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Original Article

Electromyographic analysis of constraint-induced movement therapy effects in patients after stroke in chronic course

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Abstract. [Purpose] The purpose is to analyze the effects of Constraint-induced Movement Therapy in post stroke patients in chronic course. [Subjects and Methods] This is a Quasi-experiment study and the adopted protocol consisted of a three-hour therapy for ten consecutive working days applied to a constraint intact upper limb. Surface Electromyography, Motor Activity Log, Wolf Motor Function Test and Functional Independence Measure were used for evaluating the experiment. [Results] The individuals showed reduction in the degree of spasticity, confirmed by Surface Electromyography. In relation to Motor Activity Log this study showed an increase in amount and in quality of the paretic upper limb movement. The Wolf Motor Function Test showed reduction in the average time to perform the tasks and a functional improvement was identified through the Functional Independence Measure. [Conclusion] Constraint Induced Movement Therapy proved to be a relevant method to improve motor function in chronic hemiparesis post stroke reducing the spasticity, maximizing and improving the use of committed upper limb.

Key words: Stroke, Constraint-induced Movement Therapy, Surface electromyography

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INTRODUCTION

Stroke has become a serious and common disease that interferes directly in the quality of life, representing one of the leading causes of death and disability worldwide. Findings from the Global Burden of Disease Study estimated 16.9 million cases and 5.9 million deaths related to the disease[1)].

Clinical after effects appear according to the brain injured focal areas. The classic signal is hemiparesis[2)]. Hemiparesis and spasticity arise chronically and lead to an increased muscle toning. In case of stroke there is a preference of this spasticity for the flexor muscles of the upper and extensor members of the lower limbs. Unless such conditions undermine mobility, coordination and performance in motor activities of the stricken members[3)].

After an injury of the central nervous system (CNS) the individual ceases to use the affected extremity neglecting his/her paretic limb. Such effect is called *"learned non-use"* when the patient is unable to use the paretic member and he or she shall restrict it in his-her movements, with loss of sensory-motor memory[4)]. Nevertheless, the CNS has the ability to respond to injury with a variety of morphological reparative processes. Therefore, training and attention dedicated to motor gestures are recognized and contribute to cortical plasticity[5)].

Being so, Constraint-induced Movement Therapy (CIMT) is highlighted among the possible treatments. The CIMT is a treatment that follows a behavioral approach to neurorehabilitation and derives from basic neuroscience, in order to promote

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functional improvement of people's upper limb with an asymmetrical use. The CIMT emphasizes the positive reinforcement of actions for the improvement of the members functioning through a cortical reorganization dependent use[3, 6)].

Recent researches has shown great efficacy of CIMT regarding the quality of movement and amount of movement of the paretic upper limb[2, 7)]. However, its effect on spasticity still needs more evidence[8)].

Muscle hypertonia has been linked to changes in the electrical activity measured by surface electromyography in patients with stroke. Since the 70s, the literature presents studies about electromyography exams to evaluate the rehabilitation of patients with neurological aftereffects mainly in patients with brain vascular disease[9)].

The CIMT calls attention to being an innovative therapy in upper limb rehabilitation, as it depends on a specific protocol[6)]. However, change this functional recovery into evidence for new treatment approaches is challenging for academic and practitioners. By quantifying such results, as an additional procedure to the CIMT evaluation model, the surface electromyography becomes a relevant tool as it determines the recruitment and learning gains of the motor units investigated during the protocol[9)].

In this study we sought to analyze the effects of Constraint-induced Movement Therapy taking into account the potential myoelectric behavior in patients with abnormal muscle toning after stroke in chronic course.

SUBJECTS AND METHODS

This Quasi-experiment study was conducted at the Physiotherapy Clinical School of the Community College in Santo Angelo, IESA, located in the city of Santo Angelo, Rio Grande do Sul State, Brazil. Is has been approved by the College Research Ethics Committee under the process number 45293315.4.0000.5571.

The invited individuals were people who suffered strokes and already attended physical therapy at the Clinical School of Physiotherapy IESA, Santo Ângelo.

Patients aged from 40 to 85 years were included; both genders, diagnosed with ischemic and/or hemorrhagic stroke, with a minimal period of 180 days of occurrence and Ashworth Scale Modified until grade 2. Hemiparesis of the upper limb presenting active movement of at least 45° of shoulder's flexion and abduction, 20° elbow extension, 10° wrist extension, 10° of abduction/extension of the thumb and at least 10° extension of two fingers beside the thumb[10)].

Patients who had excessive pain in the affected arm were excluded from the study; drug administration interfering in neuromuscular performance; considerable visual and hearing impairment; severe cognitive impairment; seizures; uncontrolled hypertension; multiple brain lesions.

The interview was initiated by analyzing the Motor Activity Log (MAL), a specific instrument for the evaluation of the functioning of the most affected upper limb by the hemiparesis. The MAL-Quality of Movement (QOM) and the Amount of Movement (AOM) allow for the patient to score himself/herself (0–5) considering the movements use and quality of the paretic upper limb in thirty day-to-day activities as indicated[11)].

Then, the implementation of the Functional Independence Measure (FIM) was carried out. The FIM was organized following patient classification on his/her ability to perform an activity and the need for assistance from another person or from additional adjustments. The categories were established as follows: personal care, sphincter control mobility/transfers, moving, communication and social cognition[12)].

Then the Wolf Motor Function Test (WMFT) was also applied. The WMFT enables the achievement of effective upper limb task speed comprising seventeen specific tasks. Among these seventeen tasks, two are classified as measures of force. In this study, the force items were not included, i.e., fifteen tasks were evaluated. One hundred and twenty seconds is the maximum time allowed for the performing of each task. Patients were instructed to perform these tasks as quickly as they could[4)].

Myoelectric signals were acquired by using a USB Surface Electromyograph brand Miotool with 14-bit resolution, noise <2 LSB, security isolation 5,000 V (rms) power supply NiMH batteries, approximate weight of 470 g. The electromyographic signal was picked up by surface electrodes (Electrode Meditrace 100-AG / AgCl −Solid Gel −hydrogel adhesive and conductor).

The muscle choice for the experiment was not random. The biceps brachii is very often affected by spasticity. One of its features is to increase muscle stretch resistance contributing to the pattern of the upper limb flexor[13)]. Additionally, the surface electromyography has some limitations as it fails to detect signals from deep muscles or small muscles. Therefore the biceps muscle can be easily activated and, anatomically, it is located in a good position for the electrodes to be well attached[14)].

The test patients were lying in supine position (lying on their backs) with both upper limbs placed next to the body with the palm of the hands facing up. The head was in a neutral position the knees were half-bent. The skin hygiene was performed using a swab with alcohol to remove the surface layer of dead cells and sebum before attaching the electrodes.

The electromyographic signal was picked up by surface electrodes placed on the muscle belly of the biceps of the paretic limb, according to the SENIAM protocol (EMG Surface for the Non-Invasive Assessment of Muscles). Active filters were used for signal acquisition: High Pass 20 Hz and 500 Hz Low Pass Notch: 60 Hz maximum input voltage gain to 2,000 Hz.

The raw signals were collected from the muscle belly of the biceps for 30 seconds when it was relaxed and also for five elbow flexion movements (activation of the biceps muscle).

The applied protocol CIMT consisted of three elements: (1) use of restriction glove in the unaffected limb for about 90%

of the daily period when the patient was awake, encouraging the patient to use the paretic limb; (2) upper limb training paretic through tasks repeated for three hours every day using the method of training practice Shaping-adapted tasks for 10 consecutive working days; (3) list of tasks performed at home, as well as notes in a journal in order to monitor adherence to treatment and encouragement to use the affected limb in daily life activities[15].

For each patient ten tasks of the Bank Shaping were chosen, divided into two groups of five tasks each. The two groups were managed on alternate days. For each task ten repetitions were performed. In addition, the difficulty of the task was increased progressively. The tasks were selected according to the individual motor capacity. They consisted of motor training tasks and functional activities[16].

The analysis and data processing were performed with the *Statistical Package for the Social Sciences* (SPSS) version 20.0 (SPSS Inc., Chicago, USA), considered significant when $p<0.05$. (p smaller than 0.005).

Categorical variables such as the Motor Activity Log (MAL) were presented as mean and absolute frequencies pre and post intervention. Continuous variables as the Wolf Motor Function Test (WMFT), Functional Independence Measure (FIM) were presented as mean and absolute value pre and post-intervention. The electromyographic signal was measured by peak contraction, average frequency. Baseline data: normalization by peaks, data from RMS (Root Mean Square) were analyzed by using the Student's t test with two-tailed distribution with equal variance of the two samples and normality test Kolmogorov-Smirnov.

The significance level was 0.05 two-tailed.

RESULTS

The results in Table 1 describes the data based on the features of 5 patients selected for the study.

In the Table 2 shows the measures of electromyographic capture of the biceps brachii muscle, before and after CIMT. By comparing the patients data we found that during the resting period (microvolts) they showed a reduction of post-intervention potential action (%) and such effect favors the reduction in the degree of spasticity.

Table 1. Sample features

Cases	Gender	Age (years)	Diagnosis	Time since the stroke (months)	Affected side
I	F	63	I	84	Left
II	M	66	I	168	Right
III	F	77	I/H	192	Left
IV	F	43	H	12	Left
V	M	84	I	96	Left

F: Female; M: Male; I: Ischemic stroke; H: Hemorrhagic stroke

Table 2. Measures of electromyographic capture (microvolts) of the biceps muscle, before and after CIMT

Relaxed biceps brachii

Cases	Relaxed before	Relaxed after	% Reduced signal microvolts
I	2.81 μV	1.37 μV	51%
II	2.64 μV	1.35 μV	48%
III	25.22 μV	15.73 μV	38%
IV	14.76 μV	4.03 μV	73%
V	23.88 μV	17.91 μV	25%

Contraction of the biceps brachii

Cases	before			after		p
I	59.43	± 4.80	*	65.33	± 10.08	*
II	12.16	± 1.50	*	28.90	± 5.86	*
III	19.95	± 1.62	*	24.80	± 1.28	*
IV	17.12	± 6.63	*	26.02	± 6.83	*
V	56.25	± 2.21	*	54.68	± 14.25	*

Level of significance. *p<0.05.
Mean ± SD

For the peak contraction (microvolts), we observed, except for the V patient, an increase in the potential for post-intervention action. It is more inclined to a motor learning (higher fiber recruitment) to the movement during activation of the biceps brachii muscle.

Figures 1 and 2 show the results from the Motor Activity Log (MAL).

There was a substantial improvement in MAL performance in Quantity of Movement (AOU) Scale and also in the Quality of Movement (QOM) Scale of the upper limb. Regarding the amount of movement, mean scores started with a motor disuse (0.45) for a use of about half of the arm as used before the injury (2.8). The Quality of Movement started from disuse (0.40) to an average score of slow movement or difficult (2.3)[11].

Figure 3 shows the results from the Wolf Motor Function Test (WMFT). The time used to perform the tasks reduced on average 4.62 sec ± 3.27 comparing to pre-evaluation. It shows a higher speed in the use of the affected upper limb.

Figure 4 corresponds to the score in the Functional Independence Measure Scale (FIM). This evaluation was designed to measure the level of independence of patients in this study, whose results showed an increase in functionality after CIMT.

DISCUSSION

In order to understand the CIMT operating mechanism in the spasticity it is important to highlight that after upper motor neuron injury there can be losses in the activation of muscle motor units (motor neurons), resulting in changes in the muscle recruitment and in the frequency of action potentials, triggering changes in the intrinsic properties of the neuromuscular plate[17].

As a result, spasticity expresses itself from an involuntary increase in the potential of the trigger action by a loss of inhibitory control that the motor cortex has on the spinal cord through the corticospinal tract. What provides an increase in the excitability of motoneurons[18]. At the same time, excessive inhibition of the injured hemisphere by the uninjured hemisphere also plays a role in the development of spaticity[19].

Therefore, it is common to expect a disuse of motor units of high threshold of excitement and an increased use of motor units of low threshold. In other words, motor units fatigable slow twitch can be originated from motor units quickly fatigable contraction[20].

In our research post CIMT protocol, through surface electromyography, we found that there was a reduction of spasticity in the biceps brachii muscle, due mainly to neuromotor rehabilitation as a result of intensive and repetitive tasks applied during the experiment which led to a remodeling in sensory nerve conduction and motor attenuating muscle toning during the relaxing period.

In relation to muscle contraction, an increase in the excitation threshold of muscle fibers has occurred, specially where more motor units were activated favoring a greater recruitment of the muscle. According to Kagawa et al.[3], the exception is the Surface Electromyography, a sensitive and reliable instrument for the assessment of spastic muscles.

Even Kagawa et al.[3] sought to analyze the effects of CIMT on spasticity in patients with chronic hemiparesis post stroke. He submitted ten patients to a modified protocol of CIMT (5 hours daily/10 days), which captured the electromyographic

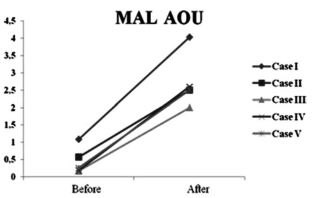

Fig. 1. Motor Activity Log (MAL) Quantity of Movement (AOU) Scale
Level of significance *p=0.001.

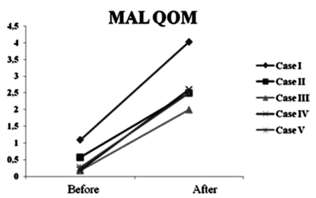

Fig. 2. Motor Activity Log (MAL) Quality of Movement (QOM) Scale
Level of significance *p=0.005.

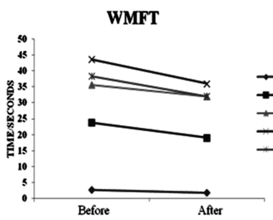

Fig. 3. Wolf Motor Function Test (WMFT)
Level of significance *p=0.018.

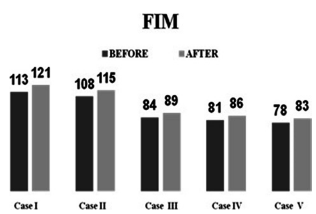

Fig. 4. Functional Independence Measure Scale (FIM)

signal of the abductor short muscle thumb. He found a reduction of spasticity post therapy.

However, a few studies have evaluated the effects of CIMT on the upper extremity spasticity affected using the Modified Ashworth Scale. In one study reduced spasticity in the flexor of the elbow and wrist after CIMT was found. The experiment consisted of six-hour training for ten consecutive days administered in twenty patients with hemiparesis[21)]. Another study reported spasticity involving shoulder, elbow and wrist muscles of the paretic upper limb in eleven post stroke patients in chronic course. The spasticity decreased after CIMT treatment for 3 hours daily for 20 days[22)]. However, modified Ashworth Scale is an ordinal scale that may not be sufficiently sensitive to spasticity changes[23)].

The increase of about two points on the scale of the Quality of Movement (QOM) and Amount of Movement (AOM) of MAL are comparable to published results of the multicenter project EXCITE (Extremity Constraint-Induced Therapy Evaluation)[7)]. They are also comparable to the results found by Morris et al.[24)] whose study states that the engine gains from the therapy are transferred to the patient's day-to-day remaining post protocol.

The traditional view in the field of rehabilitation is that patients reach a plateau in their motor recovery especially from six months to one year after the stroke[25)]. The patients of our research, however, showed an improvement in the use and quality in the movement of the paretic upper limb according to revaluation of the MAL suggesting that the injury time does not restrict satisfactory results of therapy.

Just as Miltner et al.[26)] in his study involving 15 patients after stroke, with an average of 5 years of chronicity, and of these, four patients registered nine years of injury, he found the following results: regarding MAL in QOM the mean scores increased from 1.7 (rare use of the arm) to 3.7 (use of the arm almost as much as before the injury) after CIMT, the MAL in AOM scores average increased from 1.7 (poor movement) to 2.7 (almost regular movement).

It is known that the alteration of muscle tone of these patients can lead to phenotypic changes, and these changes are consistent with intrinsic stiffness of muscle fibers. It changes the number and length of sarcomeres and leads to muscle contractures[18)]. However, WMFT data reflect a greater agility and ease of use of the paretic upper limb post CIMT[7)].

Assis et al.[27)] published the results of an experiment of 17 patients after stroke, with a mean age of 58 years and injury period of 3 years and 5 months. Patients were then submitted to CIMT protocol of daily 6 hours for 10 days. The experiment showed a mean reduction of 17 seconds in WMFT time, which is a much higher score compared with patients in our research. One explanation for this discrepancy may be the functional level of the participants and also the difference of the applied protocol.

However Taub et al.'s[28)] research compared an experimental group, which held CIMT protocol (6 hours daily for 10 days) with a placebo group, which received a physical, cognitive conditioning program and relaxation exercises for the same period of time. He found an average increase of 0.5 seconds in the performance of tasks WMFT with the placebo group, and an average reduction of 2.3 seconds from the group that received CIMT. The WMFT and MAL methods are considered primary measures of the CIMT outcomes[7)]. Taub et al.[28)] also demonstrated that the group that performed the CIMT method presented greater improvements in MAL scale of QOM and AOM.

Though, in our study, the increase in the score of the FIM came to add to the positive effects presented by CIMT. This indicator reinforces the importance of intensive care and the importance of the technique for rehabilitation of chronic hemiparesis people. Therefore, reduction of spasticity might be the key to functional improvement of the patients.

In a study involving chronic patients after stroke, Linn et al.[29)] compared a modified CIMT protocol (2 hours/three weeks) with conventional physiotherapy. Functional outcomes were assessed using the FIM and they showed that the group submitted to the modified CIMT showed substantial improvement on the FIM score (measure). Similarly, Wu et al.[30)] also compared the modified protocol CIMT (2 hours/three weeks) with conventional therapy; findings on modified CIMT patients provided higher earnings based on the FIM score. Therefore, it is attributed to the CIMT the functional improvement of the paretic upper limb, despite the variable compared protocols. Functional performance scale of the QOM and AOM of MAL were significantly improved in both studies[29, 30)].

Considering the favorable effects presented by the participants of this study, we point out that there has been an overcome disuse engine installed, one of the reasons for the success of the therapy[5)]. Thus, we believe that CIMT provides an increase to conventional physical therapy, as a method employed by proprioceptive encouragement. It stimulates the cortical pathways to send efferent impulses to the affected limb. That results in a sensory and motor input, consequently generating an interpretation system while leading to sensory and motor recovery[7)].

The small sample size corresponds to the limitation of the study.

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