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RESEARCH ARTICLE

SKIN IMPEDANCE AND MYOMETRY (ENF AND MYOTON): TWO INSTRUMENTS COMPARED IN ACUTE AND CHRONIC SOMATIC DYSFUNCTION

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ABSTRACT

In rehabilitation medicine can be observed tissue alterations that go to join in specific disease states, and may be the first signal to decode a dysfunctional state and program the rehabilitation protocol. Somatic dysfunction present alternations of tone and tissue quality, the perception of pain at specific points during the evaluation, anatomical asymmetries and reductions in the ROM. The purpose of this study was to compare in a single-bind dysfunctional areas previously identified with a clinical functional assessment studied through the use of two different devices: the ENF, an impedance evaluation system that measures the rheological skin values and the Myoton, which measures the elasticity, deformability and the tone of the tissue district with a scientifically validated system. The results were able to show all the typical neurophysiological characteristics related to somatic dysfunction, considering concepts such as facilitation, neurogenic inflammation, up to the concept of allostatic overload, the final result of the stress accumulated sum and daily dysfunction during various activities of everyday life.

INTRODUCTION

In rehabilitative medicine results important consider that the tissue alterations are mediated by diseases and autonomic reactions (Budgell *et al.,* 1998). Whatever the pain areas, often primary dysfunction becomes the first signal to decode before design and applying a rehabilitation protocol. The efferent somatic areas are often the clearest demonstration of how at spinal cord level subcortical and cortical informational alterations and the specific disease, could change myofascial tissue peripherally (Kimura, 1997; Sato, 1997). Therefore, the clinician needs to understand and manage this condition of suffering to be able to interpret somatic dysfunction and treat it in a properly physiological modality. Myofascial dysfunction, expression of many pathological conditions, can be objectified through the use of myoton and supported by the operator's functional evaluation (Kagitani *et al.,* 1996). The interpretation of the somatic dysfunction is equivalent to objectify increased discharge of "gamma motor neurons" to intrafusal fibers of the muscle spindle to "increase profits" of spindles which produce a prolonged reflex muscle contraction

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("neurological muscle tone") (Cervero, 2009). The segmental muscle contraction should produce a tissue modification and restriction of the joint segmental movement, even in apparently healthy, asymptomatic subjects. The clinical evidence of somatic dysfunction includes: alteration of the tissue quality or the soft tissue tone, the perception of pain in the points identified during the evaluation, the anatomical asymmetries, the range of motion alteration (Korr, 1975). Aim of this controlled randomized single-blind study is to compare the dysfunctional areas, found in clinical and functional assessment performed by the clinician and an impedance evaluation system that focuses on rheological values and skin impedance, with a tissue evaluation system already scientifically validated, the myoton. Examining the tone, biomechanical and viscoelastic properties of skeletal muscles is proposed a complementary, non-invasive and cost-effective technology that enables real-time assessment of muscles (Chuang *et al.,* 2013). Changes in muscle tone and properties could be used to assess effects of pathology (Dahmane *et al.,* 2001), sport-related injury or therapeutic intervention (Ratsep, 2011). Such assessments could be performed at regular intervals to monitor the stage of the pathological processes of muscles and for assessing efficacy of therapeutic interventions (Marusiak *et al.,* 2012).

The measurement method applied in the Myoton Pro is based on exertion of a quick released single mechanical impulse (time 15 ms, force 0.4 N) under constant pre-compression force (0.18 N) of the subcutaneous tissue layer above the muscle/tendon being measured. Mechanical deformation is delivered by the device testing end (d = 3 mm), held perpendicular to the skin surface. After a short mechanical impulse, the muscle or tendon responds in the form of a damped oscillation, which is registered by an acceleration sensor attached to the device's frictionless measuring mechanism. The properties of the sensor are as follows: amplitude range of ±8 g in full range; resolution of <0.001 g; output data rate and bandwidth 3,200 Hz; sensitivity of <20 mg/LSB for each axis; sensitivity ±0.1 % due to the temperature change; bias level of each axis 100 mg; noise performance of each <1.5 LSB rms; and operating temperature −10 to +50C. While stiffness, tone and elasticity are the most commonly reported parameters using Myoton devices in the literature (Aird *et al.,* 2012), We additionally investigated mechanical stress relaxation time and indication of creep in the present study to document the behaviour of all five parameters and relative changes to one another under the known influence of unloading in weightlessness. The target wants to be find a match of interpretive values of the dysfunction, among the areas identified by the operator using specific tests, with greater reduction of ROM, greater tissue alteration (using rolling test), rheological values recorded with the myoton and values of skin impedance recorded with ENF technology. ENF (Electro neurofeedback) is a tool with the ability to communicate with the body with a frequency of at least 90 times per second. It can be defined Interactive Neuroregolator for its both evaluative and rehabilitative ability. It is able to read the impedance values of the skin and to transmit electrical impulses through a special algorithm for interact with the organism.

The interactive neuromodulation is a form of electrotherapy characterized by:

- Biphasic damped sinusoidal signal variable in time, with morphological characteristics similar to ECG
- Potential of action of high amplitude, short and not harmful
- Absence of the adaptation process thanks to the feedback that always generates different signals depending on the skin impedance alterations.

Two different phases of employment are distinghuished:

- The enf identifies the area that needs treatment, it does not necessarily correspond with algic area
- The therapeutic modality is adopted by the ENF (Electro Neuro Feedback) based on the reading of the level of the skin's impedance, at the same time sends a stimulus using an algorithm that interacts with SNC.

The stimuli are represented by bipolar and biphasic electrical pulses at very low frequencies from 15 to 350 Hz. At the basis of the action of this electrotherapy and in particular of ENF, there is the interactive mechanism neuroregulation that allows the patient to obtain a dynamic balance of the organism in relation with the environment to reach the 'homeostasis and therefore the health state.

The adjustment of all the vital functions is realized through a strict connection and interaction of the endocrine and nervous systems, which effects are mediated through the release by neural cells of biologically active substances called neuromediators (NM); amines (acetylcholine, norepinephrine, etc.) and amino acids (glutamine, asparagin, etc.), characteristics elements of fibers A-Beta, myelinated nerve fibers are classic neurotransmitters (acetylcholine, norepinephrine, etc.) and have a well-defined physiological fast and short effect; neuropeptides (NP) that are, from a physiological and medical point of view , the biggest and most important group of neuromodulators include: endorphins, enkephalins, neurotensine, bradykinin, and a large number of other types (more than 2000 in total) ; These are principal neuromodulators for thin and not myelinated and particularly difficult to stimulate C fibers. These neuropeptides are produced from fibers which constitute the majority (over 70%) of the nervous pathways. Science has already shown that because of their long-term specific properties and action away from the site of production, are responsible for the formation of complex regulative chains and of drops for the control of various physiological functions, in addition to the potent analgesic effect, etc. (Laird *et al.,* 2001; Cervero, 2000). Precisely for this reason that the target tissue of the action of ENF is represented mainly by nervous tissue; Its stimulation allows to obtain results because it activates the production of an effective dose of neuropeptides, released by the stimulation of C-fibers and necessary to overcome the existing alteration of human body.

MATERIALS AND METHODS

The research protocol is compatible with the Declaration of Helsinki; as part of the Chair of Physical and Rehabilitation Medicine, University of Chieti, they were selected 20 patients (10 males 10 females), who had been diagnosed with a trigger points myofascial syndrome.

Inclusion criteria:

- Myofascial syndrome involving the trapezius muscles, minor pectorals, rhomboids, quadratus lomborum, quadriceps
- Algic syndrome involving the neck region
- Algic syndrome involving gleno-humeral joint
- Algic syndrome involving lumbar region
- Algic syndrome involving knee joint
- Age beetwen 18 and 40 years old

Exclusion Criteria

- Radicular syndrome diagnosis
- Dismetabolic disease
- Pharmacologic treatments in progress

The subjects have been subjected to a global postural clinical evaluation, divided into three phases:

- Functional and structural evaluation: to identify any limitations, asymmetries and tissue dysfunction
- Muscular evaluation, by Myoton, into the areas previously identified as dysfunctional, with altered

values of ROM and tissue quality (by rolling test) assessed by the clinician

- Tissue evaluation with enf: areas resulted dysfunctional in the tests, together with contralateral areas, are subjected to impedeziometric evaluation.

In the areas identified with the clinician's functional assessment is performed the muscluar evaluation using Myoton that will provide datas of three parameters:

- Frequency: muscular elasticity
- Decrement: musucar tone
- Stiffness: muscular rigidity

Oscillation Frequency [Hz]

Indicates the Tone (that is, intrinsic tension) of a muscle in its passive or resting state without any voluntary contraction (EMG base level). Hypertonia and respectively increased intramuscular pressure causes reduced blood supply, which brings on worse muscle recovery and quicker muscle fatigue. Oscillation Frequency in contracted state indicates the tension of a muscle.

Logarithmic Decrement - no unit of a muscle’s natural oscillation indicates the muscle’s elasticity. Elasticity is the biomechanical property of a muscle that characterises the ability to recover its initial shape after a contraction or removal of an external force. Elasticity is inversely proportional to the decrement. Decrement describes the dissipation of mechanical energy in the tissue during one oscillation cycle. If the muscle dissipates less mechanical energy then it is more elastic. If the muscle is more elastic then it is more economic and efficient in function. The inverse of Elasticity is Plasticity.

Dynamic Stiffness [N/m]

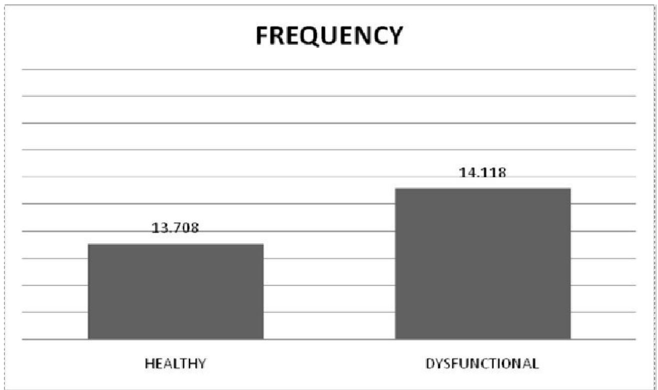
Stiffness is the biomechanical property of a muscle that characterises the resistance to a contraction or to an external force that deforms its initial shape. Greater effort is required from the agonist muscle to extend the antagonist muscle with high stiffness, which leads to inefficient economy of movement. The term Dynamic Stiffness originates from the dynamic measurement method applied in Myoton PRO. The inverse of Stiffness is Compliance. The stages to use of interactive neurostimulator ENF are two:

- The ENF identifies the area that needs treatment not corresponding with algic area
- The evaluation mode is implemented by ENF based on the reading of the skin impedance level and simultaneously is achieved a stimulus using a specific algorithm that interacts with the SNC through the interaction with the skin organ.

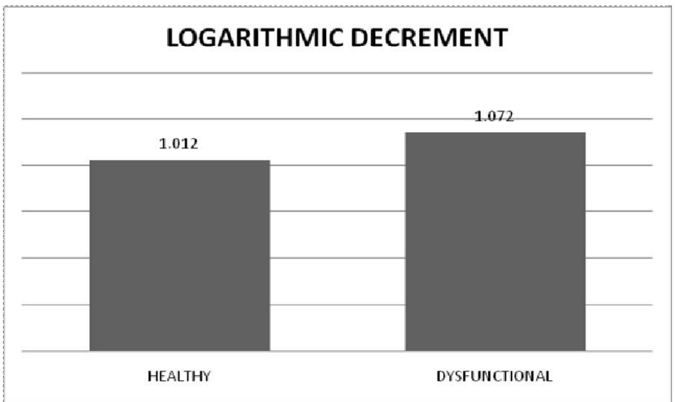
The stimuli are represented by bipolar and biphasic electrical pulses at very low frequencies from 15 to 350 Hz. Relying on his special pulse generation algorithm, the ENF modifies the output signal based on the neurological response projected on the skin. This process causes a skin reaction very quickly, easily making a first diagnostic indication on where an anomaly is manifested by the body. The first phase of ENF is called manual scan. To scan manually, the electrode is placed on the skin and the instrument is moved making a dynamic action (painting) on the area to be evaluated. The dynamic action should be repeated in four directions as to form a cross, keeping the electrode well placed while scrolling. After a few moments (typically a few seconds) they will appear some changes in the skin that we will call reactive zones, which manifest themselves with a reddening and an impedance change. The ENF digitally scan mode uses an algorythm to generate a pulse, varying the signal according to the neurological response of the skin. This process causes a skin reaction very quickly, easily forming a first diagnostic indication on where an anomaly is manifested by the body.

RESULTS

Are shown below tables and graphs are related to the assessments made with Myoton and ENF on the examined sample. From these assessments we can confirm that after the evaluation of the patient with specifical physical and clinical tests, having identified the dysfunctional area, we can corroborate the result of the functional evaluation with a second assessment by the use of ENF and myoton making a measurement of the rheological values and impedance of skin tissue. This valuations, that are not operator-linked, have confirmed the topographic location of the dysfunctional area. From the analysis of the obtained data, we separate the two groups, depending on whether it were a chronic or acute dysfunction.

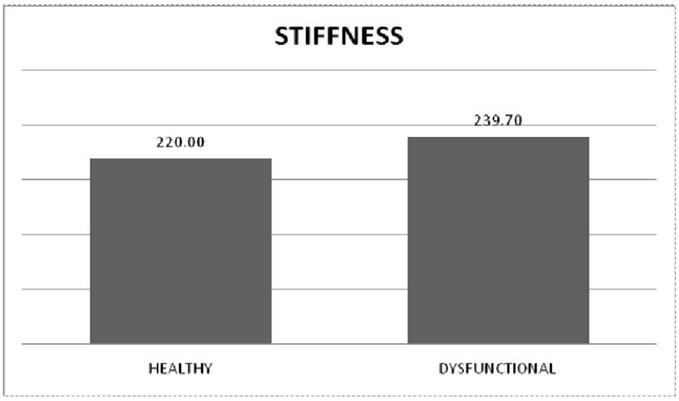


Graphic n°1. The graph shows the average values of the frequency, i.e. muscle tension, greater in the dysfunctional side than the healthy one by a value of 0.41 points

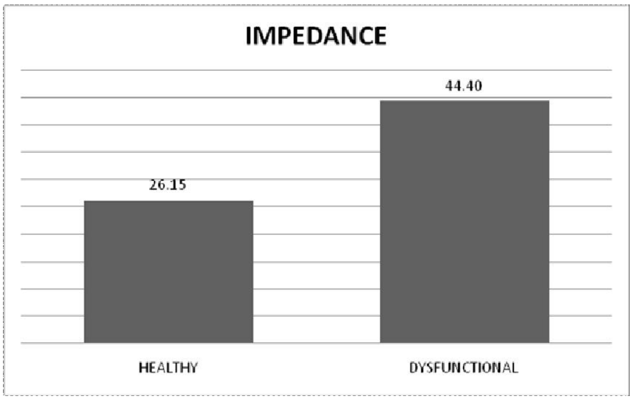


Graphic n°2. the graph shows the average values of the Logarithmic Decrement, i.e. muscle elasticity, greater in the dysfunctional side of 0.06 points compared to the healthy one

Patient			Myoton			Enf	Note
			F	D	S	FR	
Chronic	P 1	Healthy	11,06	0,98	117	15	Left upper trapezius
		Disfunctional	10,2	1,01	113	16	
Acute	P2	Healhty	13,5	0,89	233	31	Right quadricep
		Disfunctional	14,16	1,01	261	88	
Acute	P3	Healhty	10,6	1,2	125	40	Right upper trapezius
		Disfunctional	11,6	1,28	158	79	
Acute	P4	Healhty	13,7	0,92	216	39	Right quadratus lumborum
		Disfunctional	16,1	1,03	327	84	
Chronic	P5	Healhty	12,6	0,94	193	12	Left quadratus lumborum
		Disfunctional	12,2	0,88	176	8	
Chronic	P6	Healhty	15,2	1,09	258	12	Left upper trapezius
		Disfunctional	14,5	0,96	235	6	
Chronic	P7	Healhty	11,8	0,7	140	8	Right tibialis anterior
		Disfunctional	11,5	0,61	122	6	
Acute	P8	Healhty	11	0,96	125	63	Right minor pectoral
		Disfunctional	10,7	1,33	161	97	
Chronic	P9	Healhty	18,6	1,19	360	13	Left upper trapezius
		Disfunctional	17,3	1	315	9	
Chronic	P10	Healhty	9,9	1,02	132	10	Right quadratus lomborum
		Disfunctional	10	1,16	133	6	
Chronic	P11	Healhty	14,6	1,35	254	10	Left minor pectoral
		Disfunctional	15,7	1,56	279	8	
Acute	P12	Healhty	13,5	0,69	183	44	Left upper trapezius
		Disfunctional	15,9	0,7	249	94	
Chronic	P13	Healhty	13,8	1,16	198	14	Right quadricep
		Disfunctional	12,9	1,28	186	8	
Acute	P14	Healhty	12,7	0,88	204	45	Left tibialis anterior
		Disfunctional	12,3	0,78	170	67	
Acute	P15	Healhty	13,2	0,76	165	45	Left quadratus lomborum
		Disfunctional	12,7	0,68	152	78	
Acute	P16	Healhty	17,3	1,12	326	29	Right lat
		Disfunctional	17,3	1,31	335	73	
Acute	P17	Healhty	18	1,08	372	37	Left lat
		Disfunctional	18,1	1,18	377	69	
Chronic	P18	Healhty	16,3	1,2	369	8	Right medium trapezius
		Disfunctional	16,8	1,26	353	6	
Chronic	P19	Healhty	13,7	0,99	203	11	Left upper trapezius
		Disfunctional	16,2	0,94	394	7	
Acute	P20	Healhty	13,1	1,12	227	37	Right minor pectoral
		Disfunctional	16,2	1,48	298	79	

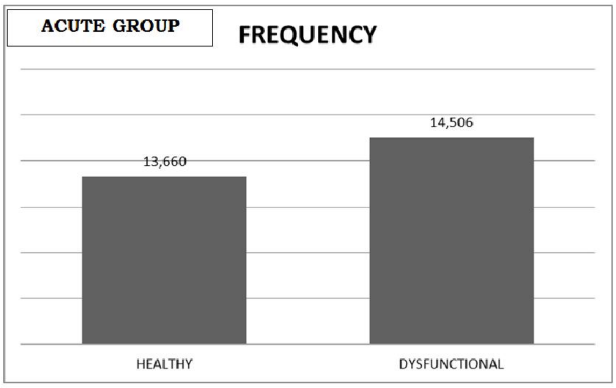


Graphic 3. The graph shows the average values of Stiffness, ie the stiffness, greater in the dysfunctional side of 19.7 points compared to the healthy one

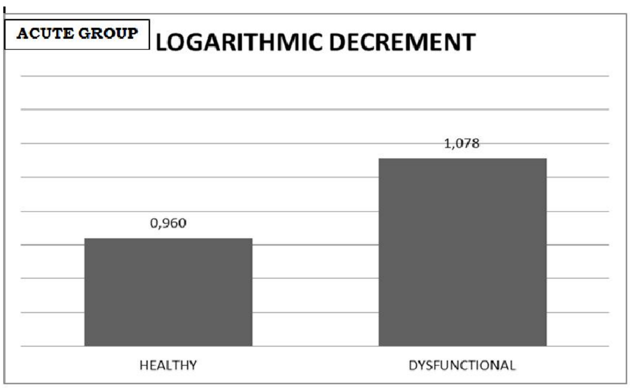


Graphic 4. The chart shows the average values of skin impedance, recorded through the use of ENF, greater in the dysfunctional side of 18.25 points compared to the healthy side

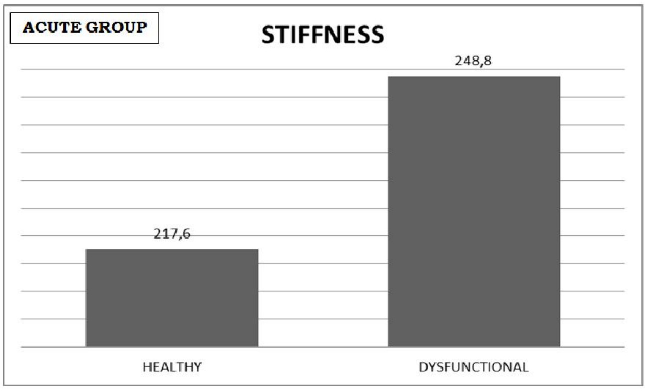
Acute group



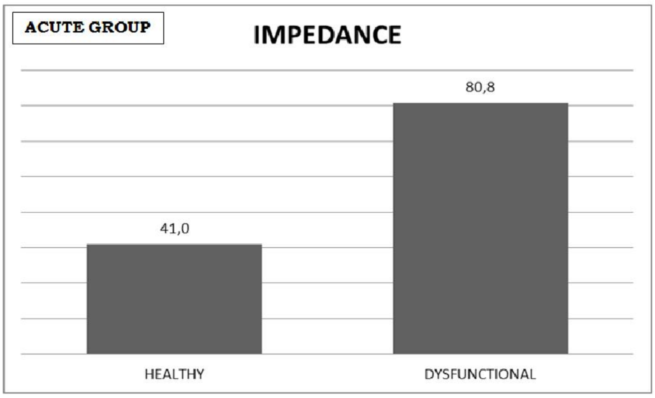
Graphic 5. The graph shows the average values of the frequency, ie muscle tension, greater in the dysfunctional side of 0.85 points compared to healthy subjects with acute dysfunction



Graphic 6. The graph shows the average values of the Logarithmic Decrement, ie the muscle elasticity, increased by 0.2 points in the dysfunctional side compared to healthy subjects with acute dysfunction



Graphic 7. The graph shows the average values of Stiffness, i.e. the stiffness, greater in the dysfunctional side of 31.2 points compared to healthy subjects with acute dysfunction



Descriptive Statistics

Variable	Count	Mean	Standard Deviation	Standard Error	95,0% LCL of Mean	95,0% UCL of Mean
C12	10	41	9,46338	2,992584	34,2303	47,7697
C16	10	80,8	10,01998	3,168596	73,63214	87,96786

T* for Confidence Limits: T* (C12) = 2,2622; T* (C16) = 2,2622

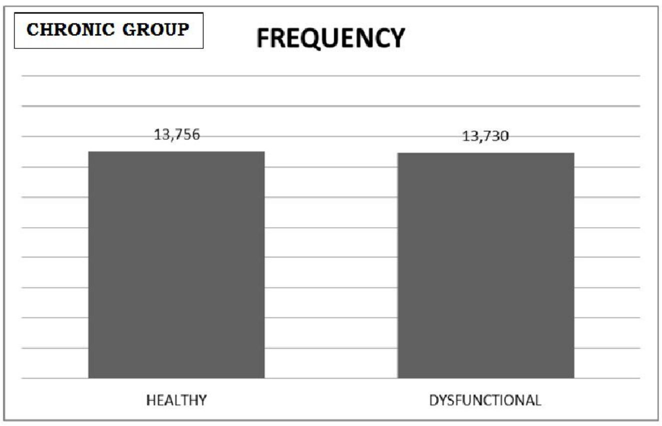
Two-Sided Confidence Interval of the Mean Difference

Variables	Count	Mean Difference	Standard Deviation	Standard Error	T*	d.f.	95,0% C. I. of Mean Diff. Lower Limit	Upper Limit
C12 - C16	10	-39,8	10,04213	3,175601	2,2622	9	-46,98371	-32,61629

Paired-Sample T-Test
Paired Difference: (C12) - (C16)

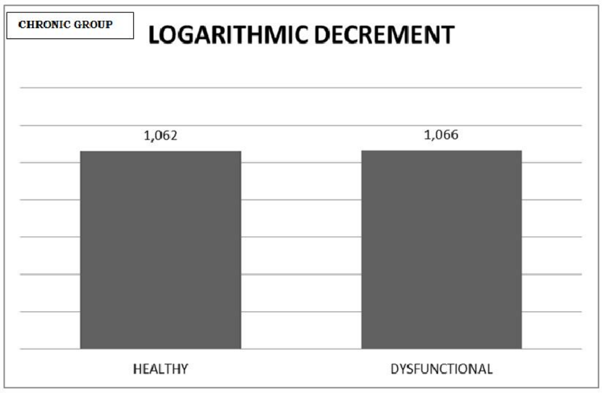
Alternative Hypothesis	Mean Difference	Standard Error	T-Statistic	d.f.	Prob Level	Reject H0 at α = 0,050
Mean Diff. ≠ 0	-39,8	3,175601	-12,5331	9	0,00000	Yes

Graphic 8. The chart shows the average values of skin impedance, greater in the dysfunctional side of 39.8 points compared to healthy subjects with acute dysfunction

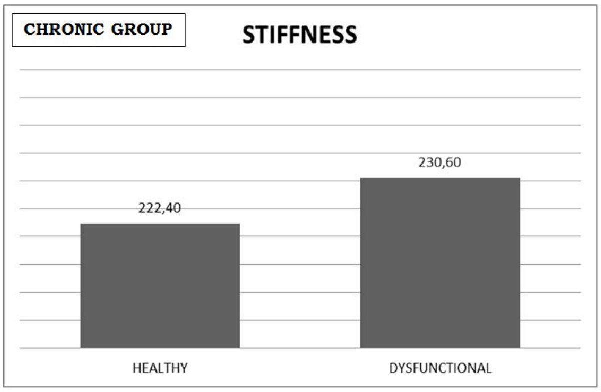


Graphic 9. The graph shows the average values of the frequency, ie muscle tension, greater in the dysfunctional side compared to healthy subjects with chronic dysfunction

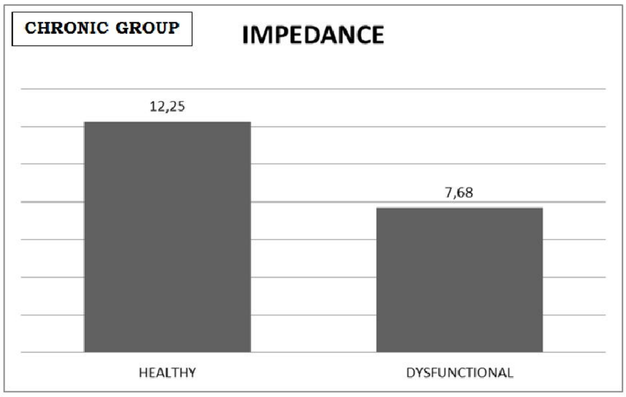
Group patients with chronic pain



Graphic 10. The graph shows the average values of the Logarithmic Decrement, ie the muscle elasticity, greater in the dysfunctional side 0,004 points compared to healthy subjects with chronic dysfunction



Graphic 11. The graph shows the average values of Stiffness, ie the stiffness, greater in the dysfunctional side of 8.2 points compared to healthy subjects with chronic dysfunction



Descriptive Statistics

Variable	Count	Mean	Standard Deviation	Standard Error	95,0% LCL of Mean	95,0% UCL of Mean
C4	10	11,3	2,359378	0,746101	9,612203	12,9878
C8	10	8	3,018462	0,9545214	5,840723	10,15928

T* for Confidence Limits: T* (C4) = 2,2622; T* (C8) = 2,2622

Two-Sided Confidence Interval of the Mean Difference

Variables	Count	Mean Difference	Standard Deviation	Standard Error	T*	d.f.	95,0% C. I. of Mean Diff. Lower Limit	Upper Limit
C4 - C8	10	3,3	2,110819	0,6674995	2,2622	9	1,790011	4,809988

Paired-Sample T-Test
Paired Difference: (C4) - (C8)

Alternative Hypothesis	Mean Difference	Standard Error	T-Statistic	d.f.	Prob Level	Reject H0 at α = 0,050
Mean Diff. ≠ 0	3,3	0,6674995	4,9438	9	0,00080	Yes

Graphic 12. The graph shows the average values of skin impedance, greater in the dysfunctional side of 4.57 points compared to healthy subjects with chronic dysfunction

In case of chronic dysfunction, the skin impedance values, measured with ENF, resulted low, while in case of acute dysfunction such values resulted to be high.

DISCUSSION AND CONCLUSION

The conducted study showed all the neurophysiological characteristics of somatic dysfunction, considering notions such as facilitation, neurogenic inflammation, until reaching definitions as "allostatic overload", true final result of the amount of stresses and the dysfunctions accumulated during daily activities. This condition must be eliminated in order to restore the health status of the patient (Cervero and Laird, 1996). The assessment is therefore an important and crucial time to plan an effective and causal intervention (Korr *et al.,* 1964). The effect of skin temperature and hydration status has been suggested by some researchers as a common cause of variation in bioimpedance measurements of the body (Podtaev *et al.,* 2015; Cornish *et al.,* 1998). This paper details a simple method of measuring the impedance of the skin, in somatic dysfunction (Thomas and Korr, 1951). The functional evaluation, operator-dependent, have been joined by two objective evaluations (Myoton-myometry- and ENF- skin impedance).

The ENF confirmed the neurophysiological and mechanic interconnection concepts of the somatic tissue with the afferent receptorial system, which is capable of synergistically express an efferent manifestation at all these levels. From the data collected we can see that the characteristics of the tissues showed different results in instrumental and even manual assessments by the operator. The tools used validate the importance of a clear identification of the dysfunctinal area needing treatment. Pressure, cleaning the skin with alcohol, and exfoliation did not affect the performance of the ENF device. Our new device has some properties which can make it a good choice for future researches. It connects and records electrical skin impedance of each probe automatically. This device has one probe and is able to connect to different locations at the same time. This can happen because most of the sensory, somatic motory and visceral nerves show a clear anatomical and functional arrangement of metameric type in their course towards and from the spinal cord and since the centers of the vertebral reflections are capable of coordinating and modeling the interchange of somatic and visceral reflex even in the complete absence of supraspinal reflex centers (Korr, 1951). It can also be used for a prolong period in recording electrical skin impedance, and for therapeutic use through specific programs (not used in this research work).

Conflict of interest

All authors declare that there is no personal interest properties, financial, professional or other of any nature or kind in any product, service or company that could be interpreted as influencing the position presented in this manuscript.

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