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Interaction of the Ability of Planned Behavior and Motor Functioning of Patients after Stroke

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Abstract

Planning and organizing activities, as well as the ability to specify the strategies by which the intentions would be implemented and the aim accomplished represent the highest level of frontal lobes functioning and is comparable to the concept of metacognition. Preservation of executive function may be important for motor function of patients after a stroke. Aim of the paper is to determine whether the ability to plan behavior in patients after a stroke is preserved, associated with the quality of motor functioning. The sample consisted of 100 subjects, 50 patients after a stroke involved in the process of rehabilitation and 50 patients randomly chosen , matched by age and general characteristics, which in its medical history and neurological examination had no symptoms of acute or chronic neurological disease. For the evaluation of this variable the following tests were used: WCST Wisconsin Card Sorting Test for assessing executive functions; FAC Functional Ambulation Category test for assessing the quality of movement and performance of motor tasks, including spatial and temporal parameters of walk. The obtained results show the statistically significant difference between the tested patients after a stroke and patients without neurological damage in the area of planned behavior ($p < .001$), as well as in the area of motor skills including parameters of walk ($p < .001$).

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Having in mind the results of this study it can be concluded that there is a significant link between low effective ability to plan behavior with mild quality of movement, worse performance of motor tasks and low values of the estimated parameters of walk.

Keywords: stroke; executive function; motor skills; walk

1. Introduction

In the last few decades many experts have been involved in the topic of executive functions in patients after a stroke, investigating a potential link between motor impairments, with an emphasis on the function of walking. The impact and interrelationship of movement control and appropriate behavior during the walk is observed. It is manifested by the awareness of the individual destination, the ability to appropriate control the limb movements that produce walking and mobility through often very complex environment conditions, in order to successfully reach the desired destination. Up until recently, a walk was generally regarded as a mostly automatic motor task, which requires minimal cognitive engagement on a higher level. Growing evidences, however, link changes in the executive functions and attention to healthy walk and walk with disabilities. The relationship between executive functions and attention and the walk itself gains the ever more importance, followed by monitoring the patients with walking difficulties. A man`s walk assumes an upright position and consists of a series of rhythmic body movements, which are accompanied by postural adjustment, aimed at moving the body from one point to another in terms of the most efficient ways of using energy. While studying the walking patterns, it is common to start with cycle of walk that begins when one foot makes a contact with the ground and ends when the same foot begins this contact one more time (support phase and phase oscillations) [1]. In the man`s walk a wide range of components of the motor system is included. First - motor cortex, basal ganglia, cerebellum, and parts of the reticular formation of the spinal cord. Cortex plays a major role in the process of walking. Motor control is willing, reflex and automatically learned activity of nervous system as a response to the external and internal stimuli, that is why the degree of preservation of motor control in neurological patients is a starting point for planning rehabilitation [1]. Normally, walking is automatic activity in which you do not pay attention to the sequence of execution. Walking starts as willingly, and centers in the central nervous system take over the role subsequently, until the termination of the activity. In situations of the damaged central nervous system, the one that appears after a stroke, this scheme as well as the majority of them are no longer present. Then the patient has to adapt to new circumstances and benefit the schemes available to him. The kinematic and kinetic aspects of locomotion in these patients vary depending on the severity of the damage [2].

2. Materials and methods

The sample consisted of 100 persons surveyed, 50 persons after a stroke, consisting of females N = 24 (48 %) and males N = 26 (52 %). These patients were included in the process of rehabilitation after a stroke. The range of their age was from 54 to 80 years, mean value (hereinafter referred to as MV) is 69.99 years, and the standard deviation (hereinafter referred to as SD) was 7.71 years. Twenty two patients (44 %) had a right-hand hemiparesis and 28 (56 %) dextral hemiparesis.

The sample of persons without neurological damage also consisted of 50 respondents, females N = 27 (54%) and males N = 23 (46 %), randomly chosen in the appropriate age. Their age range was from 51 to 82 years, MV = 67.18 years, SD = 9.27 years. This group of patients included persons who had symptoms of acute and chronic neurological diseases, Parkinson's disease, multiple sclerosis, dementia and depression in their medical chart and neurological examinations.

For the assessment of this variable the following tests were used: Wisconsin Card Sorting Test - WCST: designed for detecting perseverativity and mental rigidity of the surveyed respondents. Will or volition, planning, anticipation and implementation of the intent and verification of the performed action are estimated by this test. It is Card Sorting Test and the most popular test for detecting perseverativity and mental rigidity. Functional Ambulation Category - FAC: is for assessing the quality of movement and performance of motor tasks and assessment of the walk in hemiplegic patients. After that, the spatial - temporal parameters are being assessed trough given instructions: frequency of walk (expressed in number of steps per minute), speed of walk (expressed in meters per second) and the length of lunges (expressed in centimeters).

3. Results

Table 1 shows results of tested planning skills and perseverativity by applying WCST test for a group of patients after a stroke and a group of subjects without neurological damage

Parameter	Normative values of the test		Persons after a stroke				Persons without neurological damage			
	AS	SD	AS	SD	min	max	AS	SD	min	max
Categ.	5.4	1.3	1.28	1.39	0	5	2.53	2.03	0	8
Pers. er.	12	10	7.92	4.81	0	22	3.16	3.25	0	12

Differences in relation to the normative group

Categ.	t(73) = 12,36, p<.001	t(73) = 10,49, p<.001
Pers. er.	t(73) = 2,73, p<.01	t(73) = 5,69, p<.001

Legend: Categ. - Number of categories; Pers. er. - Number perseverative errors;

The results of t-test showed that persons after a stroke in this sample had significantly lower number of categories on the WCST test compared to the normative sample, t (73) = 12:36, p <.001. Perseverative errors were statistically significantly lower among persons after a stroke compared to the sample values obtained by the sample normative test, t (73) = 2.73, p <.01.

Persons without neurological damage from the sample had an average of a statistically significant number of categories in WCST test compared to the test norms, t (73) = 10:49, p <.001. Also, they had a statistically significantly lower number of perseverative errors compared to the test norms, t (73) = 5.69, p <.001.

Table 2 shows the results obtained by evaluation of walk in patients after a stroke and patients without neurological damage by applying a functional test of movement

FAC score	Persons after a stroke		Persons without neurological damage	
	f	%	f	%
0 not walking independently	0	0	0	0
1 assistance of one person	16	32	0	0
2 verbal support	12	24	0	0
3 independent on the flat ground	5	10	0	0
4 obstacle assistance	9	18	12	24
5 completely independent	8	16	38	76
Total	**50**	**100**	**50**	**100**
Mdn	2		5	

Legend: mdn– median

Group	Middle range FAC scores	U	r
Persons after a stroke	31.54	302.00***	.69
Persons without neurological damage	69.46		

Legends:*** p<.001

The results of Mann-Whitney test showed that there were no statistically significant differences in the level 0 .001 between the two groups of respondents in terms of average scores on FAC test, U = 302.00, p <.001, effect size was large (r = .69). The patients without neurologic defects have an average score of FAC (mdn = 5) compared to the post-stroke patients (mdn = 2).

Table 3 shows the results of measured walk frequency in patients after a stroke and patients without neurological damage

Walk frequency (number of steps per minute)										
Norm	Persons after a stroke					Persons without neurological damage				
	min	max	MV	SD	mdn	min	max	MV	SD	mdn
70-130	23.67	92.90	49.87	14.92	45.71	37.80	87.27	54.05	10.88	52.16

Legend: min - minimal determined value, max - maximal determined value, MV - mean, SD - standard deviation; MDN - median.

Group	Walk frequency (number of steps per minute) Middle range	U	r
Persons after a stroke	42.53	851.50**	.
Persons without neurological damage	58.47	27	

Legend: ** p <.01

According to the Mann-Whitney test (Table 3), persons with no neurological damage had in average a higher frequency of walk (mdn = 45.71) compared to persons after a stroke (mdn = 52.16) and the difference is statistically significant at the 0.01 level, U = 851.50, p <.01, and the magnitude of the effect is small (r = 0 .27).

Table 4 shows the results of measured walking speed compared to normative values in patients after a stroke and patients without neurological damage, and the statistical significance of differences in walking speed between persons after stroke and those without neurological damage

Group	Walking speed (m/min)					
		MV	SD	mdn	min	max
Norms	Men	86	/	/	/	/
	Women	77	/	/	/	/
Persons after a stoke	Men	10.48	5.06	8.11	5.45	20.00
	Women	7.59	1.61	7.28	5.50	10.71
Persons without neurological damage	Men	34.03	8.57	31.58	19.35	54.55
	Women	26.59	8.93	25.00	15.79	66.67

Legend: min - minimal determined value, max - maximal determined value, MV - mean, SD - standard deviation; MDN - median, *** p <.001

According to the Mann-Whitney test (Table 4), persons without neurological damage in average, had a higher walking speed (mean rank = 75.26) than persons after a stroke (mdn = 25.74) and the difference is statistically significant at 0.001, U = 12.00 p <.001, and the effect of group membership on the walking speed was high (r = 0 .85).

Table 5 shows the results of measured length of steps in patients after a stroke and patients without neurological damage and statistical significance examinations of differences in the length of stepping between the groups

Step length (cm)						
	min	max	MV	SD	mdn	Middle range
Persons after a stroke	14.00	35.00	23.28	5.39	23.00	25.84
Persons without neurological damages	26	75	52.28	8.29	52.00	75.16

Legend: min - minimal determined value, max - the highest determined value, MV - mean, SD - standard deviation; MDN - median, *** p <.001.

The Mann-Whitney tests results showed that patients without neurological damage, in average, had significantly higher assessment of foot dorsiflexion in patients after a stroke, U = 48.50, p <.001, and the effect of group affiliation on the result was large (r = .94) (Table 6).

Also, the results of Mann-Whitney test (Table 6) showed that the patients without neurologic defects had a higher score in average of knee extension in post-stroke patients, U = 221.00, p <.001, and the effect of group affiliation on the result was large (r = .81).

Table 6 shows the results of the Motor Index Leg test in patients after a stroke and those without neurological damage and the results of the statistical significance of differences between groups

Parameter	Persons after a stroke			Persons without neurological damage		
	f	%	Middle range	f	%	Middle range
Dorsiflexion of foot			26.47			74.53
No movement	3	6		0	0	
Against gravity	46	92		1	2	
Normal	1	2		49	98	
Total	**50**	**100**		**50**	**100**	
Knee extension			29.92			71.08
No movements	2	4		0	0	
Against gravity	43	86		4	8	
Normal	5	10		46	92	
Total	**50**	**100**		**50**	**100**	
Hip flexion			33.00			68.00
No movements	0	0		0	0	
Against gravity	45	90		10	20	
Normal	5	10		40	80	
Total	**50**	**100**		**50**	**100**	

Legend: *** p <.001

Results Mann-Whitney test (Table 6) showed that patients without neurological damage, in average, had significantly higher hip flexion in patients after a stroke, U = 375.00, $p < .001$, and the effect of group affiliation on the result was large (r = .70).

Table 7 shows the results obtained by analyzing the prediction of the characteristics of movement based on the indicator of planned behavior

Variable	Coef	Rc	Rc^2 (%)
Frequency of walk	.142	.416	17.31
Speed of walk	.698	**.574**	32.95
Length of pace	.474	**.611**	37.33
Autonomy Movement (FAC)	.269	.413	17.06
Foot flexion	.473	.417	17.39
Knee extension	.158	**.777**	60.37
Hip flexion	1.289	**.823**	67.73
Rc^2			54.1
Number of categories WCST	.780	**.987**	97.42
Number of perseverative errors WCST	.262	**.878**	77.09

Legend: FAC - Functional test of movement; WCST - Wisconsin Card Sorting Test;
Odds - standardized coefficient of canonical function; Rc - structural coefficient;
Rc^2 - squared structural coefficient.
Note: Structure coefficients above .450 are marked

The presented results of canonical correlation analysis show that among the studied variables of ability to plan behavior and the quality of the movement a statistically significant canonical correlation is present, whereby predictors explain 61% of variance characteristics of movement, mostly in favor of the patients after a stroke in which low efficiency of ability to plan behavior is recorded, less inner strength to move is present and a reduced motor performance is manifested.

4. Discussion

In numerous researches the relation between executive functions (EF) and the ability to walk have been studied. In InChanti study [3], where 900 non-demented elderly persons were assessed (mean age 74.6 years and cognitive performance MMSE 25.5) , using visual- motor time restricted test with dimensions of cognitive flexibility, the authors came to the conclusion that the low efficiency executive functions were correlated with a decrease in walking speed on the track with obstacles. Similar findings [4], also speak about the link between cognitive aspects and speed of walking. These authors suggest that the pace of the elderly persons is a complex task that requires a higher executive control of data processing and memorizing. Another study [5] based on the obtained results lead to the conclusion that more precise walking with a greater speed is correlated to the performance of another complex motor task. Also, the results of that study suggest that the link of executive functions with walking increases with the complexity of the task. Most authors agree that the reduced efficiency of executive functions may impact the reducing of the ability to walk, but reasons are not yet defined. Neurological patients have particular difficulties in walking when executing one more task simultaneously. Cognitive and motor tasks simultaneously given bring to the question the ability of the musculoskeletal system to perform a function of walking [3]. Many studies show that there is a connection between executive function and functional recovery after a stroke in patients who had been tested and had been involved in the rehabilitation process, but the results didn't show that based on the quality of executive functions one may predict functional recovery of patients [6].

The obtained results of this study show that patients after a stroke manifest a problem with the ability to plan and organize activities, exhibit low efficiency in defining strategies that will be implemented in realizing intentions and accomplishing the aim (Table 1). This is particularly important for patients after a stroke, when they are in a position to independently perform certain structured, purposeful and goal-directed motor activity. What makes the problem more complex is inefficient anticipation of consideration of alternatives and affiliation, whether we speak about motor or mental ability, as well as low efficiency of self-correction and requirement of assistance in overcoming obstacles. Normally, walking is automatic activity and while performing it there is no need for paying attention to the sequence of execution. When observed individually, the evaluated parameters of mobility of the lower extremities in patients tested after a stroke , the dorsal flexion of the foot movement 6 % of the respondents do not achieve, 92 % have a movement against gravity (without added resistance) and 2% have normal motility through the full range of movement with added resistance; the knee extension do not achieve 4 % of the respondents , 86 % performed movement against gravity without further resistance, and 10 % perform full amplitude of movement with added resistance; the hip flexion in most patients given in percentage - 90% of them performed a movement against gravity, while 10 % of patients perform a movement against gravity with additional resistance in the full range of motion (Table 6). Although significantly better results achieve patients without neurological damages, the decrease of the efficiency of executive movement in these joints in patients without neurological disorders could be associated with comorbidity (usually degenerative diseases) and the age of the respondents. The evaluation of motor feet index is the basis for further analysis of motor skills. The results of the assessment of motor feet index (Table 6), indicate the state of biomechanical parameters necessary for the normal activity of walking , especially they are linked to the fact that during the support the primary role of the hip muscles is to stabilize the trunk, and that the goal of swaying is to control extremities, and that during support the knee is a base for stability of extremities, and swinging is the main factor for separating the lower extremity from the ground and swaying is main factor for separating lower extremities from the ground and in the end, foot dorsiflexion during support is important for folding and amortization of the impact on the ground and swaying contributes to raising the limb [8]. This is corroborated by the results from the framework of functional test of movement in the domain of the analysis of spatial and temporal parameters of walking. From the results obtained from the evaluation of frequency of walk the statistical difference of moderate intensity in achievements among surveyed patients after a stroke and patients without neurological damage is observed (Table 3). Results of walking speed (Table 4), as well as a length of pace (Table 5), show a statistically significant difference in achievement between the surveyed patients after a stroke and patients without neurological damage. Considering that walking speed influences the kinematics, the usual normal speed of walking on a flat surface is 82m/min. (Men are faster 86m/min, women are slightly slower 77m/min), the results of this study are in favor of lower efficiency motor functioning including a walk. However, the proportion of time spent in different stages of walk also varies with speed. While walking faster, the pace length increases, because the speed proportionally increases the pace length, and decreases the support phase [1]. The obtained results of this study fully correspond to the stated facts which link the spatial and temporal parameters during walking. Surveyed persons after a stroke have a lower speed of walking compared to the normative values, and also a significantly lower achievement compared to the tested individuals without neurological damage, the effect of significance is large (Table 4). Following the spatial parameter of walk (Table 5), there is a statistically significant difference in achievement between the surveyed persons after a stroke and surveyed individuals without neurological damage, however the height of persons, as well as shoes, the width of the surface of contact and foot progression angle also have influence on the these values. The results of this study do not deny the existence of these impacts, but given the extremely low values of the pace lengths, not all of these factors, or individual can qualify as very reliable. Taking into account the results of the evaluated spatial temporal parameters important for the function of walking, the obtained results are consistent with the facts that rely on the theory of the dynamics of the return of the lower extremities, through the developmental stages of recovery. While interpreting the results, the following factors that make difficult a performance of a given activity (equilibrium, balance, uncertainty, a sense of fear) are taken into account, especially if it is hurried with the patient mobilization and when the ability of planned behavior decreases. The results of a small pilot study that aimed to examine the difference between linear and curvilinear walking in individuals with the main issues in the movement support the results of this assessment acquired by walking evaluation and overcoming obstacles in patients after a stroke. Having these patients in mind, we must not overlook the following factors: awareness of their own limitations, willingness to engage in therapy and premorbid personality traits [10]. Based on the assessment of the walking recovery in patients after a stroke, it was concluded that the practicing of functional walk should begin the same moment the patient adopts stability and controls mobility. The obtained results of this research fully confirm these facts. Observing the research results which speak in favor of motor skills and abilities of planned behavior could have an insight into the coherence and logic link between all analyzed kinematic parameters and kinesthetic walk parameters with the ability to plan, anticipate, and perform the planned action and result verification (Table 7). This means that when in surveyed patients after a stroke we have a low efficiency of ability to plan behavior we also have low efficiency on the functional test of movement, additionally reduced frequency of walking, reduced walking speed and shortened the length of paces. As the final outcome in patients after a stroke with reduced ability to plan behavior, we have a reduced efficiency in moving, difficulty in maintaining balance and equilibrium and limited ability of overcoming obstacles. Furthermore, they will additionally be faced with the difficulties in situations where the execution of the motor activity is temporal-limited. The results of this research deal with the correlation of abilities of planned behaviour and motor abilities at patients after stroke, but do not claim that the efficiency of abilities of planned behaviour can influence the quality of motor recovery at these patients. It would be necessary to supplement the used battery of tests for the evaluation of examined variables for the possibility of proving the named influence. Thus, guided by the experience of scientists who dealt with this problem and with the clinical characteristics of mental competence and motor recovery, by the results of this study, we opened additional options for new researches which will include larger sample and additional test procedures for the evaluation of of examined variables. By understanding the theoretical aspect of this problem, a possibility of therapeutic implementation will be made.

5. Conclusion

Since the acquisition of motor independence is one of the leading, but at the same time, the final aim of recovery of patients after stroke the highest attention in this study is devoted to the assessment of the multivariate relation between the indicators of the ability to plan behavior and motor function in patients after a stroke. The obtained results show that the tested patients after a stroke exhibit low efficiency in all aspects of planned, purposeful goal- directed behavior. Patients after a stroke express and motor and cognitive difficulties, and demonstrate the difficulties in functional training in various degrees. Based on the set goals of the research and on the results obtained from the conducted survey, we can conclude that there is a link between executive functions and irregularities while walking in surveyed patients after a stroke and a statistically significant difference is determined. It can also be concluded that among the tested capabilities of planned behavior and the quality of the movement there is a statistically significant correlation, that is - low efficiency of ability to plan behavior is correlated with reduced efficiency of motor functioning and difficult movement.

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