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Assocıations Between Executive Functions, Attentıon Skills and Upper Extremity Motor Abilities in Individuals with Chronic Stroke

Kronik İnmeli Bireylerde Yürütücü Fonksiyonlar ve Dikkat Becerileri ile Üst Ekstremite Motor Fonksiyonları Arasındaki İlişki

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ABSTRACT

Introduction: One of the most common problems encountered after stroke is the loss of motor function in the upper extremities. Improvement in upper extremity motor function is very important to minimize long-term limitations and improve quality of life.
Objective: This study aims to examine the relationship between executive functions, attention skills and upper extremity motor functions in chronic stroke individuals who are considered cognitively normal.
Method: 58 individuals with chronic stroke who were treated at Erenköy Physical Therapy and Rehabilitation Hospital were included in the study. Montreal Cognitive Assessment Scale (MoCA), Stroop Test TBAG Form and Digit Span Test were used to assess the cognitive, executive and attention skills of the individuals. Fugl Meyer Upper Extremity Assessment Scale (FMA-UE) and Box and Block Test (BBT) were used to assess the level of upper extremity functions.
Results: When we look at the findings of the study, the upper extremity motor functions of the individuals had a positive correlation with the MoCA and Digit Span Test scores and a negative correlation with the Stroop Test components ($p<0.05$). Cognitive functions were found to be 40% effective on upper extremity motor functions according to the regression analysis between MoCA and BBT and 17% effective on upper extremity motor functions according to the regression analysis between MoCA and FMA-UE.
Conclusion: The results of the study confirm the relationship between executive functions and attention skills and upper extremity motor functions in chronic stroke patients who are considered cognitively normal. Taking executive function and attention components into consideration when creating protocols during the rehabilitation process will help therapists create personalized and successful programs.

Keyswords: Stroke, Upper Extremity, Cognitive Fonction, MoCA.

ÖZET

Giriş: İnme sonrası en yaygın karşılaşılan sorunlardan biri, üst ekstremitelerdeki motor fonksiyon kaybıdır. Uzun vadede kısıtlılığı en aza indirmek ve yaşam kalitesini daha iyi hale getirebilmek için üst ekstremite motor fonksiyonlardaki iyileşme çok önemlidir.
Amaç: Bu çalışma, kognitif olarak normal kabul edilen kronik inmeli bireylerde, yürütücü fonksiyonlar ve dikkat becerileri ile üst ekstremite motor fonksiyonları arasındaki ilişkiyi incelemeyi amaçlamaktadır.
Yöntem: Çalışmaya, Erenköy Fizik Tedavi ve Rehabilitasyon Hastanesinde tedavi gören, kronik inmeli 58 kişi dahil edildi. Bireylerin kognitif, yürütücü ve dikkat becerilerini değerlendirmek için Montreal Bilişsel Değerlendirme Ölçeği (MoCA), Stroop Testi TBAG Formu ve Sayı Menzil Testi kullanıldı. Üst ekstremite fonksiyonlarının eğerlendirmek için Fugl Meyer Üst Ekstremite Değerlendirme Ölçeği (FMA-ÜE) ve Kutu ve Blok Testi (KBT) kullanıldı.
Bulgular: Çalışmanın bulgularına baktığımızda, bireylerin üst ekstremite motor fonksiyonları MoCA ve Sayı Menzili Testi skorları ile pozitif yönde; Stroop Testi bileşenleri ile ise negatif yönde anlamlı ($p<0,05$) bir korelasyona sahipti. Kognitif fonksiyonların, MoCA ile KBT arasındaki regresyon analizine göre %40, MoCA ile FMA-ÜE arasındaki regresyon analizine göre ise %17 üst ekstremite motor fonksiyonları üzerinde etkili olmaktadır.
Sonuç: Çalışmanın sonuçları kognitif olarak normal kabul edilen kronik inmeli hastalarda yürütücü fonksiyonlar ve dikkat becerileri ile üst ekstremite motor fonksiyonları arasındaki ilişkiyi ortaya koymaktadır. Terapistlerin rehabilitasyon sürecinde, protokollerini oluştururken yürütücü fonksiyon ve dikkat bileşeninin göz önünde bulundurması, kişiselleştirilmiş ve başarılı programlar oluşturmalarına yardımcı olacaktır.

Anahtar Kelimeler: Kronik İnme, Üst Ekstremite, Kognitif Fonksiyon, MoCA.

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INTRODUCTION

Stroke is defined as a cerebrovascular disorder due to a vascular cause, with sudden onset, rapid development and may lead to death (1). In addition to causing sensory, motor and cognitive impairments, stroke is a problem that reduces self-care and participation in social and community activities (2, 3).

Upper extremity dysfunction is associated with a large proportion of functional disorders after a stroke (4). While 85% of individuals with stroke have upper extremity problems, 55-75% of these individuals continue to live with upper extremity functional limitation that reduce the quality of life (5). Therefore, improvement in upper extremity motor function is very important to minimize limitation and improve quality of life in the long term (6).

Cognitive impairments, which are commonly observed after head injuries and cerebrovascular events, are characterised by difficulties in information processing due to brain damage (7). Patients experience many problems such as apraxia, amnesia, neglect of the affected side, loss of problem solving ability, and loss of attention (8). At the same time, cognitive impairments, which may delay functional recovery by reducing participation in rehabilitation and compliance with treatment, may cause disability with its primary effect on quality of life and functional independence (7, 9, 10).

In previous studies, cognitive and motor components were generally considered as separate systems in the design of rehabilitation programmes. Although recent studies have focused on the effect of cognitive functions and motor learning on motor recovery (11), there is no general consensus in the literature on the relationship between cognitive disorders and motor functions.

In a study by Boe et al. no correlation was found between cognitive recovery and motor recovery (12), while in another study examining the correlation between upper extremity motor functions and cognitive functions, a weak but significant relationship was found (13).

In a study by Skidmore et al. it was emphasised that cognitive impairment was not effective in the improvement of motor functions (14), whereas in studies in which upper extremity functions were evaluated, it was reported that the effect on executive functions was effective in the improvement of upper extremity motor functions (15, 16).

While a significant correlation was found between attention and upper extremity functions in two studies examining the relationship between affected upper extremity and cognitive functions in patients with stroke (17, 18), in a recent meta-analysis, it was emphasized that attention and memory disorders were more common in the acute period after stroke, while impairment in executive functions was more common in the chronic period, and it was stated that more evidence-based studies should be conducted on the relationship between impaired cognitive functions and motor functions (19).

A better understanding of the effect of cognitive impairment on motor functions may lead to more effective rehabilitation protocols for stroke survivors and improve their quality of life, facilitating faster return to activities of daily living. When examining studies on the relationship between cognition and motor functions, we see that participants with low cognitive levels and functionally dependent participants are concentrated (20, 21). In a study examining the relationship between the functional levels of stroke patients with normal and low cognitive status, there was no significant difference between the two groups, although the functionality level of cognitively normal patients was better 22). When we look at the literature, there are limited studies examining the relationship between stroke patients with normal cognitive levels and motor function.

This study aims to examine the relationship between executive functions, attention skills and upper extremity motor functions in cognitively normal individuals with chronic stroke.

METHOD

Study Design and Participants

The prospectively planned study was carried out on 58 patients diagnosed with stroke who received outpatient or inpatient treatment at Erenköy Physical Therapy and Rehabilitation Hospital between 30.04.2022-10.08.2024. Inclusion criteria were being diagnosed with hemiplegia for the first time, being 18 years of age or older, having a stable medical condition, having upper extremity stage 3 or above according to Brunnstrom motor staging, having a score of 21 or above on the Montreal Cognitive Assessment Scale, being literate and agreeing to participate in the study. Patients with visual problems, risk of subluxation and fracture in the shoulder, limitation of joint movement in the upper extremity on the hemiplegic side, any botulinum toxin application or surgical operation in the last 6 months were excluded from the study. The study was approved by the ethics committee of Marmara University Faculty of Medicine in accordance with the Helsinki principles (date: 12.04.2022, number: 654). All participants were informed about the study and informed consent forms were obtained.

In the collection of research data; Demographic Information Form was used to obtain personal and clinical data of the patients, Fugl Meyer Upper Extremity Assessment Scale (FMA-UE), Box and Block Test (BBT) to evaluate upper extremity motor functions, Stroop Test to evaluate executive functions, and Digit Span Test to evaluate attention skills.

Fugl Meyer Upper Extremity Assessment Scale (FMA-UE)

The Fugl Meyer Upper Extremity Assessment Scale (FMA-UE) is widely recommended for use in stroke patients and is based on performance measurement. The test consists of subsections such as reflex activity, flexor and extensor synergy, combined synergy movements, non-synergy movements, normal reflex activity, wrist and hand evaluation, coordination and speed evaluation. It consists of 33 items in total and the total score is 66. It is easy to apply, does not require much equipment, household items are sufficient, and takes about 30 minutes (23).

Box and Blocks Test (BBT)

The Box and Blocks Test (BCT) is used to evaluate gross manual dexterity. Patients are asked to move the cubes in a single compartment of the box to the opposite side as fast as possible within 1 minute. This test is easy to administer even for patients with impaired perception, distractibility and reduced endurance (24, 25).

Montreal Cognitive Assessment Scale (MoCA)

The Montreal Cognitive Assessment Scale (MoCA) assesses various cognitive functions, including executive functions, visual-spatial skills, memory, language, abstract thinking, attention, calculation, orientation, and concentration. The tracking test tests abstract thinking such as clock drawing and similarity, as well as executive functions with cube copying. Scoring is between 0 and 30 points. Scores below 21 are considered cognitive impairment. The Turkish validity and reliability study was conducted by Selekler et al. (26, 27).

Stroop Test TBAG Form

The Stroop Test is a widely used executive function test that evaluates selective attention, information processing speed, and cognitive flexibility. Developed by John Ridley Stroop in 1935, the test is based on measuring the reaction time of the reader in the face of this confusing effect when the color of the written word is different from the color the word expresses in meaning. It consists of five separate parts: Part 1, saying the names of colors written in black ink; Part 2, saying the names of colors written in different colors; Part 3, saying the color of circles printed in color; Part 4, saying the color of neutral words printed in color; Part 5, saying the color of color names printed in different colors (28).

Digit Span Test

This test is included in the attention/concentration section of the Wechsler Memory Scale Improved Form and measures auditory attention. Firstly, the forward digit span is applied. Then the backward digit span is applied. If the person who is tested in both sections is successful, the next trial is started. If he/she fails in both trials, the test is discontinued (29).

Statistical Analysis

IBM SPSS Statistics 23.0 program was used to analyze the data. Normality analysis using the Shapiro-Wilk test indicated that the data followed a normal distribution ($p > 0.05$). Pearson's correlation analysis was used to examine the relationships between data. The results of the correlation analysis were classified as follows: $r = 0\text{-}0.3$ as weak correlation; 0.3-0.6 as moderate correlation; and >0.6, strong correlation [30]. Statistical significance (with a 95% confidence interval) was accepted as $p < 0.05$. Linear regression analysis was used to determine the effect of cognitive function on motor function.

RESULTS

In our study, 58 participants who met the inclusion criteria participated. The participants icluded 36 males (62.1%) and 22 females (37.9%). Demographic data of the participants are shown in Table 1. The mean and standard deviation values of the parameters used to evaluate cognitive and motor function in our study are given in Table 2.

Statistical correlation values between MoCA, Stroop Test, Digit Span Test, BBT and FMA-UE are given in Table 3. The difference in duration, number of errors and spontaneous correction units of the Stroop test were included in the statistical analysis. Statistical analysis showed a significant ($p< 0.05$) correlation between cognitive and motor parameters.

When we looked at the correlation coefficients between MoCA and BBT (r=0,633) and MoCA and FMA-UE (r=0,415), we observed a moderate correlation between MoCA and FMA-UE and a strong positive correlation between MoCA and BBT. There was a significant negative correlation ($p<0.05$) between the Stroop Test components and motor functions, and a significant positive correlation ($p<0.05$) between the Digit Span Test and motor functions(Table 3).

In line with these findings, it was determined that executive functions and attention were effective on motor functions in daily life in patients with chronic stroke. Regression analysis was performed to determine he magnitude of the effect of cognitive function on upper extremity motor functions. Cognitive function was found to be 40% effective on upper extremity motor functions according to the regression analysis between MoCA and BBT and 17% effective on upper extremity motor functions according to the regression analysis between MoCA and FMA-UE (Table 4).

Table 1. Demographic data

Variables		Mean±SD	
Age		59.05±13.23	
Height(cm)		168.34±8.13	
Weight(kg)		78.40±13.43	
BMI (kg/ ^{m2}		27.59±3.86	
Duration of stroke (Months)		13.45±6.73	
		n	%
Type of stroke	Ischemic	49	84.48
	Hemorrhagic	9	15.52
Effected side	Right	27	46.55
	Left	31	53.45

BMI: body mass index, SD: Standard Deviation, n: Number, %: Percent.

Table 2. Mean and standard deviation values of evaluation parameters

Variables	Mean±SD
MoCA	23.88±1.93
Stroop SF	32.34±7.32
Stroop HS	5.48±192
Stroop SD	4.86±1.30
Forward SM	4.67±0.83
Back SM	3.24±0.63
KBT	18.32±7.49
FMA-ÜE	39.66±7.98

MoCA : Montreal Cognitive Assessment Scale, BBT: Box-Block Test, FMA-UE: Fugl Meyer Upper Extremity Assessment Scale, SF: Time Difference, HS: Number of Errors, SD: Spontaneous Correction, SM: Digit Range, SS: Standard Deviation.

Table 3. Correlation between cognitive functions and motor functions

Variable		MoCA	Stroop SF	Stroop HS	Stroop SD	Forward SM	Back SM
KBT	r	0.633 **	-0.545 **	-0.495 **	-0.433 **	0.403 **	0.470 **
	P	0.000	0.000	0.000	0.001	0.002	0.000
FMA-ÜE	r	0.415**	-0.375**	-0.324*	-0.319*	0.291*	0.417**
	p	0.001	0.004	0.013	0.015	0.027	0.001

MoCA : Montreal Cognitive Assessment Scale, BBT: Box-Block Test, FMA-UE: Fugl Meyer Upper Extremity Assessment Scale, SF: Time Difference, HS: Number of Errors, SD: Spontaneous Correction, SM: Digit Range, r: correlation coefficient, *p<0.05, **p<0.01.

Table 4. Linear Regression analysis examining the effect of cognitive functions on motor functions

	Variable	B	SS	95%CI		t	R2	P
				UB	LB			
KBT	Constant	-40.14	9.57	19.81	21.93	39.46		0.000
	MoCA	2.45	0.400	0.11	0.21	6.126	0.40	0.000
FMA-ÜE	Constant	-1.102	11.99	17.48	22.27	16.62		0.000
	MoCA	1.708	0.500	0.04	0.16	3.42	0.17	0.001

MoCA : Montreal Cognitive Assessment Scale, BBT: Box-Block Test, FMA-UE: Fugl Meyer Upper Extremity Assessment Scale, r: correlation coefficient, p<0.05.

DISCUSSION

The results of this study reveal a relationship between general cognitive level, executive functions, attention skills and upper extremity motor functions in chronic stroke individuals without cognitive impairment. It also suggests that MoCA explains 40% of the results of the BBT test, which evaluates upper extremity functions, and 17% of the FMA-UE, which evaluates upper extremity functions in general. It is known that the upper extremity, which has an important place in the fulfilment of daily living activities, is affected more than the lower extremity after stroke, and motor recovery is slower, depending on the localisation and severity of the stroke (31, 32). Very few patients can completely recover upper extremity functions and most patients have permanent motor loss (33). Therefore, it is important to determine the influencing factors to minimise motor deficits in patients with chronic stroke. Cognition is also considered as one of the parameters affecting functional performance in stroke patients (34).

In our study, in which we utilised MoCA scores to evaluate general cognitive functions, we found a strong correlation between cognitive functions and BBT, which assesses upper extremity dexterity, and a moderate correlation with FMA, which assesses general upper extremity functions. This relationship was clearly observed in multiple linear regression modelling. In their study supported by neuroimaging, Lin et al. associated BBT performance with dorsal anterior insula involvement, which is an important region for complex cognitive functions, in addition to sensorimotor structures (35). In a study conducted by Roh et al. in patients with chronic stroke, cognitive level and upper extremity FMA scores showed a significant correlation and it was suggested that these two parameters were effective on activities of daily living (30). Similar to our study, another recent study evaluating cognitive level with MMSE test in patients with chronic stroke found a relationship between general cognitive level and upper extremity functions (13). The fact that MoCA, which we used in our study, was more predictive in terms of cognitive skills than MMSE (36) strengthens the connection between cognitive and upper extremity functions. Based on the studies in the literature, it can be stated that there is a relationship between upper extremity functions and cognitive skills (19, 35, 37, 38). However, the result that MoCA explained 40% of the results of the BBT test, in which gross manual dexterity was evaluated in our study, may be based on the fact that this assessment is more activity-based than FMA-UE (39) and that cognitive functions can be used more actively in activities. From the findings of our study, it can be inferred that cognitive function is an important parameter in evaluating chronic activity performance in stroke patients.

Executive functions include skills such as focusing, directing attention, initiating movements, inhibition, cognitive flexibility and planning (40, 41). It is observed that 19-75% of individuals with acute stroke have executive function deficits and these deficits persist in a significant proportion of individuals even years after the onset of stroke (42). Dancause et al. reported that individuals with stroke have problems in initiating and maintaining correct and consistent movements in the upper extremity due to deficits in executive functions. The researchers stated that individuals with executive function deficits may benefit less from motor training programmes planned for stroke patients (15). In another study conducted with stroke patients, it was shown that executive functions had a greater effect on upper extremity functions compared to other cognitive skills (43). Similarly, Rodriguez et al. reported a relationship between executive functions and manual dexterity in a study conducted with upper extremities (44). Uwa-Agbonikhena et al. evaluated upper extremity function with FMA and suggested that the part of this scale that evaluates the hand and wrist part is related to cognitive functions, especially executive functions (45). Although we did not analyse the sub-sections of the FMA and cognitive skills separately in our study, similar to the results of these studies, we observed a relationship between the FMA and BBT results evaluating the gross dexterity of the hand and executive functions. We thought that the relatively stronger relationship observed in the BBT compared to the FMA was related to the assertion of Uwa-Agbonikhena et al. that 'there is a relationship between manual dexterity and executive functions'. These findings may be explained by the fact that the frontal lobe plays a role in both executive function and motor control (46). The results of our study support this neurophysiological view and show that there is a relationship between executive function level and upper extremity functions.

In our study, in which we used the Digit Span test to assess attention, a significant correlation was observed between the BBT and FMA-UE tests, which assess attention and upper extremity functions. For BBT performance, the person's ability to understand the instructions and to maintain target-orientated grasping and releasing movements for one minute requires sustained attention. In accordance with the literature, the findings in our study make the relationship between the attention tests we used and the BBT test understandable (47, 48).

Wong et al. examined the relationship between upper extremity motor functions and structural connectivity measured using the FMA-UE and Action Research Arm Test in patients with chronic stroke. As a result, they mentioned that brain networks may change in order to adapt to the changes that occur after stroke in brain regions distant from the lesion and stated that there are strong connections between upper extremity motor functions and the areas responsible for the attention network (49). Although we did not use neuroimaging methods in our study, the significant relationship between FMA-UE and attention tests supports the literature.

It is stated that attention deficits are quite common in the acute period after stroke and have a significant effect on functionality, although they show improvement over time (11, 18). Therefore, it is emphasised that rehabilitation programmes to be planned by considering attention deficits will be more effective in terms of functionality (18). Although the individuals with chronic stroke included in our study were cognitively normal, 19% of them were found to have attention deficits in our evaluations. The data of this study indicate that attention problems may be present even if the individuals are within the norms in global cognitive screening tests. The results of our study, which confirm the data of neuroimaging and clinical evaluations in the literature on the relationship between attention and upper extremity, show the necessity of rehabilitation protocols for motor functions combined with cognitive training.

Limitations

According to the literature, although the MoCA cut-off score is taken as the basis for the definition of cognitive impairment (27), impairment in lower cognitive skills may be observed and other parts may compensate for frust impairments. Attention disorder was observed in 19% of the individuals in our study. This was considered as a limitation since it may have an effect on the results of our study.

CONCLUSION

The results of the study confirm the relationship between executive functions and attention skills and upper extremity motor functions in cognitively normal chronic stroke patients. Clinicians and researchers should take into account that executive function and attention component may affect motor functions when establishing assessment and treatment protocols, which will help them to create personalised and successful programmes.

DESCRIPTIONS

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