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Limb apraxia in multiple sclerosis

Apraksija udova kod multiple skleroze

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Abstract

Background/Aim. There are almost no studies on apraxia in people with multiple sclerosis. Although the white matter is damaged in MS, it is not the only location in which the pathological changes are present. Demyelinated lesions in the cortex have recently been recognized as important components of multiple sclerosis pathology. The aim of this study was to determine whether apraxia is present among people with MS, and the importance of demographic characteristics and impairment of functional systems at conceptualization and execution of movements. **Methods.** The experimental group consisted of 30 patients, mean age 51.34 ± 7.70 years. The patients in the experimental group were diagnosed with MS according to the McDonald criteria. The control group consisted of 30 healthy subjects, mean age 50.30 ± 10.47 years. For research purposes, we used the following instruments: Questionnaire for Collecting Demographic Data, Kurtzke Functional Systems Scores, Waterloo-Sunnybrook Apraxia Battery (WatAB). Execution of motion tasks that are a part of the WatAB were incorporated in the System for the Observation and Analysis of Motor Behavior. **Results.** Our study showed that limb apraxia was common in people with MS. Apraxia was present during pantomime in 26.70% of the patients, and during the imitation of movements in 44.80% of the patients. Gender, age, education level, duration of disease and a form of MS did not determine the quality of conceptualization and execution of movements. The time elapsed from the last exacerbation was a determinant of quality of executed movements. Impairments of functional systems predicted impairments of movement execution. The expanded disability scale score correlated with the severity of apraxia. **Conclusion.** Our study confirm the presence of apraxia in MS. It is necessary to carry out further studies using functional magnetic resonance imaging, as well as the conduct longitudinal studies to determine the precise structure of motor behavior in people with MS.

Key words:
apraxias; diagnosis; multiple sclerosis; questionnaires; severity of illness index.

Apstrakt

Uvod/Cilj. Istraživanja apraksije kod osoba sa multiplom sklerozom (MS) gotovo da nema. Iako je oštećenje bele mase prisutno, ono ne predstvlja jedinu lokaciju u CNS-u na kojoj su prisutne patološke promene kod MS. U skorije vreme smatra se da je kora velikog mozga veoma važna lokacija na kojoj dolazi do patoloških promena kod osoba koje boluju od MS. Cilj ovog istraživanja bio je da se utvrdi da li među osobama sa MS ima onih kod kojih je prisutna apraksija, kao i značaj demografskih karakteristika i oštećenja funkcionalnih sistema za konceptualizaciju i izvođenje pokreta. **Metode.** Eksperimentalnu grupu činilo je 30 učesnika starosti 51,34 ± 7,70 godina. Učesnicima eksperimentalne grupe dijagnostikovana je MS prema Mekdonaldovom dijagnostičkom kriterijumu. Kontrolnu grupu sačinjavalo je 30 zdravih osoba starosti 50,30 ± 10,47 godina. Za potrebe istraživanja korišćeni su podaci dobijeni Upitnikom za prikupljanje demografskih podataka i osnovnih podataka o bolesti, Kurzke-ovim skorovima funkcionalnih sistema i Adaptiranom Vaterlo baterijom za procenu apraksije (ova baterija korišćena je u kombinaciji sa Sistemom za opservaciju i analizu motornog ponašanja). **Rezultati.** Naše istraživanje je pokazalo da apraksija udova predstavlja čestu pojavu od osoba sa MS. Apraksija na zadacima izvođenja pantomime bila je prisutna kod 26,70% bolesnika, a na zadacima izvođenja imitacije pokreta kod 44,80% bolesnika. Pol, godine života, stepen obrazovanja, dužina trajanja bolesti i oblik bolesti nisu determinisali kvalitet konceptualizacije i izvođenja pokreta kod osoba sa MS. Vreme proteklo od poslednje egzacerbacije predstavljalo je determinantu kvaliteta izvedenih pokreta. Oštećenja funkcionalnih sistema kod osoba sa MS predviđala su pristustvo oštećenja izvršenja pokreta. Proširena skala funkcionalne onesposobljenosti bila je u korelaciji sa težinom apraksije. **Zaključak.** Naše istraživanje otkrilo je prisustvo apraksije kod MS. Potrebno je izvršiti dalja istaživanja uz korišćenje funkcionalne magnetne rezonance, kao i sprovođenje longitudinalnih studija kako bi se preciznije utvrdila struktura motornog ponašanja kod osoba sa MS.

Ključne reči:
apraksija; dijagnoza; multipla skleroza; upitnici; bolest, indeks težine.

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Introduction

Apraxia is defined as a disorder of learned movements, which is not caused by muscle and/or neurological factors (e.g. weakness, akinesis, aphasia, cognitive resources decline, vision problems, etc.) [1–3]. Neuropsychology was mostly engaged in studying apraxia especially in persons with brain injury, Alzheimer's disease, Parkinson's disease, corticobasal degeneration, and other. The most investigated relationship was the one between the localized impairment and apraxia occurrence.

Multiple sclerosis (MS) is usually regarded as a disease of the white matter [4]. Lesions of the white matter that include demyelination and neuronal damage are very visible on magnetic resonance imaging (MRI) and macroscopically during autopsy [5, 6]. Detecting white matter lesions with MRI is an essential signal for the presence of MS. Cortex has recently been recognized as an important location in which pathological changes occur in patients suffering from MS [7, 8]. MS is a chronic inflammatory disease of the central nervous system characterized by multifocal demyelination and axonal damage, which affects both white and gray matter of the cerebral cortex, deep gray matter nuclei and the spinal cord. The appearance of apraxia is expected due to lesions or degeneration of certain areas of cortex and/or by damaging the parietofrontal pathways [9].

There are almost no scholarly papers on apraxia in persons with MS. The only research that addresses the relationship of MS and apraxia is the one conducted by Kamm et al. [9].

For that reasons the aim of this study was to determine the frequency of aproxia in patients with MS, and its relation to demographic characteristics, severity of illness, type of illness, disease duration, and time elapsed since the last exacerbation.

Methods

This study included participants of both sexes, 18–65 years of age, divided into control and experimental groups of similar size. The sample was unrepresentative and convinient, depending on the avalilability of the participants.

The experimental group included patients with MS diagnosed by the McDonalds diagnostic criteria [10]. One of the criteria for inclusion in the sample was the score achieved on the Expanded Disability Status Scale (EDSS) that was greater than or equal to 1. All the patients of the experimental group were the members of the Multiple Sclerosis Society of Serbia. Also, the inclusive criteria for the experimental group meant that the subject was able to independently read and understand the information from the form which confirmed the consent to participate in the research. All the patients of the experimental group read, understood and signed a form confirming the consent for participation in the research. The patients of the experimental group did not have the history of nor are currently subjected to alcohol and/or psychoactive substance use, in the last two years pregnant women, persons with the history of neurological damage which cannot be treated as a result of MS, persons with dementia, persons suffering from psychiatric disorders, persons with significant motor disorders (such as tremor, bradykinesia, dyskinesia), persons with peripheral conditions (e.g., arthritis) that may compromise motor function, individuals with developmental disabilities, persons that cannot understand the assessment procedure due to some cognitive deficit.

The control group formation criterion was to be healthy, and as for the experimental group, to read, understand and sign the form, confirming their consent to participate in research. Exclusive criteria for the control group were the same as for the experimental one.

The control group was introduced to demographic characteristics of the experimental group.

The System for the Observation and Analysis of Motor Behavior (SOAMB) consists of hardware and software components. Required central processing unit (CPU) and memory of the system were provided by the computer Dell Inspiron PP29L. An additional monitor for displaying tasks was used, 20-inch diagonal display with 1,280 × 1,024 resolution and the image refresh rate of 75 Hz. For the audio material reproduction loudspeakers Genius were used. For the purpose of recording movements a web camera Logitech Webcam C905 was used, which could record in high definition, 1,600 × 1,200 resolution, 30 frames per sec.

The computer program for acquisition, analysis and partial data processing was created in Java programming language. The program allows creation of the profile for each participant. The task creation which participants should perform, using sound, pictures or video files, was enabled.

In this study all the tasks of WatAB were developed in video format and uploaded into the program. In this way we avoided the possibility for the examiner to issue tasks at different times and in different manners. For example, the possibility that some of the examiner perform movement imitation tasks in different ways for different participants in the study was avoided, providing a greater degree of objectivity in the use of WatAB [11].

The research was conducted in the facilities of the Society of MS Serbia, on the territory of Belgrade and Aranđelovac.

For data analysis and processing, software packages Microsoft Excel and SPSS were used. From the statistical techniques we used descriptive, correlation, regression, and discriminate techniques. The results are presented in tables and figures.

Results

The demographic characteristics of the control and the experimental group are presented in Table 1. Health status characteristics in the patients with MS are presented in Table 2.

The results of the participants of the control and experimental groups in the WatAB

We compared the results of both groups in WatAB. Table 3 shows the comparative values of the results of the participants on the scales and subscales. For the group comparison, we used the *t*-test for independent samples. There was a

Table 1

Demographic characteristics of the study participlants

Characteristics	Control group	Multiple sclerose group
Age (years), $\bar{x}$ ± SD	50.30 ± 10.47	51.34 ± 7.70
Sex, n (%)		
male	50 (15)	46.7 (14)
female	50 (15)	53.3 (16)
The highest education completed (years), n (%)		
0	3.30 (1)	0 (0)
8	20.00 (6)	3.30 (1)
12	46.7 (14)	70.10 (21)
15+	30.00 (9)	26.60 (8)

Table 2

Characteristics of the patients with multiple sclerosis (MS)

Type of MS	Distribution	Age (year)	Age at time of diagnosis (year)	Last remission period (years)	EDSS (points)
	n (%)	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD
RRMS	10 (33.3)	49.41 ± 7.61	32.20 ± 10.28	5.14 ± 3.34	4.20 ± 2.26
PPMS	10 (33.3)	53.48 ± 7.38	35.50 ± 9.58	8.00 ± 0.23	4.00 ± 1.93
SPMS	2 (6.7)	58.92 ± 0.11	34.50 ± 7.78	3.00 ± 0.12	5.50 ± 3.53
N/A*	8 (26.6)	48.96 ± 8.19	35.42 ± 6.24	2.85 ± 5.43	4.94 ± 2.81
Total	30 (100)	/	/	/	/
Average	/	51.34 ± 7.70	34.28 ± 8.74	4.49 ± 3.91	4.42 ± 2.30

***New available date is not present in documentation; EDSS – Expanded Disability Status Scale; RRMS – relapsed-remitting MS; PPMS – primary progressive MS; SPMS – secondary progressive MS.**

statistically significant difference between the control and the experimental group on the conceptual scale, $p < 0.05$. The difference between the mean values of group characteristics was large [eta squared (n2) = 0.10)]. There was a statistically significant difference in the recognition subscale ($p < 0.05$, n2 = 0.10).

Also, a statistically significant difference between the two groups on productive scale and almost all of its subscales was found.

Figure 1 shows deviations of those with MS, compared to a typical population. Deviations are represented by Z scores.

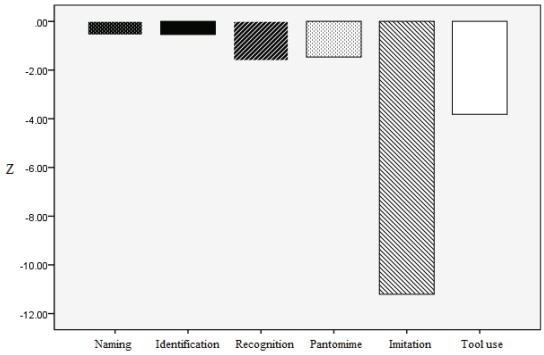

Fig. 1 – Z-scores at the Adapted Waterloo-Sunnybrook Apraxia Battery.

The presence of apraxia in the patients with MS

In order to determine the number of the study patients with from MS and the presence of apraxia we used the Roy`s research group approach. We analyzed the subscale of pantomime, imitation as well as the whole production scale. The patietns with a deviation up to 1 SD were classified as those with no present apraxia. Those with discrepancy in scores greater than 1 SD, and less than 2 SD were classified as borderline conditions, while those with a variation in perform-

Table 3

The scores of the control and the multiple sclerose (MS) group on the Adapted Waterloo-Sunnybrook Apraxia Battery

Types of tasks	Control group ($\bar{x}$ ± SD)	MS group ($\bar{x}$ ± SD)
Conceptual scale*	97.17 ± 4.43	92.61 ± 9.81
naming	97.04 ± 4.99	94.25 ± 8.20
identification	97.83 ± 5.27	95.29 ± 8.27
recognition*	95.97 ± 5.92	85.60 ± 21.91
Production scale*	97.16 ± 2.90	84.84 ± 23.34
pantomime*	93.98 ± 6.08	85.07 ± 15.83
concurrent imitation*	99.20 ± 1.08	83.83 ± 27.60
delayed imitation*	98.09 ± 2.54	78.86 ± 33.84
Tool use*	98.39 ± 3.29	85.83 ± 24.34

***$p < 0.05$ (statistically significant difference).**

ance in these subscales and scales greater than 2 SD belonged to the group with the presence of apraxia. In this way, the obtained results showed that the performance on the subscale pantomime among those with apraxia can be classified in 8 (26.70%) participants. At the subscale movement imitation in the group with MS and the presence of apraxia, was classified in 13 (44.80%) participants. On the overall production scale apraxia was present in 12 (42.90%) of the patients. The overall results of this procedure are shown in Table 4.

tional impairment of the system and the time from the last exacerbation. Comparisons were performed by analysis of variance.

There was no statistically significant difference in the results of these subscales in relation to the form of the disease (the group 1: relapsing-remitting, the group 2: primary progressive, the group 3: secondary progressive).

There was no statistically significant difference in the results, nor in the duration of MS (the group 1: up to 12.33; the group 2: from 12.34 to 18.83, and the group 3: over 18.84).

Table 4

The presence of apraxia in the patients with multiple sclerosis

The presence of apraxia	Pantomime	Imitation	Production scale
	n (%)	n (%)	n (%)
Yes	8 (26.70)	13 (44.80)	12 (42.90)
Borderline	6 (20.00)	4 (13.80)	2 (7.10)
No	16 (53.30)	12 (41.40)	14 (50.00)

The WatAB results concerning gender, age and the level of education

The results of the patients in the subscales of the WatAB in relation to gender were compared by *t*-test for independent samples, while the analysis of variance was used to compare these results in relation to age and the level of education. The results were compared on the subscales of naming, identification, recognition, pantomime, imitation and use of tools/objects.

There was no statistically significant difference in relation to the results of these subscales regarding gender (Figure 2), as well as age (group 1: < 45.42 years; the group 2: from 45.53 to 55.00 years; and the group 3: more than 55.01 years) and the degree of education (group 1: 0 years of education; the group 2: 8 years of education; the group 3: 12 years of education; group 4: 15+ years of education)].

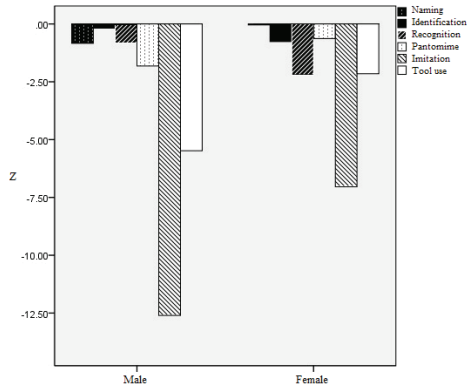

Fig. 2 – Z-scores at the Adapted Waterloo-Sunnybrook Apraxia Battery in relation to gender.

The WatAB results concerning type, duration, degree of functional impairment of the system and the time elapsed from the last exacerbation

The results on the subscales of naming, identification, recognition, pantomime, imitation and use of tools/objects were compared in relation to type, duration, degree of functional impairment of the system and the time from the last exacerbation. Comparisons were performed by analysis of variance.

The results on subscales identification, recognition, pantomime, imitation and use of tools/objects in relation to the time from the last exacerbations were compared by the *t*-test of independent samples. The group 1 consisted of participants with the last exacerbation 4 years ago or less, while the group 2 consisted of participants with the last exacerbation 4 years or more before. We found only one statistically significant difference between the group 1 (= -1.57 ± 2.03) and the group 2 (= -0.65 ± 0.39) in the pantomime subscale, t (11) = -2.62, p = 0.024 (two-sided). The difference between the mean values o f the characteristics of the groups (mean difference = -2.22, 95% Cl: -4.09 to -0.35) was very large (n = 0.38).

In order to additionally explain the obtained results, we used the Pearson's correlation to establish whether there was a relationship between the time from the last exacerbation and the results of the subscales WatAB. The assumptions of the normality, linearity and homogeneity were satisfied. There was a correlation between achievements on the subscale of recognition and the time elapsed from the last exacerbation (r = 0.59, p < 0.05), as well as correlations between scores on the subscale of pantomime and the time from the last exacerbation (r = 0.58, p < 0.05). Shorter time elapsed from the last exacerbation was accompanied by lower Z scores on the subscales of recognition and pantomime people with MS.

The possibility for the degree of functional systems impairments to predict the results in the subscales pantomime, imitation and use of tools of the WatAB

The possibility of the degree of damage measured by FSS to predict results in the WatAB subscales was estimated in a sample of patients with MS. We used the standard multiple regression, for each of WatAB subscales.

For predicting the results on the subscale of pantomime, a preliminary analysis showed that the assumptions of normality, linearity, multicollinearity and homogeneity of variance were not violated. The model as a whole explained 50.1% of the total variance, F (7, 22) = 5.15, p < 0.05, so it can be said that scores on the FSS significantly predict the results

on the subscale of pantomime in the WatAB. The regression coefficients and standard errors are shown in Table 5.

Table 5

Regression coefficients and standard errors (SE) in predicting the quality the performance of pantomime, imitation and using tools

Variable	Pantomime			Imitation			Using tools		
	B	SE_B	β	B	SE_B	β	B	SE_B	β
Constant	2.01	0.86		17.37	6.28		5.89	2.60	
Pyramidal	-0.15	0.27	-0.08	-3.01	1.97	-0.22	-1.42	0.82	-0.28
Cerebellar	-0.16	0.31	-0.09	-1.56	2.30	-0.11	-0.81	0.95	-0.15
Brainstem	-0.32	0.30	-0.16	-3.52	2.19	-0.24	-2.18	0.91	-0.39*
Sensory	0.18	0.43	0.06	2.45	3.14	0.11	-0.96	1.30	-0.12
Visual	-0.34	0.29	-0.19	-1.11	2.12	-0.08	-0.27	0.88	-0.05
Cerebral or Mental	-1.01	0.37	-0.38*	-7.75	2.71	-0.38*	-0.54	1.12	-0.07
Bowel and Bladder	-1.13	0.35	-0.54*	-6.86	2.58	-0.43*	-1.21	1.07	-0.20

***$p < 0.05$; B – non-standardized regression coefficient, β – standardized coefficient.**

For predicting the results in the motion imitation subscale preliminary analysis showed that the assumptions of normality, linearity, multicollinearity and homogeneity of variance were not violated. The model as a whole explained 54.8% of the total variance, $F(7, 21) = 5.85$, $p < 0.05$, so it can be said that scores on the FSS significantly predict the results on the subscale of motion imitation on WatAB. The regression coefficients and standard errors are shown in Table 5.

For predicting results in the use of tools subscale preliminary analysis showed that the assumptions of normality, linearity, multicollinearity and homogeneity of variance were not violated. The model as a whole explained 46.8% of the total variance, $F(7, 20) = 4.39$, $p < 0.05$, so it can be said that scores on the FSS significantly predict the results on the subscale of using tools in WatAB. The regression coefficients and standard errors are shown in Table 5.

The results in WatAB associated with EDSS scores

We used the Pearson's correlation to establish whether there was any relationship between the EDSS and achievements of the WatAB subscales. The assumptions of the normality, linearity and homogeneity were satisfied. There were strong correlations between the results on the subscales of pantomime ($r = -0.72$, $p < 0.01$), imitation ($r = -0.76$, $p < 0.01$), tool use ($r = -0.75$, $p < 0.01$) and the EDSS. A higher EDSS was accompanied by lower Z scores on the subscales of pantomime, imitation and tool use in people with MS.

Discussion

The obtained results indicate that limb apraxia very often occurs in population with MS. In this population apraxia is present more often in imitation than in pantomime tasks. The obtained results consist of the results of a few other studies in terms of the general presence of apraxia in persons with MS. According to Staff et al. [12] the percentage of apraxia presence in the population of persons with MS is much lower – only 13%. On the other hand, Kamm et al. [9] have found that limb apraxia is present in 26.3% of participants with MS.

Praxic abilities of women are better than in men throughout their entire development [13] and healthy women perform voluntary movement with fewer errors than men [14]. In patients with brain lesions praxis system is much more dependent on the anterior region of the left hemisphere in women than in men [15–17], which may suggest that more focused representation allows greater precision of voluntary movements control in women [15]. Women have a better ability to implement complex motion and pre-planning movement than men during the execution and control [18]. Pozzilli et al. [19] in their study using MRI show that there are differences in lesion characteristics between men and women with MS. The authors conclude that lesions in men are less inflammatory, but more destructive than in lesions in women. Therefore, we considered the possibility that the general tendency for women to have less apraxic errors in the execution of movements than men does not have to be present in persons with MS. We showed the parallel display of the results of men and women on the WatAB subscales. It is obvious that women in the subscales of the pantomime, imitation and use of tools have minor deviations from the control group in comparison to men. However, the difference between men and women did not reach statistical significance.

The participants in the study did not have different results in the WatAB in relation to age and disease duration. We believe that this result is quite expected considering the nature of progression of the disease, which is indicated by the existence of its subtypes according to the mode of progression (relapsing-remitting, primary progressive, secondary progressive, etc). This means that the disease can quickly progress to some younger people than in older or *vice versa*, and that there is no rule or correlation between age and disease progression. Kamm et al. [9] designed a linear regression model, for which the result on the EDSS is the best single predictor, while among other predictors are the duration of MS and the age of the participants. Participants in their study had lower EDSS compared to participants in our study. That could be the reason for results diversity. Also, the authors, did not consider the individual effects of these variables within the model. Dimeck et al. [20] conducted a study in which the sample consisted of healthy participants who performed concurrent and delayed imitation of movement. A statistically significant difference between older and younger participants had been obtained. Changes in conditions of imitation also gave a statistically significant differ-

ence in achievements. If the age and duration of disease play a role in the results of participants with MS, for more accurate determination of their impact a longitudinal study on a number of people, with occasional reevaluation of praxic abilities should be carried out. Otherwise, the influence of age and disease duration on the results of the tasks of apraxia assessment is not visible due heterogeneous illness progression of the participants in the study.

It was expected that this claim would be supported by the results of the participants regarding MS type. However, there was no statistically significant difference between the groups, while conflicting results have been obtained by Kamm et al. [9]. Participants in their study with the relapsing-remitting form of MS had significantly higher scores on the praxis assessment compared to the participants with primary progressive and secondary progressive forms of MS. There were no statistically significant differences between the groups of participants with primary progressive and secondary progressive type of MS. It remains to be further explored.

The time from the last exacerbation has great effect only on the results on the subscale of pantomime. These results contribute to the statement that the time after exacerbations in people with MS leads to recovery of the function, and that this recovery implies the features of conceptualization and execution of movement. We will refrain from further interpretation of the obtained results because they are limited in the sense that they represent only the condition in one timely moment for each individual, that is, they do not have a longitudinal character. Stamenova et al. [21] investigated the long-term recovery of limb apraxia after brain injury. Participants in the study (with acute and chronic conditions) on all tasks showed signs of recovery except on the tasks of identifying actions. Faster recovery showed acute and subacute patients on the tasks of pantomime. The study of Stamenova et al. [21] has similarity to the results from our study.

The degree of functional system impairments in patients with MS predicted the success of the performance of pantomime imitation and use of tools. Patients with apraxia often do not have problems in using real tools. Our study confirms that significant predictors of the success in performing pantomime and imitation differ from significant predictors of the success in the use of tools. When performing pantomime and imitation, requirements for use of cognitive functions could be increased. In the case of pantomime performance it is necessary to create visual representations of the tools used or representations of social situations in which persons use some form of representative nontransitive pantomime. In case of movement imitation it is essential to receive information about the action performed by someone else, to decode information about what is seen, to form ideas about the movement that is to be executed and to properly activate effectors for movement performance. On the other hand, when using the real tools, through the sensory system the information about the tool (shape, weight, etc.) is obtained. In this sense, action performance with real tools requires a higher degree of activation of other systems in the brain (especially learned actions), as well as greater load of the musculoskeletal system.

The role of the system for bladder and bowel control in the prediction of apraxia may seem surprising at first glance, but it should be emphasized that from the neurological point of view some elements of this system overlap with other functional elements of other systems. The bladder and bowel control is partly influenced by our own will. Fowler et al. [22] suggest that clinical observation studies and observation studies using MRI suggest that the frontal lobe plays an important role in determining the appropriate moment for micturition. Some studies [23, 24] show that the right inferior frontal gyrus, which is a part of the prefrontal cortex was active when the bladder was full in patients. It is believed that the prefrontal cortex is involved in planning complex cognitive behaviors, personality characteristics reflects, plays a role in the expression of appropriate social behavior as well as the functions of attention and response selection [25]. This system damage in our research emerges as a predictor of quality of pantomime and imitation together with impairment of mental function.

Finally, higher EDSS were associated with poorer performance on tasks of pantomime, imitation and tool use. EDSS and apraxia connection exists solely to the production of movement tasks, but not the conceptualization of movement (identification, recognition and naming). EDSS is based on FSS and other motor skills, which is why this correlation is understandable. Unlike Kamm et al. [9], who showed that more MS patients having apraxia have higher EDSS, our research in this regard did not address the frequency of apraxia in relation to EDSS. Our research confirms that if EDDS is higher, there will be present a more severe form of apraxia as shown by the results in all the production subscales.

Conclusion

Limb apraxia is frequent in persons with multiple sclerosis, and its occurrence is different when it comes to performing pantomime and movement imitation. Praxic performance depends on the time elapsed from the last exacerbation and the Expended Disability Scale score. Functional systems impairments in patients with MS may predict the quality of movement execution. A connection between sex, age, type of disease and apraxia in people with multiple sclerosis should be the subject of further research.

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