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Original Article

Physiotherapy Section

Analysis of Functional Tasks to Provoke Contraction in Paretic Anterior Tibial Muscles in Individuals with Early Subacute Stroke: A Quasi-experimental Study

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ABSTRACT

Introduction: Improving control of ankle dorsiflexors is crucial for enhancing gait and posture control after a stroke. Several training methods have been explored for their efficacy in promoting contraction of the weakened dorsiflexor muscles. However, majority of studies have been done in chronic stroke survivors, leaving a need to study their effect in early subacute phase of stroke.

Aim: To test the effectiveness of commonly used functional tasks in stimulating dorsiflexor activity in early subacute phase of stroke.

Materials and Methods: The present quasi-experimental study was conducted with 27 subjects recruited at an acute stroke care set-up at Sri Ramachandra Medical centre, Tamil Nadu, India. India. Twenty-seven subjects with first-time stroke with hemiplegia/paresis with Brunnstrom stage less than 2 were enrolled in the study from March 2023 to July 2023. Dorsiflexor activity was tested in five different functional task. The evaluation of muscle activity was conducted using Surface Electromyography (SEMG). The average output in microvolts (μV) of SEMG was recorded and taken for analysis. Analysis of Variance (ANOVA) and Post-hoc Tuckey were used to compare the differences in dorsiflexor activity between each functional task. Statistical significance was kept at $p<0.05$.

Results: All the five functional task provoked dorsiflexor activity. Among the five functional tasks, stand and reach (18.49 μV) elicited a more pronounced contraction in the dorsiflexors. Wall-leaning in a standing position (15.5 μV), reaching while sitting (14.2 μV), transitioning from sitting to standing (12.8 μV), and triple flexion in the supine position (10.42 μV) also elicited dorsiflexor activity in decreasing level of efficacy. Moreover, they did not exhibit a statistically significant difference in quantum of EMG activity recorded when tested with ANOVA at $p<0.05$.

Conclusion: All the five functional tasks provoked dorsiflexor activity in early subacute phase of stroke in a varying level. In particular stand and reach was the most effective functional task to provoke paretic side dorsiflexor activity.

Keywords: Stroke, Foot drop, Ankle dorsiflexors, Electromyography

INTRODUCTION

Stroke is a prevalent transformative event that often has a profound impact on individuals who have suffered a stroke, their family members, healthcare resources, and society as a whole. Lack of proper walking function manifests in more than 80% of stroke survivors. Despite diligent endeavours in rehabilitation, a quarter of all stroke survivors exhibit persistent impairments in ambulation necessitating comprehensive physical support prior to their discharge from medical facilities [1]. Consequently, impairments in gait pose challenges in executing routine activities and mobility. Dorsiflexion of the ankle is one of the determinants of gait [2]. Dorsiflexor strength is considered to be a determinant of walking speed after stroke [3]. Ng SS et al., reports that dorsiflexor strength is the independent determinant of gait endurance in stroke survivors with spastic plantarflexors [4].

Multiple methods have been explored to improve the activation of the dorsiflexor muscles in individuals with hemiplegia. Functional electrical stimulation, task-specific training, robotic-assisted gait training, Wearable ankle robotics, walking ankle isokinetic exercise stepping over obstacles, mirror therapy, and reaching from unstable surfaces are among the techniques employed to promote dorsiflexor activity in the weakened lower extremity [5-10]. Majority of these methods have been tested in chronic phase of stroke. Traditional stroke rehabilitation principles endorsed by Bobath [11] and Carr and Sheperd (Motor Relearning Program) [12] suggest a limited number of functional tasks to elicit dorsiflexor activity. These functional tasks are commonly employed in clinical practice to foster dorsiflexor engagement especially during early subacute phase of stroke. The provocation of dorsiflexor activity in most of these functional tasks is predicated on the assumptions of synergistic muscle effort or postural reactive activation. A few typical functional tasks include: 1) Triple flexion, where the subject in a supine position is instructed to flex at the hip and knee to place the foot on the bed; 2) transitioning from sitting to standing; 3) engaging in reaching movements while sitting; 4) engaging in reaching movements while standing; and 5) standing and leaning against a wall, where the individual stands with their back against a wall and then leans against it before returning to an upright position. These functional tasks are tailored to the abilities of stroke survivors. However, the efficacy of these techniques in promoting dorsiflexor activity has yet to be explored in early subacute phase of stroke. A better understanding of the effects of these techniques on dorsiflexor activity will be useful for the therapist to choose the method for rehabilitation.

The current study was designed to evaluate the effectiveness of these functional tasks in individuals in the early subacute phase of stroke to determine their capacity to elicit dorsiflexor muscle contractions. It was assumed that this knowledge will aid in the selection of appropriate methods to achieve optimal outcomes in rehabilitation. It was hypothesised that different functional tasks will elicit different level of dorsiflexor activity. The null hypothesis stated that there will not be any difference in dorsiflexor activity between different functional tasks used in this study.

The aim of the present study Was to test the effectiveness of commonly used functional tasks in stimulating dorsiflexor activity in

early subacute phase of stroke. The study also attempted to rank the functional tasks based on their effectiveness.

MATERIALS AND METHODS

The present quasi-experimental study was conducted in an acute stoke care set up between March 2023 to July 2023 in Sri Ramachandra Medical Centre, Chennai, Tamil Nadu, India. The study was approved by the Institutional Ethical Committee (REF: CPS/23FEB/123/127).

Sample size calculation: The sample size was calculated with a priory to difference between Surface EMG recording from five different functional tasks that can provoke dorsiflexor contraction in the paretic side, using omnibus one-way ANOVA. G-power calculator version 3.1.9.4 was used for sample size calculation [13]. As it was planned to test five different functional tasks, a pilot testing of these five different functional tasks was performed on a sample of five acute stroke survivors meeting the inclusion criteria of the study. The five mean values in microvolt (13.2, 9.5, 8.27, 7.33, 9.53) and pooled SD 5.16 was used to calculate the effect size. The calculated effect size was 0.38. Further using alpha error as 0.05, and power as 0.95 the software calculated sample size was 135. The sample requirement calculated for each activity was 27 for ANOVA.

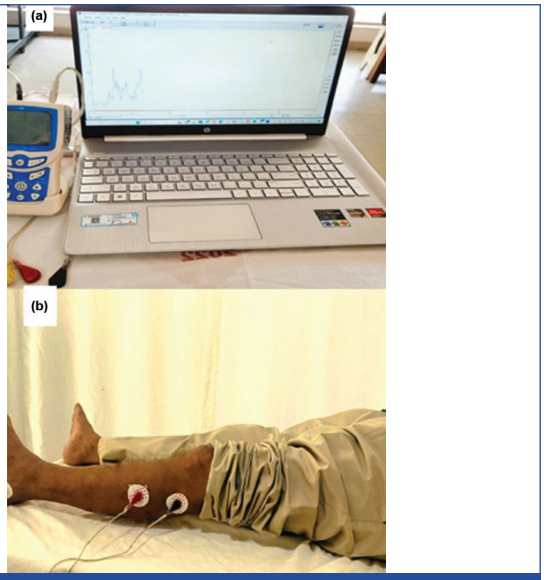
Inclusion and Exclusion criteria: Individuals with first-time hemispheric cerebral infarction, who possessed the ability to comprehend oral commands, underwent screening to determine their eligibility for inclusion in the study. Those individuals with Brunnstrom motor recovery stage 2 [14] and below, who were capable of sitting without support on a chair and standing without support, though not able to transfer weight completely on the paretic lower limb, were considered for inclusion in the study. Patients with orthopaedic, sensory, or other neurological impairments that could potentially restrict the study's outcomes were excluded from participation.

Study Procedure

The purpose of the study was explained in detail to those individuals who met the requirements, and informed consent was obtained from those who willingly agreed to participate. In cases where the individual was unable to sign the written consent, consent was acquired from the caregivers. A total of twenty-seven subjects were recruited from the Neuromedicine Ward of a multispecialty hospital after screening 62 patients. SEMG was conducted on all participants, specifically focusing on the dorsiflexor muscle group.

The SEMG recordings were performed using Neurotrac software 4.0 [Table/Fig-1] from VM (Verity Medical Ltd., United Kingdom) [6]. Adhesive electrodes made of silver chloride were placed on the dorsiflexor muscles according to the standardised testing protocol. The active electrode was positioned on the tibialis anterior muscle bulk, the reference electrode was placed 4 cm distally at the neck of the fibula, and the ground electrode was situated below the lateral malleolus (www.seniam.org). Prior to electrode application, the surface impedance was reduced using alcohol.

SEMG recordings were obtained from the dorsiflexor muscles during five different tasks aimed at facilitating muscle contraction. Firstly, in the supine position, the participant was instructed to lie down with the paralysed leg bent at the knee and hanging down at the side of the bed. The participant was then asked to flex at the hip and knee in order to place the foot flat on the couch [Table/Fig-2]. In the second task, the participant was assisted in standing up from a chair [Table/Fig-3]. The height of the chair was adjusted to ensure that the participant's hip and knee were positioned at a 90-degree angle. For the third task, the participant was instructed to sit on a chair with their hip and knee also at a 90-degree angle, and their feet resting on the floor [Table/Fig-4]. From this position, the participant was guided to reach a target in the sagittal plane using their unaffected upper extremity, at a distance of one-and-a-half arm lengths. In the fourth task, the participant was assisted in standing and reaching a target located at a distance of one-and-a-half arm lengths in a forward direction, using their unaffected upper extremity [Table/Fig-5]. Lastly, in the fifth task, the participant was instructed to stand one foot away from a wall with their back facing the wall [Table/Fig-6]. The participant was then requested to lean towards the wall without bending their knees, and subsequently, they were assisted in returning to an upright standing position. Each activity was repeated three times, with a 10-second intertrial rest period. A two-minute rest period was provided between each activity.



[Table/Fig-1]: a) NeuroTrac.MyoPluse 2-Surface EMG; b) Placement of EMG electrodes in paretic lower limb.

[Table/Fig-2]: Triple flexion.

[Table/Fig-3]: Sit to stand.

[Table/Fig-4]: Sit and reach.

[Table/Fig-5]: Stand and reach.

[Table/Fig-6]: Wall leaning.

STATISTICAL ANALYSIS

The data analysis was done using Jeffreys's Amazing Statistics Program (JASP) statistical software, version 18.3 (https://jasp-stats.org). The average (microvolts) SEMG during each trial of functional task was collected for analysis. A one-way ANOVA was utilised to examine the SEMG differences between the functional tasks. Significance of statistical tests were set at p≤0.05. A post-hoc turkey analysis was conducted to identify specific differences among the functional tasks. The mean value of the average SEMG recording was reported to determine the most effective functional task for facilitating dorsiflexor contraction following a stroke.

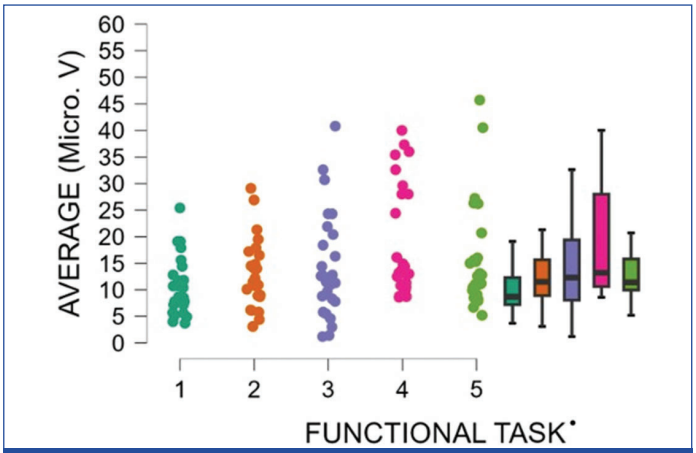
RESULTS

Twenty-seven individuals with mean age of 46 years (SD 8.84) were recruited for the study. Twenty-five male and two female with 13 right sided CVA and 14 left-side CVA participated in the study.

Among the functional tasks examined, the mean value of SEMG recording was highest for standing and reaching, followed by wall leaning, sit and reach, and sit and stand. Triple flexion had the lowest value among all the tasks [Table/Fig-7,8]. The ANOVA [Table/Fig-9] demonstrated a statistically significant difference among the groups, (F (4,130) = 3.29, p=0.013). However, the post-hoc turkey HSD test indicated that the difference between Triple flexion and stand and reach only reached a significant level {p=0.07, 9% CI (-15.07 to -1.61)} [Table/Fig-10].

Functional Task (n=27)	Mean (microvolts)	SD
1.Triple Flexion	10.426	5.285
2. Sit to Stand	12.8	6.308
3. Sit And Reach	14.237	9.807
4. Stand and Reach	18.496	10.57
5. Wall leaning	15.504	9.848

[Table/Fig-7]: Average SEMG values recorded in five different functional tasks used to facilitate paretic dorsiflexors.



[Table/Fig-8]: Dot plot showing the distribution average SEMG values recorded in five different functional tasks used to facilitate paretic dorsiflexors.

SEMG values	Sum of Squares	df	Mean Square	F	p
Between the group	980.639	4	245.16	3.29	0.013
Within the group	9687.514	130	74.519		

[Table/Fig-9]: ANOVA comparing the average SEMG values recorded in five different functional tasks used to facilitate paretic dorsiflexors.

Functional tasks	Comparison	Mean difference (95% CI)	p (tukey)
1	2	-2.374 (-9.04 to 3.92)	0.85
	3	-3.811 (-10.5 to 2.46)	0.486
	4	-8.07 (-15.04 to -2.06)	0.007*
	5	-5.078 (-11.73 to 1.23)	0.201
2	3	-1.437 (-7.94 to 5.02)	0.973
	4	-5.696 (-12.48 to 0.488)	0.115
	5	-2.704 (-9.18 to 3.79)	0.779
3	4	-4.259 (-11.02 to 1.94)	0.371
	5	-1.267 (-7.72 to 5.24)	0.983
4	5	2.993 (-3.18 to 9.78)	0.708

[Table/Fig-10]: Post-hoc Tukey HSD comparing the average SEMG values recorded in five different functional tasks used to facilitate paretic dorsiflexors. *p≤0.05 Significant (1. Triple flexion; 2 Sit to Stand; 3 Sit and Reach; 4 Stand and Reach; 5 Wall Leaning).

DISCUSSION

The findings of the study revealed that all five functional tasks could elicit dorsiflexor activity in the affected limb. However, the stand and reach tasks resulted in a greater activation of dorsiflexors compared to the other functional tasks. Although these functional tasks are frequently employed in clinical practice, their impact on dorsiflexor activity during the early subacute phase of stroke was predicated upon physiological and biomechanical assumptions. A side from the sit and reach method, other approaches have not been evaluated for their efficacy in eliciting dorsiflexor activity on the paretic side during the early subacute phase of stroke. It may be contended that, unless substantiated by evidence that supports their influence on dorsiflexor activity, the application of these methods in practice based solely on assumptions cannot be regarded as a scientifically grounded therapeutic intervention. The current study has furnished evidence through SEMG recordings to substantiate the impact of frequently utilized functional tasks on dorsiflexor contraction on the paretic side during the early subacute phase of stroke,hence not supporting the null hypothesis.

Both Bobath and Carr and Sheperd advocate for the use of Triple flexion as an activity to stimulate dorsiflexors [11,12]. It is assumed that dorsiflexors will contract as part of the flexor synergy. This movement is recommended to improve the swing phase of gait. In the present study, it was observed that the movement elicited the contraction of the dorsiflexor muscle, although it was the least active among the tested functional tasks. This activity is one of the commonly used activity to provoke dorsiflexor contraction, when subjects have not even gained ability to sit. The current study has provided a scientific evidence for its impact on dorsiflexor contraction.

Previous studies have reported the activation of the Tibialis anterior as a preparatory muscle for sit to standing [15,16]. However, we did not find any studies that used sit to stand as a measure to enhance dorsiflexor activity following stroke. In the present study, sit to stand elicited dorsiflexor activity, but it was the second weakest stimulus among the five functional tasks tested. This may be attributed to the amount of weight transferred by the patient onto the affected leg during the sit to stand task [17].

Sitting and reaching triggers activity in the dorsiflexors of the affected lower extremity [6,18]. The nature of the task varies depending on the stability of the sitting surface. In the present study, sitting and reaching was performed from a stable base and with the use of the non-affected upper extremity. The recordings of dorsiflexor activity were higher compared to the sit to stand activity. Previous studies have reported that forward reach is more effective in eliciting dorsiflexor contraction compared to lateral reaches. Dorsiflexor is consistently contracted during a forward reaching task in standing [19,20]. The activation of the dorsiflexor during forward reach has been found to be slower compared to individuals without any impairments [21]. In the present study, forward reaching in standing was highly effective in eliciting Dorsiflexor activity compared to the other functional tasks tested. Wall leaning was the second most provocative functional task, as it elicits dorsiflexor activity through the ankle strategy and the contraction of dorsiflexors in response to backward weight shifting [12].

The present study is the initial exploration to compare the impact of different movements on the contraction of the dorsiflexor muscle in the early subacute stroke population and to measure the contraction using SFEMG. Based on the findings of the present study, these functional tasks can be used with confidence to elicit dorsiflexor contraction in individuals experiencing early subacute stroke. The study also reveals functional activities are effective intervention in provoking dorsiflexor activity in early subacute stroke with profound weakness. Activities in standing like stand and reach or wall-leaning in standing are more effective compared to functional tasks performed in sitting or lying. Hence using them to train whenever functional level of the patient permits could be the better therapeutic choice to facilitate dorsiflexor contraction.

Limitation(s)

The site and size of lesion could influence the outcome of the study. In the current study, The authors did not take measures to control the effect of lesion profile. Though not intentional to exclude, anterior cerebral artery infarcts were not part of this study. This exclusion could limit generalisation of the outcome of the study. Sensory deficits could influence the outcome, however, measures were not taken to control this variable in this study.

CONCLUSION(S)

An examination of five commonly employed functional tasks to facilitate the contraction of the paretic dorsiflexor muscle demonstrated that all of these functional tasks have the capacity to induce the contraction, albeit to varying extents. The selection of these movements may be contingent upon the functional abilities of the stroke survivor. Wherever, possible choosing the activity that could facilitate better dorsiflexor contraction is warranted for an optimal outcome.

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