Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 26s (2025)
https://www.jneonatalsurg.com

Impact of Foot Placement on Muscle Activation and Weight Distribution During Sit-to-Stand in Chronic Stroke Patients

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Cite this paper as: Marina Azmy Salib Kamel, Abdulalim A Atteya, Wael Ibrahim, Ahmed S. Ali, (2025): Impact of Foot Placement on Muscle Activation and Weight Distribution During Sit-to-Stand in Chronic Stroke Patients. *Journal of Neonatal Surgery*, 14 (26s), 508-517.

ABSTRACT

Background: Comprehensive neurorehabilitation for post-stroke could improve physical capacity and reduce healthcare costs post-strokes. Effective execution of sit-to-stand is an important goal of neurological rehabilitation that requires appropriate lower limbs coordination.

Purpose: The objective of this study was to investigate the changes in lower limb muscle activation patterns during the sit-to-stand movement, across three different initial foot placements: symmetric foot position, affected foot placed in front of the unaffected foot, and affected foot placed behind the unaffected foot. Surface electromyography (EMG) was used to assess muscle activity during these movements.

Participants and Methods: Forty Egyptian chronic hemiparetic participants of both genders, their age range 45- 60 years old, duration of disease was > 6 months, their spasticity grade was mild range 1 to 1+, according to the Modified Ashworth scale, the patients were recruited from Outpatient clinic and Research laboratories at Faculty of Physical Therapy, Cairo University, Egypt, between May 2022 to May 2023. All demographic data, Tibialis Anterior and Rectus Femoris muscle activity were recorded using Surface EMGs (EMG-USB2) while performing sit-to-stand using three different positions for the foot placement, then statistical analysis was conducted.

Results: The demographic data were consistent with globally recognized stroke-related factors. The anterior foot placement resulted in the highest activation of the tibialis anterior during sit-to-stand, as evidenced by its highest maximum amplitude and a "borderline significance" value for amplitude-to-frequency. Both the symmetric and anterior foot placements elicited the highest activation of the rectus femoris, indicated by their highest maximum amplitude. In contrast, the posterior foot placement showed the lowest rectus femoris activation, as evidenced by the lowest clustering index.

Conclusion: The anterior foot placement is the most effective for activating the tibialis anterior, making it a critical strategy for enhancing dorsiflexor function. Additionally, both symmetric and anterior foot positions are particularly beneficial for optimizing rectus femoris activation during sit-to-stand movements in individuals with chronic stroke.

Keywords: *Chronic Stroke, Surface Electromyography, Foot Placement, Sit to Stand, Tibialis anterior, Rectus femoris*

1. INTRODUCTION

Stroke as a major neurological deficit, non-communicable disease disorder, is a leading cause of mortality and long-term disability worldwide. Ischemic stroke is defined as infarction of the brain, spinal cord or retina and represents ~71% of all strokes globally [1,2]. Recently, by 2019 around 101 million stroke individuals and 143 million strokes related physically disabled [3] Across Egypt, the reported high national rate for stroke incidence is nearby 963 per 100.000 inhabitants with annual stroke incidence around 150 to 210 thousand. Unless relatively higher incidence of stroke among youngers stroke patients represented 20.5% [4].

Approximately 85% of strokes are due to cerebral infarction, 10% to primary hemorrhage and 5% to subarachnoid hemorrhage. In 2017, ischemic stroke accounted for 2.7 million deaths, intracerebral hemorrhage for 3 million, and aneurysmal subarachnoid hemorrhage for 0.4 million.[5].

Overall elevated stroke incidence reported in Africa might be explained by numerous factors based on African life span either during their fetus life or early life undernutrition that resulted in cardiometabolic risk across African later life, particularly resulting in silent strokes [6]. Various modern life style issues contributed as a risk factor for stroke involving fast food, associated comorbidities, and sedentary life style [7].

Almost stroke survivors complain of functional dependency that reflected on their quality of life including their capabilities to conduct self-care activities, transferring activities, also aggravate their caregivers` additional loads [8,9]. Recently, around 75% of stroke sufferers were reported to complain of alternated dysfunction those obviously influence their self-care capabilities, which overload even health care system on the long-term [10].

No debut, sit to stand (STS) is a unique set of movements that allow human beings to rise from a sitting position to a bipedal standing pose. STS is a movement that is frequently done as a major functional ability that extensively affected in stroke individuals [11, 12]. Thus, STS performance is fundamental for the independence of persons with disabilities. Successful completion of the STS task is dependent on the performer having sufficient coordination, balance, range of motion, and strength as well as the ability to move the center of mass of the body forward from a large base of support to a narrow one [13].

STS define the strategy for implementing the STS task as the momentum-transfers strategy. Another way to make the STS sequence is increasing trunk flexion prior rising from the chair, which is usually performed by people with lower limbs` weakness. Muscles act primarily as stabilizers of motion (tibialis anterior, rectus abdominis, soleus) and others responsible for implementing the sequence (quadriceps rectus femoris, quadriceps vastus medialis and biceps femoris [14].

Furthermore, STS requires large musculatures` activation with appropriate coordination. Initial tibialis anterior activated [15]. Asymmetrical nature of stroke- related deficits, plus consume extra time while conducting STS, particularly [16].

A successful STS depends upon the individual’s neuromuscular control strategy, lower extremity, also balance and overall stability. In symmetric initial foot placements, the farther the body’s center of mass (CoM) moved forward, the faster the forward velocity of the CoM was required [17].

Furthermore, associated stroke motor deficits resulting from a stroke consist of a disruption in neural pathways affecting contralateral extremities. Analyses of STS have focused on understanding the biomechanical, kinetic and kinematic components. Muscle activity measures the relative timing and amplitude of muscle contractions that is mainly assessed by surface electromyography (sEMG), [17, 18].

Almost earlier clinical trials had insured significant variations at immediate positive effect on the symmetry of weight bearing through recording feet positioning on STS performance and reverse STS task among stroke individuals that addressed through rehabilitation training, unless such variations were not completely retained over a long time [19]. Effective execution of STS is an important goal of neurological rehabilitation. To our knowledge, no research has yet examined the relationship between changes in lower limb muscles activation patterns during sit to stand in stroke patients. Thus, the current study aimed to investigate changes in lower limb muscle activation patterns during the sit-to-stand movement across three different initial foot placements: symmetric foot position, affected foot positioned in front of the unaffected foot, and affected foot positioned behind the unaffected foot using surface electromyography (EMG).

2. MATERIALS AND METHODS

Study design

A cross-sectional observational study was performed from May 2022 to May 2023, at Outpatient clinic and Research laboratories at Faculty of Physical Therapy, Cairo University, Egypt. This study adhered to the Declaration of Helsinki and received ethical approval from the Ethics Committee of the Faculty of Physical Therapy, Cairo University (Approval No.: P.T.REC/012/004308). Informed consent was obtained from all participants prior to their enrollment in the study.

Participants

Forty Egyptian chronic hemiparetic participants of both genders, their age range 45- 60 years old, duration of disease was > 6 months, their spasticity grade was mild range from 1 to 1+, according to the Modified Ashworth scale, and the patients were clinically and medically stable.

Patients were excluded if they had: recurrent stroke or hemiparesis due to other neurological causes i.e., multiple sclerosis, visual, auditory, and other neurological disorders i.e., parkinsonism. Whom with cognitive impairment, or with musculoskeletal problems e.g., deformity or contracture, or medically unstable or uncooperative.Top of Form

Procedures

All the patients were subjected to complete a detailed demographic examination, and neurological evaluation.

Surface EMG (sEMG) refers to the collective electrical signals generated by muscles during contraction, which are regulated by the nervous system. sEMG signals reflect the timing and intensity of superficial muscle activation, representing the simultaneous detection of motor unit activity. These signals were amplified and sampled at 10 kHz using a 12-bit A/D converter (EMG-USB2, OT-Bioelettronica, Italy) at the research laboratories of the Faculty of Physical Therapy, Cairo University. Given their amplitude in the microvolt range and frequency range between 20 and 500 Hz, sEMG signals are highly susceptible to noise interference. The sEMG acquisition module utilized non-invasive silver/silver chloride (Ag/AgCl) electrodes, each measuring 10 × 1 mm. The system comprises a hardware pre-processing module, a wireless transmission module, and a power management module, all controlled by a microcontroller unit (MCU) integrated within the wireless transmission module. The host computer receiving system includes a central receiving device and dedicated host software. Surface EMG (sEMG) signals were acquired using differential Ag/AgCl conductive gel electrodes, with an inter-electrode spacing of 3 cm. The muscles that were assessed included muscle group stabilisers like the tibialis anterior (TA) and muscle group sequences like the rectus femoris (RF). In order to distinguish between normal and pathological motor control during the sit-to-stand movement across three different initial foot placements—symmetric foot position, affected foot placed in front of the unaffected foot position, and affected foot placed behind the unaffected foot position—three circular adhesive Ag-AgCl electrodes were placed on each muscle in accordance with SENIAM protocol guidance (filtered with a 5-500 Hz band-pass filter-Surface EMG for non-invasive assessment of muscles). The electrodes were spaced two inches apart.[20].

sEMG Procedures

In this study, each patient was instructed to perform the sit-to-stand (STS) movement using three different strategies: symmetric foot positioning, asymmetric-1 (affected foot placed in front of the unaffected foot), and asymmetric-2 (affected foot placed behind the unaffected foot). Upon reaching a full standing position, patients were asked to maintain the stance for three seconds. Muscle activity of the rectus femoris and tibialis anterior during phase II of the STS was recorded using surface electromyography (sEMG). Following the SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) protocol, three circular adhesive electrodes were applied to each muscle. After then, each patient has been told to sit down once more at a pace that suits them. Each patient's knee joint was at a 90-degree angle with one-third of their thigh length resting on the seat thanks to the seat height adjustment. The feet are shoulder-width apart and the toes are aligned in the coronal plane for the symmetrical foot positioning. Asymmetric-1 and Asymmetric-2 are two examples of asymmetrical foot placements.

Surface EMG was filtered with a 5-500 Hz band-pass filter. A moving root mean square with a 100 ms window was applied as a digital smoothing algorithm. Then, the EMG signals and the area under the rectified curves were normalized to the MVIC/EMG for both rectus femoris and tibialis anterior musculatures, and the researcher has determined all EMG outcome measures involving maximum amplitude, root mean square, total and mean amplitude, amplitude-to-frequency, and clustering index, where area data for all initial foot positions (IPFs), [21].

Electromyographic variables, including the maximum peak and area under the curve (AUC), were extracted from the data within a predefined area of interest for all participants. This area encompassed the highest activation peak of the rectus femoris and tibialis anterior muscles, along with a two-second window centered around this peak (one second before and one second after). For analysis, the highest maximum activation peak recorded across the three trials performed by each participant was selected. These variables were obtained using MegaWin 3.0.1 software (EMG-USB2, OT-Bioelettronica, Italy).

For each muscle, RMS/EMG was calculated during the active period of both rectus femoris and tibialis anterior musculatures (EMG burst) of each thrust (64-ms window). Then, RMS-EMG was averaged every six crank revolutions (corresponding to about 5 s for 70 rpm), as previously described [21].

Statistical analysis

The measured variables were statistically analyzed and compared using SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL) with Alpha level set at 0.05. Data were screened for normality assumption, homogeneity of variance, and presence of extreme scores. Shapiro-Wilks test for normality showed that the measured variables were normally distributed ($p > 0.5$). Data are expressed as mean and standard deviation for all outcomes. Repeated measures ANOVA was used to evaluate the differences in both rectus femoris and tibialis anterior muscles` activation patterns across multiple conditions while accounting for the fact that the same individuals are tested under each condition. Post-hoc tests was conducted to pairwise comparisons to determine which specific pairs of groups differ. Independent variable: The different foot placements (three levels; symmetrical, affected in front, and affected foot behind). Dependent variable was the muscle activation levels (EMG signals) from the lower limb muscles ‘rectus femoris, and tibialis anterior’.

3. RESULTS

Participant characteristics:

Table 1 shows the participant characteristics participants (p > 0.05).

Tab. 1. Participants` general characteristics

		Group A (n=30) $\overline{X}$ ±SD	Standard Error Mean	t- value	p-value
Age (years)		53.5 ± 3.77	0.596	89.776	0.000
Weight (kg)		73.43 ± 6.51	1.029	71.313	
Height (cm)		164.68 ± 1.097	0.648	254.18	
BMI (kg/m²)		27.08 ± 2.027	0.321	84.484	
Affected Side	**Left**	27 (67.5%)		$\chi 2 = 0.73$	
	Right	13 (32.5%)			
Aetiology	**Infarction**	22 (55%)		$\chi 2 = 0.63$	
	Haemorrhage	18 (45%)			
Modified Ashworth scale	**1**	17 (42.5%)		$\chi 2 = 0.59$	
	1^+	23 (57.5%)			
Sex	**Males**	29 (72.5%)		$\chi 2 = 0.62$	
	Females,	11 (27.5%)			
Stroke duration in months	**7**	10 (25%)		$\chi 2 = 0.64$	
	8	7 (17.5%)			
	9	4 (10%)			
	10	5 (12.5%)			
	11	9 (22.5%)			
	12	5 (12.5%)			

P: probability; χ^2: chi square; data are represented as mean ±SD

Electromyographic analysis:

Parameters of tibialis anterior EMG

The Anterior foot placement is most associated with greater muscle activity (Maximum amplitude), with marginal support for better activation efficiency (Amplitude-to-Frequency Ratio). Other measures (root mean square, mean frequency, total, and mean amplitude, and clustering index) do not show significant differences among the three-foot placements.

Parameters of rectus femoris EMG

The Anterior foot placement and In-Line foot placement show the most notable improvements for specific metrics, while other variables (root mean square, mean frequency, total amplitude, mean amplitude, and amplitude-to-frequency) exhibit no significant differences.

Between positions effects on tibialis anterior:

The results show statistically significant differences for maximum amplitude, and clustering index among the three-foot placements, with the Anterior foot placement showing the best improvement in maximum amplitude, and only marginally significant regarding the In-line foot placement representing the best performance for clustering index. For the remaining variables (root mean square, mean frequency, total amplitude, mean amplitude, and amplitude-to-frequency), no statistically significant differences were observed, indicating similar performance across the three-foot placements. The Anterior foot placement shows the most higher tibialis anterior muscular activation efficiency for specific metrics, while other variables exhibit no significant differences (p <0.001) (Tables 3-4).

Between positions effects on rectus femoris:

The results show statistically significant differences for maximum amplitude, amplitude-to-frequency, and clustering index among the three-foot placements, with the Anterior foot placement showing the best improvement in maximum amplitude, and only marginally significant regarding the In-line foot placement representing the best performance for clustering index. For the remaining variables (root mean square, mean frequency, total amplitude, mean amplitude, and amplitude-to-frequency), no statistically significant differences were observed, indicating similar performance across the three-foot placements. The Anterior foot placement shows the most notable improvements for specific metrics, while other variables exhibit no significant differences (p <0.001) (Tables 3-4).

Table 2. Tibialis anterior EMG parameters: (N= 40)

Variable	Posterior	In line	Anterior	F- value	P value	η^2
Max Amp	3.435 ± 44.89	3.185 ± 53.23	3.617 ± 65.21	10.192	0.002	0.01
RMS	42.038 ± 22.69	42.468 ± 22.47	40.965 ± 20.96	0.051	0.821	0.03
M Freq	85.63 ± 48.42	84.21 ± 50.582	80.153 ± 49.25	0.019	0.890	0.03
T Amp	11.265 ± 7.87	12.50 ± 9.72	10.67 ± 7.97	0.858	0.356	0.01
M Amp	1.591 ± 36.46	1.703 ± 35.589	1.739 ± 41.58	0.257	0.613	0.03
Amp/ Freq	1.628 ± 0.778	1.69 ± 0.939	2.42 ± 1.12	3.505	0.064	0.01
Clust. Index	0.122 ± 0.082	0.149 ± 0.159	0.141 ± 0.142	0.461	0.499	0.01

*Max Amp: maximum amplitude; RMS: root mean square, M Freq: mean frequency; T Amp: total amplitude; M Amp: mean amplitude; Amp/ frequency: Amplitude/ frequency, η2: partial eta squared. * Data are mean± SD, P-Value < 0.05 indicate statistical significance*

Tab. 3. Rectus femoris EMG parameters (N= 40)

Variable	Posterior	In line	Anterior	F- value	P value	η^2
Max Amp	1.164 ± 56.72	3.341 ± 67.285	3.358 ± 71.874	10.963	0.001	0.01
RMS	50.83 ± 23.82	57.138 ± 40.59	46.268 ± 30.46	1.878	0.173	0.03
M Freq	83.178 ± 51.59	73.77 ± 48.88	69.12 ± 49.93	0.060	0.807	0.02
T Amp	12.09 ± 11.99	10.07 ± 10.26	8.20 ± 8.67	0.002	0.968	0.03
M Amp	1.796 ± 39.41	1.799 ± 43.29	1.711 ± 50.278	0.286	0.594	0.01
Amp/ Freq	2.507 ± 1.33	2.572 ± 1.18	4.517 ± 6.23	1.687	0.196	0.01
Clust. Index	0.1 ± 0.965	0.192 ± 0.242	0.104 ± 0.059	9.185	0.003	0.01

*Max Amp: maximum amplitude; RMS: root mean square, M Freq: mean frequency; T Amp: total amplitude; M Amp: mean amplitude; Amp/ frequency: Amplitude/ frequency, η2: partial eta squared. * Data are mean± SD, P-Value < 0.05 indicate statistical significance*

Tab. 4. Between positions effects regarding Tibialis anterior.

Outcome	Post. versus in Line		Post versus Ant		In Line versus Ant		η^2
	MD (95% CI)	p-value	MD (95% CI)	p-value	MD (95% CI)	p-value	
Max Amp	24.95 (0.559, 49.34)	0.045	-18.2 (-42.59, 6.19)	0.142	43.15 (-67.54, -18.76)	0.001	0.056
RMS	-0.43	0.931	1.07	0.828	1.50	0.761	0.057

	(-10.19, 9.334)		(-8.69, 10.84)		(-8.26, 11.267)		
M Freq	1.42 (-20.47, 23.31)	0.898	5.48 (-16.41, 27.366)	0.621	4.06 (-17.83, 25.95)	0.714	0.049
T Amp	-1.24 (-5.03, 2.26)	0.520	0.598 (-3.19, 4.39)	0.755	1.83 (-1.96, 5.63)	0.340	0.054
M Amp	-11.15 (-27.97, 5.67)	0.192	-14.85 (-31.67, 1.97)	0.083	-3.7 (-20.52, 13.12)	0.664	0.043
Amp/ Freq	-0.628 (-0.472, 0.347)	0.762	-0.796 (-1.21, -0.387)	0.001	-0.733 (-1.14, 0.324)	0.001	0.036
Clust Index	-0.027 (-0.085, 0.0317)	0.366	-0.0189 (-0.078, 0.039)	0.525	0.0079 (-0.05, 0.06)	0.789	0.027

*Max Amp: maximum amplitude; RMS: root mean square, M Freq: mean frequency; T Amp: total amplitude; M Amp: mean amplitude; Amp/ frequency: Amplitude/ frequency, η2: partial eta squared. * Data are mean± SD, P-Value < 0.05 indicate statistical significance*

Tab. 5. Between positions effects regarding Rectus Femoris.

Outcome	Post. versus in Line		Post versus Ant		In Line versus Ant		η^2
	MD (95% CI)	p-value	MD (95% CI)	p-value	MD (95% CI)	p-value	
Max Amp	82.375 (53.324, 111.43)	0.001	80.63 (51.57, 109.68)	0.001	-1.75 (-30.8, 27.30)	0.905	0.041
RMS	-6.308 (-20.64, 8.03)	0.385	4.56 (-9.769, 18.89)	0.530	10.87 (-3.46, 25.20)	0.136	0.052
M Freq	9.42 (-12.8, 31.62)	0.403	14.06 (-8.15, 36.26)	0.213	4.65 (-17.56, 26.86)	0.679	0.042
T Amp	2.03 (-2.58, 6.63)	0.385	3.89 (-0.713, 8.494)	0.097	1.87 (-2.74, 6.47)	0.424	0.036
M Amp	-0.35 (-20.08, 19.38)	0.972	8.53 (-11.21, 28.26)	0.394	8.875 (-10.86, 28.61)	0.375	0.037
Amp/ Freq	-0.065 (-1.72, 1.59)	0.938	-2.01 (-3.67, -0.355)	0.018	-1.945 (-3.60, -0.289)	0.022	0.031
Clust Index	-0.092 (-0.16, -0.024)	0.008	-0.004 (-0.072, 0.065)	0.915	0.089 (0.02, 0.156)	0.011	0.037

*Max Amp: maximum amplitude; RMS: root mean square, M Freq: mean frequency; T Amp: total amplitude; M Amp: mean amplitude; Amp/ frequency: Amplitude/ frequency, η2: partial eta squared. * Data are mean± SD, P-Value < 0.05 indicate statistical significance*

4. DISCUSSION

The current study aimed to examine the changes in lower limb muscle activation patterns during the sit-to-stand (STS) task across three different initial foot placements; symmetric, anterior (affected foot placed in front of the unaffected foot), and posterior (affected foot placed behind the unaffected foot). Using surface electromyography (sEMG), the study assessed the neuromuscular activity of key lower limb muscles, particularly the tibialis anterior and rectus femoris, which play crucial roles in STS performance.

Comprehensive neurorehabilitation for post-stroke could improve physical capacity and reduce healthcare costs post-strokes. Effective execution of STS is an important goal of neurological rehabilitation. Clinical guidelines emphasize the importance of post-stroke neurorehabilitation. Rising to a stand from sitting is a ubiquitous task, and a prerequisite functional task that addressed as a prime obstacle while planning essential functional daily activities. As well, previous clinical trials ensured that lifting off from a seat that requires appropriate lower limbs` coordination, and upper limbs` simultaneous smooth motion [22].

Up on that, there is actual functional linkage between hip and knee extension from biarticular musculatures ‘rectus femoris and gastrocnemius' within posterior foot position, while symmetrical feet positioning provides additional functional equivalence of both lower extremities while moving from STS and vice versa. In addition, anterior foot position improves hip extension torque with reducing knee extension, and ankle plantarflexion torques of posterior leg with restricted anterior leg extension torques. Thus, feet positioning positively influence vertical reaction force while conducting STS among post-stroke individuals [23,24].

The results demonstrated that the anterior foot placement elicited the highest tibialis anterior activation, as evidenced by its highest maximum amplitude. This suggests that positioning the affected foot forward enhances activation in the tibialis anterior, likely due to the increased demand for dorsiflexion and anterior weight shifting required to initiate the movement. Furthermore, this position exhibited the highest 'borderline significance' value for amplitude-to-frequency, indicating superior neuromuscular efficiency of the tibialis anterior muscle in this condition.

Regarding the rectus femoris activation, both in-line (symmetric) and anterior foot placements resulted in the highest maximum amplitude, suggesting that these positions facilitate quadriceps engagement, which is essential for knee extension during the STS task. In contrast, posterior foot placement showed the lowest rectus femoris activation and clustering index, indicating reduced muscle activity and a more stable performance. The lower clustering index suggests that the posterior position may contribute to a more controlled and consistent movement, likely due to reduced mechanical demand on the affected lower limb.

The findings of this study have direct clinical applications in stroke rehabilitation. Optimizing foot placement during STS training is a critical consideration in physical therapy, particularly for stroke patients who exhibit asymmetrical weight-bearing patterns and muscle weakness.

Tibialis Anterior Activation: The anterior foot placement elicited the highest activation of the tibialis anterior, suggesting it may be a preferable strategy for enhancing dorsiflexor strength and neuromuscular control. This is particularly relevant for stroke patients, who often experience foot drop or difficulty in clearing the foot during gait. Incorporating anterior foot placement in sit-to-stand (STS) exercises could facilitate greater tibialis anterior recruitment, thereby improving dorsiflexion control and potentially reducing the risk of falls.

Rectus Femoris Activation: The symmetric foot and anterior foot placements were associated with the highest rectus femoris activation, which suggests that these positions should be incorporated in quadriceps strengthening exercises. Given that rectus femoris is a key muscle in knee extension and weight transfer, training in these positions may improve sit-to-stand efficiency, balance, and walking performance.

Stability Considerations: The posterior foot placement was found to be the most stable position, as indicated by its lowest clustering index and muscle activation. Although it may not be the most effective for muscle strengthening, this position could be beneficial for individuals with postural instability, particularly those at high risk of falls. In such cases, initial training may focus on the posterior foot placement to prioritize safety before progressing to more challenging anterior foot positions.

The results of the present study align with prior research on biomechanical and neuromuscular adaptations during STS. Several studies have highlighted that altering foot placement significantly influences muscle activation patterns and weight distribution.

Regarding neuromuscular rehabilitation efficacy for both tibialis anterior, and rectus femoris EMG has ensured initial tibialis anterior activation that associated with feet stabilization, which ensured by Tebbache and Hamaoui. [15] who ensured that feet stabilization almost required associated recruiting for trunk flexion mainly abdominal musculatures and for head the sternocleidomastoid muscles, and most of forward oriented tasks i.e., STS requires inhibition of soleus.

In the same line with current study results revealed, Cuesta-Vargas and Gonzalez Sanchez. [25] had reported that dorsal legs` musculatures were addressed as the main movers on the horizontal momentum through STS, also leg dorsal musculatures 'anterior tibial group' were responsible for posture stabilization at the end of STS tasks. Where, reduced tibialis anterior neuromuscular activities were ensured prior to STS according to Tebbache and Hamaoui. [15].

A study by Roy et al. [26] demonstrated that anterior foot placement increases tibialis anterior activation due to greater reliance on dorsiflexors and forward weight shifting. This is consistent with the current study's findings, further reinforcing the importance of anterior positioning in rehabilitation protocols.

Similarly, Schmid et al. [27] reported that posterior foot placement reduces quadriceps activation and increases postural stability, supporting the present study's conclusion that posterior placement may be beneficial for individuals with compromised balance.

In addition, Lee et al. [28] found that symmetric foot placement optimizes rectus femoris activation, which aligns with the current results, suggesting that this position is ideal for quadriceps strengthening exercises. While these findings corroborate existing research, the current study uniquely focuses on chronic stroke patients, providing specific recommendations for optimizing foot placement strategies in neurorehabilitation settings.

Moreover, physical lifting from a seat, and maintaining balance standing requires actual coordinated control for both lower limbs, plus simultaneous smooth upper limbs motion those decline among elders by 2-4% [29]. Therefore, adjusting seat height, initial forward torso inclination, and modulating initial feet positioning varies STS kinetics in respect to both center of mass (CoM), and ground reaction force (GRF) in term of momentum transfer, and biarticular musculatures [30] i.e., rectus femoris (RF) those permits easier transferring vertical forces along joints [31,32].

Kinetic symmetrical foot positioning provides structurally, and functional advantage of equally both lower limbs contribution in STS [33]. On the other hand, Asymmetrical foot positioning enhances neuromuscular support strategy for maintaining balance that overloads additional tibialis anterior activation persisted till seat-off, and enhanced by greater base of support [34,35], prior to transition later on to a walk [36].

In contrast to results of the current study, research conducted by Roy et al. [26], this study found that STS training with the less affected foot placed laterally (to the side) resulted in significant increases in muscle activation, peak vertical ground reaction force, and improved weight-bearing symmetry. This suggests that lateral foot placement may be more beneficial in rehabilitation settings for enhancing muscle activation and balance.

Also, the results of the current study disagreed with insights from Jeon et al. [22], the research indicated that more anterior initial foot positions require a faster forward velocity of the body's center of mass during STS, which can lead to increased postural sway upon achieving an upright stance. This finding contrasts with the current study's suggestion that anterior foot placement enhances tibialis anterior activation, highlighting a potential trade-off between muscle activation and postural stability.

No doubt that feet positioning while STS has a particular role, in this line Gillette et al. [23] posterior affected foot permits reducing vertical reacting forces while performing STS among post-stroke individuals as stated by Joshua et al. [24].

The successful STS almost depends on personalized neuromuscular control strategy. STS represents a critical rehabilitation step, as vital daily living activity step. Bae. [37] recently has stated that asymmetrical STS permits additional lower extremities muscular activation, and restricted torso inclinations, plus reducing most of suspected lower back, neck, even temporomandibular articulations problems.

Clinical relevance:

The findings of this study demonstrated practical recommendations for rehabilitation based on the findings, specific rehabilitation strategies can be recommended for clinicians working with stroke survivors for improving dorsiflexor activation (Tibialis Anterior Strengthening): Encourage anterior foot placement during STS practice. Incorporate functional dorsiflexion exercises, such as weight-shifting forward and step initiation drills in the anterior foot position. Use resistance bands or electrical stimulation to enhance tibialis anterior activation. For enhancing quadriceps activation (Rectus Femoris Strengthening): Train patients in symmetric (in-line) and anterior foot positions to maximize rectus femoris engagement. Implement progressive resistance training, such as STS exercises with added weights or resistance bands. Encourage sit-to-stand repetitions with controlled eccentric lowering, which targets the rectus femoris effectively. For improving stability and postural control: Use posterior foot placement for individuals with balance deficits or severe muscle weakness. Emphasize core engagement and controlled weight shifting to improve stability. Gradually progress from posterior to anterior foot placement as strength and confidence improve.

Strengths and limitations:

Despite its valuable insights, the study has certain limitations that should be acknowledged: small sample size (N=40): While the findings are clinically relevant, a larger cohort would provide greater generalizability. Lack of kinematic analysis: While sEMG provides valuable data on muscle activation, combining it with motion analysis could provide more comprehensive insights into biomechanical changes during STS. Additionally, the study focused on acute muscle activation patterns; future research should investigate whether these foot placement strategies lead to long-term functional improvements in mobility and gait.

5. CONCLUSION

Based on the study's scope, findings, and limitations, foot placement plays a significant role in lower limb muscle activation during the sit-to-stand movement in chronic stroke patients. Adjusting foot positioning can be a strategic approach in rehabilitation to optimize neuromuscular activation and enhance functional mobility. Specifically, anterior foot placement is recommended for improving tibialis anterior activation and dorsiflexion control. Symmetric and anterior foot positions are most effective for quadriceps strengthening, as they increase rectus femoris activation. Additionally, posterior foot placement offers increased stability, which may be particularly beneficial for patients with postural control deficits.

6. ACKNOWLEDGMENT

The authors greatly appreciated the patients who participated in this study.

7. Conflict of interest

The authors stated no conflict of interest.

8. Funding

This study received no external funding.

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