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# Effect of functional electrical stimulation on changes in muscle mass following stroke and functional abilities in hemiplegic subjects

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## Abstract

**Introduction**: Stroke frequently causes hemiplegia associated with muscle atrophy. Functional electrical stimulation (FES) is proposed to limit this muscle loss and support recovery.

**Objective**: To evaluate the effect of FES on quadriceps and hamstring muscle thickness, as well as on the functional abilities of post-stroke hemiplegic subjects.

**Methods**: This prospective observational study included 31 post-stroke hemiplegic patients, evaluated on day 0 and day 30. Quadriceps and hamstring muscle thickness was measured by ultrasound, and functional performance was assessed using the NIHSS, muscle strength, and the ABILICO scale.

**Results**: After 4 weeks of FES applied to the paretic limb, no significant change in muscle thickness was observed in the stimulated quadriceps and hamstrings. However, a significant increase in quadriceps thickness was found in the non-paretic limb. No significant changes were noted in NIHSS, muscle strength, or functional performance, and no correlation emerged between muscle trophicity and neurological severity.

**Conclusion**: These results indicate that short-term FES is not sufficient to influence muscle mass or functional recovery, highlighting the need for longer-term protocols integrated into.

**Keywords:** Hemiplegic Subjects; Electrical Stimulation; Muscle Mass; Muscle Trophicity; Functional Performance

## 1. Introduction

Stroke is the leading cause of acquired disability in adults and the second leading cause of death worldwide [1]. After a stroke, more than 60% of patients remain disabled, 50% suffer from hemiparesis, and 30% are unable to walk without assistance [2]. The resulting hemiplegia often leads to rapid muscle atrophy, exacerbating functional loss. Skeletal muscle is suggested to be the main effector organ responsible for physical disability in the stroke population [3]. Previous studies have shown that chronic stroke survivors (> 6 months after stroke) experience muscle mass loss and decreased muscle strength in both paretic and non-paretic limbs [4].

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Rehabilitation is the most effective means of limiting the extent of disability and improving patient functionality (motor function, balance, walking speed, and activities of daily living) after a stroke [5].

Functional electrical stimulation (FES) has been proposed as an adjunct to rehabilitation in order to preserve muscle mass and stimulate motor recovery [6]. However, its effectiveness on muscle trophicity and functional recovery remains debated, with sometimes contradictory results.

The objective of this study was to evaluate the effect of SEF on quadriceps and hamstring muscle thickness measured by ultrasound, as well as on functional recovery (NIHSS, muscle strength, ABILICO scale) in post-stroke hemiplegic patients.

## 2. Materials and methods

### 2.1. Study population

This was a prospective observational study that included 31 hemiplegic patients admitted to CNHU-HKM (Cotonou) and CHUD-BA (Parakou) after a clinically and/or radiologically confirmed stroke. To be included in the study sample, patients had to: have a diagnosis confirmed by brain scan; be admitted to hospital within 7 days of the onset of stroke with hemiplegia; be at least 18 years of age; have a medical record that provides information on the patient's characteristics; have authorization from the attending physician to undergo the assessments required for the research; give written informed consent to participate in all phases of the study. Patients who have had a recurrent stroke, those whose medical records are incomplete, or those who are unable to perform the proposed tests are not included. The exclusion criteria were as follows: having neurological and muscular impairments prior to the stroke; leaving the hospital early before the end of the investigation.

### 2.2. Research protocol

At inclusion (D0), a clinical examination was performed, including measurement of vital signs, neurological assessment (NIHSS), measurement of muscle strength, and assessment of walking ability using the ABILICO scale.

The muscle thickness of the quadriceps and hamstrings was measured by ultrasound according to a standardized protocol, performed by the same operator to limit inter-examiner variability. For all patients, the thickness of the quadriceps and hamstring muscles was assessed by measuring the diameter of the rectus femoris at the proximal, medial, and distal levels, as well as the transverse diameter of the semitendinosus, semimembranosus, and biceps femoris muscles on the day the patients gave their informed consent and 30 days after the first measurement. These various measurements were taken on both lower limbs (paretic and non-paretic).

An FES protocol was applied to the paretic lower limb, at a rate of 5 sessions per week for 4 weeks. The stimulation parameters were adjusted to achieve a visible and tolerated contraction. The skin was carefully cleaned. Large-surface (90 × 50 mm, réf G0465), pre-gelatinized, easily removable transcutaneous surface electrodes that adhere to the skin were placed at the motor points of the quadriceps and hamstrings of the paretic leg [7]. The Globus Premium 400 stimulator (ref. JFB-296-1119) with 4 channels delivered biphasic and symmetrical pulses of 50 Hz, with a pulse duration of 300 s, 12 s on and 6 s off, at intensities capable of causing visible contractions and at the maximum intensity tolerated by the subject (range, 20 mA–50 mA). The session lasted 50 min.

On day 30, the same assessments were repeated. Statistical analysis used appropriate parametric or non-parametric tests. The significance threshold was set at $p < 0.05$.

## 3. Results

The study population had a mean age of 57.9 ± 9.9 years, a mean BMI of 25 ± 2.3, and was composed of 64.5% men. The average body temperature was 38.3 ± 1.0 °C, the average blood pressure was 157.1 ± 13.7 mmHg (systolic) and 89.6 ± 10.2 mmHg (diastolic), and the average heart rate was 71.3 ± 3.9 beats/min.

Regardless of the side of the paresis, no significant difference ($p > 0.05$) was observed between D0 and D30 in the quadriceps and hamstrings of the paretic leg. In contrast, the non-paretic leg showed a significant increase in quadriceps thickness ($p < 0.05$), but no difference in the hamstrings.

The NIHSS score decreased from 11 ± 3.7 to 10.7 ± 3.5 with no significant difference ($p > 0.05$). Muscle strength remained stable between D0 and D30. No patient was able to complete all 15 items on the ABILICO scale. Finally, no correlation ($p > 0.05$) was found between muscle thickness and NIHSS score.

## 4. Discussion

The average age of the subjects in this study was 57.9 ± 9.9 years. The results of this study are similar to those of Lipenguet et al. (2023), who noted an average age of 58.44 ± 13.73 years in their study evaluating the direct hospital costs of medical care for patients hospitalized for stroke in Gabon [8]. Our results corroborate the work of Kong et al. (2022), who noted an average age of 57.2 ± 12.3 years in a prospective study on the ultrasound evaluation of changes in the muscle architecture of the brachial muscle after a stroke, which included 50 patients in China [9].

Our results confirm the assertion that stroke is affecting younger and younger people in developing countries, particularly in Benin. Indeed, as indicated by several studies conducted in Benin and Africa, the average age of stroke victims is around 60 years [10, 11]. This average age is well below that often observed in developed countries. Kunt et al. (2024) noted an average age of 70.3 ± 12.8 years in a multicenter study involving 1,136 patients and focusing on the clinical, epidemiological, and radiological characteristics of stroke patients [12]. The work of Iwasa et al. (2024) reported an average age of 74.80 ± 12.19 years in their study entitled Impact of functional independence and sociodemographic factors on discharge destination after stroke in a very elderly rural community in Japan, which included 160 patients [13].

Furthermore, in the present study, males were more affected by stroke (64.5% versus 35.5%). These values are similar to those reported in the literature, with 56.98% of men in Nigeria [14] and 61.3% of men in Vietnam [15].

Our results also showed that four weeks of SEF applied to the paretic lower limb was not sufficient to induce a significant change in muscle thickness or to improve overall neurological severity or muscle strength. These observations are consistent with those reported by Suzuki et al. (2017), who showed that FES applied in the acute phase prevents muscle atrophy without resulting in early functional gains [6]. FES can improve muscle mass by modifying muscle-specific transcriptional mechanisms. During muscle contraction, muscle fibers produce and release myokines, which have local and systemic effects on the body [16]. Functional electrical stimulation may alter myokine secretion, particularly that of insulin-like growth factor-1 in older adults [17].

The lack of improvement in NIHSS and muscle strength can be explained by the initial neurological severity of our patients (mean NIHSS > 10), the limited duration of the intervention, and the fact that the NIHSS is an overall score that is not very sensitive to peripheral muscle changes [18]. In addition, several recent studies have shown that muscle quality (fat infiltration, fiber architecture) and strength are better predictors of functional recovery than muscle mass alone [19].

Finally, the inability of patients to meet the ABILICO scale criteria reflects the low functional locomotor level of our cohort, confirming that 30 days is probably too short a period to expect significant improvement in walking, especially in patients with severe hemiplegia [20].

## 5. Conclusion

Functional electrical stimulation, applied for 4 weeks in post-stroke hemiplegic patients, did not significantly alter the muscle thickness of the paretic leg, nor did it improve the NIHSS score, muscle strength, or walking ability as assessed by the ABILICO scale. These results suggest that longer protocols, combined with intensive functional rehabilitation programs, may be necessary to observe clinical benefits.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors have no relevant financial or non-financial interests to declare.

### *Data availability*

Data are available upon reasonable request.

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*Author contributions*

All authors contributed to the design and implementation of the study. They also contributed to all sections and the drafting of the first version of the manuscript. All authors have read and approved the final manuscript.

## References

[1] Katan M, Luft A. Global Burden of Stroke. Semin Neurol. 2018 Apr;38(2):208-211. doi: 10.1055/s-0038-1649503. Epub 2018 May 23. PMID: 29791947

[2] Scherbakov N, Pietrock C, Sandek A, Ebner N, Valentova M, Springer J et al. Body weight changes and incidence of cachexia after stroke. J Cachexia Sarcopenia Muscle. 2019; 10(3): 611-20. [DOI 10.1002/jcsm.12400]

[3] Scherbakov N, Doehner W. Sarcopenia in stroke-facts and numbers on muscle loss accounting for disability after stroke. J Cachexia Sarcopenia Muscle. 2011 Mar;2(1):5-8. doi: 10.1007/s13539-011-0024-8. Epub 2011 Mar 25. PMID: 21475676; PMCID: PMC3063875

[4] Hunnicutt JL, Gregory CM. Skeletal muscle changes following stroke: a systematic review and comparison to healthy individuals. Top Stroke Rehabil. 2017 Sep;24(6):463-471. doi: 10.1080/10749357.2017.1292720. Epub 2017 Mar 2. PMID: 28251861; PMCID: PMC5801663

[5] Legg LA, Lewis SR, Schofield-Robinson OJ, Drummond A, Langhorne P. Occupational therapy for adults with problems in activities of daily living after stroke. Cochrane Database Syst Rev. 2017; 7(7): CD003585. [DOI 10.1002/14651858.CD003585.pub3]

[6] Suzuki T, Sonoda S, Misawa K, Saitoh E, Shimizu Y, Kotake T, et al. Incidence and predictors of lower extremity muscle atrophy during the acute phase of stroke. *J Stroke Cerebrovasc Dis.* 2017;26(10):2228-33

[7] Segers J, Hermans G, Bruyninckx F, Meyfroidt G, Langer D et Gosselink R. Feasibility of neuromuscular electrical stimulation in critically ill patients. J Crit Care. 2014; 29(6):1082-8. [DOI 10.1016/j.jcrc.2014.06.024]

[8] Lipenguet GM, Ngoungou EB, Ibinga E, Amani PG, Engohang-Ndong J, Bivigou EA et al. Assessment of the direct hospital cost of medical care for patients hospitalized for a stroke in Gabon. Pan Afr Med J. 2023; 45: 95. [DOI 10.11604/pamj.2023.45.95.35702].

[9] Kong KH, Shuen-Loong T, Tay MRJ, Lui WL, Rajeswaran DK et Kim J. Ultrasound Assessment of Changes in Muscle Architecture of the Brachialis Muscle After Stroke-A Prospective Study. Arch Rehabil Res Clin Transl. 2022; 4(3): 100215. [DOI 10.1016/j.arrct.2022.100215].

[10] Noukpo SI, Triccas LT, Bonnechère B, Adoukonou T, Feys P et Kossi O. Physical Activity Level, Barriers, and Facilitators for Exercise Engagement for Chronic Community-Dwelling Stroke Survivors in Low-Income Settings: A Cross-Sectional Study in Benin. Int J Environ Res Public Health. 2023; 20(3): 1784. [DOI 10.3390/ijerph20031784].

[11] Kunt R, Çınar BP, Yüksel B, Güllüoğlu H, Sayılır İ, Çeliker Uslu S et al. Clinical-epidemiological and radiological characteristics of stroke patients: a multicentre study. Int J Clin Pract. 2021; 75(12): e14963. [DOI 10.1111/ijcp.14963].

[12] Iwasa S, Uchiyama Y, Tauchi Y, Koyama T, Domen K. Impact of functional independence and sociodemographic factors on post-stroke discharge destination in a super-aged rural community in Japan. J Rural Med. 2024; 19(1): 33-9. [DOI 10.2185/jrm.2023-033].

[13] Eze CO, Okoro FC. Comparison of acute haemorrhagic and acute ischaemic stroke in a tertiary hospital at abakaliki, nigeria: a retrospective study. West Afr J Med. 2024; 41(11): S18-9. [PMID 39535518].

[14] Ton MD, Dao PV, Nguyen DT, Nguyen TH, Tran CC, Duong HQ et al. Sex disparity in stroke outcomes in a multicenter prospective stroke registry in Vietnam. Int J Stroke. 2023; 18(9): 1102-11. [DOI 10.1177/17474930231177893].

[15] Carraro U, Kern H, Gava P, Hofer C, Loefler S, Gargiulo P et al. Recovery from muscle weakness by exercise and FES: lessons from Masters, active or sedentary seniors and SCI patients. Aging Clin Exp Res. 2017; 29(4): 579-90. [DOI 10.1007/s40520-016-0619-1].

[16] Leal LG, Lopes MA, Batista ML Jr. Physical Exercise-Induced Myokines and Muscle-Adipose Tissue Crosstalk: A Review of Current Knowledge and the Implications for Health and Metabolic Diseases. Front Physiol. 2018; 9: 1307. [DOI 10.3389/fphys.2018.01307].

[17] Du J, Wang Y, Che B, Miao M, Bao A, Peng Y et al. The relationship between neurological function trajectory, assessed by repeated NIHSS measurement, and long-term cardiovascular events, recurrent stroke, and mortality after ischemic stroke. Int J Stroke. 2023; 18(8): 1005-14. [DOI 10.1177/17474930231180446].

[18] Ushizawa H, Igarashi K, Takahashi H, Mizuno K. Relationship between skeletal muscle echo intensity and functional outcomes in patients after stroke. *Top Stroke Rehabil.* 2022;29(5):375-83.

[19] Matsushita T, Ishii D, Nakashima H, Fujita T, Sonoda S. Association between muscle quality assessed by ultrasound and gait independence in subacute stroke patients. *Eur Stroke J.* 2022;7(4):333-41.

[20] Veerbeek JM, Kwakkel G, van Wegen EE, Ket JC, Heymans MW. Early prediction of outcome of activities of daily living after stroke: a systematic review. *Stroke.* 2011;42(5):1482-8.