REVISTA NEUROCIÊNCIAS

Original

Effect of trunk and upper limb retention on the motor function after stroke: randomized clinical-trial pilot study

Efeito da retenção de tronco e membros superiores na função motora após acidente vascular cerebral: estudo piloto de ensaio clínico randomizado

Efecto de la retención del tronco y las extremidades superiores sobre la función motora después de un accidente cerebrovascular: un estudio piloto de ensayo clínico aleatorizado

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Resumo

Objetivo. As compensações do tronco não permitem que o membro superior utilize todo o seu potencial para realizar atividades funcionais. Portanto, o objetivo deste estudo foi analisar os efeitos da terapia de retenção e indução de movimento (TRIM) com estabilização de tronco e membros superiores em pacientes hemiparéticos após acidente vascular cerebral. **Método.** Estudo piloto clínico com 18 indivíduos com sequelas de acidente vascular cerebral que foram distribuídos aleatoriamente em um de três grupos: grupo controle (GC), grupo experimental TRIM sem restrição de tronco (GET) e grupo experimental TRIM com restrição de tronco (GETT). Os grupos GET e GETT foram submetidos à terapia TRIM baseada no protocolo *Shaping* por dez sessões consecutivas, com duração de 1 hora cada, durante 2 semanas. Para avaliação, foi utilizada a Escala de Avaliação da Função Sensório-Motora (FAS) de Fugl-Meyer, o Inventário de Atividade dos Extremidades Superiores (MAL), a eletromiografia de superfície (EMG) dos flexores do cotovelo, extensores e flexores superficiais do punho, bem como medidas goniométricas do membro superior. **Resultados.** Foram observadas diferenças significantes ao longo do tempo nos grupos GET e GETT para os escores totais das escalas FAS e MAL, bem como na amplitude de movimento para flexão de ombro ($p<0,05$). Não foram encontradas diferenças significantes para as variáveis EMG. **Conclusão.** O TRIM combinado com a estabilização do tronco não apresentou efeitos significativos nas atividades funcionais, sensório-motoras ou nas variáveis EMG e amplitude de movimento quando comparados diferentes grupos.

Unitermos. Acidente vascular cerebral; reabilitação; função; hemiparesia

Abstract

Objective. Trunk compensations do not allow the upper limb to use its full potential to perform functional activities. Therefore, the objective of this study was analyzing the effects of movement retention and induction therapy (TRIM) with trunk and upper limb stabilization in

hemiparetic patients following a stroke. **Method.** This was a clinical pilot study with 18 individuals with sequelae from a stroke were randomly assigned to one of three groups: a control group (CG), an experimental TRIM group without trunk restriction (GET), and an experimental TRIM group with trunk restriction (GETT). The GET and GETT groups underwent TRIM therapy based on the Shaping protocol for ten consecutive sessions, lasting 1h each, over 2 weeks. Fugl-Meyer Sensory-Motor Function Assessment Scale (FAS), the Upper Extremity Activity Inventory (MAL), surface electromyography (EMG) of the elbow flexors, extensors, and superficial wrist flexors, as well as goniometric measurements of the upper limb were utilized for evaluation. **Results.** Significant differences were observed over time in the GET and GETT groups for the total scores on the FAS and MAL scales, as well as in the range of motion for shoulder flexion ($p<0.05$). No significant differences were found for the EMG variables. **Conclusion.** TRIM combined with trunk stabilization did not exhibit any significant effects on functional, sensorimotor activities, or EMG and range of motion variables when comparing different groups.
Keywords. Stroke; rehabilitation; function; hemiparesis

Resumen

Objetivo. Las compensaciones del tronco no permiten que el miembro superior utilice todo su potencial para realizar actividades funcionales. Por lo tanto, el objetivo de este estudio fue analizar los efectos de la terapia de inducción y retención del movimiento (TRIM) con estabilización del tronco y las extremidades superiores en pacientes hemiparéticos después de un accidente cerebrovascular. **Método.** Estudio piloto clínico con 18 personas con secuelas de un accidente cerebrovascular fueron asignadas aleatoriamente a uno de tres grupos: un grupo de control (CG), un grupo TRIM experimental sin restricción del tronco (GET) y un grupo TRIM experimental con restricción del tronco (GETT). Los grupos GET y GETT se sometieron a terapia TRIM basada en el protocolo Shaping durante diez sesiones consecutivas, de 1 hora cada una, durante 2 semanas. Para evaluación, el estudio utilizó la Escala de Evaluación de la Función Sensorial-Motriz (FAS) de Fugl-Meyer, el Inventario de Actividad de las Extremidades Superiores (MAL), la electromiografía de superficie (EMG) de los flexores, extensores y flexores superficiales de la muñeca del codo, así como Mediciones goniométricas del miembro superior. **Resultados.** Se observaron diferencias significativas a lo largo del tiempo en los grupos GET y GETT para las puntuaciones totales en las escalas FAS y MAL, así como en el rango de movimiento para la flexión del hombro ($p<0,05$). No se encontraron diferencias significativas para las variables EMG. **Conclusión.** TRIM combinado con estabilización del tronco no mostró ningún efecto significativo sobre las actividades funcionales, sensoriomotoras o EMG y las variables de rango de movimiento al comparar diferentes grupos.
Palabras clave. Ictus; rehabilitación; función; hemiparesia

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INTRODUCTION

A cerebral vascular accident, also known as a stroke, refers to a neurological deficit, whether transient or permanent, resulting in a loss of function or even death[1]. This condition exerts a significant global impact on the healthcare landscape, ranking as one of the leading causes

of disability[2]. Remarkably, around 70% of individuals who experience a stroke fail to regain their daily functioning due to resulting complications, and nearly 50% become reliant on others for assistance[3]. Among the various functional challenges posed by stroke, hemiparesis stands out as the most prevalent, affecting approximately 80% of individuals during the acute phase and over 40% in the chronic phase[4]. This often results in the disuse of the affected upper limb, a factor that significantly impedes the recovery process[5].

One treatment approach is retention therapy and movement induction (TRIM), which focuses on motor learning through intensive training, stimulating cortical reorganization and promoting nervous system adaptation through neuroplasticity[2]. This technique has been employed to enhance the functionality of the affected upper limb. It involves the execution of repetitive motor activities while restraining the unaffected limb using a restraint device[6].

This therapy has proven effective in alleviating various impairments observed in this patient population[7-9]. While numerous studies highlight the efficacy of TRIM[7-9], research specifically examining the concurrent effects of trunk and limb stabilization remains scarce. Consequently, the primary objective of the current study was to assess the impact of applying TRIM with both trunk and upper limb stabilization in hemiparetic patients, focusing on motor function. The secondary objective was to evaluate the electrical muscle activity of the bicep's muscles, superficial wrist flexors/extensors, and the range of motion of the upper limb.

METHOD

Study Design

This study is a randomized clinical trial, specifically a pilot study. The research took place from February 2014 to February 2015. The study adhered to the ethical guidelines for clinical research involving human subjects, as outlined in Resolution 466/12 of the National Health Council. It received approval from the Research Ethics Committee at the Faculdade of Medical Sciences, Dr. José Antônio Garcia, under the reference number 534.979. After obtaining approval, participants were provided with comprehensive information regarding the study's objectives, methodological procedures, and potential risks before the evaluation commenced. Upon agreeing to participate, they formally signed the Consent Form.

Sample

The sample comprised patients diagnosed with stroke and exhibiting sequelae of hemiparesis with a predominant focus on the brachial region. Participants were recruited from two locations: the physiotherapy outpatient clinic at Hospital das Clínicas Samuel Líbano in Pouso Alegre-MG, Brazil, and Clínica Fisioterapêutica in Alfenas, MG, Brazil.

Inclusion Criteria

In this study, we included patients with chronic stroke sequelae characterized by hemiparesis primarily affecting the brachial region, aged between 40 and 86 years.

Additionally, participants had experienced their stroke more than 6 months prior, exhibited impaired motor function in the upper extremities (as assessed by the Fugl-Meyer sensorimotor function assessment scale (FM) with a score above 22)[10], possessed adequate visual and auditory acuity either with or without corrective measures, and underwent cognitive function assessment using the mini-mental state examination scale (with a score above 18 points for individuals with low to medium education, i.e., one to eight years of schooling)[11].

Exclusion Criteria

Individuals with bilateral hemiparesis resulting from stroke, head trauma, encephalitis, or other neurological conditions, whether of central or peripheral origin, were excluded from the study. Additionally, patients with severe cognitive deficits, language impairments (such as sensory aphasia), or those who had received botulinum toxin injections in the brachial biceps' muscles, wrist flexors, or extensors within the past three months were also excluded.

Procedure

The participants were divided into two groups: EGTT, which received TRIM along with trunk restriction; and EGT, which received TRIM without any restrictions on the trunk. Both groups underwent individual interventions five times a week, each session lasting 1h for a consecutive 2-week period.

In both EGT and EGTT, patients were required to wear a glove on their hand, which restricted the movement of their wrists and fingers on the unaffected limb during the therapy sessions. In the case of EGTT, trunk restraint was achieved using a figure-of-eight immobilizer on a chair with a backrest. This immobilizer was adjustable to accommodate the size of each individual's trunk and effectively prevented any trunk movements during the therapy sessions.

Throughout the entire therapy session, the patient remained seated in a chair equipped with a backrest but without arm support. The patient engaged in prescribed activities designed for the paretic upper limb, following the shaping protocol[12]. When the patient encountered significant difficulty in task execution, the therapist assisted.

The selection of activities was initially based on the patient's specific motor deficits. Initially, these activities were lighter and did not involve added degrees of difficulty. Subsequently, as qualitative improvements were observed in the patient's performance, various levels of progression were introduced for the activities. This progression included actions such as placing objects at greater distances, increasing object weights, and reducing object sizes.

The EGT group followed the same treatment protocol as the TRIM group, with the exception that they did not have trunk restrictions. Participants in both experimental groups were explicitly instructed to refrain from engaging in neurofunctional physiotherapy during the 2-week training period.

The CG did not undergo any intervention as part of the TRIM protocol; instead, they were directed to continue with neurofunctional physiotherapy throughout the two-week duration of their participation in the study. Blood pressure and heart rate measurements were taken both before and after the interventions.

Randomization

Following the sample selection, a blind researcher who was not involved in the evaluation and intervention phases conducted the randomization of volunteers. Simple randomization was employed in this study. A research assistant assigned numerical identifiers to the volunteers' names using a computer, placed these identifiers in sealed envelopes, and during the selection process, opened an envelope to randomly allocate the volunteers into one of three groups: the control group (CG), the TRIM experimental group without trunk restriction (EGT), and the TRIM experimental group associated with trunk restriction (EGTT).

Evaluation Instruments

The evaluation was conducted by two research assistants who were trained and blinded to the study's details, while the intervention was performed by another researcher who had received prior training. Clinical and demographic data, including age, gender, functional assessment, cognitive status, impaired motor function in the upper extremity and affected hemibody, shoulder, elbow,

wrist, and finger range of motion, muscle strength, and time since the stroke occurred, were collected.

Instruments For Primary Outcome

Fugl-Meyer Sensory-Motor Function Scale (FM)

The Fugl-Meyer Scale was employed to evaluate the sensorimotor function of the research participants. This scale was chosen for its user-friendliness and its capability to gauge motor recovery[10]. The Brazilian version utilized in the study demonstrated remarkable inter and intra-observer reliability with coefficients of 0.99 and 0.98, respectively[10,13].

The scale evaluates six aspects of the patient, including range of motion, pain, sensitivity, upper and lower extremity motor function, and balance, as well as coordination and speed, for a total of 226 points. Each item is scored on a three-point ordinal scale: 0 - cannot be performed, 1 - partially performed, and 2 - completely performed. In this study, the evaluation focused on upper extremity motor function, comprising a total of 66 points, range of passive movement with a total of 44 points, and sensitivity (both exteroceptive and proprioceptive), accounting for 12 points.

Upper Extremity Activity Inventory (MAL)

In the current study, the MAL was employed to assess the motor function and spontaneous utilization of the affected upper limb among the research participants. Specifically, the study utilized the 30-item version of MAL (MAL-30)[14]. The Brazilian adaptation of MAL utilized in this

research is noteworthy for its outstanding psychometric properties, boasting an impressive Intraclass Correlation Coefficient of 0.98 for both the quantity and quality scales of the MAL.

The MAL-30 comprises 30 questions designed to evaluate both the quantity and quality of movement in the affected upper limb. Each scale, whether quantitative or qualitative, allows for scores ranging from 0 to 5, resulting in a cumulative total of 300 points (150 for quality and 150 for quantity)[14].

Secondary Outcome Evaluation Instruments

Assessment of muscle electrical activity – surface electromyography

In the present study, Electromyography (EMG) was employed to detect electrical signals generated by muscle fibers. Surface EMG was chosen due to its non-invasive nature, posing no risks to the individuals involved[15].

The EMG signal was acquired using the EMG System do Brasil device (Model EMG-800C, São José dos Campos, São Paulo, Brazil), which features an analog/digital conversion board boasting 16-bit resolution. It incorporates an EMG amplifier with a total amplification gain of 2000×, a 20 to 500Hz bandpass filter, a 20× gain preamp, a shielded cable with end clips, and an exceptional common mode rejection exceeding 100dB. The software utilized for signal collection and analysis operates on a Windows platform, offering a sampling frequency of 2000Hz per channel. Furthermore, the

module demonstrates a common rejection of >100dB, preamplifier gains (cables) set at a 20x gain (utilizing a differential amplifier), and a configurable channel gain of 100 times. The system's impedance stands at 109 Ohms, with a signal-to-noise ratio of <3μV Root Mean Square (RMS). The device incorporates hardware filters, including a high-pass with a 20Hz cutoff frequency and a low-pass with a 500 Hz cutoff frequency, both implemented via a two-pole Butterworth analog filter.

To obtain the electromyographic records, volunteers were seated in a chair with a backrest and instructed to maintain their affected upper limb in a neutral shoulder position, with the elbow flexed at approximately 90º and the forearm in the supine position. Prior to electrode placement, the skin was cleaned with 70% alcohol and, if necessary, shaved. Subsequently, five unipolar electrodes were affixed to the skin. Specifically, two active electrodes were positioned in alignment with the biceps brachii muscle fibers, two active electrodes were placed over the superficial flexor muscle and wrist extensors, and a reference electrode was secured on the right lateral malleolus. The electrode placement and fixation adhered to the Seniam protocol[15].

The initial recording was conducted with the muscles in a resting state to assess for any potential interference. If no interference was detected, the subsequent recording was performed during maximal voluntary isometric contraction (MVIC). Volunteers executed the MVIC while seated, with instructions to simultaneously flex the elbow and wrist

against an elastic resistance applied to their affected hand. The researcher provided verbal commands to motivate and guide the contraction. Each recording comprised three repetitions, with each contraction lasting 5 s, and an interval of 1 min was observed between each repetition, adhering to the Seniam guidelines[16].

EMG signal processing

The EMG signal processing was conducted as follows: The data underwent processing using the EMG System do Brasil Ltda.® program, which employed a three-second "windowing" technique. This involved excluding the initial and final seconds and then determining the median frequency for each data collection to be used in the subsequent analysis. To normalize the electromyographic signal, the mean of the median frequency values from the three collections was computed[16].

Range of motion assessment (ROM)

To assess angular measurements, a Mundial Réguas® universal goniometer made of 100% acrylic and measuring 36 cm was employed. This goniometer featured a complete circle body spanning from 0 to 360 degrees. The evaluator analyzed the active range of motion, evaluating the following ranges of motion: shoulder extension, flexion, adduction, and abduction; elbow flexion and extension; wrist flexion and extension; and metacarpophalangeal flexion and extension[17].

Statistical Analysis

Descriptive statistics were utilized to characterize the sample with respect to clinical and anthropometric variables. The Shapiro-Wilk test was employed to assess data normality. One-way analysis of variance (ANOVA) was conducted to compare the clinical and demographic characteristics of each group. For the primary outcome variables, which included the Fugl-Meyer sensorimotor function assessment and the Upper Extremity Activity Inventory, as well as the secondary outcome variables of range of motion (ROM) and electromyography (EMG), repeated measures ANOVA tests were applied for both intra and intergroup comparisons.

All statistical analyses were carried out using the SPSS software program (version 20.0), and the chosen significance level was set at $p<0.05$.

RESULTS

Table 1 presents an overview of the clinical and sociodemographic characteristics of the study sample. It is important to highlight that a significant difference was observed in the muscle strength of the elbow flexors ($p=0.03$). However, for all other variables, there was no significant difference.

Table 2 provides detailed statistics for the primary outcome variables, including the mean, standard deviation, 95% confidence interval, sample power, effect size, and p-value. It is worth noting that significant differences were

observed within the groups for certain variables: FM total score – Fulg-Meyer for both the EGTT (p=0.00) and EGT (p=0.00) groups, MAL total score for the EGTT groups (p=0.00) and EGT (p=0.02), MAL frequency for the EGTT group (p=0.00), and MAL quality for both the EGTT (p=0.00) and EGT (p=0.01) groups. Most of the EGTT data exhibited high power and effect sizes, whereas for the EGT group, the power was high, and the effect size was low.

Table 1. Clinical and demographic data of the study groups.

Variable	CG	EGTT	EGT	P value
Sex (%)				
Feminine	16.7	50.0	33.3	0.52
Masculine	83.3	50.0	66.7	
Stroke time over six months (%)	100	100	100	-
Affected hemibody				
Right (%)	33.3	33.3	50.0	0.82
left (%)	66.7	66.7	50.0	
Age (years)	56.50±10.82	57.83±8.81	69.50±13.83	0.12
Mini-mental state examination scale	26.16±3.65	22.66±4.22	24.00±3,22	0.28
Motor function of the upper limb	45.00±17.43	39.50±10.59	42.50±17.10	0.82
Range of motion SF	110.83±43.86	95.83±40.79	97.50±65.85	0.85
	110.00±36.33	115.83±61.83	130.00±18.70	0.71
EF	32.50±21.85	35.00±20.49	44.16±21.31	0.61
	34.16±23.32	24.66±22.73	45.83±20.59	0.26
WF				
FF				
Força muscular				
SMF	3.16±0.40	3.16±0.40	3.33±0.51	0.76
FME	3.16±0.40	2.66±0.81	3.83±0.75	**0.03**
WFM	3.00±0.63	2.83±0.40	9.83±16.79	0.38
FFM	3.00±0.89	2.66±0.81	3.50±1.04	0.39

CG: Control Group; EGTT: TRIM experimental group associated with trunk restriction EGT: TRIM Experimental group without trunk restriction; SF: Shoulder Flexion, EF: Elbow flexion; WF: Wrist flexion; FF: fingers Flexion; SFM: Shoulder Flexor muscle, EFM: Elbow Flexor muscle; WFM: Wrist Flexor muscle; FFM: fingers Flexor muscle.

Table 2. Mean, standard deviation, 95% confidence interval, sample power, effect size and p value of upper limb motor function variables.

Variable	CG (n=6) Mean±standard deviation 95%CI			EGTT (n=6) Mean±standard deviation 95%CI						EGT (n=6) Mean±standard deviation 95%CI						
	Pre intervention	Pos intervention	P value intragroup	Pre intervention	Pos intervention	P value intra group	Mean intragroup difference 95%CI	Sample power	Effect size	Pre intervention	Pos intervention	P value intragru po	Mean intragroup difference 95%CI	Sample power	Effect size	P value intergroup
FM (total score)	91.50±24.86	96.50±20.88	0.06	83.16±16.01	94.33±13.07	**0.00**	11.16	0.95	0.75	87.33±23.54	96.00±21.90	**0.00**	8.66	0.95	0.38	0.90
	65.40 to 117.59	74.57 to 118.43		66.35 to 99.97	80.60 to 108.05		-16.52 to -5.81			62.62 to 112.04	73.00 to 118.99		-14.02 to -3.31			
MAL - Frequency (score)	71.66±35.30	76.00±40.99	0.45	62.66±23.80	88.50±12.64	**0.00**	25.83	0.96	1.25	63.50±54.42	72.50±47.00	0.12	-	-	-	0.53
	34.61 to 108.72	32.98 to 119.01		37.68 to 87.64	75.22 to 101.77		-37.73 to -13.92			6.38 to 120.61	23.17 to 121.82					
MAL - Quality (score)	47.83±25.79	52.50±25.82	0.36	38.83±21.70	61.50±14.69	**0.00**	22.66	0.96	1.18	30.66±22.52	44.00±27.77	**0.01**	13.33	0.95	0.52	0.93
	20.76 to 74.90	25.39 to 79.60		16.05 to 61.60	46.08 to 76.91		-33.35 to -11.97			7.02 to 54.30	14.84 to 73.15		-24.02 to -2.64			
MAL (total score)	119.50±60.29	128.50±62.99	0.31	101.50±44.63	150.00±26.71	**0.00**	48.50	0.96	1.24	94.16±72.84	116.50±71.15	**0.02**	22.33	0.95	0.30	0.79
	56.22 to 182.77	62.39 to 194.60		54.65 to 148.34	121.96 to 178.03		-67.07 to -29.92			17.71 to 170.61	41.82 to 191.17		-40.91 to -3.75			

CG: Control Group; EGTT: TRIM experimental group associated with trunk restriction EGT: TRIM Experimental group without trunk restriction; 95% CI: 95% confidence interval; FM: Fugl-Meyer Sensory-Motor Function Scale; MAL: Upper Extremity Activity Inventory.

Table 3 outlines the mean, standard deviation, 95% confidence interval, and p-value for the ROM of the affected upper limb in both study groups. It is important to highlight that a significant difference was observed when comparing pre-intervention and post-intervention measurements for shoulder flexion movement (p=0.01). The mean difference amounted to 22.50, and the confidence interval ranged from -39.35 to -3.31, indicating a tangible and meaningful effect.

Table 4 presents the mean, standard deviation, 95% confidence interval, and p-value for the EMG variables, specifically focusing on the median frequency and RMS of the MVIC for both study groups. Importantly, it should be noted that there were no significant differences observed in the analyzed variables.

DISCUSSION

This study found no significant impact on functional and sensorimotor activities when comparing the groups. However, when examining the time-based data, positive effects were observed in both the EGT group and the EGTT group. These positive effects were evident in both the quality and quantity of functional movement in the affected upper limb. In terms of clinical response, we observed an improvement in the ROM of the affected shoulder flexion. Nevertheless, there was no discernible effect on the EMG variables of the biceps muscle, wrist flexors, and extensors.

Table 3. Mean, standard deviation, 95% confidence interval and p value of the range of movement of the affected upper limb in the groups.

Variable (degree)		CG (n=6) Mean±standard deviation 95%CI		EGTT (n=6) Mean±standard deviation 95%CI			EGT (n=6) Mean±standard deviation 95%CI						
	Pre intervention	Pos intervention	P value intragroup	Pre intervention	Pos intervention	P value intragroup	Pre intervention	Pos intervention	P value intragroup	Mean intragroup difference 95%CI	ample power	Effect size	P value intergroup
Shoulder flexion ROM	110.83±43.86 64.79 to 156.86	105.00±47.11 55.55 to 154.44	0.47	95.83±40.79 53.02 to 138.64	105.00±45.38 57.36 to 152.63	0.26	75.00±46.90 25.77 to 124.22	97.50±65.85 28.38 to 166.61	**0.01**	22.50 -39.35 to -3.31	0.05	0.06	0.73
Shoulder extension ROM	33.33±20.65 11.65 to 55.01	35.83±9.70 25.64 to 46.01	0.62	27.50±16.04 10.65 to 44.34	33.33±13.29 25.64 to 46.01	0.26	33.33±13.66 18.99 to 47.67	42.50±19.17 22.38 to 62.61	0.08				0.67
Shoulder adduction ROM	26.66±12.11 13.95 to 39.37	31.66±20.41 10.24 to 53.08	0.30	26.66±15.05 10.86 to 42.46	33.33±16.63 15.87 to 50.78	0.18	32.50±22.74 8.62 to 56.37	35.00±21.44 12.49 to 57.50	0.60				0.89
Shoulder abduction ROM	100.0±52.44 44.96 to 155.03	93.33±39.20 52.19 to 134.47	0.50	77.5±32.51 43.37 to 111.62	91.66±48.02 41.26 to 142.06	0.17	82.50±57.85 21.78 to 143.21	83.33±55.55 25.02 to 141.63	0.93				0.85
Elbow flexion ROM	110.0±36.33 71.87 to 148.12	115.83±34.41 79.72 to 151.94	0.52	115.83±61.83 50.93 to 180.73	109.16±44.90 61.95 to 156.38	0.47	119.16±24.98 92.94 to 145.38	130.0±18.70 110.36 to 149.63	0.24				0.82
Elbow extension ROM	110.0±36.33 71.87 to 148.12	115.83±34.41 70.72 to 151.94	0.62	115.83±61.18 51.61 to 180.04	114.16±42.71 69.34 to 158.98	0.88	109.16±43.86 63.13 to 155.20	120.83±37.47 81.50 to 160.15	0.33				0.99
Pronation of the forearm ROM	58.33±45.35 10.74 to 105.92	115.83±34.41 79.72 to 151.94	0.76	63.33±32.65 29.05 to 97.60	114.16±42.71 69.34 to 158.98	0.23	55.83±29.73 24.62 to 87.03	120.83±37.47 81.50 to 160.15	0.10				0.89
Supination of the forearm ROM	56.66±44.12 10.36 to 102.96	55.83±41.52 12.25 to 99.40	0.89	62.50±32.51 28.37 to 96.62	73.33±16.02 56.52 to 90.14	0.09	70.00±30.82 37.65 to 102.34	70.0±25.88 42.83 to 97.16	1.00				0.73
wrist flexion ROM	32.50±21.85 9.56 to 55.43	31.66±22.06 8.5 to 54.81	0.88	35.0±20.49 13.49 to 56.50	45.0±16.12 28.07 to 61.92	0.10	38.33±25.62 11.44 to 65.22	44.16±21.31 21.80 to 66.53	0.32				0.70
wrist extension ROM	30.83±22.0 7.74 to 53.92	22.50±14.74 7.02 to 37.97	0.14	28.33±20.65 6.65 to 50.01	35.83±15.30 19.77 to 51.89	0.19	31.66±24.22 6.24 to 57.08	32.50±17.53 14.09 to 50.90	0.88				0.83
finger flexion ROM	34.16±23.32 9.68 to 58.64	42.50±29.28 11.76 to 73.23	0.33	24.66±22.73 0.81 to 48.52	42.50±13.32 28.51 to 56.48	0.05	39.19±31.21 6.41 to 71.92	49.16±19.08 29.14 to 69.19	0.25				0.70
finger extension ROM	15.83±12.81 2.38 to 29.27	17.50±13.69 3.13 to 31.87	0.78	9.66±7.39 1.90 to 17.42	19.16±15.30 3.10 to 35.22	0.13	24.16±19.60 3.59 to 44.73	35.0±17.60 16.52 to 53.47	0.09				0.12

CG: Control Group; EGTT: TRIM experimental group associated with trunk restriction EGT: TRIM Experimental group without trunk restriction; 95% CI: 95% confidence interval; ROM: range of motion.

Table 4. Mean, standard deviation, 95% confidence interval and p-value of the EMG variables at the median frequency and RMS of MVIC.

Variable (%)	CG (n=6) Mean±standard deviation 95%CI			EGTT (n=6) Mean±standard deviation 95%CI			EGT (n=6) Mean±standard deviation 95%CI			
	Pre intervention	Pos intervention	P value intragroup	Pre intervention	Pos intervention	P value intragroup	Pre intervention	Pos intervention	P value intragroup	P value intergroup
Median frequency of wrist extensors	99.65±12.97 86.03 to 113.27	89.13±19.14 69.03 to 109.22	0.15	106.55±18.71 86.90 to 126.19	103.45±20.11 82.34 to 124.56	0.66	117.61±26.16 90.15 to 145.07	110.44±21.92 87.44 to 133.45	0.32	0.21
Median elbow flexor frequency	64.06±7.80 55.87 to 72.26	68.84±13.21 54.97 to 82.70	0.26	55.76±21.31 33.39 to 78.13	59.23±11.05 47.63 to 70.84	0.41	64.50±7.25 56.89 to 72.11	64.33±10.65 53.15 to 75.51	0.98	0.40
Median frequency of the wrist flexors	96.45±20.54 74.89 to 118.01	103.35±32.56 69.17 to 137.52	0.46	89.21±31.53 56.12 to 122.30	103±13.60 89.41 to 117.96	0.13	99.87±25.95 72.63 to 127.11	104.75±17.19 86.71 to 122.79	0.60	0.89
RMS of the wrist extensors	87.48±7.48 79.62 to 95,33	85.55 ± 7.27 77.91 to 93.19	0.65	84.31±10.35 73.44 to 95.17	85,55±7,27 77,91 to 93,19	0.38	85.04±12,09 72.34 to 97.73	86.04±10.88 74.62 to 97.46	0.81	0.66
RMS of the elbow flexors	87,44±5,40 81.77 to 93.11	81,65±15,80 65.07 to 98.23	0.21	90,32±9,36 80.49 to 100.15	86,56±7,67 78.51 to 94.61	0.41	83,81±6,04 77.46 to 90.15	84,43±6,87 77.21 to 91.65	0.89	0.55
RMS of the wrist flexors	84.85±10.12 74.22 to 95.47	87.68±13.10 73,92 to 101.43	0.65	85.29±11.20 74.22 to 95.47	85.35±8.27 76.66 to 94.03	0.99	90.65±3.48 86.98 to 94.31	81.91±16.21 64.89 to 98.92	0.17	0.97

CG: Control Group; EGTT: TRIM experimental group associated with trunk restriction EGT: TRIM Experimental group without trunk restriction; 95% CI: 95% confidence interval; RMS: Root Mean Square; MVIC: maximal voluntary isometric contraction.

The rationale behind this improvement can be attributed to brain plasticity, which has been observed even in the late stages of injury[18]. Brain plasticity entails processes such as collateral sprouting, activation of latent synapses, and the strengthening of existing synapses, all of which involve structural changes in neurons[19]. Studies that have employed TRIM have demonstrated an increase in gray matter, both contralaterally and ipsilaterally, in sensory and motor areas following stroke[6,19,20].

The literature consistently supports significant improvements in both the quantity and quality of function in the affected upper limb when subjected to TRIM, as indicated by several studies[6,21-24]. These findings align with the results of the present study.

The TRIM protocol involving ten consecutive days of six-hour daily training yielded significant improvements in the

functionality of the affected upper limb. However, in the present study, we employed a modified protocol consisting of 1-h daily sessions for ten consecutive days, excluding Saturday and Sunday. Interestingly, our findings revealed similar responses to protocols involving 3 and 6h of daily training, consistent with the observations made by[25]. Notably, studies that implemented 6 h of daily TRIM training reported the most pronounced effects, particularly in motor function[23,26]. These results suggest that the duration of each session and the extended limb restraint may influence the outcomes[23].

The TRIM group exhibited improvements in the active ROM for shoulder flexion. This discovery aligns with the findings of[27], although it is worth noting that their study focused on the impact of TRIM on brachial plexus injuries. Similar results were also documented in the study by[28], which suggested that restricting trunk movement can result in more pronounced improvements in reach and grip movements in patients with chronic stroke when compared to upper limb exercises without trunk restriction.

Studies suggest that both active and passive movement exercises can reactivate existing connections and facilitate the formation of new connections, a phenomenon known as brain plasticity[29,30]. Moreover, the physical movement and the load applied to joint cartilage contribute to the maintenance and regeneration of proteoglycans, thereby positively influencing tissue functions[31].

In addition to the adaptations and modifications of the central nervous system after injury, it is well-documented that disuse of the affected upper limb can lead to alterations in the intrinsic properties of the musculoskeletal system. These alterations include muscle weakness, spasticity, and contractures, which subsequently lead to compensation due to the inability to initiate and control movements[32,33].

At the time of assessment and between the groups, there were no differences observed in the variables RMS and median frequency of EMG (Electromyography). These findings can be attributed to both the timing of therapy application and the disuse of the affected limb. Prolonged disuse leads to the reduction of high-threshold excitation motor units and an increased reliance on low-threshold motor units, resulting in alterations in motor unit recruitment and firing times[34].

We believe that the intensive use of the limb for two consecutive weeks may not have been sufficient to induce adaptive responses in motor units. Motor unit recruitment is known to depend on exercise intensity, as per Henneman's Principle[35,36]. Low-intensity exercises tend to preferentially recruit small-caliber, fatigue-resistant motor units. In this study, training primarily involved low intensity exercises[12]. The assessment of muscle electrical activity was conducted during high-capacity exercises aimed at generating maximum voluntary isometric contractions. For future studies, it may be worth considering modifications to the evaluation methodology.

One limitation of the present study is its small sample size, which raises the hypothesis that a study with a larger number of participants might yield more significant results. While numerous studies demonstrate the applicability and effectiveness of TRIM (Trunk Restraint-Induced Movement therapy) in patients with hemiparesis resulting from stroke, only a few have compared the responses of the affected upper limb to therapy combined with trunk restraints. Therefore, there is a need for future studies with well-defined protocols and an ample participant pool to further investigate this area.

CONCLUSION

In conclusion, the application of TRIM in conjunction with trunk stabilization did not exhibit a significant impact on functional and sensorimotor activities when comparing the groups. Nonetheless, when analyzing changes over time, positive effects were observed concerning sensorimotor function and the ROM in shoulder flexion for the GET (Group with Exercise Therapy) and GETT (Group with Exercise Therapy and Trunk Restraint).

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