated in a subsample of 30 patients who re-took the P- FAB two weeks later [17, 19]. Test re-test and inter-judge reliabilities were assessed using the intraclass correlation coefficient (ICC), calculated from a two-way random effects model with absolute agreement and average measure. Reliability was classified as fair (0.40–0.59), good (0.60–0.75), or excellent (≥0.75) [12]. Additionally, standard error of measurement (SEM) and minimal detectable change (MDC) were calculated using the Equations 1 and 2:

1. SD_√1-ICC

2. 1.96×SEM×√2, respectively.

Concurrent validity was assessed by calculating Spearman correlation coefficients between the P-FAB and scores on the WCST, MMSE, and Stroop test, with the

tests administered in a random order to the patients. Discriminant validity was assessed by comparing the average FAB scores of TBI patients with healthy controls [28]. A receiver operating characteristic curve analysis determined the cut-off for the FAB total score to identify TBI patients from controls, with sensitivity and specificity calculated to validate this threshold.

Statistical Analysis

Descriptive statistics, including frequencies and means, were used to summarize participant demographics. Mean was compared using t tests or the Mann-Whitney U test, depending on data distribution. Spearman correlation tests assessed relationships between FAB scores and variables, such as sex, age, and education. Reliability (test re-test and inter-judge) was measured using ICC analysis with a 95% CI. Post-hoc analysis in analysis of variance (ANOVA) was used for multiple comparisons. The Youden index identified the optimal FAB cut-off score, with the highest index indicating the best threshold [29]. Analyses were conducted using SPSS software, version 22, with statistical significance set at P<0.05.

Results

Demographic data

A total of 130 participants (65 PwTBI and 65 healthy controls) completed the study. Table 1 presents the demographic details of both groups. No significant relationships were identified between the P-FAB total score and demographic variables among PwTBI (P>0.05). However, a significant relationship was found between the P-FAB overall score and age in the healthy control group (P<0.05) (Table 2).

Post-hoc analysis using analysis of variance (ANOVA) indicated no significant differences in P-FAB total scores across specific age groups within the healthy control group at a conventional significance level (P>0.05). However, at a 0.10 significance level, significant differences were observed between participants under 25 years and those over 45, as well as between participants aged 25–35 and those over 45.

Reliability

Table 3 presents the test re-test and inter-judge reliability results for the P-FAB. This version exhibited strong internal consistency across all six subtests, with a Cronbach's α coefficient of 0.863. Test re-test reliability (n=30) assessed after a two-week interval showed excellent stability, with an ICC of 0.882 (95% CI, 0.77%, 0.95%). Inter-judge reliability was also outstanding, with an ICC of 0.994 (95% CI, 0.77%, 0.95%), further confirming excellent reliability in both test re-test and inter-judge measures for the P-FAB. Table 3 presents the SEM and MDC.

Validity

Concurrent Validity

Table 4 presents the results for the concurrent validity of the P-FAB about the MMSE, WCST, and Stroop tests. A strong and statistically significant correlation was observed between the total P-FAB score and the MMSE score (r=0.791, P<0.001). Furthermore, the P-FAB score showed a significant correlation with the number of categories completed on the WCST (r=0.745, P<0.001) and the number of perseverative errors (r=0.307, P<0.05). Additionally, significant correlations were found between the P-FAB score and all conditions of the Stroop test (P<0.001), except for the interference score, which assesses the difference between word reading and colour naming times, where no significant correlation was observed (P>0.05).

Table 1. Demographic data of PwTBI and healthy participants

Variables		Mean±SD/No. (%)		P
		TBI Group (n=65)	Healthy Group (n=65)	
Age		34.55±14.01	33.52±13.51	0.67
Education	High education*	11(16.92)	37(58.46)	<0.001
	Low education**	54(83.08)	28(41.54)	
Sex (% female)		15.4	15.4	0.812

*Participants with academic education, **Participants with non-academic education.

Table 2. P-FAB total score differences based on sex, education, and age categories

Variables		TBI		Healthy	
		Mean±SD	P	Mean±SD	P
Sex	Male	10.64±4.04	0.68	17.018±0.89	0.65
	Female	10±4.69		17.1±1.1	
Education	High education	11.9±4.63	0.612	17.27±0.83	0.098
	Low education	10.25±4.01		16.71±0.93	
Age (y)	<25	10.27±4.44	0.091	17.26±0.81	0.021
	25-35	11.38±4.09		17.3±0.86	
	35-45	12.09±3.64		16.57±0.78	
	> 45	8.53±3.64		16.53±0.99	

TBI: Traumatic brain injury.

Table 3. Test re-test reliability and inter-judge reliability of P-FAB

Reliability	ICC	SEM	MDC	95% Confidence Interval	
				Lower Bound	Upper Bound
Test re-test reliability	0.882	1.05	2.91	0.751	0.944
Inter-judge reliability	0.994	0.32	0.89	0.986	0.998

Abbreviations: MDC: Minimal detectable change; SEM: Standard error of measurement; ICC: Intraclass correlation coefficient.

Discriminant validity

Table 5 presents the subtest scores of the P-FAB for both PwTBI and healthy control groups. Analysis using the Mann-Whitney test revealed a significant group effect on the total P-FAB score and each subtest score ($P<0.01$). The PwTBI scored lower both on the total P-FAB and across each subtest compared to healthy controls, supporting the P-FAB's strong discriminant validity in distinguishing between these groups.

Table 6 shows that a P-FAB score cut-off of 15 provided excellent sensitivity and specificity for distinguishing PwTBI from healthy participants. This cut-off yielded a sensitivity of 0.98 and a specificity of 0.90, indicating high accuracy in identifying TBI-related executive dysfunction.

Discussion

This research was conducted to evaluate the validity and reliability of the (P-FAB) in PwTBI. Additionally, we sought to establish a suitable cut-off score for the P-FAB to distinguish between PwTBI and healthy controls.

Previous studies have indicated that age, sex, and education do not influence FAB scores in patients with dementia [30, 31], a finding corroborated by our study. However, other research has shown a positive correlation between education and FAB scores and a negative correlation with age among healthy participants and those with Parkinson's disease [14, 20]. This discrepancy may be due to the younger average age and broader age range of participants in our study. Furthermore, unlike Parkinson's disease, which is degenerative and leads to progressive cognitive decline, TBI is not a degenerative condition [32]. A considerable proportion of present PwTBI also had less education attainment. This is consistent with reports showing a rising prevalence of TBI in economically disadvantaged and middle-income countries due to increased motor vehicle usage and the greater likelihood of people with lower education being employed in high-risk jobs [33].

Our results showed that the FAB demonstrates strong test re-test and inter-judge reliability, in addition to acceptable concurrent and discriminant validity. Moreover, present results revealed significant correlations between

Table 4. Concurrent validity of P-FAB, MMSE, WCST and stroop test

Tests*	P-FAB Score			
	TBI Group (n=65)		Healthy Group (n=65)	
	Spearman Correction Coefficient	P	Spearman Correction Coefficient	P
MMSE	0.791	<0.001	0.228	0.067
WCST number of categories	0.745	<0.001	_**	_**
WCST perseverative errors	-0.307	0.013	-0.094	0.454
Stroop word reading duration	-0.79	<0.001	-0.269	0.031
Stroop word reading error number	-0.731	<0.001	-0.044	0.728
Stroop colour naming duration	-0.754	<0.001	-0.368	0.003
Stroop colour naming error number	-0.799	<0.001	-0.345	0.005
Interference (the difference between the time duration of the word reading part and colour reading part)	-0.109	0.389	-0.327	0.008

Abbreviations: TBI: Traumatic brain injury; MMSE: Mini-mental state examination; WCST: Wisconsin card sorting test.

*All results are related to raw scores, **This score is unavailable because all healthy controls could complete all six categories of the WCST.

the P-FAB and other tests evaluating frontal lobe functions, including the MMSE, WCST, and various conditions of the Stroop test, confirming the FAB's concurrent validity for measuring executive dysfunction [9, 17, 20, 34, 35]. The FAB showed a strong correlation with the MMSE. However, since the MMSE assesses non-EFs, this brings into question the FAB's ability to discriminate in measuring frontal lobe functions specific to TBI. A more detailed subgroup analysis would be beneficial for further understanding the relationship between FAB and cognitive assessments, such as the MMSE. Moreover, the FAB was significantly correlated with WCST performance, particularly in terms of the number of categories achieved and perseveration errors. Since perseveration errors in WCST are associated with executive dysfunction, this suggests that the FAB is effective in evaluating executive dysfunction.

The present study also revealed significant relationships between the Stroop test's time length and error rates, even though these measures primarily assess processing speed and cognitive flexibility rather than EFs. Additionally, the absence of a significant correlation between the FAB and the Stroop interference score, which directly

Table 5. Mean P-FAB subtest scores

Subtests	Mean±SD		P	Effect Size
	TBI Group (n=65)	Healthy Group (n=65)		
Similarities (conceptualization)	2.21±0.087	2.95±0.21	<0.001	0.54
Lexical fluency	0.078±0.89	2.47±0.64	<0.001	0.73
Motor series (programming)	1.75±1.31	3±0	<0.001	0.59
Conflicting instructions (sensitivity to interference)	1.41±1.11	2.81±0.39	<0.001	0.66
Go-no go (inhibitory control)	1.61±0.094	2.76±0.45	<0.001	0.61
Prehension behaviour (environmental autonomy)	2.75±0.075	3±0	0.007	-0.23

TBI: Traumatic brain injury.

Table 6. Cut-off for total P-FAB score for differentiating between PwTBI and healthy participants

Cut-off for Total P-FAB Score	Sensitivity	Specificity	Youden's J
11	1	0.57	0.57
12	1	0.59	0.59
13	1	0.65	0.65
14	1	0.8	0.8
15	0.93	0.91	0.85
16	0.72	0.96	0.69

measures EFs, could indicate that different regions within the frontal lobe underlie the tasks assessed by each test [11, 36, 37]. Stroop performance, for instance, is thought to involve the left frontal region, particularly the anterior cingulate cortex and orbital parts of the prefrontal cortex, while other studies suggest that FAB functions may be more associated with the left precentral and bilateral callosomarginal areas [11, 38].

Literature showed significant differences in FAB scores between patients with small sub-cortical infarcts and also patients with Alzheimer's disease compared to the control group [16, 17]. Consistent with these results, our study found that the FAB can effectively distinguish between healthy individuals and TBI patients. Given its stronger correlation with the MMSE compared to WCST, the FAB may be especially useful for identifying mild cognitive impairments that other tests may overlook (WSCT, Stroop test) and for assessing the severity of executive dysfunction, with lower scores indicating more pronounced dysfunction [9]. Thus, the FAB is a promising functional screening tool in clinical situations.

In this study, we determined a cut-off score of 15 for the FAB as optimal for differentiating TBI patients from healthy individuals, providing high sensitivity (0.93) and specificity (0.9). Adjusting the cut-off below 15 reduced specificity, while increasing it beyond 15 lowered sensitivity, as detailed in Table 6.

Conclusion

This research demonstrated that the P-FAB provides adequate validity and reliability to evaluate frontal lobe functions and executive dysfunction in PwTBI, effectively distinguishing them from healthy participants. We recommend the P-FAB as a rapid, convenient assessment tool for TBI screening. Further research using computer-based tests is recommended to validate these findings.

Limitations

This study had limitations regarding patient accessibility for retesting and challenges in encouraging participation. The hospital permission process for sampling also restricted our efforts. Additionally, we lacked information on injury severity and time since injury for some patients, as well as subgroup scores for the MMSE, which limited our methodology.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics committee of the University of Social Welfare and Rehabilitation Sciences (Code: IR.USWR.REC.1397.016).

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The paper was extracted from the master thesis of Ramin Banimahdi, approved by University of Ottawa.

Authors' contributions

Conceptualization and supervision: Nazila Akbarfahimi, Seyed Ali Hosseini and Seyed Majid Akhavan Hejazi; Methodology: Mohsen Vahedi and Ramin Banimahdi; Writing the original draft: Ramin Banimahdi; Investigation, review & editing: All authors.

Conflict of interest

The authors declared no conflict of interest.

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