Elhamrawy *et al.*
Egypt J Neurol Psychiatry Neurosurg (2024) 60:31
https://doi.org/10.1186/s41983-024-00795-y

The Egyptian Journal of Neurology, Psychiatry and Neurosurgery

RESEARCH **Open Access**

Effect of functional electrical stimulation of interscapular muscles on trunk performance and balance in post-stroke elderly patients

Mohammed Youssef Elhamrawy[1*], Wafik Said Bahnasy[2], Sabah Mohamed Elkady[3] and Mohamed Taha Said[4]

Abstract

Background Disability in the upper limb in post-stroke survivors may have a variety of effects, particularly in the elderly, that require planning therapeutic actions to restore function. Thirty-four patients were randomly assigned to the control group (CON) and the Functional Electrical Stimulation (FES) group. For 12 weeks, the CON group received core stabilization exercises (CSEs). The FES group received (FES) for the interscapular muscles with CSEs for the first six weeks and completed the following six weeks with only CSEs. Patients were assessed at baseline, 6 and 12 weeks post-intervention. The trunk impairment scale (TIS) and the Postural Assessment Scale for Stroke (PASS) were used to assess trunk performance. A palpation meter was used to measure the scapular horizontal position (SP). Balance was assessed by the Berg Balance Scale (BBS), and the Timed Up-and-Go test (TUG). Function was assessed with Barthel Index (BI).

Results Both groups improved significantly ($P < 0.001$ for both groups, d = 1.1–3.7 for control group and d = 1.9–6.1 for FES group) post-treatment (at 6 and 12 weeks) in all outcomes except SP in the control group ($P < 0.05$ at both times, d = 0.6 at 6 weeks and 0.8 at 12 weeks).

Conclusion FES for interscapular muscles may have positive effects on trunk performance, scapular position, balance, and function in stroke patients. Also, additional improvements were observed post-intervention compared to baseline. FES is recommended to be part of the rehabilitation program of elderly post-stroke patients.

Keywords Functional electrical stimulation, Stroke, Trunk control, Scapular position, Balance

*Correspondence:
Mohammed Youssef Elhamrawy
dr_melhamrawy@yahoo.com
[1] Department of Physical Therapy, Faculty of Allied Medical Sciences, Middle East University, Amman, Jordan
[2] Department of Neurology, Faculty of Medicine, Tanta University, Tanta, Egypt
[3] Physiotherapy, Department of Basic Science, Faculty of Physical Therapy, Cairo University, Beni-Suef, Egypt
[4] Department of Physical Therapy for Elderly and Cardiovascular/Respiratory Disorders, National Institute for Longevity Elderly Sciences (NILES), Beni-Suef University, Beni-Suef 62511, Egypt

Background

Cerebrovascular stroke (CVS) is the most widespread acquired neurological disease affecting adults worldwide [1]. Improved stroke survival due to the quantum leap in early management is in ultimate need of parallel development in post-stroke recovery and rehabilitation programs as CVS is still the third-leading cause of disability [2, 3].

A few proportions of stroke survivors could attain practical upper extremity functions while the majority experience significant upper extremity (UE) disability due to weakness, subluxation, pain, spasticity, and pain leading to scapulothoracic dyskinesis [4, 5]. Changing scapular orientation, lack of scapular stability (scapula becomes winged away from the trunk caused by serratus anterior weakness), and increased motor deficiency in the upper extremity, are deficits that impair the routine of activities of daily living (ADLs), mainly the self-care activities and social interactions [6].

Balance disorders and the risk of falling in stroke survivors are among the most prevalent consequences resulting from impaired postural control, postural sway, weight-bearing asymmetry, and impairments in movement [7]. Additionally, balance and trunk stability are crucial for gait [8]. As a result, there may be a general decline in independence and quality of life, as well as a higher chance of having another stroke in the future [9].

Stroke also causes a significant loss of trunk muscle strength, which in turn lowers trunk performance. Additionally, a significant predictor of post-stroke functional and motor recovery is a balanced sitting position [10].

The scapula acts as dynamic stability with organized mobility and range of motion at the glenohumeral joint (GH). It plays a major role in smoothing UE actions. A biomechanical alternation of the scapula could lead to instability of the GH joint, which can cause subluxation, dysfunction, or pain around the shoulder joint [11].

FES of the upper limb is attracting interest as a therapeutic approach in post-stroke rehabilitation. A meta-analysis of controlled studies found that FES promotes muscle strength recovery after cerebrovascular accidents. It enables muscle relearning, improves range of motion, strength, postural tone, and motor control, enabling patients to practice meaningful tasks more effectively [12].

The FES, in which muscles are coordinatedly activated with the goal of providing function, can contribute to neuronal plasticity by antidromic muscle stimulation, or muscle concurrent stimulation of afferent fibers resulting in a greater synaptic remodeling [13].

Core-stabilization exercises (CSEs) promote strength, endurance, neuromuscular control, and coordination of the muscles that are predominant in maintaining trunk and spine dynamic stability. In combined kinetic chain activities, it is possible to construct, transfer, and regulate motion and forces to all segments by controlling the trunk's motion and position above the pelvis and leg [14].

Most ADLs, including sitting, standing, walking, and supporting the lower limbs, require core stability and precise trunk muscle control. Stroke causes aberrant muscle activation and disturbances in motor patterns [15, 16].

Methods

The study followed a randomized controlled trial aimed at evaluating the effects of functional electrical stimulation (FES) for intrascapular muscles on trunk performance, scapular position, and balance in elderly post-stroke hemiparetic patients. The secondary outcome was to evaluate the functional performance of the participants. The study was conducted between September 2022 and February 2023. All patients were informed about the study's nature, purpose, and potential risks, all the patients gave informed consent, stating that they were willing to participate.

The study enrolled 34 patients with post-stroke hemiparesis. Using a computer-based randomization program, they were divided into two equal groups: the control (CON) group (underwent CSEs only) and the study group (underwent FES first 6 weeks + CSEs and the next 6 weeks CSEs). The Mini-Mental State Examination (MMSE), which is closely connected to stroke and age, was used to rule out any cognitive abnormalities that would interfere during the application of the FES, as well as to assure that all participants follow the instructions accurately.

Inclusion criteria: Patients were ≥ 60 years old of both sexes, had a first-time-right or left CVS within the preceding 6 months that damaged the cerebral cortex confirmed by (medical chart, neurological examination, and computed tomography or MRI report) and were able to stand and walk independently, a Modified Ashworth Scale (MAS) of upper limb muscle ≤ 1 +.

Exclusion criteria: Patients with orthopedic, neurological problems, epilepsy, paralysis neglect, behavioral abnormalities, any shoulder dysfunction before or post-stroke (dislocation or subluxation), or those who used upper limb splints.

For 12 weeks, the CON group completed 45 min of CSEs (4 days/week), Fig. 1. Each conventional core stability program consisted of exercises to improve core stability and balance [17]; each exercise was repeated 15–20 times. Sitting position with slow forward bending, and then slowly rotating the trunk alternatively in clockwise and counterclockwise directions to keep the trunk muscles engaged. Sitting position with extended shoulders, clasped hands together (holding 1 KG weight), and then alternately punch laterally to the right, and then to the left to complete lateral punches, as shown in Fig. 2a, return to resting position and repeat. Sitting position with alternating bending right leg back into the chest, try to relax the leg muscles by engaging the core muscles to lift the leg. Crock-lying position with feet flat on the floor, knee bending then alternating roll both hips to the right and left. Crock-lying position with pushing heels into the floor tightening the gluteus and abdominal muscles and lifting hips and back from the floor (bridging), as shown in Fig. 2b. Sitting on a ball with eyes open, with foam feet, and alternately shifting weight toward the right and the left sides while maintaining trunk in the erect position.

The FES group received FES for the interscapular muscles in the paretic side 30 min per session (4 days/week),

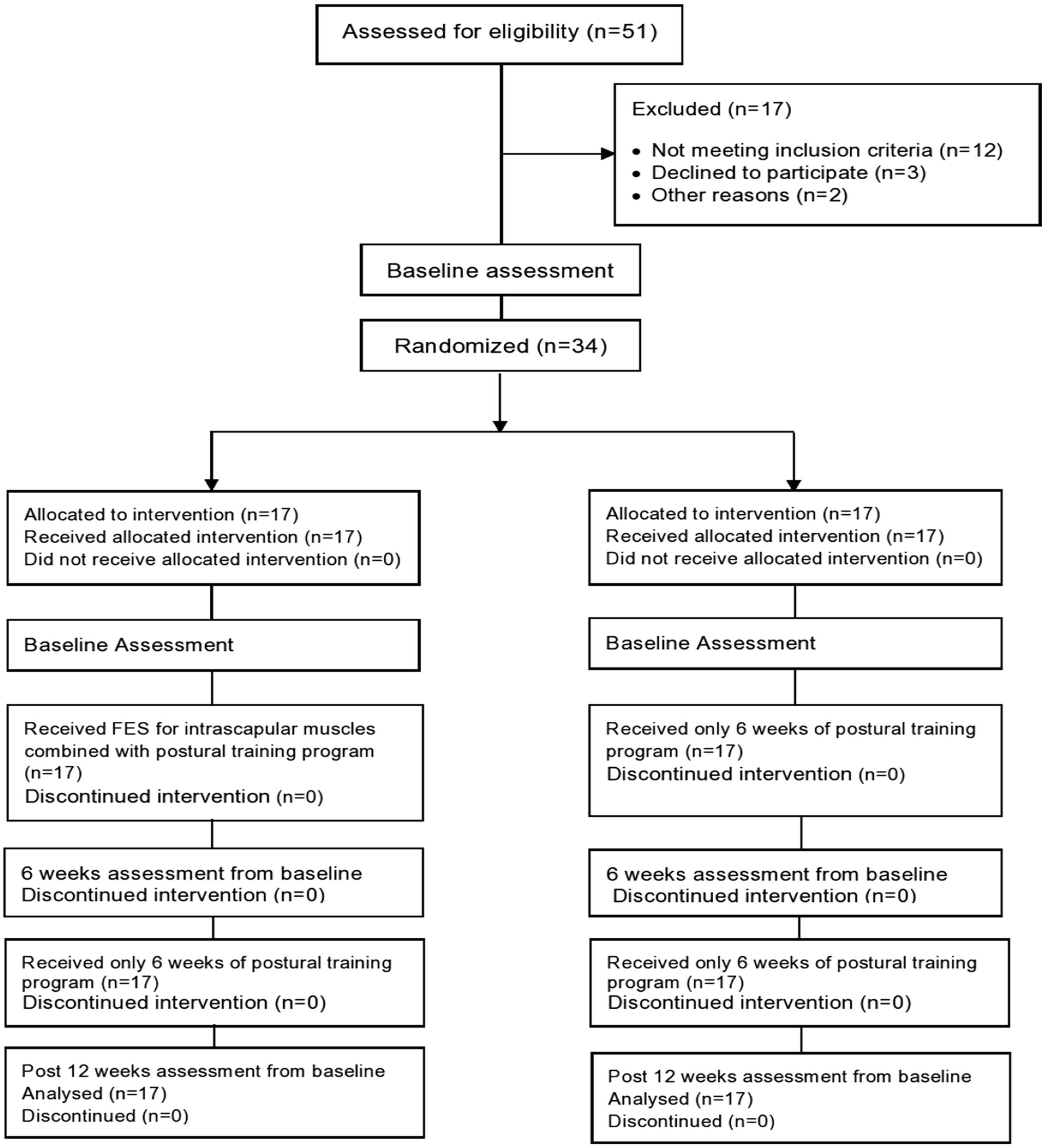

Fig. 1 Patients' flowchart

with core stabilization exercise (CSEs) 45 min four days per week for the first six weeks and completed the next six weeks with only (CSEs) 45 min four days per week. We did not discontinue training the patients in both groups because core stability exercises (CSEs) are considered part of the rehabilitation regimen for patients with chronic hemiplegia following stroke.

The electric stimulation device was used to deliver interscapular muscle stimulation as FES with (pulse width 300 μs, frequency 33 Hz, 6 s on followed by 6 s off, 4 days/week for 6 weeks), (5 cm × 5 cm) six Dura-Stick® electrodes were used [18]. Three muscle groups were selected the lower fiber of the trapezius muscle (LT), the upper fiber of the trapezius muscle (UT), and the serratus anterior muscle (SA) [19], Two electrodes were placed for each muscle according to the points where the optimum contraction was obtained; each muscle received stimulation through a separate channel, as shown in Fig. 3. Electrodes were initially placed over the nerve(s) that innervate the muscle to be stimulated, and stimulation

Fig. 2 **a** Patient sitting with extended shoulders, clasped hands together and then alternately punch laterally to the right, and then to the left. **b** Patient crock-lying position with pushing heels, tightening the gluteus and abdominal muscles and lifting hips and back

Fig. 3 Patient with the functional electrical stimulation device on intrascapular muscles

was applied. The process was complete if the final movement was the desired one. Otherwise, electrodes were adjusted (typically with minor modifications of no more than a few centimeters) and the procedure was repeated until the required movement was achieved. The intensity of the stimulation was gradually increased, usually in increments as small as the stimulator allows [20]. The patients were instructed to inform about any uncomfortable skin sensation or muscle contraction.

Both groups were evaluated for spinal performance, scapular position, balance, and function at baseline, 6, and 12 weeks after the intervention. Spinal performance scores were identified by the Trunk Impairment Scale (TIS), and the Postural Assessment Scale for Stroke (PASS). The 17-item TIS assesses trunk coordination and sitting balance (static and dynamic) on a 2, 3, or 4-point ordinal scale. A higher score indicates a better performance. The total score is a number between 0 and 23, where 0 represents the lowest score and 23 the greatest [10].

PASS measures the patient's capacity to maintain stable postures as well as equilibrium in changes of position. It is typically used as an independent predictor of the functional outcome in stroke survivors [21, 22]. The PASS test consists of 12 items that get harder as they go, measuring balance while lying down, sitting up, and standing up [23]. Compared to the Berg Balance Scale and the Fugl-Meyer Assessment modified balance scale, the PASS exhibits better psychometric properties [24, 25].

A Palpation meter (Baseline[@] Evaluation Instrument, SKU FS628, USA) was used to measure the scapular horizontal distance. The distance in centimeters (cm) between the closest horizontal spinous process of the thoracic spine and the inferior angle of the scapula. Three measurements were conducted, and the mean was used in the results [26].

The most valid and reliable tests used scales to evaluate balance problems in stroke survivors are the Berg Balance Scale (BBS), and the timed up and go (TUG), also used to evaluate functional mobility, fall prediction, and reaction rate [27]. The Barthel index (BI) is frequently used to assess stroke patients' ability to perform activities of daily living (ADL) during the phases of drug treatment and rehabilitation [28].

Statistical analysis of the data was performed using IBM SPSS Statistics (version 25.0 for Windows, IBM Corp., Armonk, NY). A repeated measures analyses of variance (ANOVA, with a Tukey post hoc multiple comparison) and an independent t test were used to compare differences within and between groups, respectively. The effect sizes (Cohen's d) were determined by averaging the differences between the changes post 6 and 12 weeks and the baseline. The significance level was set at $P < 0.05$.

Table 1 Baseline characteristics of the patients

Variables	FES group	CON group	P between group
Number	17	17	–
Age mean ± SD	66.4 ± 3.6	68.5 ± 3.8	0.1079
Sex, *n* (% male)	11 (68.75)	10 (62.5)	–
BMI (kg/m^2)	28.4 ± 1.2	28.3 ± 1.8	0.8172
Months post-stroke	7.3 ± 1.2	7.2 ± 1.8	0.8501
Ischemic/hemorrhagic	12/5	11/6	0.0606
Side of paralysis Rt/Lt	14/3	13/4	–
MMS	26.4 ± 0.9	26.9 ± 1.1	0.1567
FMA	81.8 ± 2.11	80.7 ± 2.7	0.6336

BMI: body mass index, CON: control, FES: functional electrical stimulation, Lt: left, N: number, Rt: right, SD: standard deviation, MMSE: Mini-Mental Status Exam, FMA: Fugl-Meyer Assessment

Sample size was calculated using G* power software (3.1) expecting effect size d = 0.65 (two-tailed t test of difference between two independent means) based on previous study [29]. Power was set at 80% and alpha was set at 0.05.

Results

Table 1 displays the patients' initial characteristics. Age, sex, body mass index (BMI), months post-stroke, causes of the lesion, Mini-Mental State Examination (MMSE), or Fugl-Meyer Assessment (FMA) scores were not significantly different between the groups at baseline. Tables 2 and 3 show the changes in trunk performance (evaluated by TIS and PASS), scapular position (SP) evaluated by the distance (cm) between the inferior angle of the scapula and the closest horizontal dorsal spinous process, and balance (evaluated by BBS and TUG) scores in the FES and CON groups. Data were analyzed using ANOVA and a Tukey post hoc multiple comparison.

The CON group showed significant improvement ($P \leq 0.001$) in TIS, PASS, BBS, TUG, and BI with large effect size (Cohen d between 1.1 and 3.7) at 6 and 12 weeks. The SP showed statistically non-significant, but clinically significant, reduction after 6 and 12 weeks compared to the baseline ($P = 0.4946$, d = 0.6, and $P = 0.4113$, d = 0.8, respectively), as shown in Table 2 and Fig. 4.

The FES group showed significant improvement ($P \leq 0.001$) in TIS, PASS, SP, BBS, TUG, and BI with large

Table 2 Changes in variables in the CON group pre- and post-intervention

CON group	Baseline	6 weeks	12 weeks	Baseline versus 6 weeks		Baseline versus 12 weeks	
				p-value	d	p-value	d
TIS (range 0–23)	14.06 ± 1.03	15.2 ± 0.97	15.9 ± 0.75	< 0.001*	1.14	< 0.001*	1.84
PASS	20.8 ± 1.2	21.6 ± 1.1	22.1 ± 0.8	< 0.001*	0.8	< 0.001*	1.3
SP (cm)	10.9 ± 2.9	10.3 ± 2.1	10.1 ± 2.7	0.4946	0.6	0.4113	0.8
BBS	44.06 ± 1.24	46.4 ± 1.27	47.5 ± 1.28	< 0.001*	2.34	< 0.001*	3.74
TUG (s)	17.5 ± 1.1	15.3 ± 1.3	14.5 ± 0.94	< 0.001*	2.2	< 0.001*	3.2
BI	51.9 ± 1.46	54.1 ± 1.45	58.2 ± 1.04	< 0.001*	2.16	< 0.001*	6.3

*Significant, BBS: Berg Balance scale BI: Barthel Index, cm: centimeters, CON: control, PASS: Postural Assessment Scale, s: seconds, SP: scapular position, TIS: Trunk Impairment Scale, TUG: Timed-Up-and-Go test

Table 3 Changes in variables in the FES group pre- and post-intervention

Study group	Baseline	6 weeks	12 weeks	Baseline versus 6 weeks		Baseline versus 12 weeks	
				p-value	d	p-value	d
TIS (range 0–23)	14.2 ± 1.07	16.1 ± 1.2	16.8 ± 0.9	< 0.001*	1.9	< 0.001*	2.6
PASS	20.6 ± 1.6	21.9 ± 1.3	22.7 ± 0.9	< 0.001*	1.3	< 0.001*	2.1
SP (cm)	11.36 ± 2.06	9.05 ± 1.9	8.45 ± 2.1	< 0.001*	2.3	< 0.001*	2.9
BBS	43.8 ± 1.36	48.47 ± 1.4	49.8 ± 1.3	< 0.001*	4.67	< 0.001*	6.1
TUG (s)	17.7 ± 1.3	14.5 ± 1.06	13.4 ± 1.2	< 0.001*	3.2	< 0.001*	4.3
BI	49.1 ± 1.6	53.46 ± 0.6	58.9 ± 0.7	< 0.001*	4.36	< 0.001*	8.9

*Significant, BBS: Berg Balance scale BI: Barthel Index, cm: centimeters, FES: functional electrical stimulation, PASS: Postural Assessment Scale, s: seconds, SP: scapular position, TIS: Trunk Impairment Scale, TUG: Timed-Up-and-Go test

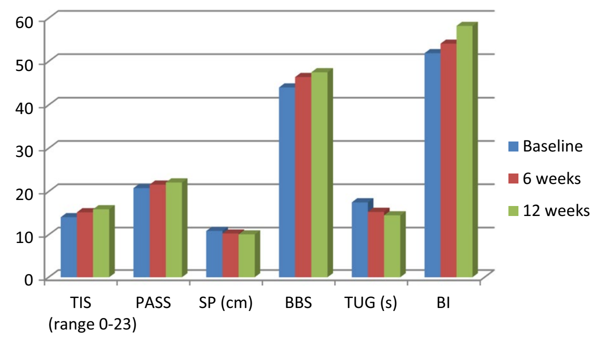

Fig. 4 The CON group mean values of Trunk Impairment Scale (TIS), and the Postural Assessment Scale for Stroke (PASS), Scapular Position (SP), Berg Balance Scale (BBS), Timed Up and Go (TUG), and Barthel index (BI) in the control group at baseline, 6 and 12 weeks post-intervention

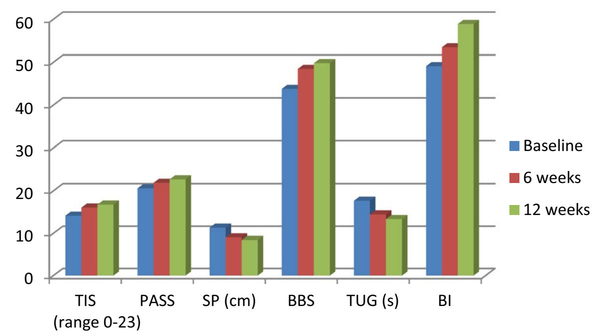

Fig. 5 The FES group mean values of Trunk Impairment Scale (TIS), and the Postural Assessment Scale for Stroke (PASS), Scapular Position (SP), Berg Balance Scale (BBS), Timed Up and Go (TUG), and Barthel index (BI) in the control group at baseline, 6 and 12 weeks post-intervention

effect size (Cohen d between 1.9 and 8.9) at 6 and 12 weeks, as shown in Table 3 and Fig. 5.

Between-group comparisons, using independent t tests, at baseline, 6 and 12 weeks post-intervention in all outcomes showed that there are significant differences between groups ($P<0.05$) in TIS, BBS, and BI at 6 and 12 weeks, and PASS and TUG at 12 weeks, in favor of study group. While, SP at 12 weeks tends to be significant in favor of study group as well ($P=0.054$) (Table 4).

Table 4 Between-group comparisons at baseline, 6 and 12 weeks post-intervention in all outcomes

CON group versus FES group		t	Sig. (2-tailed)	Mean difference
TIS	Baseline	− 0.326	0.75	− 0.12
	Post 6 weeks	− 2.764	0.01*	− 0.94
	Post 12 weeks	− 3.292	0.002*	− 0.94
PASS	Baseline	0.473	0.64	0.24
	Post 6 weeks	− 0.587	0.56	− 0.24
	Post 12 weeks	− 2.102	0.04*	− 0.59
SP	Baseline	− 0.580	0.57	− 0.50
	Post 6 weeks	1.863	0.07	1.26
	Post 12 weeks	2.003	0.054	1.68
BBS	Baseline	.393	0.70	0.18
	Post 6 weeks	− 4.662	0.000*	− 2.12
	Post 12 weeks	− 4.990	0.000*	− 2.24
TUG	Baseline	− 0.721	0.48	− 0.29
	Post 6 weeks	1.906	0.066	0.76
	Post 12 weeks	2.976	0.006*	1.12
BI	Baseline	5.247	0.000*	2.76
	Post 6 weeks	1.687	0.02*^	0.65
	Post 12 weeks	− 2.060	0.000*^	− 0.65

*Significant at $P<0.05$, ^analysis of covariance (ANCOVA, with pretest score as covariate) as there as significant difference at baseline, BBS: Berg Balance Scale, BI: Barthel index, CON: control, FES: functional electrical stimulation, PASS: Postural Assessment Scale for Stroke, SP: scapular position, TIS: Trunk Impairment Scale, TUG: Timed Up and Go

Discussion

The results of this study showed that both groups demonstrated a significant improvement in trunk performance (evaluated by TIS and PASS), balance (evaluated by BBS and TUG), and function (evaluated by BI) in elder patients with post-stroke hemiparesis, but the FES exercise had a superior improvement. Also, the FES showed a significant improvement in the scapular position as the distance (cm) measured between the inferior angle of the scapula and the closest horizontal dorsal spinous process decreased, and this improvement was continued after stimulation, and there was a further improvement in the trunk performance and balance compared to baseline.

The control group did not show statistical significant improvement, but had significant clinical improvement which necessitates a further research on a larger sample to prove this effect.

Balance disorders post-stroke are caused by motor impairments, sensory disturbance, perceptual deficits, and changes in spatial cognition. Weight-bearing asymmetry, the smaller surface of stability, increased sway, and body tilting [30]. In our study, the improvement of balance and trunk performance in both groups might be attributed to that core stability has well-established reliability of improving trunk muscle performance as support for the lumbo-pelvic-hip complex. Additionally, previous studies have shown that core stability training can enhance balance and mobility in addition to improving trunk performance [31, 32].

An earlier study found that exercising core stability training for 400 min (20 min/day for 20 days) may increase mobility, stability, and trunk function. These findings provide proof that stroke patients benefit from interventions based on the core stability theory that target trunk muscle activation [33].

The deficits in trunk and scapular movement patterns that exist in stroke survivors make it difficult to achieve selective and an optimal activation of their muscles, which negatively impacted the function and position of the UE. A suitable starting position at the level of the scapula and the trunk is essential for proper UE function [34]. The improper scapular muscle activation causes excessive trunk movement, stimulation at this level should improve movement patterns and reduce the propensity for forward trunk bending. The activation of the abdominal and multifidus muscles to stabilize the body and head both before and during limb movements forms the basis of core stabilization exercises [35].

FES uses a low-energy electrical pulse to cause muscle contractions, which can enable functional movements in people with upper motor neuron lesion paralysis [20]. Due to an increase in muscle mass and strength, which also improved scapular alignment and postural adjustment, FES showed a superior improvement in trunk performance and balance [36].

Previous research demonstrating an increase in muscle strength in middle-aged stroke patients treated with FES raises the possibility that FES also has positive effects on muscle mass, which is inversely correlated with muscle strength. Strength and muscle mass may be related to stroke survivors. The majority of studies involved participants who were 50 on average, a group that includes older adults as well. As a result, older adults may experience the same outcomes, though studies with larger samples of older adults are necessary [37, 38].

The study's findings are in line with those of previous studies, in terms of improving scapular stabilization, it has been established that training of scapular muscles by exercise or by FES might result in improvement of scapular position and can have a positive impact on the shoulder joint, resulting in improved UE function and, consequently, the trunk and balance [6, 39].

According to a recent study in 2022, when applying FES to the upper limb, one should consider the need to recruit muscle synergy. FES is a promising tool that can integrate postural control muscles in other anatomical areas, like the ipsilesional side and the trunk, which are needed to enhance the affected UE functions in the hemiparetic side after a stroke [40]. This explained the superior improvement in the FES group that might be a result of improved scapular stabilization and postural adjustment.

Scapular malalignment (dyskinesis), is the absence of natural scapular movement, is the term used to describe changes in the position and motion of the scapula. In this study, the distance (cm) between the inferior angle of the scapula and the nearby spinal vertebra decreased as the range of motion of the scapula in stroke patients was further altered by the activation of scapular muscles by FES [41].

The findings of this study show that the improvement of ADLs performance measures by BI in both groups is because of improvement in dynamic balance while sitting and standing, as the CSEs are effective in restoring lower trunk muscle activity, which is primarily impacted by hemiplegia [35].

This study has some strength in that it is the first study to investigate the medium term (12 weeks) effect of FES of the interscapular muscles on trunk performance (evaluated by TIS and PASS), scapular position (evaluated by Palpation meter), balance (evaluated by BBS and TUG), and function (evaluated by BI) in elderly patients with post-stroke hemiparesis, according to the authors.

Conclusions

FES for interscapular muscles (UT, LT, and SA) significantly improve scapular alignment, shoulder position, and shoulder muscle power. FES combined with core stabilization exercises has a beneficial effect on improving trunk performance, postural adjustment, scapular alignment, balance, and ADLs performance in chronic stroke survivors. FES should be used in rehabilitation programs for stroke survivors.

Recommendations

As a result, more research (randomized controlled trials) on the long-term effects of FES on a bigger sample are required. Also the applications of FES on different neurological cases like traumatic brain injuries or spinal cord injuries.

Limitations

This study is restricted by a lack of long-term follow-up and a true control group, as well as the inclusion of a small sample size.

Abbreviations

ADLs	Activities of daily living
BBS	Berg Balance Scale
BI	Barthel index
BMI	Body mass index
CON	Control
CSEs	Core stabilization exercise
CVS	Cerebrovascular stroke
FES	Functional electrical stimulation
FMA	Fugl-Meyer assessment
LT	Lower fiber of the trapezius muscle
MMSE	Mini-Mental State Examination
PASS	Postural Assessment Scale for Stroke
SA	Serratus anterior muscle
SP	Scapular horizontal position

TIS Trunk Impairment Scale
TUG Timed Up-and-Go test
UE Upper extremity
UT Upper fiber of the trapezius muscle

Acknowledgements
We would like to thank the National Institute for Longevity Elderly Sciences (NILES) staff for their great help in patients' selection and evaluation.
The work was carried out in, the National Institute for Longevity Elderly Sciences (NILES), Beni-Suef University, Beni-Suef, Egypt 62511.

Author contributions
MYE: participated in the study's idea, design, patients' selection, statistical analysis, data analysis, references collection, manuscript writing, revision and final approval, WSB: participated in study's idea and design, patients' assessment and inclusion, neurological examination, data analysis, statistical analysis, references collection, manuscript writing, revision and final approval, SME: participated in the study's idea, design, patients' selection, and evaluation, data analysis, references collection, manuscript revision and final approval. MTS: participated in study's design, patients' assessment, exercise prescription and application of electrotherapy, references collection, manuscript revision and final approval.

Funding
No funding had been received.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The manuscript was approved by the Institutional Ethics Committee of the Faculty of Medicine, Beni Suef University, Egypt. The URL: https://www.bsu.edu.eg/ContentSide.aspx?section_id=4732&cat_id=9&lang=en. Approval Code: FMBUREC/04012023/Saeed. National institute for longevity elderly sciences. Promotion research. January 2023. The study's protocol had approved by approved by the Institutional Ethics Committee of the Faculty of Medicine, Beni Suef University, Egypt. Participation was voluntary, informed consents were approved by all participants and any possible risks were clarified.

Consent of publication
Not applicable.

Competing interests
All authors disclose that they have no competing interests related to the study.

Received: 22 August 2023 Accepted: 20 January 2024
Published: 23 February 2024

References

1. Ju YW, Lee JS, Choi Y-A, Kim YH. Causes and trends of disabilities in community-dwelling stroke survivors: a population-based study. Brain Neurorehabilit. 2022;15(1): e5.
2. Murphy SJ, Werring DJ. Stroke: causes and clinical features. Medicine. 2020;48(9):561–6.
3. Seitz RJ, Donnan GA. Recovery potential after acute stroke. Front Neurol. 2015;6.
4. Kumar P, Fernando C, Mendoza D, Shah R. Risk and associated factors for hemiplegic shoulder pain in people with stroke: a systematic literature review. Phys Ther Rev. 2022;27(3):191–204.
5. Ebaugh DD, McClure PW, Karduna AR. Three-dimensional scapulothoracic motion during active and passive arm elevation. Clin Biomech (Bristol, Avon). 2005;20(7):700–9.
6. Park S-E, Kim Y-R, Kim Y-Y. Immediate effects of scapular stabilizing exercise in chronic stroke patient with winging and elevated scapula: a case study. J Phys Ther Sci. 2018;30(1):190–3.
7. Youssef Elhamrawy M, Mohamed S, Bahnasy W, Yasser Saif M, Elkholy A, Said M. Effect of vestibular rehabilitation therapy on spatio-temporal gait parameters in elderly patients with post-stroke hemineglect. Adv Rehabil. 2021;35(3):17–24.
8. Lee NG, You JH, Yi CH, Jeon HS, Choi BS, Lee DR, et al. Best core stabilization for anticipatory postural adjustment and falls in hemiparetic stroke. Arch Phys Med Rehabil. 2018;99(11):2168–74.
9. Rose DK, DeMark L, Fox EJ, Clark DJ, Wludyka P. A Backward Walking Training program to improve balance and Mobility in acute stroke: a pilot randomized controlled trial. J Neurol Phys Ther. 2018;42(1):12–21.
10. Sorrentino G, Sale P, Solaro C, Rabini A, Cerri CG, Ferriero G. Clinical measurement tools to assess trunk performance after stroke: a systematic review. Eur J Phys Rehabil Med. 2018;54(5).
11. da Costa BR, Armijo-Olivo S, Gadotti I, Warren S, Reid DC, Magee DJ. Reliability of scapular positioning measurement procedure using the Palpation Meter (PALM). Physiotherapy. 2010;96(1):59–67.
12. Eraifej J, Clark W, France B, Desando S, Moore D. Effectiveness of upper limb functional electrical stimulation after stroke for the improvement of activities of daily living and motor function: a systematic review and meta-analysis. Syst Rev. 2017;6(1).
13. Quandt F, Hummel FC. The influence of functional electrical stimulation on hand motor recovery in stroke patients: a review. Exp Transl Stroke Med. 2014;6(1):1–7.
14. Cabanas-Valdés R, Boix-Sala L, Grau-Pellicer M, Guzmán-Bernal JA, Caballero-Gómez FM, Urrútia G. The effectiveness of additional core stability exercises in improving dynamic sitting balance, gait and functional rehabilitation for subacute Stroke patients (CORE-trial): study protocol for a randomized controlled trial. Int J Environ Res Public Health. 2021;18(12):6615.
15. Marchesi G, Ballardini G, Barone L, Giannoni P, Lentino C, De Luca A, et al. Modified Functional Reach Test: upper-body kinematics and muscular activity in chronic stroke survivors. Sensors (Basel). 2021;22(1):230.
16. Segal M. Muscle overactivity in the upper motor neuron syndrome. Phys Med Rehabil Clin N Am. 2018;29(3):427–36.
17. Chung E-J, Kim J-H, Lee B-H. The effects of core stabilization exercise on dynamic balance and gait function in stroke patients. J Phys Ther Sci. 2013;25(7):803–6.
18. Cuesta-Gómez A, Molina-Rueda F, Carratala-Tejada M, Imatz-Ojanguren E, Torricelli D, Miangolarra-Page JC. The use of functional electrical stimulation on the upper limb and interscapular muscles of patients with stroke for the improvement of reaching movements: a feasibility study. Front Neurol. 2017;8.
19. Kapadia N, Moineau B, Marquez-Chin M, Myers M, Lon Fok K, Masani K, et al. Feasibility and significance of stimulating interscapular muscles using transcutaneous functional electrical stimulation in able-bodied individuals. J Spinal Cord Med. 2021;44(sup1):S185–92.
20. Marquez-Chin C, Popovic MR. Functional electrical stimulation therapy for restoration of motor function after spinal cord injury and stroke: a review. Biomed Eng Online. 2020;19(1).
21. Estrada-Barranco C, Cano-de-la-Cuerda R, Abuín-Porras V, Molina-Rueda F. Postural Assessment Scale for Stroke Patients in acute, subacute and chronic stage: a construct validity study. Diagnostics (Basel). 2021;11(2):365.
22. Barros de Oliveira C, Torres de Medeiros ÍR, Frota NAF, Greters ME, Conforto AB. J Rehabil Res Dev. 2008;45(8):1215.
23. Blum L, Korner-Bitensky N. Usefulness of the Berg Balance Scale in stroke rehabilitation: a systematic review. Phys Ther. 2008;88(5):559–66. https://doi.org/10.2522/ptj.20070205.
24. Mao H-F, Hsueh I-P, Tang P-F, Sheu C-F, Hsieh C-L. Analysis and comparison of the psychometric properties of three balance measures for Stroke Patients. Stroke. 2002;33(4):1022–7.
25. Hendricks HT, van Limbeek J, Geurts AC, Zwarts MJ. Motor recovery after stroke: a systematic review of the literature. Arch Phys Med Rehabil. 2002;83(11):1629–37.
26. Sobush DC, Simoneau GG, Dietz KE, Levene JA, Grossman RE, Smith WB. The Lennie test for measuring scapular position in healthy young

adult females: a reliability and validity study. J Orthop Sports Phys Ther. 1996;23(1):39–50.
27. Son H, Park C. Effect of turning direction on Timed Up and Go test results in stroke patients. Eur J Phys Rehabil Med. 2019;55(1).
28. Li Q-X, Zhao X-J, Wang Y, Wang D-L, Zhang J, Liu T-J, et al. Value of the Barthel scale in prognostic prediction for patients with cerebral infarction. BMC Cardiovasc Disord. 2020;20(1).
29. Robbins SM, Houghton PE, Woodbury MG, Brown JL. The therapeutic effect of functional and transcutaneous electric stimulation on improving gait speed in stroke patients: a meta-analysis. Arch Phys Med Rehabil. 2006;87(6):853–9.
30. Tasseel-Ponche S, Yelnik AP, Bonan IV. Motor strategies of postural control after hemispheric stroke. Neurophysiol Clin. 2015;45(4–5):327–33.
31. Durall CJ, Udermann BE, Johansen DR, Gibson B, Reineke DM, Reuteman P. The effects of preseason trunk muscle training on low-back pain occurrence in women collegiate gymnasts. J Strength Cond Res. 2009;23(1):86–92.
32. Cabanas-Valdés R, Bagur-Calafat C, Girabent-Farrés M, Caballero-Gómez FM, Hernández-Valiño M, Urrútia CG. The effect of additional core stability exercises on improving dynamic sitting balance and trunk control for subacute stroke patients: a randomized controlled trial. Clin Rehabil. 2016;30(10):1024–33.
33. Haruyama K, Kawakami M, Otsuka T. Effect of core stability training on trunk function, standing balance, and mobility in stroke patients: a randomized controlled trial. Neurorehabil Neural Repair. 2017;31(3):240–9.
34. De Baets L, Van Deun S, Monari D, Jaspers E. Three-dimensional kinematics of the scapula and trunk and associated scapular muscle timing in individuals with stroke. Hum Mov Sci. 2016;48:82–90.
35. Yu S-H, Park S-D. The effects of core stability strength exercise on muscle activity and trunk impairment scale in stroke patients. J Exerc Rehabil. 2013;9(3):362–7.
36. Shin HE, Kim M, Lee D, Jang JY, Soh Y, Yun DH, et al. Therapeutic effects of functional electrical stimulation on physical performance and muscle strength in post-stroke older adults: a review. Ann Geriatr Med Res. 2022;26(1):16–24.
37. Akazawa N, Harada K, Okawa N, Tamura K, Moriyama H. Muscle mass and intramuscular fat of the quadriceps are related to muscle strength in non-ambulatory chronic stroke survivors: a cross-sectional study. PLoS ONE. 2018;13(8): e0201789.
38. Sabut SK, Sikdar C, Kumar R, Mahadevappa M. Improvement of gait & muscle strength with functional electrical stimulation in sub-acute & chronic stroke patients. In: 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE; 2011.
39. Cuesta-Gómez A, Carratalá-Tejada M, Molina-Rueda F, Miangolarra-Page JC. Functional electrical stimulation improves reaching movement in the shoulder and elbow muscles of stroke patients: a three-dimensional motion analysis. Restor Neurol Neurosci. 2019;37(3):231–8.
40. Sousa ASP, Moreira J, Silva C, Mesquita I, Macedo R, Silva A, et al. Usability of functional electrical stimulation in upper limb rehabilitation in post-stroke patients: a narrative review. Sensors (Basel). 2022;22(4):1409.
41. Kazi EN, Post Graduate Student, D.V.V.P. F'S College of Physiotherapy, Ahmednagar, Maharashtra, India., Ganvir SS, Head of the Department, D.V.V.P. F'S College of Physiotherapy, Ahmednagar, Maharashtra, India. Scapular Malalignment in patients with stroke: a narrative review. Int J Physiother Res. 2021;9(6):4051–7.

Publisher's Note