Neuroscience Insights: Advances in Brain Studies

Review Article

Open Access Full Text Article

Effectiveness of Neuromuscular Electrical Stimulation Associated with Exercise or Conventional Physiotherapy on Walking Speed in Post-Stroke Patients: A Systematic Review with Meta-Analysis

Bianca Veronese Da Silva[1], Mayara Louise Beltrame[1], Dartel Ferrari de Lima[1], Gladson Ricardo Flor Bertolini[1], Márcia Rosângela Buzanello[1]

[1]Universidade Estadual do Oeste do Paraná – UNIOESTE.

Correspondence:

Gladson Ricardo Flor Bertolini,
Universitaria St. 2069. Cascavel, Paraná, Brazil.

Received: January 21, 2026; **Published:** February 19, 2026

How to cite this article:

Silva, BVD., Beltrame, ML., Lime, DFD., Bertolini,GRF., Buzanello, MR. Effectiveness of Neuromuscular Electrical Stimulation Associated with Exercise or Conventional Physiotherapy on Walking Speed in Post-Stroke Patients: A Systematic Review with Meta-Analysis. *Neurosci Insights Adv Brain Stud*. 2026;2(1):1-9.

Abstract

Aim: To conduct a systematic review with meta-analysis evaluating the effects of functional electrical stimulation (FES) combined with exercise or conventional training on gait speed in individuals after stroke.

Methods: The databases searched included PubMed, Cochrane Library, PEDro, Scopus, Web of Science, Embase and LILACS. Gray literature sources included Google Scholar, OpenGrey and ProQuest. Risk of bias was assessed using the Cochrane RoB 2 tool by two blinded reviewers, with disagreements resolved by consensus. Outcomes analyzed were gait speed (10MWT/5MWT) in meters per second, with subgroup analyses based on electrode placement, stroke phase, comparator type, intervention duration and FES frequency.

Results: No statistically significant effects were observed for gait speed between FES and control groups (MD = –0.01 m/s; 95% CI: –0.02 to 0.01; $p = 0.29$; $I^2 = 0\%$). Similarly, no significant differences were found across subgroup analyses: electrode placement ($p = 0.41$), stroke phase ($p = 0.55$), comparator type ($p = 0.38$), intervention duration ($p = 0.47$) or stimulation frequency ($p = 0.60$), indicating no modification of treatment effect in any category assessed.

Conclusion: The findings indicate that functional electrical stimulation did not provide additional benefits in improving gait speed when combined with conventional rehabilitation after stroke. Despite the consistency and low heterogeneity observed, further high-quality and standardized clinical trials are needed to determine whether specific patient subgroups may respond differently to FES.

Keywords: Stroke; Gait; Electrical stimulation; Physical therapy; Rehabilitation.

Introduction

Cerebrovascular Accident (CVA), commonly known as a stroke, results from the sudden interruption of cerebral blood flow, whether due to ischemic or hemorrhagic etiology, leading to neurological damage that can cause plegia or paresis, sensory alterations, spasticity, and cognitive and psychoaffective impairments. Among the main sequelae are motor function deficits, characterized by changes in muscle tone, associated reactions, and impaired postural control.[1,2] Stroke remains one of the leading causes of long-term disability,[3] and the loss of descending modulation by the corticospinal and corticoreticular tracts predominantly results in muscle weakness, defined as the inability to generate normal levels of force even with maximum voluntary effort.[4,5]

In this context, physical therapy plays an essential role in rehabilitation, promoting the recovery of movement and postural balance. The functional reintegration of adults after stroke is a complex challenge, not only because of the diversity of deficits involved, but also because the condition represents the leading cause of acquired physical and cognitive disability.[3,6] Among the resources used in motor rehabilitation, neuromuscular electrical stimulation (NMES) stands out, capable of producing contractions in paralyzed muscles through the activation of peripheral nerves, generating functional movements synchronized with specific phases of gait, such as dorsiflexion during swing.[7] In addition to immediate mechanical effects, NMES can induce neurophysiological adaptations, including changes in nerve conduction, synaptic reorganization, increased motor recruitment, and reduced fatigue, contributing to motor relearning.[8,9] However, technical limitations, such as fatigue induced by stimulation and reduced efficiency of artificial movement when compared to voluntary movement, still restrict its clinical applicability.[7]

The literature presents heterogeneous results, while a previous review indicated improved walking speed compared to ankle-foot orthoses (AFOs),[10] a more recent meta-analysis pointed to low-quality evidence and uncertain effects of FES when combined with physical therapy.[11] Thus, despite the potential of NMES as a therapeutic resource, the findings remain inconsistent, highlighting a scientific gap and the need for updated syntheses on its effectiveness in post-stroke gait function. Thus, the objective of this study was to conduct a systematic review with meta-analysis to investigate the effectiveness of NMES, associated or not with physical exercise, in improving gait in post-stroke individuals.

Methods

Registration

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Registered with the Open Science Framework DOI 10.17605/OSF.IO/SUT6V.

Eligibility criteria

O acrônimo PICOS foi utilizado para formular a questão focada neste estudo: P – (population of men and women after stroke), I – intervention (FES associated or not with physical exercise), C – comparator (exercise or conventional physical therapy), O – outcome (gait performance), and S – study design (randomized clinical trials).
Designs from retrospective studies, case studies, cohort studies, pilot studies, studies published in expanded abstract format, systematic reviews, literature reviews, editorials, studies whose texts are not available in full, reviews, letters, personal opinions, books, and book chapters were excluded. Those using animal samples were also excluded.

Sources of information

The initial search was conducted using keywords in the PubMed database, with the Medical Subject Headings (MeSH) medical metadata system, descriptors defined in Health Sciences (DeCS), from the Virtual Health Library (VHL) website, and free terms. Individual search strategies were developed for the following databases: Web of Science, PubMed, Embase, Scopus, and LILACS. For gray literature, the following were used: Google Scholar, Brazilian Library of Thesis and Dissertations, LIVIVO, and Open Grey. The reference lists of all studies included in the review were checked. No language or publication date restrictions were applied.

Selection of studies and data collection process

The EndNote Web and Rayyan QCRI (Qatar Computing Research Institute) reference managers were used to remove duplicate articles, both automatically and manually. Phases 1 and 2 were selected according to eligibility criteria by two blinded reviewers, with conflicts resolved by a third reviewer. The studies included in Phase 1 were defined for reading titles and abstracts. Phase 2 was based on reading the full texts.

Data collected

The main data collected were in accordance with the characteristics of the study (authors, year of publication, country), sample characteristics (sample size, mean age, and sex), description of the intervention, outcome, and conclusion. The outcome studied was gait performance.

Assessment of individual bias risk in studies

The risk of bias assessment was performed by two independent reviewers using Cochrane tools, Rob 2. Disagreements were resolved by a third reviewer. The judgments were low risk, some concerns, and high risk.

Results

Selection of studies

The searches were conducted in all databases on July 21, 2024, and will be updated prior to publication (Appendix 1). During the search, 3,140 records were found, 2,856 in the main indexed databases and 284 in the gray literature. Of the total, 234 duplicate studies were automatically and manually excluded. This left 2,906 studies for Phase 1 (reading of titles and abstracts) and 321 studies for Phase 2 (reading of the full studies). Nine studies were included in this review (Figure 1).

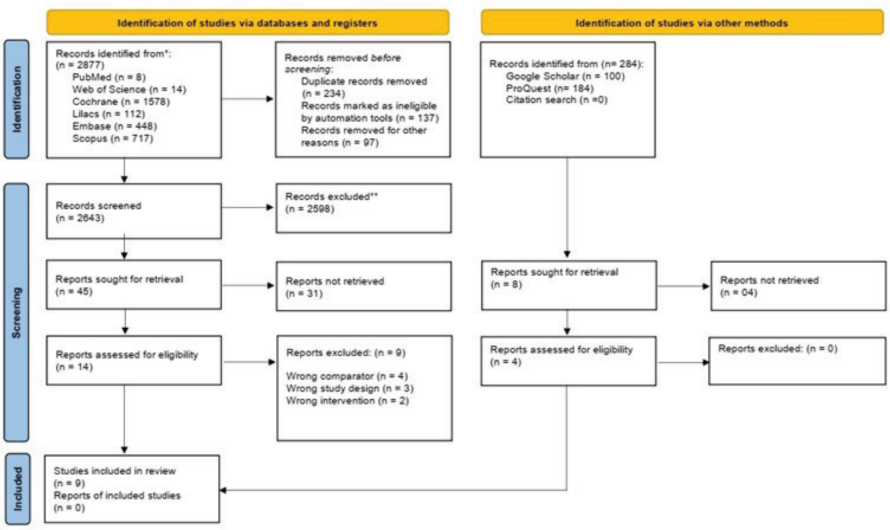

Figure 1: Flow diagram of the literature search and selection criteria adapted from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses).

Individual study results

Nine randomized clinical trials were included in this review: Burridge et al.[12] was conducted in the United Kingdom; Peurala et al.[13] in Finland; Tong et al.[14] in China; Lee et al.,[15] Shim et al.,[16] and Li et al.,[17] in the Republic of Korea; Yang et al.,[18] in Taiwan; Dantas et al.[8] in Brazil; and finally Mijic et al.[19] in Germany. A total of 298 individuals, including both men and women, were sampled in this review (Table 1).

Table 1: Summary of the most important findings from the included randomized clinical trials (n = 9).

Eligible studies	Type of study	Sample description	Protocolo de intervenção	NMES application site	Evaluation period	Outcome/measurement tool	Conclusion
Burridge et al., 1997 United Kingdom	RCT	N = 32 EG: (n=16) CG: (n=16) Chronic hemiplegics after stroke	EG: NMES + Bobath CG: Bobath 10 sessions/over a period of 1 month	Common fibular nerve + motor point of the tibialis anterior muscle (40 Hz, 0.3 ms)	T0: baseline T1: post-intervention (week 4/5) T2: follow up semana 12/13	• Walking performance: Walking speed (m/s): 10MWT Walking effort (beats/min per m/min): physiological cost index (PCI)	NMES for equinus correction improves gait speed and efficiency in patients with chronic stroke, but the effects are immediate.
Peurala et al., 2005 Finland	RCT	N = 30 EG: (n=15) CG: (n=15) Chronic stroke	EG: NMES + Treadmill training CG: Treadmill training 15 sessions/20 min/for 3 weeks	NMES: weaker muscles of the paretic MI (25 Hz, 0.3 ms)	T0: baseline T1: 2 weeks T2: post-intervention (3 weeks) T3: follow up 6 months	• Walking performance: Walking speed (s): 10MWT	NMES associated with gait training was not significantly better when compared to gait training without FES after 3 weeks.
Tong et al., 2006 China	RCT	N = 30 EG: (n=15) CG: (n=15) subacute stroke	EG: NMES + Electromechanical gait training CG: Electromechanical gait training 5 times/week, 20 minutes/session, for 4 weeks	NMES: Anterior tibialis and quadriceps (requiring assistance with knee extension) (40 Hz, 0.3 ms)	T0: baseline T1: 2 weeks T2: post-intervention (4 weeks) No follow up	• Walking performance: Walking speed (m/s): 5MWT	The combination of NMES with electromechanical training did not result in any additional significant effects on walking ability compared to the control group.
Lee et al., 2013 Republic of Korea	RCT	N = 30 EG: (n=15) CG: (n=15) Post-stroke period ≈ 4 months (late subacute/early chronic)	EG: PAFES (EMG-triggered NMES) + treadmill training CG: treadmill training (5 times/week, 30 minutes/day for 4 weeks) Both standard rehabilitation groups	PAFES (EMG-triggered NMES): in tibialis anterior. (rectangular biphasic, 50 µs, adjustable intensity 0–160 Vpp).	T0: Baseline T1: 4 weeks No follow up	• Gait performance (GAITRite® system): Walking speed (cm/sec) Cadence (steps/min) Step length on affected side (cm) Stride length (cm)	PAFES promoted greater improvements in gait pattern, increasing speed, cadence, and stride length, resulting in more efficient locomotion after stroke.
Yang et al., 2018 Taiwan	RCT	N = 16 EG: (n=8) CG: (n=8) Men and women who have suffered a stroke. Average age: 52 years old.	EG NMES 20 min + 15 min walking workout CG: ADM exercises and stretching 20 min + walking training 15 min 3x/week/35 min/ for 7 weeks	NMES: Anterior tibial (AT) motor point Middle third of the muscle, on the line between the head of the fibula and the medial malleolus (50 Hz, 0.2 ms - 200 µs)	T0: 7 days before the first session T1: 7 weeks (post-intervention)	• Gait performance (GAITRite® system): Speed (cm/sec); Cadence (steps/min); Stride length (affected side, cm); Stride length (unaffected side, cm); Spatial asymmetry; Temporal asymmetry.	The combination of NMES to the tibialis anterior muscle with gait training significantly improves functional walking ability in post-stroke patients.

Shim et al., 2020 Republic of Korea	RCT	N = 40 EG: (n=20) CG: (n=20) Between 6 and 24 months after stroke	EG: (EMG-triggered NMES) + PNF CG: PNF 5 times/week, 30 minutes/session, for 4 weeks	NMES: (EMG-triggered NMES) External oblique muscle and Latissimus dorsi muscle (35 Hz, 200 µs, 10 and 20 mA/1.5 s rise time, 5 s active time (ON), followed by 1.5 s fall time, with a 3 s pause between contractions (OFF)).	T0: baseline T1: 4 weeks No follow	• Gait performance in complex functional tasks: Dynamic Gait Index (DGI)	There was improvement in gait in both groups, with no significant difference, indicating that trunk PNF, with or without NMES, improves dynamic gait after stroke.
Dantas et al., 2023 Brazil	RCT crossover	N = 28 GAB: (n=14) GBA: (n=14) ≥ 3 months post-stroke (late subacute or chronic phase) Average age: 50 years.	GAB: (TT- FES) followed by (TT) GBA: (TT) followed by (TT- NMES) 2x/week/30 min/ for 6 weeks	NMES: common fibular nerve (33-40Hz, 300 µs)	T0: baseline T1: after 6 sessions T2: after 12 sessions sessions	• Walking performance: Walking speed (m/s): 10MWT	Changes in walking speed were similar between groups, with no statistically significant difference.
Li et al., 2023 China	RCT	N = 60 EG: (n=30) CG: (n=30)	EG: NMES + core training CG: core training 5x/week/for 8 weeks	NMES: 1st electrode: on the hyoid bone •2nd electrode: on the upper thyroid notch (just below the first) •3rd and 4th electrodes: placed between the 1st and 2nd, dividing the distance into equal parts (80 Hz/0-30 mA/20 beats/min/700 ms)	T0: baseline T1: 8 weeks No follow up	• Walking performance: 10MWT (m/s) Functional Ambulation Category (FAC)	The combination of core training with NMES improved walking speed and increased the level of independence in walking, showing superior walking performance compared to conventional training.
Mijic et al., 2023 Germany	RCT crossover	N = 32 GA: (n=16) GB: (n=16) Acute stroke	GA: NMES 2 weeks + followed by standard physical therapy GB: standard physical therapy + followed by NMES 5 times/week/30 min/for 4 weeks	NMES: common fibular nerve and tibialis anterior muscle (42 mA/ 200 ou 300 µs/ 30 a 50 Hz)	T0: baseline T1: Week 2 (pre- or post-intervention, depending on the group) T2: Week 4 (after the two periods of the crossover study) At follow-up	• Walking performance: Walking speed (m/s): 10MWT	Group A showed faster improvement in 10MWT time in the first two weeks, while group B showed slower progress until starting FES. Both groups improved throughout the study.

Caption: EG: experimental group; CG: control group; RCT: randomized controlled trial; min: minutes; ADLs: activities of daily living; NMES: Neuromuscular Electrical Stimulation; MWT10: 10-minute walk test; MWT5: Five-meter walking speed test; stroke: cerebrovascular accident.

Measuring instruments

TThe nine studies evaluated gait performance mainly through speed (10MWT/5MWT). Complementary measures included DGI,[16] FAC,[17] and instrumented systems such as GAITRite,[18] in addition to PCI.[12]

Intervention protocols

Comparators

The studies compared NMES to different conventional interventions, including Bobath, treadmill training with or without NMES, gait trainer, PNF, core training, and conventional physical therapy, in addition to two crossover trials.[8,19]

Site of application of functional electrical stimulation

NMES was applied in various regions, such as the common fibular nerve, anterior tibial, quadriceps, weaker muscles, trunk, and cervical region, with different frequency and pulse width parameters according to the therapeutic objective of each study.

Frequency and duration of treatment

The duration of the interventions ranged from 3 to 8 weeks, with a frequency of 2 to 5 sessions per week, reflecting different strategies of FES exposure associated or not with locomotor training.

Outcome: gait performance

All studies reported improvement in gait throughout treatment, but without consistent differences between groups, indicating that NMES did not increase speed gains when compared to equivalent conventional interventions.

Risk of bias analysis – ROB2

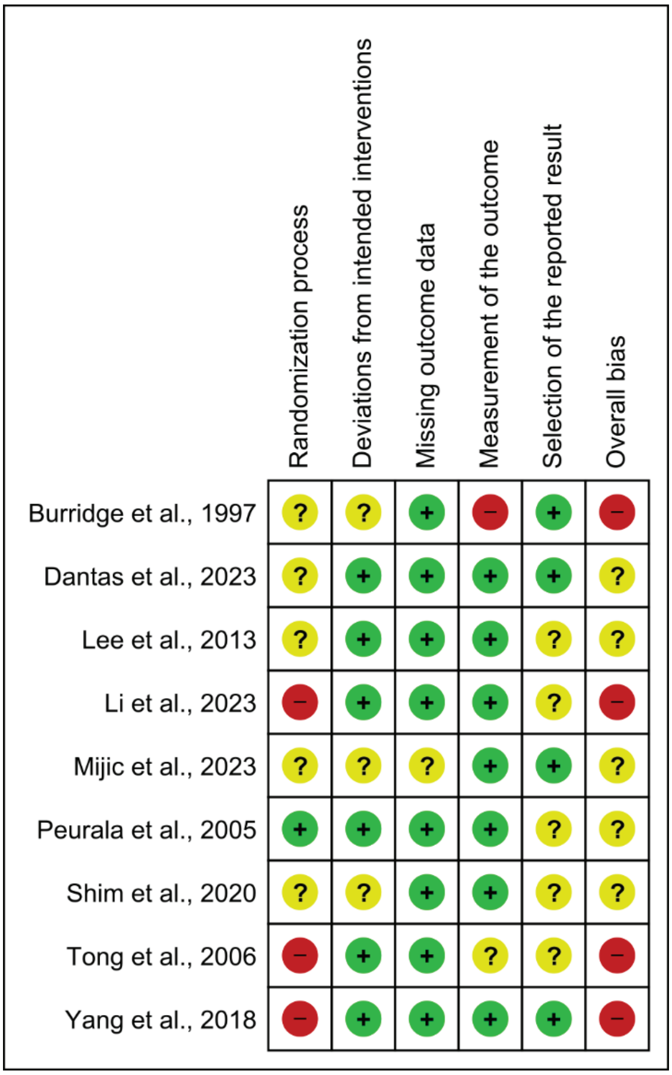

Figure 2: Presentation of individualized bias risk results.

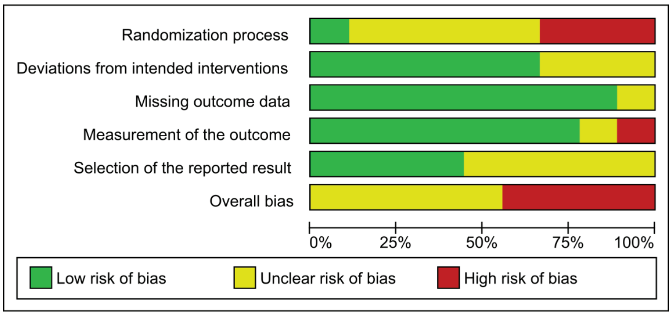

Figure 3. Presentation of bias risks, in percentage terms, according to the final scale assigned.

Meta-analysis

Outcome – Gait speed - 10-Meter Walk Test/ 5-Meter Walk Test (m/s)

A meta-analysis of walking speed (m/s), assessed using the standardized 10-Meter Walk Test (10MWT) and 5-Meter Walk Test (5MWT), was conducted to investigate the effect of FES on improving walking performance after stroke. Six clinical trials were included,[8,12–14,17,19] totaling 132 participants in the experimental group and 132 in the control group.

The studies presented consistent results, with zero heterogeneity ($I^2 = 0\%$), indicating stability of the estimates. Individually, no study showed a significant difference between the groups. Burridge et al.,[12] Dantas et al.,[8] and Peurala et al.[13] showed effects close to zero, while Tong et al.[14] showed a slight favorable trend toward control. Li et al.[17] and Mijić et al.[19] also did not show superiority of FES, with effect estimates centered on nullity.

When combining the six studies, the overall effect showed no statistically significant difference between the experimental and control groups (MD = –0.01 m/s; 95% CI: –0.02 to 0.01; p = 0.29), suggesting that adding FES to conventional training did not promote additional walking speed gains compared to the same training without electrical stimulation.

These findings reinforce that, based on the available evidence, FES does not modify gait performance when assessed by speed in 5- or 10-meter tests, and that the observed effects appear to result from the training performed by both groups, and not specifically from electrical stimulation (Figure 4).

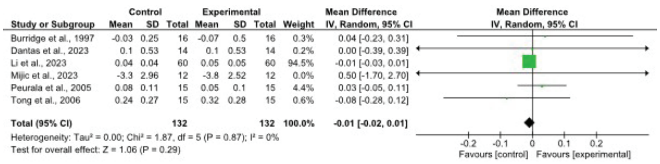

Figure 4. Forest plot comparing the experimental and control groups for the outcome Gait speed (m/s).

Outcome – Gait speed (m/s) according to electrode placement

The meta-analysis of the outcome walking speed (m/s) was conducted considering the different electrode placement sites, as categorized in the forest plot, with the aim of identifying whether any specific region would be more effective in improving post-stroke walking. Six clinical trials were included,[8,12–14,17,19] totaling 132 participants in the experimental group and 132 in the control group.

The studies were grouped into five distinct subgroups: Tibialis anterior, Tibialis anterior/Common peroneal, Weakest muscle in the lower limb, Common fibular, and Hyoid bone/superior thyroid notch. In the Tibialis anterior subgroup, represented by Tong et al.,[14] there was no significant difference between the groups, with an effect close to zero. The Tibialis anterior/Common peroneal subgroup, composed of Burridge et al.[12] and Mijić et al.,[19] also showed no significant difference, presenting discrete effect estimates and confidence intervals crossing the null line, in addition to zero heterogeneity ($I^2 = 0\%$). In the Weakest muscle in the lower limb subgroup, corresponding to the study by Peurala et al.,[13] a small improvement in walking speed was observed in the experimental group; however, the confidence interval included zero, indicating no statistical significance. Similarly, the Common fibular subgroup, represented by Dantas et al.,[8] showed no difference between the groups. Finally, the Hyoid bone/superior thyroid notch subgroup, referring to the study by Li et al.,[17] after correction of the extracted values, presented a discrete and non-significant effect, consistent with the other studies.

When combining all studies, the overall effect showed no statistically significant difference between the experimental and control groups, with a mean estimate close to zero and a confidence interval crossing the null line, in addition to low heterogeneity. The interaction test between subgroups did not identify a significant difference between the different electrode application sites, indicating that none of the stimulated regions proved superior in improving post-stroke gait speed (Figure 5).

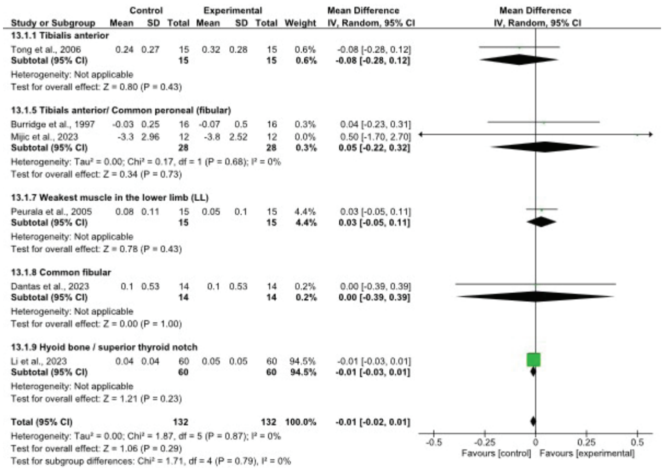

Figure 5. Forest plot comparing the experimental and control groups for the outcome Gait speed (m/s), grouped by electrode placement site.

Outcome – Stroke phase and gait speed (m/s)

The meta-analysis investigated whether the stage of stroke would influence the effect of FES on walking speed (m/s), based on the categorization presented in the forest plot. Six clinical trials were included,[8,12–14,17,19] involving participants at different times after stroke.

The studies were grouped into three subgroups according to the stroke phase: subacute, chronic, and mixed/undetermined. In the subacute subgroup, the studies showed no significant difference between the groups, with effect estimates close to zero and confidence intervals crossing the null. In the chronic subgroup, although there was a slight trend toward improvement in both groups throughout treatment, no superiority of NMES over control was observed. The mixed subgroup, represented by studies that included participants in different stages of recovery, maintained the same pattern, with no significant difference between interventions.

When combining all subgroups, the overall effect remained insignificant, indicating no statistical difference between the experimental and control groups for walking speed, regardless of the post-stroke phase. Heterogeneity was low, reinforcing the consistency of the findings, and the interaction test between subgroups did not identify a significant difference, suggesting that the stroke phase does not modify the effect of NMES on walking speed (Figure 6).

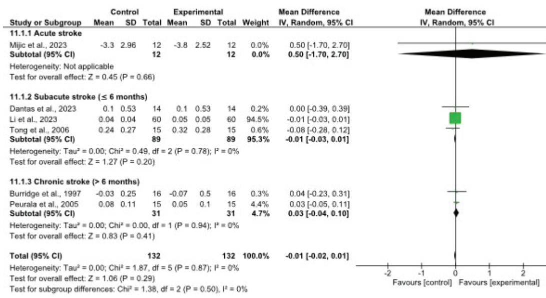

Figure 6. Forest plot comparing the experimental and control groups for the gait speed (m/s) outcome, grouped by stroke phase.

Outcome – Gait speed (m/s) according to comparator type

The meta-analysis of the outcome walking speed (m/s) was performed considering the different types of comparators used in the included clinical trials, as categorized in the forest plot. The objective was to verify whether the efficacy of NMES varied according to the type of conventional intervention used as a control. Six studies were included,[12–14,17,19] totaling 132 participants in the experimental group and 132 in the control group.

The studies were divided into four subgroups, corresponding to the comparators presented in the forest plot: Core training[17]: there was no significant difference between the groups, with an effect close to zero and a confidence interval crossing the nullity. Gait trainer [8,13,14]: the three studies presented consistent results, with no superiority of FES over the gait trainer alone, with zero heterogeneity and a non-significant pooled effect. Bobath[12]: a slight improvement was observed in both groups, but with no significant difference between intervention and control. And standard physiotherapy[19]: the study demonstrated an individual effect close to zero, indicating that the addition of FES did not result in additional benefit.

When combining all studies, the overall effect showed no statistically significant difference between the experimental and control groups (MD = –0.01 m/s; 95% CI: –0.02 to 0.01; p = 0.29), with zero heterogeneity ($I^2 = 0\%$), indicating consistency of findings. The interaction test between subgroups did not identify significant differences, suggesting that the type of comparator does not modify the effect of FES on post-stroke gait speed (Figure 7).

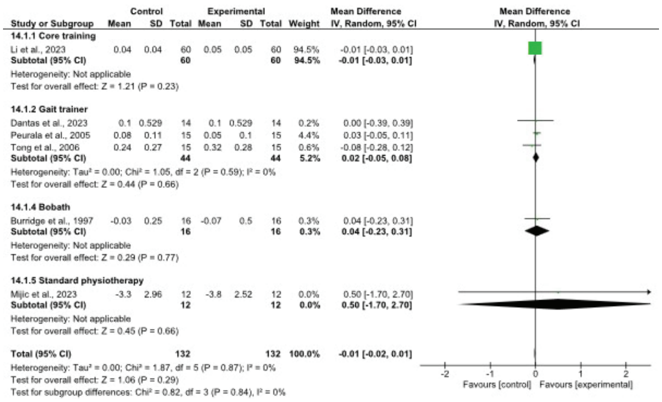

Figure 7. Forest plot comparing the experimental and control groups for the gait speed (m/s) outcome, grouped by type of comparator.

Outcome – Intervention duration and gait speed (m/s)

The meta-analysis of the outcome walking speed (m/s) was performed considering the intervention time, as categorized in the forest plot, with the aim of assessing whether the duration of treatment influences the effect of FES on post-stroke gait recovery. Six clinical trials were included,[8,12–14,17,19] totaling 132 participants in the experimental group and 132 in the control group.

The studies were grouped into two subgroups according to the duration of the intervention: ≤ 4 weeks[8,12–14,19]: individual results were consistent, with effects close to zero and confidence intervals crossing nullity, indicating no significant difference between groups. The pooled effect also did not demonstrate superiority of FES, with zero heterogeneity, reinforcing the stability of the estimates. And > 4 weeks[17]: although a slight improvement was observed throughout the treatment in both groups, there was no significant difference between intervention and control, maintaining the same pattern observed in the subgroup with shorter duration.

When combining the subgroups, the overall effect remained insignificant, indicating no statistical difference between the experimental and control groups for walking speed, regardless of the duration of intervention. The interaction test between subgroups did not identify any significant difference, suggesting that the duration of treatment did not modify the effect of FES on walking speed after stroke (Figure 8).

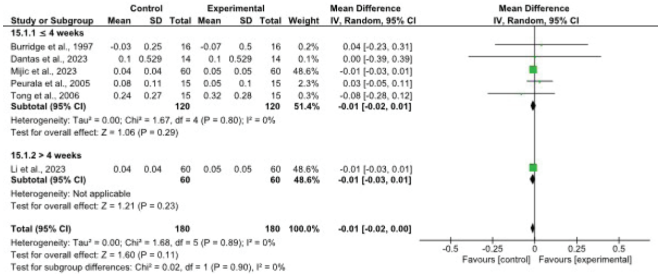

Figure 8. Forest plot comparing the experimental and control groups for the gait speed (m/s) outcome, grouped by intervention time.

Outcome – Gait speed (m/s) according to FES frequency

The meta-analysis of the outcome walking speed (m/s) was conducted considering the frequency of electrical stimulation, as categorized in the forest plot, with the aim of investigating whether different dosimetry parameters could influence the clinical response to FES in post-stroke rehabilitation. Six clinical trials were included,[8,12–14,17,19] totaling 132 participants in the experimental group and 132 in the control group.

The studies were grouped into two subgroups according to the frequency used: ≤ 40 Hz [8,12–14,19]: individual results showed effects close to zero and confidence intervals crossing nullity, with no evidence of FES superiority over control. The pooled effect showed no statistical significance, with zero heterogeneity, indicating consistency between studies. And > 40 Hz[17]: despite slight improvement throughout the intervention, there was no significant difference between the experimental and control groups, maintaining the same pattern observed in the ≤ 40 Hz subgroup.

When combining both subgroups, the overall effect remained insignificant, indicating no statistical difference between the experimental and control groups for walking speed, regardless of the frequency used. The interaction test between subgroups did not identify any significant difference, suggesting that the FES frequency did not modify the effect of treatment on post-stroke walking speed (Figure 9).

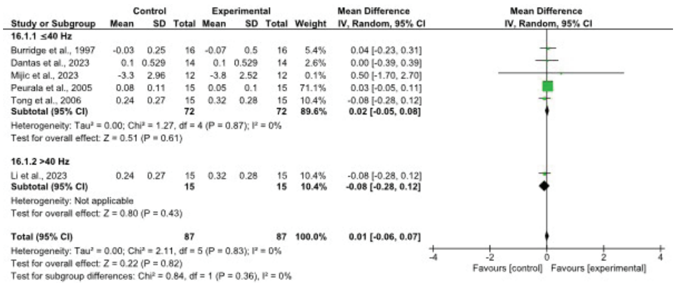

Figure 9. Forest plot comparing the experimental and control groups for the gait speed (m/s) outcome, grouped by electrical stimulation frequency.

Discussion

The results of this meta-analysis indicated that adding NMES to conventional training did not promote additional gains in walking speed, a finding that is consistent with previous evidence. Several clinical trials have shown that, although NMES can improve parameters such as activation pattern and segmental alignment, its direct impact on speed is not superior to functional training alone. Kluding et al.[20] observed similar improvement between NMES and ankle-foot orthoses in individuals with chronic stroke, suggesting that gait recovery appears to be more associated with repetitive training than with the type of device used. Similarly, Everaert et al.[21] did not identify significant differences in gait speed between NMES and dynamic orthoses, despite perceived benefits in comfort and user preference.

Sheffler and Chae[22] highlighted that FES has important benefits for foot drop during the swing phase, but the transfer to functional speed depends primarily on the intensity of locomotor training. Furthermore, the results of the dosimetry analysis in this study showed that frequencies ≤ 40 Hz and > 40 Hz had similar effects. They are also in line with the literature. Kottink et al. [10] reported that variations in stimulation parameters did not result in significant functional differences, suggesting that dosimetry alone is not a clinical determinant of gait recovery. Bethoux et al.[23] reinforced that, although NMES may favor continued use and patient satisfaction, the measurable functional impact remains modest.

Together, these findings reinforce that NMES can be used as a complementary resource in post-stroke gait rehabilitation, especially in situations of dorsiflexion deficit, but it should not be considered an isolated factor capable of enhancing speed gain. The literature suggests that functional recovery depends predominantly on factors such as training dose, task specificity, and intensive repetition, and not only on electrotherapeutic parameters.

Some limitations should be considered when interpreting the findings of this meta-analysis. First, although six clinical trials were included, the total sample size remained small, which limits the statistical power to detect subtle differences between groups. In addition, the studies had significant methodological variations, including differences in the post-stroke phase, training protocols, stimulation parameters, and session frequency, which may have contributed to the absence of differentiated effects.

Another limitation refers to the fact that only walking speed was analyzed as the primary outcome, making it impossible to assess the influence of NMES on other components of mobility, such as aerobic endurance, symmetry, step variability, or energy efficiency. Clinical heterogeneity was also amplified by the inclusion of studies with different devices (e.g., NMES for foot drop versus cervical stimulation), which prevents broad extrapolations. Finally, most studies did not perform follow-up, limiting understanding of the maintenance of effects over time. Thus, despite the consistency of the findings, the results should be interpreted with caution and reinforce the need for more robust clinical trials, with standardized dosimetry, longer intervention duration, and functionally meaningful outcomes

The results indicate that NMES should not be used with the primary goal of increasing walking speed, as the gains obtained are similar to those achieved with conventional training. Nevertheless, NMES remains useful as a complementary resource, especially in cases of foot drop, as it can assist in walking safety, selective motor control, and reduction of compensations. Functional recovery after stroke depends mainly on intensive, task-oriented locomotor training rather than on NMES dosimetry adjustments, as no dose-response relationship was observed. Thus, clinical choices should be guided by individual needs, tolerance, and functional goals rather than by expectations of additional speed improvement.

Conclusion

It was concluded that the addition of functional electrical stimulation did not result in additional gains in walking speed when compared to equivalent conventional interventions in post-stroke individuals. This result remained consistent across all subgroup analyses, regardless of electrode placement site, stroke phase, comparator type, intervention duration, or stimulation frequency, with no evidence of a dose-response relationship. Thus, the findings indicate that the improvement observed in both groups is mainly due to task-specific locomotor training, reinforcing that NMES should be used as a complementary resource, especially in cases of specific deficits such as foot drop, and not as a primary strategy to increase walking speed. Future studies with greater standardization of stimulation parameters, longer follow-up times, and expanded functional outcomes are needed to determine whether specific subgroups may benefit differently from NMES during post-stroke rehabilitation.

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