Original Article
DOI: 10.5152/tftrd.2015.25932
Turk J Phys Med Rehab 2015;61:333-8

Correlation between Functional Independence and Quality of Executive Functions in Stroke Patients

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Abstract

Objective: The rehabilitation of stroke patients is complex. It is believed that there is a correlation between the quality of functional independence and degree of preserved executive and cognitive functions. The aim of this work was to investigate potential correlations between the quality of executive and cognitive functions and the achieved level of functional independence during the rehabilitation of stroke patients.
Material and Methods: The study included 50 stroke patients evaluated during rehabilitation and 50 beneficiaries of the Gerontology Center as control subjects randomly chosen, with no diagnosed neurological damage. The following tests were used: Wisconsin Card Sorting Test (WCST) for executive function assessment, Mini-Mental State Examination (MMSE) for cognitive screening, and Functional Independence Measure (FIM) test for functional independence assessment. The statistical analyses included the Mann–Whitney U test for comparisons between two independent samples, canonical correlation analysis, and χ^2-test.
Results: Our results show a statistically significant difference in all assessed functions between the two groups (p<.001). Furthermore, we show a positive correlation between executive functions and achieved functional independence in stroke patients (p<.001). Moreover, a positive correlation exists between cognitive functions and level of functional independence in stroke patients.
Conclusion: Our results show that stroke patients with lower executive function scores achieve less functional independence. Stroke patients with existing cognitive impairment achieve less functional independence in all domains compared with stroke patients without cognitive impairment.
Keywords: Stroke, executive functions, cognitive functions, functional independence

Introduction

Stroke is the third most common cause of death and the second most common cause of functional disability worldwide, according to the World Health Organization (1). Stroke results in a high rate of mortality and a high level of functional disability. Statistics show that high levels of functional disability resulting from stroke, which range from mild (35.8%) to medium (33.3%) and severe (30.9%), are worrisome and highlight the role and importance of medical rehabilitation (2).

The rehabilitation of stroke patients is a complex and multidimensional problem. In the last few decades, healthcare experts have approached stroke-related alterations in executive functions and their impact on functional activities by emphasizing on locomotion in stroke patients. Given the correlation

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Received: April 2014 Accepted: February 2015

Cite this article as:
Arsic S, Eminovic F, Konstantinovic L, Pavlovic D, Kljajic D, Despitovic M. Correlation between Functional Independence and Quality of Executive Functions in Stroke Patients. Turk J Phys Med Rehab 2015;61:333-8.

between the quality of motor recovery and functional training and preserved cognitive functions, functional assessments that include cognitive functions are crucial prior to the implementation of rehabilitation in stroke patients.

The level of cognitive impairment after a stroke is complex because the level of impairment in executive functions depends on the affected regions in the cerebral hemispheres. Although it is agreed that reduced efficiency in executive functions may contribute to altered locomotion, the underlying mechanism is not yet defined. Patients with neurological impairments have particular difficulties when performing simultaneous cognitive and motor tasks such as walking while engaging in an additional task; these simultaneous activities raise concerns about the musculoskeletal system performance (3). Although many studies show a correlation between executive functions and functional recovery in stroke patients evaluated before enrolling in the rehabilitation process, these results do not necessarily suggest that the functional recovery of patients can be predicted by the quality of executive functions (4).

Functional activities are the measure of motor skills because they relate to activities of daily living (ADLs). The basic functional skill of a stroke patient involves achievements in elemental functional activities with regard to ADLs, including self-care, mobility, transfer, locomotion, communication, and socialization. Thus, physical disability, to a greater or lesser extent, may negatively impact ADLs and the ability to work (5) as well as complicate the rehabilitation because majority of these patients are still productive members of the society. For this reason, optimal rehabilitation includes medical, cognitive, social, and vocational processes.

Because functional independence is the primary and ultimate goal of medical rehabilitation in stroke patients and the presence of cognitive deficits may affect its course and outcome, we assessed the multidisciplinary approach for the diagnosis and treatment of stroke patients in this study.

Material and Methods

Participants

The study was conducted at the Department of Extended Care and Treatment with Rehabilitation at the General Hospital of Cuprija and Gerontology Center of Jagodina from August 1, 2012 to March 1, 2013. The Ethics Committee of the General Hospital of Cuprija approved the research that was conducted in accordance with the ethical standards of the Helsinki Declaration. All subjects were informed about the objectives of the study and gave their consent.

We included 100 patients in our study. Our stroke group included 50 ischemic stroke patients [24 females (48%) and 26 males (52%)] between the ages of 50 and 80, who had hemiparesis and were in the sub-acute phase. All stroke patients had received rehabilitation before admission to our department for further rehabilitation measures and procedures. For our control group, 50 age- and gender-matched subjects without neurological damage [27 females (54%) and 23 males (46%)] were recruited. The subjects in the control group were screened for Parkinson's disease, multiple sclerosis, dementia, and depression. The subjects had already undergone early rehabilitation. The primary objective was to compare stroke patients with control subjects to examine the relationships between the quality of attention, cognitive functions, and motor skills.

Assessment of control functions by Wisconsin Card Sorting Test (WCST)

WCST is a card sorting test for the detection of perseveration and mental rigidity, and the evaluation of abstraction in healthy subjects. In our study, WCST was used to assess the will, planning, anticipation, intent implementation, and the verification of activities (6). In the standard version of the test, subjects were given two identical decks of 64 stimulus cards (a total of 128 cards) with painted figures: cross, circle, star, and triangle. The cards differed in color (red, green, yellow, and blue), number (1–4), and shape, while the number of pieces on the map of 1^{st}–4^{th}. On one map, all figures were of the same color. They represent the four stimuli cards, according to which should be stacked, the map below each map stimuli. Respondents were instructed to reveal the actual pairing of principle cards based on the stimulus deck of cards without prior instruction. The test administrator then told the respondent whether the answer was right or wrong. The test is sensitive to impairments in planning, formation of concepts, and perseveration. Scoring is based on measurements of 11 concepts. In a clinical research setting, the most important outcome measures are perseveration and the number of concepts achieved. The standards used for adults: the total number of categories achieved arithmetic mean (AM) 5.4; SD 1.3; no per-severativity response AM 12; SD 10.

Assessment of Cognition by Mini-Mental State Examination (MMSE)

MMSE is a simple to use, sensitive, and valid screening for assessing the cognitive status of patients. It has been proven to be a reliable and suitable test for the initial assessment and follow-up of mental status in clinical practice. MMSE assesses the temporal and spatial orientation, memory skills (immediate and delayed), attention, oral and written language, and constructional abilities in two dimensions. The test itself lasts 10–30 min, and measures11 tasks, wherein each task receives a specific score: the total score ranges from 0 to 30. Severe cognitive impairment is defined as an MMSE score between 0 and 17, medium impairment is defined as an MMSE score between 18 and 23, and no impairment is defined as an MMSE score between 24 and 30. It is important to note that MMSE provides only a rough evaluation of cognitive impairment because the level of education of patients must also be taken into account. For classifying patients into a category of cognitive impairment based on their MMSE scores, we used the following modified MMSE scores adjusted to the level of education: 21 or less for people who only completed primary school, 23 or less for those who completed high school, and 24 or less for those who completed higher education were considered to be cognitively impaired.

Assessment of Functional Independence by Functional Independence Measure (FIM)

The main purpose of FIM is an adequate, prompt, valid, and general assessment of the functional abilities of patients with neurological impairments to determine their functional independence (7). FIM includes eighteen tasks covering six domains: self-care, sphincter control, mobility, movement, communication, and socialization. Each task is precisely defined and contains a number of actions. Scores are given on a seven-level scale and are graded according to the degree of independence: complete aid (respondents=0%: 1 point), maximum assistance (respondents=25%: 2 points); medium assistance (respondents=50%: 3 points); minimal assistance (respondents=75%: 4 points); monitoring (respondent only requires control: 5 points), partial independence (respondent using assistance: 6 points), and complete independence (respondent requires complete temporal and spatial safety: 7 points). Total score is obtained by adding points of each task and is expressed in row number. The maximum score is 126.

Statistical Analysis

The comparisons between stroke patients and control subjects were performed by Mann–Whitney U test as a nonparametric test for two independent samples, and canonical correlation analysis. Data was processed using Statistical Package for the Social Sciences (SPSS Inc.; Chicago, IL, USA) version 14.0.

Results

The stroke group had significantly fewer completed categories on the WCST test compared with the control group [t (73)=12:36, p<.001]. Perseverative errors were significantly lower in the stroke group compared with the control group [t (73)=2.73, p<.01] (Table 1, p<.01).

People without neurological damage from the sample had a statistically significant lower number of categories on average than the standard WCST test [t (73)=10:49, p<.001]. In addition, these patients had a significantly lower number of the perseverative errors [t (73)=5.69, p<.001]. The difference between the two groups was statistically significant (p<.001) (Table 1, p<.001).

The MMSE results showed that among stroke patients, 11 (22%) were without any cognitive impairment, 36 (72%) had mild cognitive impairment, and 3 (6%) had severe cognitive impairment. In the control group, none of the subjects had cognitive impairment as assessed by the MMSE. The rate of cognitive impairment between the stroke and control groups was statistically significant (Table 2, p<.001).

The comparison of functional independence between the two groups revealed that on an average, the stroke group had significantly lower scores compared with the control group across all domains included in the FIM (Table 3, p<.001).

Based on the forecasts of structural coefficients, we observed that subjects that achieved more concepts and had less errors on the perseveration component of the WCST had a higher degree of functional independence in self-care and socialization (Table 4, r=.565; r=.993).

The results of the Mann–Whitney U test (Table 5) showed a statistically significant difference in the following domains of FIM when stroke patients were compared according to the presence of cognitive impairment: self-care, sphincter control, and locomotion. We also found that patients without cognitive impairment achieved significantly higher scores on an average in the communication and socialization domains compared with patients with cognitive impairment. The differences were statistically significant at p<.05.

Discussion

One of the most important questions for healthcare professionals dealing with stroke patients is whether the extent of stroke is a cause of cognitive decline and whether reduced executive functions and cognitive impairment influence the extent, course, and outcome of medical rehabilitation. The consensus is

Table 1. WCST scores assessing planning skills and perseveration in stroke patients and control subjects without neurological damage

Parameter	Normative values of the test		Stroke patients				Control subjects			
	AM	SD	AM	SD	min	max	AM	SD	min	max
Category	5.4	1.3	1.28	1.39	0	5	2.53	2.03	0	8
Perseverative errors	12	10	7.92	4.81	0	22	3.16	3.25	0	12
		Differences in relation to the normative group								
Category		t (73)=12.36, p<.001				t (73)=10.49, p<.001				
Perseverative errors		t (73)=2.73, p<.01				t (73)=5.69, p<.001				

AM: arithmetic mean; SD: standard deviation; min–max; **p<.001 Mann–Whitney U in statistics; WCST: Wisconsin Card Sorting Test

Table 2. MMSE scores assessing frequency and degree of cognitive impairment in stroke patients and control subjects without neurological damage

Sum	Damage patients n (%)	Stroke subjects n (%)	Control
24–30	Without cognitive impairment	11 (22)***	50 (100)
18–23	Mild cognitive impairment	36 (72)***	0 (0)
0–17	Severe cognitive impairment	3 (6) ***	0 (0)
Total		50 (100)	50 (100)

***p<.001 (χ^2 test); MMSE: mini-mental state examination

Table 3. FIM scores assessing domains in stroke patients and control subjects without neurological damage

Domain	Stroke patients			Control subjects		
	AM (SD)	mdn	Middle range	AM (SD)	mdn	Middle range
Self-care	29.00 (10.45)	30	30.75	41.90 (.58)	42	70.25**
Sphincter control	10.40 (3.21)	12	32.00	14.00 (.00)	14	69.00**
Mobility	14.06 (5.24)	15	31.02	20.74 (.99)	21	69.98**
Locomotion	8.94 (3.40)	9	31.54	13.44 (.58)	13	69.48**
Communication	10.42 (1.99)	11	37.08	12.32 (1.65)	13	63.92**
Socialization	15.02 (3.04)	15	37.24	17.88 (2.59)	19	63.76**
Motor domain	62.40 (21.23)	63.50	31.47	90.08 (1.63)	90.00	69.53**
Cognitive domain	25.44 (4.68)	25.00	36.47	30.20 (4.16)	32.00	64.53**
Total			29.85			71.15**

AM: arithmetic mean; SD: standard deviation; mdn: median; FIM: functional independence measure **p<.001 Mann-Whitney U in statistics

Table 4. Table showing the forecasted achievement of functional independence in self-care and socialization, based on the indicator of planned behavior in stroke patients

Variable	Odds	Rc	Rc^2 (%)
Self-care	0.133	0.565	31.9
Socialization	0.931	0.993	98.60
Rc^2			37.6
Number of categories (WCST)	0.799	0.989	97.8
Number of perseverative errors (WCST)	-0.241	-0.872	76.0

Odds: standardized canonical function coefficients; Rc: structural coefficient; Rc^2: squared structural coefficient; WCST: Wisconsin Card Sorting Test

Table 5. Table showing statistical significance of differences in the results obtained for all investigated domains using the FIM test in the group of stroke patients with and without cognitive impairment

Domain	Stroke patients without cognitive damage	Stroke patients with cognitive damage	U	r
	Middle range	Middle range		
Self-care	33.64	23.21	125.00*	0.21
Sphincter control	29.68	24.32	168.50*	0.11
Locomotion	33.00	23.38	132.00*	0.19
Communication	38.36	21.87	73.00*	0.33
Socialization	38.73	21.77	69.00*	0.34

U: Mann–Whitney U in statistics; r: effect size; * p<.05

that in these patients, although global cognitive disorders may not be overt, specific cognitive deficits that may impact motor recovery and functional independence after a stroke may be affected.

Cognitive functions include perception, memory, and thinking. In accordance with the theory of information processing, perception is used for selection, admission, organization, and classification of stimuli from the environment, whereas memory is used for the encoding and storage of information received. Cognitive dysfunction can manifest itself as measurable disturbances in various activities. In patients with a mild stroke, a subtle language disorder, spatial and visual disorders, or altered motor activity may occur (Table 2, p<.001).

The results of this study show that there is a link between mild cognitive impairment and functional independence. On all FIM domains, stroke patients with cognitive impairment achieved significantly lower levels of functional independence than patients without cognitive impairment (Table 5, p<.05).

Motor and cognitive impairments in stroke patients may affect functional training to variable degrees. One study investigating the correlation between cognitive and motor defects (8) suggests that after stroke, patients experience limitations in a number of activities, ranging from mobility to communication and self-care. These limitations negatively affect movement as well as the social and professional aspects of training. The same research study also shows that some stroke patients typically favor the cognitive functions of motor task and that only certain cognitive functions interfere with motor skills. The study also shows that the intensity of the motor task should be adjusted to achieve the desired motor activity (9). Functional activities essentially measure the level of motor skills. In our group of stroke patients, a decreased level of functional independence manifested as a difficulty in performing given activities without stimulation and instruction, reduced impulse control, or reduced insight into their own mental and motor skills.

The results obtained by stroke patients being assessed for all FIM domains show that majority of the enrolled patients needed assistance in the range of moderate help to surveillance. The control subjects had better FIM scores, and majority of them were completely independent. The comparison of the two groups revealed a statistically significant difference in achievements (Table 3, p<.001).

There are few studies that investigated the impact of comorbidity on the outcome of medical rehabilitation and functional recovery, with 50% of stroke patients showing at least one comorbidity. The results of one study that assessed the association between comorbidity and functional recovery showed that a satisfactory level of functional independence, particularly in locomotion, was important (10). In our study, when we assessed the socialization domain in addition to the environmental interaction, we found that stroke patients achieved a lower efficiency in problem comprehension and memorization compared with control subjects that did not show neurological damage (Table 3, p<.001).

The basic components of executive functions and its attributes are the ability to organize, which include the will, planning, premeditated action, and efficient execution in the presence of cognitive inhibition (11). Thus, a lower efficiency in one of these components will inadvertently affect the functional activities. This is reflected in our results; there is a clear link between the planned behavior and functional outcomes in the locomotion domain (Table 1, p<.001). For example, a low awareness of limitations as well as a low level of voluntary dynamism may result in an increased risk of falling. The ability to plan implies an ability or strategy that will convert the implemented intentions to achieve a goal with an insight into the real circumstances, involving prediction and appropriate choice (12). In principal, functional abilities measure the achieved level of motor skills. Our results also show that stroke patients exhibit a low level of elementary functional abilities in the context of ADL. Our results show a statistically significant correlation between the ability to organize an activity and functional recovery in stroke patients (Table 4).

The current study also suggests that executive dysfunction is a key factor contributing to limitations in ADL and that it leads to an early loss of productivity and a significant decrease in functional recovery, aggravating rehabilitation. Assuming that the reductions in the measured cognitive traits may be an indicator of damage, this may be an indicator of the recovery of functional capacity in stroke patients. If this is indeed the case, cognitive stimulation to correct reduced cognitive abilities associated with motor skills should be considered as an integral part of medical rehabilitation. A study suggested that inclusion of cognitive stimulation in medical rehabilitation may improve a stroke patient's cognitive abilities after adjusting for preexisting cognitive deficits, and may enable faster recovery, allowing for a higher level of functional independence (13).

One limitation of the study is the relatively small number of participants; however, several previous studies were conducted on similar-sized cohorts. In addition, only those patients with hemiparesis, those who completed early rehabilitation, and those who participated in advanced rehabilitation were included, creating a potential selection bias. However, our results serve as a solid foundation for future comprehensive research.

Conclusion

Our results demonstrate that stroke patients with good executive functions have a higher degree of functional independence in all tested domains, particularly in self-care and socialization. Stroke patients with preexisting cognitive impairment achieve significantly less functional independence across all domains than control subjects without cognitive impairment. The comparative analysis of the existing relevant literature provides further support to our findings: executive dysfunction observed in stroke patients necessitates the development of new procedures and adjustments to existing methods in medical rehabilitation for increased efficacy and for optimal functional.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of General Hospital Cuprija.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.A.; Design - S.A., L.K., F.E.; Supervision - D.P.; Resources - M.D.; Materials - D.K.; Data Collection and/or Processing - S.A.; Analysis and/or Interpretation - S.A., L.K.; Literature Search - D.P.; Writing Manuscript - S.A.; Critical Review - L.K., D.P.; Other - S.A., F.E., D.P.

Acknowledgements: The authors acknowledge professors who contributed with their expertise and practical experience to the preparation of the study, the medical personnel department for extended care, and Rehabilitation Research Associates Gerontology Center that allowed the research to be conducted.

Conflict of Interest: No conflict of interest was declared by the authors

Financial Disclosure: The authors declared that this study has received no financial support.

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