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Neuromuscular assessment in the study of structural changes of striated muscle in multiple sclerosis

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Abstract

The aim of this research is to present the results of neuromuscular assessment using tensiomyography (TMG) in multiple sclerosis for prediction the muscle changes. This study consists of 20 patients, selected conform to certain criteria. Thus, according to diagnosis and MS level, the studied group was divided into two subgroups: subgroup A, consisting of 13 MS patients with clinically detectable gait disorders, and subgroup B, made up of seven MS patients without clinically detectable gait disorders. TMG determines the diagnosis of a certain muscular type and muscular status/condition (fatigue, stress influence on the body, etc.), the diagnosis of a functional muscular symmetry. The investigation has been performed on the shank muscles. The parameters evaluated through TMG were: contraction time (Tc) and the amplitude of muscular displacement in transverse direction – Dm (mm) a parameter which is also correlated with Tc values and depends on the flexibility of muscular tissue. *Results*: Dm in the case of gastrocnemius muscles (mG) data analysis shows an evolution of functional bilateral right-left asymmetry, which is more pronounced in subgroup A. At the level of posterior shank, Dm values in subgroup A are lower, which means that patients in subgroup A have a higher muscular tone and a maximum response to stimulation. Concerning Tc values, this parameter indicates muscular fatigue at the level of anterior tibialis. *Conclusions*: TMG, besides classical methods of paraclinical investigation, improves data generation, standardization, identifies correlations, which may facilitate a precocious diagnosis in morphofunctional changes evolution at muscular level at MS patients.

Keywords: neuromuscular, muscle fatigue, functional asymmetry, multiple sclerosis, assessment.

Introduction

Multiple sclerosis (MS) is a demyelinising disease with a large heterogeneity in terms of clinical evolution, neuroradiological images of the lesions, involvement of susceptible genes and therapy response. All this is supported by experimental studies that demonstrate the involvement of certain different processes, such as autoimmunity and viral infection, which may induce the appearance of demyelinising inflammatory plates [1, 2]. The associated symptomatology includes motor abnormalities, [3] visual and somatosensitive alterations [4, 5], intestinal dysfunctions and dysfunctions of urinary bladder.

There is no specific test or evaluation algorithm able to detect MS, in most cases the patients are diagnosed according to clinical neurological symptoms, anamnesis and laboratory investigations [6].

Paraclinical evaluation in MS relies on MRI examinations of the encephalon and bone marrow, visual evoked potentials, cephalospinal fluid analysis and blood tests. The evaluation may be completed by tensiomyography (TMG), a new method of neuromuscular investigation.

The purpose of this paper is to present the results of tensiomyographic investigation on patients with MS, which enables us to appreciate the evolution of morphofunctional muscular changes suffered by MS subjects.

Patients and Methods

This study consists of 20 patients, 9 men and 11 women. The patients were selected conform to certain criteria: patients residing in Dolj County, diagnosed with MS in compliance with clinical and paraclinical criteria, with motor capacity [7], members of the National Association of MS. Thus, according to diagnosis and MS level [8], there were selected the patients clearly diagnosed with MS, namely two flares and clinical picture of two distinct lesions or clinical picture of one lesion and another subclinical lesion (determined by neurophysiologic or neuroimagistic analyses) [9]. The patients' average age was 38.15 years, with a standard deviation of 11.19.

The studied group was divided into two subgroups: subgroup A, consisting of 13 MS patients (seven men and six women) with clinically detectable gait disorders[10], and subgroup B, made up of seven MS patients (two men and five women) without clinically detectable gait disorders [11].

TMG is a non-invasive method which determines the diagnosis of a certain muscular type (types of muscular fibers) and muscular status/condition (fatigue, stress influence on the body, etc), the diagnosis of a functional muscular symmetry [12, 13], either temporal or morphological, the evaluation of muscular synchronization, fast detection of an infra-clinical lesion of the muscle in situ (less than 5 minutes).

TMG also demonstrates a connection between the twitch contraction time of the entire muscle and the percentage determined histochemmically in the muscular fibers with slow contraction. We will present the protocol of TMG below. This protocol has been applied following the rules of the Ethics Committee of the Research Centre and is compliant with the Helsinki Declaration principles. In this respect, the investigated subject has been informed about the proceedings of this study, based on inform consent. Tensiomyography (TMG) is an evaluation method for the morphofunctional potential of the muscle, which allows the detection of the muscular reaction to electrical stimulation. Through this method we can appreciate the ratio between type I (fatigue-resistant) and type II (white, fast-twitch, with low resistance to fatigue – this phenomenon appearing before the completion of the electrical stimulation process) muscular fibers. In order to complete the data supplied by the clinical and paraclinic examination, we have suggested the use of TMG as an evaluation method for muscular fatigue and skeletal muscle composition, which have taken place within MS and have been necessary to establish the connection between the structure and morphofunctional properties of the muscle on the one hand, and its functional potential on the other hand. The evaluation of muscular fatigue can be made under intermittent electrical stimulation of the muscle. This stimulation is made with a TMG–S1 electrostimulator (Furlan & Co., Ltd.), using 5/5 cm platinum-type electrodes. The stimulation is performed under increasing electrical current intensities, between 10–65 mA, the length of the stimulation being one millisecond. An isometric contraction is produced because of electrical stimulation. The detection of the muscular response to the electrical stimulus is performed with a G40, RLS Inc. sensor, perpendicular to the muscle surface, in the area in which the muscular geography is well displayed (this can be more precisely determined if the subject is requested to perform an isotonic contraction, if a muscle strength higher than 2 is possible). The sensor is placed at this level; it will exert a 0.7 N/mm^2 pressure on the contact surface. This pressure is called pretension [14] and its role is to increase the response to the applied electrical stimulus. Because of the electrical stimulation, a transversal movement of the muscular fibers will occur and the sensor will record this. The amplitude of this transversal movement is proportional with the muscular force and the percentage of type I muscle fibers, which enables us, together with the data from the other parameter, to evaluate muscle fatigue and transmission speed. The measurement of the muscular response and the data storage and analysis have been made with a dedicated TMG software.

Signal recording

The TMG signals are received by a Matlab Compiler Toolbox on a 1 kHz frequency. Two supra-maximal responses are stored and then the average is calculated. The supra-maximal stimulation [12] is regarded as corresponding to a minimal stimulation and it determines maximal amplitude of muscular deformation, recorded as Dm.

The investigation has been performed on the shank muscles, on lateral gastrocnemius (mGL), medial gastrocnemius (mGM) and tibialis anterior (mTA); the way the investigation has been performed is presented below:

▪ For lateral gastrocnemius (LG) and medial gastrocnemius (MG) the subject is in prone position with support on anterior regions of the ankle. Maximum contraction point in this position is determined through plantar flexion with resistance (Figures 1 and 2).

▪ For tibialis anterior (TA) the subject is in supine position and maximum contraction point is determined through dorsal flexion of the leg, with resistance (Figure 3).

We specify that the sensor, which receives the muscular response to stimulation, is placed in the maximum contraction point, and the electrodes are placed on both sides of the sensor.

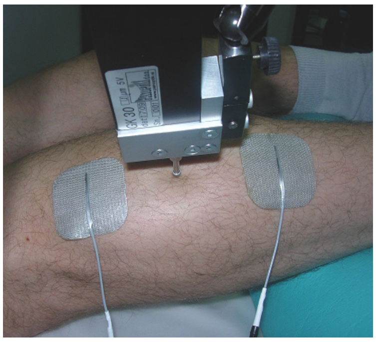

Figure 1 – ***Placement of stimulation electrodes and displacement sensor for lateral gastrocnemius.***

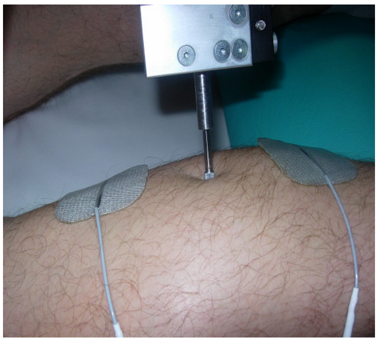

Figure 2 – ***Placement of stimulation electrodes and displacement sensor for medial gastrocnemius.***

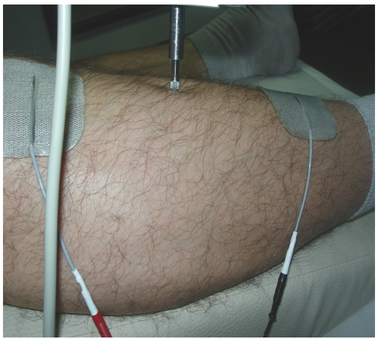

Figure 3 – ***Placement of stimulation electrodes and displacement sensor for anterior tibialis.***

The parameters evaluated through TMG were:

▪ Contraction time (Tc) – the time between the moment the muscular contraction is 10% and the moment the contraction reaches 90% out of maximum (ms). The value of contraction time depends on the percent of fast or slow fibers [15] in the studied muscle. Thus, the values decrease once the percent of type II fibers increases, and they increase when the percent of fibers of type II is reduced and that of type I fibers increased.

▪ The amplitude of muscular displacement in transverse direction – Dm (mm) – is a parameter which is also correlated with Tc values and depends on the flexibility of muscular tissue. Therefore, Dm values increase when explosive force is developed and thus, movement amplitude is higher, and decrease under the conditions of a high muscular tone.

The two parameters enabled us to appreciate the muscular composition of the studied muscular groups and to observe the muscular fatigue, correlated with the increase of contraction time and the decrease of muscular displacement amplitude [16]. These parameters have normal average values for Tc – of 32.83 ms for mTA and 44.75±4 ms for mGM and mGL – the average Dm value is of 8.17 mm for all muscular groups. We mention that Dm is a parameter whose decrease is correlated with Tc and muscular tone growths.

Results

Muscular displacement (Dm) has an average, normal value of 8.17 mm; the values obtained in our study are presented in Table 1 and Figure 4. We notice quite similar Dm values for lateral gastrocnemius (mGL) in right lower limb; 3.39 mm in subgroup A, 3.30 mm in subgroup B, in comparison with left lower limb where the decrease is of 3.63 mm in subgroup B.

Concerning medial gastrocnemius (mGM), we notice that Dm in right lower limb registers values of 2.16 mm in subgroup B, comparatively with subgroup A who registers an important decrease (1.43 mm). Dm values obtained in left lower limb are average and quite similar in both subgroups, namely 1.32 mm in subgroup A and 1.13 mm in subgroup B.

In the case of gastrocnemius muscles data analysis shows an evolution of functional bilateral right–left asymmetry, which is more pronounced in subgroup A.

Concerning anterior tibialis (mTA), we notice in Table 1 a dominance of increased values, however similar, in both MS subgroups (4.97 mm, respectively 4.01 mm) for the right limb. For the left limb, we can notice decreased values in subgroup B (3.36 mm), comparatively with 4.40 mm in subgroup A. There are not significant differences between the two MS subgroups. We also notice that both subgroups register a dominance of higher values in left lower limb in posterior region, while in anterior regions the dominance is noticed in right lower limb.

At the level of posterior shank Dm values in subgroup A are lower, which means that patients in subgroup A have a higher muscular tone and a maximum response to stimulation. At the level of gastrocnemius muscles, the average values are lower than normal value, which means that the muscular tone is higher in this muscular group.

Contraction time (Tc) is correlated with the type of muscular fibers, thus the lower values indicate the dominance of fast type II fibers. Tc average values, considered normal values, are of 32.83 ms; the values obtained in our investigation are presented in Table 2 and Figure 5.

We notice that Tc normal value for gastrocnemius muscles (mGL, mGM) is of 44.75 ± 4 ms, in subgroup A mGL mean is of 44.76 ms in the right limb, of 48.63 ms in the left limb and mGM mean is of 28.93 ms in the right limb and of 28.33 ms in the left limb. The average values registered in subgroup B are of 32.61 ms for mGL, 26.73 ms for mGM in the right lower limb and of 37.74 ms for mGL, 32.19 ms for mGM in the left lower limb. Concerning mGL, the values registered in subgroup A are similar to normal values, comparatively with subgroup B whose values are lower. The lower values indicate a higher percent of type II fibers.

Concerning mGL for the right limb, intramuscular coordination speed is of 0.10 m/ms in control group and subgroup B, of 0.07 m/ms in subgroup A; for the left limb of 0.17 m/ms in control group, of 0.09 m/ms in both subgroups studied. For mGM, we notice average values of 0.04 m/ms for both limbs in subgroup A, of 0.08 m/ms for right lower limb, of 0.03 m/ms for left lower limb. In subgroup B, the values are of 0.07 m/ms and in control group of 0.06 m/ms. We notice slightly higher values of intramuscular coordination speed at the patients in subgroup B.

Table 1 – ***Average Dm values for the analyzed muscles in each group***

		mGL		mGM		mTA	
		Right	*Left*	*Right*	*Left*	*Right*	*Left*
MS with gait disorders (Subgroup A)	*Average*	3.39	4.49	1.43	1.32	4.97	4.40
	Std. dev.	2.33	2.72	0.68	1.06	2.16	2.34
	Min.	0.50	0.90	0.50	0.00	0.70	1.20
	Max.	8.60	8.80	2.50	3.80	9.00	8.50
	Val. no.	13.00	13.00	13.00	13.00	13.00	13.00
MS without gait disorders (Subgroup B)	*Average*	3.30	3.63	2.16	1.13	4.01	3.36
	Std. dev.	2.34	2.39	2.56	0.88	2.48	2.57
	Min.	0.00	0.00	0.00	0.00	0.00	0.00
	Max.	5.60	6.20	7.30	2.50	6.20	6.90
	Val. no.	7.00	7.00	7.00	7.00	7.00	7.00

mGL – lateral gastrocnemius muscle; mGM – medial gastrocnemius muscle; mTA – anterior tibialis muscle.

Table 2 – ***Average Tc values for the analyzed muscles at each group***

		mGL		mGM		mTA	
		Right	***Left***	***Right***	***Left***	***Right***	***Left***
MS with gait disorders (Subgroup A)	*Average*	47.76	48.63	28.98	28.33	59.73	60.71
	Std. dev.	24.60	24.85	9.91	18.79	15.94	20.21
	Min.	24.00	23.40	15.00	0.00	33.20	10.40
	Max.	102.00	101.60	53.70	63.40	91.00	91.30
	Val. no.	13.00	13.00	13.00	13.00	13.00	13.00
MS without gait disorders (Subgroup B)	*Average*	32.61	37.74	26.73	32.19	46.41	60.99
	Std. dev.	17.80	12.49	20.53	14.56	24.03	23.04
	Min.	0.00	17.00	4.40	18.00	4.00	19.00
	Max.	56.00	55.00	67.40	62.00	69.10	91.90
	Val. no.	7.00	7.00	7.00	7.00	7.00	7.00

mGL – lateral gastrocnemius muscle; mGM – medial gastrocnemius muscle; mTA – anterior tibialis muscle.

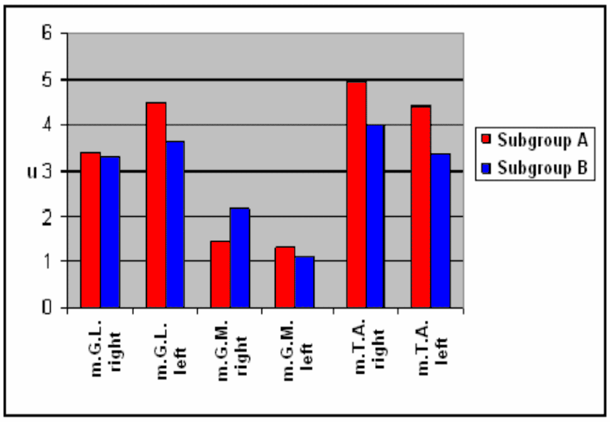

Figure 4 – ***Average Dm values depending on the stimulated muscle.***

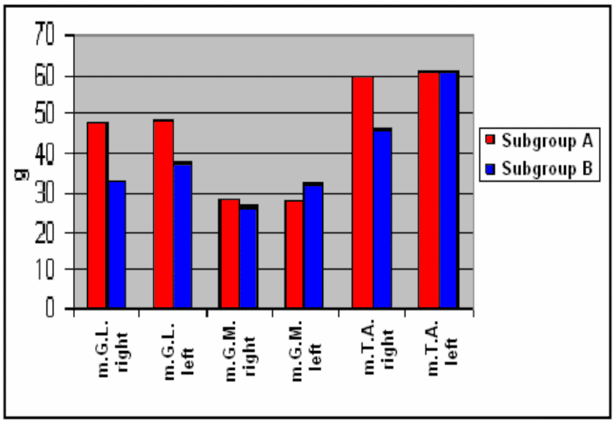

Figure 5 – ***Average Tc values depending on the stimulated muscle.***

As far as mTA is concerned, Tc determined in our study has much higher values, namely of 59.73 ms in subgroup A, 46.41 ms in subgroup B, for the right limb, respectively of 60.71 ms in subgroup A, 60.99 ms in subgroup B, for the left limb, which indicates muscular fatigue [17] and the decrease of type II fibers and probably, in compensation, the increase of type I fibers percent [18]. The correlation between Tc high values and Dm low values makes us notice a higher muscular tone.

mTA intramuscular coordination/conduct speed for the right limb has a value of 0.07 m/ms in subgroup A, and of 0.05 m/ms in subgroup B, which shows no significant difference between the two subgroups.

Concerning Tc values, this parameter indicates muscular fatigue at the level of anterior tibialis.

Discussion

Motor performances of lower limb, influenced by muscular properties, can be quantified through TMG [19], which enabled us to get relevant information of morphofunctional modifications in skeletal muscles [15] of MS patients. The two components, which were greatly modified in MS patients, are: muscular tone and muscular strength, components dependent on the presence or absence of muscular atrophy. This study makes its contribution to complete the database regarding morphofunctional changes of muscles in MS, besides the results offered by MRI, CT and EMG [20]. TMG enabled us to get information both of the way in which motor units are recruited and of the muscular fibers type. Analyzing TMG parameters in the shank posterior region, we can notice the similar Dm values for mGL, which are lower at the patients in subgroup B in left lower limb. We conclude that gait and motor control disorders [21] developed in MS induce asymmetric structural changes at muscular level because of differentiate mechanical right-left strain, generated by these balance disorders and, probably, by muscular fatigue.

The decrease of Dm values is correlated with a high muscular tone. For mGM we notice a reverse situation which is probably the result of developed compensatory mechanisms, namely extremely low Dm values. This aspect shows an important right–left functional asymmetry at the patients in subgroup A, at the shank level, affecting leg motor control. This observation, obtained through TMG, completes the present studies involving muscular biopsy at the level of anterior tibialis, conform to which the process of atrophy and a high muscular tone are specific to hemiplegia [22].

Deeply analyzing the shank anterior region, more exactly mTA group, we notice the high Dm values at MS subgroups, which are much higher at the patients in subgroup A, at the level of gastrocnemius muscles. This aspect indicates a lower muscular tone than in the posterior shank region, which probably allows the maintenance of ankle kinetics as an important item in gait onset [23].

Tc values are low in gastrocnemius muscles due to the increase of type II fibers, aspect noticed by Kent-

Braun JA *et al.* (1997) and explained through enzymatic modifications. This increase can also be explained by the tendency of decrease in the area of transverse section noticed by Kent-Braun JA *et al.*, in type II fibers in MS and correlated with the atrophy process of type II fibers. It is likely to consider this increase as a compensatory reflex mechanism, generated by structural modifications [22].

Concerning mTA, Tc values are high, resulting an increase in the percent of type I fibers at this level, as an adaptive consequence to pathologic process.

Conclusions

Analyzing Dm through TMG, we notice a high muscle tone, more pronounced in gastrocnemius muscles, which explains the decrease in the leg motor control during gait.

Tc, as TMG parameter, registers high values in anterior muscular group of the shank (54.93–60 ms), in correlation with the increase of type I muscular fibers and with muscular fatigue.

Functional deficiency and coordination shortage of the leg during gait may be explained by the low recruitment of motor units in the anterior muscular group of the shank.

TMG, besides classical methods of paraclinical investigation, improves data generation, standardization and acquisition, identifies correlations, which may facilitate a precocious diagnosis in morphofunctional changes evolution at muscular level at MS patients. This evaluation type enables us to elaborate a functional prognosis of lower limb in MS.

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