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Acute effect of ultrasound on the spastic pattern of the biceps brachii in individuals with neurological disorders.

Acute effect of ultrasound on the spatial pattern of the biceps brachii in individuals with neurological disorders

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Summary

Spasticity is a common neuromuscular dysfunction in various neurological conditions, characterized by an abnormal increase in muscle tone and resistance to passive movement, negatively affecting functionality and quality of life. Therapeutic ultrasound, due to its thermal and mechanical effects, emerges as a viable option to help control this condition. This study aimed to evaluate the effects of therapeutic ultrasound on spasticity of the biceps brachii muscle in individuals with various neurological disorders. The sample consisted of seven participants who presented with spasticity in the biceps brachii muscle, who underwent electromyography and ultrasound evaluation before and after the intervention. The intervention protocol consisted of a single application of continuous therapeutic ultrasound, with a frequency of 1 MHz, intensity of 0.8 W/cm², 4 ERAS, and a duration of 10 minutes. The collected data were analyzed using SPSS software version 21.0, employing descriptive statistics and the non-parametric Wilcoxon paired-samples test, with a significance level set at pÿ0.05.

Following the application of therapeutic ultrasound to the spastic muscle, a trend towards reduced muscle activity and increased muscle thickness was observed; these findings were statistically significant in right isotonicity and left maximal voluntary contraction. Thus, it is concluded that the acute application of therapeutic ultrasound was able to promote significant changes in muscle tone in only two of the clinical conditions analyzed, in individuals with neurological disorders. However, a clinical trend towards improved spasticity control was identified, suggesting the need for studies with larger samples and repeated interventions to confirm these experimental findings.

Keywords: Therapeutic ultrasound, Spasticity, Neurological disorders, Surface electromyography, Muscle tone.

Abstract

Spasticity is a common neuromuscular dysfunction observed in various neurological conditions, characterized by an abnormal increase in muscle tone and resistance to passive movement, which negatively impacts functionality and quality of life. Owing to its thermal and mechanical effects, therapeutic ultrasound has emerged as a potential modality to assist in spasticity management. This study aimed to evaluate the effects of therapeutic ultrasound on the spasticity of the biceps brachii muscle in individuals with different neurological disorders. The sample consisted of seven participants presenting spasticity in the biceps brachii muscle, who were evaluated using electromyography and ultrasonography before and after the intervention. The intervention protocol

involved a single application of continuous-mode therapeutic ultrasound at a frequency of 1 MHz, intensity of 0.8 W/cm², 4 ERAS, and a duration of 10 minutes. Data were analyzed using SPSS software version 21.0, applying descriptive statistics and the nonparametric Wilcoxon paired-sample test, with a significance level set at p ÿ 0.05. Following the therapeutic ultrasound application to the spastic muscle, a trend toward reduced muscle activity and increased muscle thickness was observed.
Statistically significant differences were identified for right isotonia and left maximal voluntary

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contraction. In conclusion, the acute application of therapeutic ultrasound could promote significant changes in muscle tone in two of the clinical conditions analyzed among individuals with neurological disorders. However, a clinical trend improved toward spasticity control was observed, suggesting the need for studies with larger samples and repeated interventions to confirm these preliminary findings.

Keywords: Therapeutic Ultrasound, Spasticity, Neurological Disorders, Surface Electromyography, Muscle Tone.

Introduction

Spasticity is a sensorimotor disorder resulting from an interruption in the control of movement triggered by the central nervous system. This alteration is primarily associated with Upper motor neuron lesions. Characterized by muscle hyperactivity and increased reflexes. velocity-dependent stretching, which compromises voluntary motor function and contributes significantly for functional disability (GAL *et.* al., 2025; AMATYA *et.* al., 2024). THE Spasticity can also be defined as the involuntary, intermittent, or sustained activation of muscles, resulting from neurogenic disorders, reflecting changes in both the excitability of reflexes as well as in the central regulation of muscle activity (GAL *et* al., 2025).

Spasticity is present in several neurological conditions, such as stroke. brain injury, spinal cord injury, and multiple sclerosis, which can lead to significant complications, such as contractures, joint deformities, fatigue, muscle pain, and difficulty performing activities simple everyday problems, generating a negative impact on the mobility, independence, and quality of life of these people (PORTAL REABILITAÇÃO, 2024; AMATYA *et* al., 2024). With high Prevalence and clinical impact, their assessment and management represent significant challenges in practice. clinical practice, especially due to the complexity of its pathophysiological mechanisms, and the limitations of... assessment tools currently available, and because they rely exclusively on the experience of therapist (HE *et* al., 2023).

1. Theoretical Framework / Results

Physical therapy plays an important role in the rehabilitation and management of spasticity. seeking a reduction in muscle hypertonia, improvement in motor function and conditioning of a A more functional standard. Through approaches based on and validated by the literature with a treatment. Individualized kinetic-functional therapy for each individual. Currently, there is a constant search for New techniques and therapeutic combinations to reduce spasticity include: whether the use of TENS, botulinum toxin, therapeutic ultrasound, passive stretching and thermotherapy (ROMAN *et.* al., 2023; VERDUZCO-GUTIERREZ *et.* al., 2024). In this context, research Studies conducted by Sahin, Ugurlu, and Karahan (2011) investigated the effects of passive stretching on spasticity, highlighting that this practice increases intramuscular tension and activates the tendinous organs.

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Golgi apparatus and promotes muscle relaxation. Furthermore, studies conducted by the same authors... (2011) suggest that applying heat or cold before stretching can enhance its effects. Therapeutic approaches as a form of intervention in the management of spasticity.

In this sense, the application of therapeutic ultrasound becomes an option for controlling the the individual's spastic pattern, since it is a therapeutic resource based on mechanical vibrations. high-frequency waves, which generate oscillations in tissues through acoustic cavitation, a phenomenon that It involves compression and expansion of piezoelectric ceramic, which can generate tissue heat (MEYER *et al.* (al., 2012). The frequencies used in physiotherapy vary between 0.75 and 3.0 MHz, with the The application of these sound waves is capable of penetrating different layers of tissue. Although the The classic concept of two frequencies, 1 MHz for deep tissues and 3 MHz for superficial tissues, still While this approach may be accepted, it has been revised due to technological advancements and a scarcity of studies. about the mechanisms of action of acoustic waves in biological tissues. Continuous ultrasound It combines physiological effects with heat generation, and its thermal effect is dose-dependent. This warming of the tissues increases metabolic activity, blood supply, and perfusion, in addition to... to improve the extensibility of tissues, especially those rich in proteins such as collagen. and elastin. It also stimulates the release of catecholamines, induces lipolysis, and mobilizes triglycerides. and breaks the fat cell membrane (JONHS, 2002; SAVOIA *et* al., 2012).

In addition to the thermal and mechanical effects of therapeutic ultrasound, it is also possible to observe an inhibitory effect on the excitability of alpha motor neurons, which contributes to the reduction of spasticity. A study conducted by Monaghan et al. (2017) analyzed the parameters of the reflex. H (Hmax/Mmax ratio) and demonstrated a decrease in this ratio after the application of ultrasound. indicating an inhibitory modulation of reflex activity. Therefore, ultrasound acts both in... Peripheral tissues, such as in neural modulation, favor the control of muscle tone.

The application of therapeutic ultrasound in physiotherapy has been a possible alternative. for the management of spasticity in neurological disorders, however, the literature demonstrates a There is a scarcity of recent studies on the subject. In this context, the present work aimed to... to evaluate the acute effect of therapeutic ultrasound on spasticity of the biceps brachii muscle in individuals with neurological impairments, seeking to understand their effects on modulation muscle tone, spasticity reduction, and its contribution to functional rehabilitation.

2. Material and Method

This is a self-controlled, longitudinal, experimental clinical study, in which... The study aimed to evaluate the acute effect of therapeutic ultrasound in controlling spastic patterns in people with neurological disorders. The project was submitted to the Research Ethics Committee of the Center. UNIFAFIBE University student and approved under CAAE 89447225.9.0000.5387 and opinion 7.652.547.

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Participants were assessed before and immediately after the intervention using electromyography. surface at rest, maximum voluntary contraction and isotonicity, and by ultrasound imaging of biceps brachii at rest and maximum voluntary contraction, allowing for comparison of their effects. A therapeutic intervention with continuous ultrasound was performed in individuals with spasticity in the biceps brachii, using a frequency of 1 MHz, intensity of 1 W/cm², 4 ERAs for 10 minutes. The study was conducted at the University Center – UNIFAFIBE and at the Clinic. School of Physiotherapy, same institution, in the city of Bebedouro-SP.

2.1 Participants

The sample consists of seven participants, aged 25 to 65, with neurological disorders. that presents with a spastic pattern in the upper limbs, and that are not in the acute phase of the disease and who are not participating in other clinical studies that could interfere with the present study, in addition to regularly attend the Physiotherapy Clinic School at UNIFAFIBE.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria:

The study included participants who had: • The ability to understand and follow simple commands (collected previously from the participant's evaluation form);

• Individuals undergoing treatment at the teaching clinic;
• Individuals aged between 25 and 65 years;
• Absence of recent use (last 6 months) of botulinum toxin in the affected upper limb; • Absence of wounds, infections or dermatological changes at the ultrasound application site; • Good skin integrity and preserved sensitivity in the brachial region.

Exclusion criteria:

Participants who had the following were excluded from the study:
•Application of botulinum toxin in the last six months;
• Presence of metallic implants or electronic devices (such as pacemakers) in the area where ultrasound is applied;
• Diagnosis of associated neuromuscular diseases (e.g., amyotrophic lateral sclerosis, muscular dystrophies);

• History of uncontrolled epilepsy;
• Significant changes in sensation in the affected upper limb;
• Open wounds, skin infections, or other dermatological conditions at the application site;
• Uncontrolled high blood pressure or cardiovascular instability;
•Participation in other clinical studies in the last 3 months that could interfere with the present study;
• History of neoplasms in the area where ultrasound will be applied;
• Severe pain in the affected upper limb, incompatible with the execution of the proposed techniques;

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2.3 Data collection

2.3.1 Protocol applied to individuals with neurological disorders

The participants in this study underwent the following clinical routine:

- Staging and Classification of the Disease;
- Electromyographic evaluation of the biceps muscle at rest, during maximal voluntary contraction, and during isotonic contraction, twice with a two-minute interval;
- Ultrasound imaging assessment of the biceps brachii at rest and during maximum voluntary contraction twice for each clinical condition;
- Application of therapeutic ultrasound to the biceps for ten minutes.

The same pre- and post-intervention assessments were performed.

2.3.2. Staging and Classification of the disease

Participants who had suffered a stroke were also assessed for Staging using the Modified Rankin Scale, capable of assessing the individual's level of disability. and functional dependence, it allows for the evaluation of the individual's physical and non-physical aspects, in addition It exhibits good inter- and intra-rater reliability (WILSON *et* al., 2002).

2.3.3. Surface Electromyography - Collection of Muscle Activity

The electromyograph model 804C, manufactured by EMG *System* of Brazil, was used. Portable equipment with eight channels, four of which were dedicated to signal reception. Electromyographic (EMG) devices, compatible with active and passive electrodes, and four auxiliary channels. The system features a high-performance data acquisition module, accompanied by software. proprietary device intended for the control, storage, processing, and analysis of the collected signals.

The equipment connectors feature ±12V DC outputs with Current capacity up to ±100 mA. The device has a high mode rejection rate. Common frequency response (CMRR) of 112 dB @ 60 Hz, input impedance of 10¹ÿ Ohms/6 pF for electrodes passive and input bias current of ±2 nA for active electrodes. Additionally, The equipment features surge protection and low-pass filters with a frequency range. Adjustable between 5 Hz and 5 kHz, ensuring the minimization of interference and noise in the signals. acquired.

Simple differential active electrodes, consisting of two contacts, were used. made of silver with dimensions of 10.0 x 1.0 mm and spacing of 10.0 mm between them, fixed in Resin encapsulation measuring 40 x 20 x 5 mm, ensuring stability and precision in detection of electromyographic signals.

To prepare the participants before undergoing the electromyographic assessment, it was The skin was disinfected using a 70% alcohol solution in order to remove impurities. oiliness and possible residues that could compromise electrical conductivity and adhesion of electrodes. When necessary, trichotomy (hair removal) was performed in the application area.

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of the electrodes with a disposable razor, in order to ensure better contact between the The electrode and the skin surface optimize the quality of the electromyographic signal. Two active electrodes. differentials were positioned over the muscle belly of the biceps brachii muscle, respecting longitudinal alignment with the muscle fibers.

The fixation was performed on the anterior portion of the arm, approximately in the proximal two-thirds. of the segment between the acromion process of the scapula and the cubital fossa, in accordance with the Standardized guidelines from the *Surface Electromyography for the Non-Invasive Assessment of* project *Muscles* (SENIAM). The reference electrode was positioned over a bony prominence, preferably in the ulnar styloid process, in order to minimize interference. electromagnetic interference and artifacts during signal acquisition, as suggested by Singla *et al.* (2018).

The clinical conditions used in this study were: resting in a seated position. Maximum voluntary contraction in a seated position through elbow flexion and movement. Active isotonic elbow flexion and extension. All clinical conditions were performed twice. Repeat for 5 seconds each time, respecting a 2-minute interval between each repetition.

2.3.4. Ultrasound Imaging – Muscle Thickness Measurement

For measuring muscle thickness, a portable Doppler ultrasound device was used. The Youkey Soloscan P50, weighing 160g and measuring 150mm x 40mm x 25mm, connects via Wi-Fi and Equipped with a high-frequency linear probe (model L11-4Ks), ideal for examinations. musculoskeletal. The ultrasound images were collected in a quiet environment with pleasant temperature (20-25°) and reduced lighting for better visibility of equipment. The assessment was performed on the biceps brachii muscle bilaterally, under the conditions of rest and maximum voluntary contraction, while the participant remained seated. Comfortable with the upper limb in slight abduction and lateral shoulder rotation. All collections The data were collected by the same examiner through two measurements for each muscle. assessed under two previously established clinical conditions, with a two-minute interval. between each measurement. The transducer was positioned transversely over the described motor points. using the SENIAM protocol, the image was applied to the skin so that the resulting image could demonstrate the thickness. muscular of the central portion of the biceps brachii (GAO, J. *et* al., 2018).

2.3.5. Therapeutic intervention

For the procedure, the Sonopulse III Therapeutic Ultrasound device was used. (Ibramed, Amparo/SP, Brazil). The volunteers received a session of therapeutic ultrasound. continuous movement with the device directed at the belly of the biceps brachii muscle. The protocol used the the following parameters: frequency of 1 MHz, in continuous mode and with an intensity of 0.8 W/cm², 4 ERAs lasted for 10 minutes. The application was performed only once. Participants remained

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in a comfortable position, with the arm slightly abducted and laterally rotated for better exposure of target muscle. (SANTOS; COSTA; ABREU, 2023).

2.4 Data Analysis

The electromyographic data were processed with offset removal and filter application. Butterworth and the data were normalized by the maximum voluntary contraction of the individuals. Muscle thickness values were tabulated directly from the average of the two repetitions of each clinical condition. The final data were subjected to statistical analysis using the software. SPSS version 21.0 (SPSS Inc.; Chicago, IL, USA). The results were obtained through analysis. descriptive (means, standard deviations, maximum value, and minimum value) for each variable. The values They were compared using the non-parametric Wilcoxon test (p<0.05).

3. Results and Discussion

Seven participants underwent the intervention, five of whom had been diagnosed with stroke and Two diagnosed with TBI had a mean age of 49 ± 12 years and a mean weight of 89 kg ± 15,19. These data are described below in Table 1.

Table 1 – Presentation of participants undergoing interventions based on age, gender, weight (Kg), height (m), Body Mass Index (BMI), underlying disease, neurological pattern, stroke classification (according to the Modified Rankin Scale), and dominant limb.

Age, Gender, Weight			Height the	IM W	Standard Disease		Classification of disease member	dominant
57 M 94			1.69	32, 91	stroke	Right spastic hemiparesis	3	Right
42 M 69			1.77	22, 02	stroke	left spastic hemiplegia	4	Right
58 M 92			1.70	31, 83	stroke	left spastic hemiplegia	4	Right
32	F	84	1.63	31, 62	TCE	spastic diplegia (MMII)	-	Right
60	F	75	1.68	26, 57	stroke	left spastic hemiplegia	4	Right
29 M 120			1.80	37, 04	TCE	Right spastic hemiparesis	-	Right
61	F	90	1.58	36, 05	stroke	Left spastic hemiparesis	3	Right

In the assessment of muscle activity, a decrease in tone was observed. muscular in all clinical conditions and muscles evaluated (table 2). The values are

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statistically significant for the right isotonic clinical condition (p>0.05).

In terms of muscle thickness, an increase in muscle thickness was observed for all... Clinical conditions, except for left-sided rest (Table 3). The values are statistically... significant for the clinical condition of maximum left voluntary contraction (p>0.05).

Table 2 – Comparison of normalized values of muscle activity (µV) pre- and post-intervention based on means, standard deviation, and significance values for the clinical conditions: Right rest, left rest, right isotonic, and left isotonic (Wilcoxon test, pÿ0.05).

Condition Period Clinical	of	Average	Standard Deviation	Value P
Rest Right	Pre- intervention		±0.04	0.49ns
	evaluation 0.5 Post-		±0.07	
Rest Left	intervention 0.07 Pre-		±0.17	0.73ns
	intervention 0.15 Post-		±0.18	
Isotonic Right	intervention 0.14 Pre-intervention	1.12	±1.07	0.01*
	Post-intervention 0.35		±0.26	
Isotonic Left	Pre-intervention 1.18		±1.95	1.00ns
	Post-intervention 0.58 -		±0.25	

* statistically significant values (pÿ0.05) ns - non-significant values (pÿ0.05)

Table 3 – Comparison of muscle thickness values (cm) pre- and post-intervention based on means, standard deviation, and significance values for the clinical conditions: Right and left resting position, right and left maximal voluntary contraction. (Wilcoxon test, pÿ0.05).

Condition Period Clinical	of	Average	Standard Deviation	Value P
Rest Right	Pre- intervention **assessment** 1.74		±0.37	0.61ns
	Post-intervention assessment		±0.31	
Rest Left	1.79 Pre-intervention		±0.20	0.73ns
	assessment 1.44 Post-intervention assessment 1.31		±0.60	
Contraction Volunteer Maximum Right	Pre-intervention 2.85		±0.50	0.06ns
	Post-intervention 3.39		±0.36	
Contraction Volunteer Maximum Left	Pre-intervention 2.38		±0.80	0.02*
	Post-intervention the	2.66	±0.77	

* - statistically significant values (pÿ0.05) ns - non-significant values (pÿ0.05)

Spasticity triggers myotatic reflex manifestations that result in stretching. muscular and, consequently, resistant to passive movement, compromising the activity of The daily lives of individuals with this type of neurological disorder are affected, and assessing this pattern is essential for the clinical monitoring of the individual (MINISTRY OF HEALTH, 2022).

In this sense, this study used tools that are considered the gold standard for analysis. muscular imaging, such as electromyography, which stands out for capturing muscle electrical activity, allowing

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to measure motor unit recruitment and assess muscle tone. Ultrasound imaging, on the other hand, In turn, it allows for the analysis of muscle morphology through the cross-sectional area. (HE *et.* al., 2023; MARTINEZ *et.* al., 2014).

In this study, therapeutic ultrasound was used as a tool to control the muscle tone of the participants, since its thermal effects reduce hyperexcitability of the Alpha motor neurons. The equipment emits waves in a frequency range inaudible to the ear. human, decreasing parameters such as the H-reflex (Mmax/Hmax ratio) and producing the effect "antispastic" as described by Monaghan *et al.* (2017). The following parameters were adopted Application: intensity of 1.0 W/cm², frequency of 1 MHz, continuous mode, for 10 minutes. as per the protocol described by Santos; Costa; Abreu (2013). However, in one of the participants, This intensity caused pain, leading to the interruption of the intervention. After reducing it to 0.8 W/cm², No painful episodes were reported. We believe that the intensity of 1.0 W/cm² generated Intense stimuli in the motor units triggered this episode, which generated the need. a procedural restructuring of this study.

These clinical findings regarding the need for a reduction in therapeutic doses are already a current literature trend, as observed in the study by Santana-Rodrigues *et al.* (2019), which They used therapeutic ultrasound with an intensity of 0.5 W/cm² in a clinical trial aimed at Tissue stimulation was used, and significant improvements in functional outcomes and pain control were noted. when compared to higher doses. Similarly, Korelo and Silva (2020) used the therapy combined with ultrasound at 0.5 W/cm² and transcutaneous electrical nerve stimulation, obtaining results Positive aspects in pain control and functional improvement in the postoperative period of cesarean section. Regarding the topic... As proposed in this study, there are few studies on therapeutic dose control in humans for control of spasticity, highlighting the relevance of this study.

Regarding the evaluation of the acute effects of therapeutic ultrasound in people with In the case of biceps brachii spasticity, the overall analysis of muscle activity showed... decreased muscle electrical activity in all clinical conditions and muscles evaluated, after the application of therapeutic ultrasound, being statistically significant for the clinical condition in Right isotonicity. These findings corroborate Blackmore *et al.* (2019), who report a reduction. of muscle electrical activity, fiber recruitment, and neuromuscular excitability after Application of therapeutic ultrasound at low intensities.

Another important factor is related to the fact that the findings of this study demonstrate that the increase in tone is caused by an excitability of the motor units, which corroborates with the results of Xie *et al.* (2024), who identified greater electromyographic activity of the biceps brachial region compared to healthy individuals, indicating increased excitability of the motor units. Similar trends are also observed in the study by Silva *et al.* (2012)

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evidencing the increased electromyographic activity of the biceps brachii, suggesting greater recruitment of these hyperexcitable motor units typical of spasticity.

Therefore, it is believed that therapeutic ultrasound is capable of reducing spasticity, because Ultrasonic waves generate micro-vibrations and pressure variations that alter the cell membrane. and the local action potential, resulting in a decrease in associated muscle activity. to muscle relaxation and decreased tone. These effects suggest that ultrasound acts as a modulator of neuromuscular function, capable of decreasing excitability and promoting relaxation, It is useful in cases of hypertonia, spasms, or muscle pain. The result depends on the parameters. applied, such as mode, intensity, and exposure time as described by Blackmore *et al.* (2019).

This study also showed an increase in muscle thickness for all the clinical conditions after the application of therapeutic ultrasound, except for left-sided rest, being statistically significant for the clinical condition of maximum left voluntary contraction. These The findings corroborate those of Kamble *et al.* (2024), who investigated the effect of dry needling on muscle. Spastic soleus muscle and a significant increase in muscle thickness was observed after the intervention. accompanied by a reduction in spasticity. The authors attributed this result to the release of areas intramuscular stiffness and the consequent relaxation of the fibers, allowing the muscle to... returned to its physiological length and volume. They also corroborate with Hong *et al.* (2018) who observed that individuals with spasticity exhibit a reduction in muscle thickness and length of the medial gastrocnemius fascicles compared to the unaffected side, indicating spasticity is associated with shortening of muscle fibers and increased tissue stiffness, which results with less muscle thickness.

Thus, this study focuses on the application of therapeutic ultrasound. which was able to generate significant clinical effects even with a reduced energy dose, which It proves to be positive from a therapeutic point of view. The application with reduced intensity compared to literary trends (SAHIN; UGURLU; KARAHAN, 2011; GÜN; KARABOCE; YURDALAN, 2022) promoted favorable responses, such as a decrease in spasticity and the Increased muscle thickness without causing discomfort or adverse effects. This observation reinforces the importance of individualizing the dose, since lower intensities can maintain the physiological effectiveness while simultaneously reducing the risk of excessive thermal effects and injuries. Tissue. Previous studies corroborate this evidence, indicating that ultrasound protocols Continuous low-intensity exercises are capable of stimulating muscle regeneration and modulating activity. neuromuscular and promote the tissue repair process safely and effectively (BAKER *et al.,* 2001; ROMERO-MÉNDEZ *et* al., 2021). Thus, the present study contributes to the Consolidation of safer and more efficient therapeutic approaches that prioritize clinical response.

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with the lowest possible level of energy exposure.

This study was limited by its small number of participants, however When conducting a clinical study, the difficulty in recruiting patients is well known, since in The vast majority of them present with heterogeneous clinical conditions. Another important fact that limited This study was the number of studies on this topic.

Final Considerations

Therapeutic ultrasound applied acutely was able to significantly alter the Muscle tone in individuals with neurological disorders, as observed in electromyography by Right isotonic condition and ultrasound imaging under maximum voluntary contraction condition. left. Observing a clinical trend of spasticity control, seen by the decrease in Muscle tone and increased muscle thickness due to muscle tone.

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