Original Article

Feasibility of Neuromuscular Electrical Stimulation for Gait Improvement in Post-Stroke Hemiplegia- A Case Series From an Outpatient Neurorehabilitation Unit

[1]Shruti Patil, [2]Archana Gore

[1]Professor, Department of Neurophysiotherapy, AIMS College of Physiotherapy, Thane,
[2]Associate Professor, Department of Neurophysiotherapy, Seth GS Medical College and KEM Hospital, Mumbai

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Abstract

Background: Post-stroke hemiplegia significantly impairs gait and mobility, particularly in outpatient settings with limited access to advanced rehabilitation technologies. Neuromuscular Electrical Stimulation (NMES) may offer a feasible adjunct to conventional physiotherapy.

Methods and materials: This prospective case series included 20outpatients (mean age: 51.7=/- 5.6 years; stroke onset: 6-12 months) with moderate gait dysfunction (Wisconsin Gait Scale ≥26). Participants received 4-week intervention combining NMES targeting the tibialis anterior and hamstrings with conventional physiotherapy. Gait quality and functional mobility were assessed using the Wisconsin Gait Scale (WGS) and Timed Up and Go (TUG) test respectively. Data was analyzed using Wilcoxon signed-rank tests, with 95% confidence interval reported.

Results: Median WGS scores improved from 24.5 to 18.97 ($p< 0.001$; 95% CI: 4.375-6.515), and mean TUG scores decreased from 21.05s to 17.4s ($p<0.001$; 95% CI: 2.483-3.487). Improvements exceeded the MCID and MDC thresholds. Qualitative gains included enhanced toe clearance, knee flexion, and increased weight- shifting on affected lower limb. No adverse events occurred.

Conclusion: NMES combined with conventional therapy is feasible, safe and clinically meaningful in low-resource outpatient stroke rehabilitation. These findings support further controlled trials to isolate NMES effects and evaluate long-term outcomes.

Keywords: Stroke rehabilitation, NMES, Wisconsin Gait Scale, Timed-Up and Go Test, low-resource setting

Background

Stroke is a leading cause of long-term disability worldwide, with hemiplegia affecting gait and independence in 80% of survivors [1]. Common deficits include foot drop, reduced knee flexion during swing phase, and compensatory movements such as hip circumduction or pelvic retraction, all

Corresponding Author: Shruti Patil, Professor, Department of Neurophysiotherapy, AIMS College of Physiotherapy, Thane

E-mail: tishru20@gmail.com.

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of which contribute to asymmetric, inefficient, and unstable walking patterns due to tonal abnormalities, poor motor control and weakness in affected lower limb[2,3].

Foot drop reduces ankle dorsiflexion, leading to inadequate toe clearance during the swing phase and increasing tripping risk, while decreased knee flexion exacerbate this by further limiting foot-ground clearance and causing a dragging gait pattern.These impairments heighten the likelihood of falls, with stroke survivors experiencing significantly elevated fall rates due to gait instability[4, 5]. Frequent falls can slow recovery by promoting fear of falling, reducing physical activity, causing deconditioning, and leading to injuries that interrupt rehabilitation[6].

These impairments not only limit mobility but also increase fall risk and reduce independence, severely impacting quality of life [7].

While advanced rehabilitation technologies—such as robotic gait trainers and body-weight-supported treadmills—have demonstrated efficacy in improving post-stroke gait, their high cost and infrastructural requirements render them inaccessible in rural and low-resource settings [8]. In outpatient settings, especially in rural or semi-urban areas, patients often face delayed access to rehabilitation, limited infrastructure and inconsistent therapy schedules. Conventional therapy alone may not fully address neuromuscular deficits such as foot drop or stiff-knee gait.

Neuromuscular Electrical Stimulation (NMES) offers low-cost adjunct that activates paretic muscles, improves gait kinematics and promotes neuroplasticity [9]. Studies suggest that NMES improves dorsiflexion during swing phase, reduces spasticity, and restores more natural gait kinematics [10,11]. However, evidence on its feasibility and effectiveness in resource-constrained environments remains limited and underexplored.

This case series investigates whether NMES combined with conventional physiotherapy an improve gait quality in post-stroke hemiplegic outpatients attending a neurorehabilitation clinic. The study evaluates practical aspects of NMES delivery in real-world outpatient care treated at a rural Indian hospital.

While NMES efficacy was established in urban/ tertiary settings and African contexts like Tanzania[13] (community NMES yielding 14.1% gait speed gains) and Ghana[14] (task-sharing models), evidence remains scarce for rural/semi-urban Indian outpatients-where only approximately 17% of stroke survivors access rehabilitation due to infrastructure, cost and awareness barriers. This study addresses this critical global gap by demonstrating NMES feasibility in a real-world Indian neurorehabilitation unit serving underserved populations.

Our findings may guide rehabilitation strategies in regions where advanced technologies are unavailable, ultimately improving functional outcomes and quality of life for stroke survivors in rural communities**.**

Methodology

Ethical Approval and Study Design

This prospective case series was approved by the Ethics Committee of Seth GS Medical College and KEM Hospital (Approval No. 18/2011). Written informed consent was obtained from all participants in their preferred language prior to enrolment.

Setting and participants recruitment: Twenty participants with post-stroke hemiparesis (mean age: 51.7 ± 5.6 years; time since stroke onset: 8.75 ± 1.77 months) were recruited from the outpatient neurorehabilitation unit at Seth GS Medical College and KEM Hospital, Mumbai- a tertiary care centre serving rural and semi-urban populations with limited access to advanced rehabilitation technologies.

Inclusion Criteria

Participants were eligible if they had experienced a first-ever ischemic or haemorrhagic stroke between 6- 12 months prior to recruitment; were ambulatory before stroke with no pre-existing gait abnormalities (confirmed via patient history and clinical assessment); demonstrated moderate gait impairment as indicated by WGS score of

≥ 26 (threshold selected to ensure sufficient baseline dysfunction for detecting clinically meaningful changes). ; had comparable pre-stroke activity levels (eg, independent household or community ambulation); Brunnstrom stage of recovery between 1-3 for lower limb and absence of contraindication to NMES. Gender was documented but not used as an exclusion factor given its established influence on recovery trajectories.

Exclusion Criteria

Severe comorbidities, inability to follow commands, MMSE score < 24, previous history of stroke or any pre-stroke gait abnormality (including mild musculocutaneous conditions like arthritis of limb length discrepancy, verified through history and examination to minimize bias). Additional exclusions included significant visual or vestibular impairments and uncontrolled medical conditions affecting gait.

Outcome Measures

The WGS was used to quantify the quality of gait particularly in post-stroke hemiparetics, to evaluate the qualitative aspects of gait, including stance time, step length and synergy patterns. It has been shown to have excellent interrater (ICC- 0.83) and intra-rater reliability (ICC-0.91).The WGS was used both as an inclusion criterion and as a primary outcome measure. At baseline, a WGS score of ≥ 26 was required to conform moderate gait dysfunction. The same scale was then used to assess changes in gait quality following the intervention. Functional mobility was evaluated using the TUG test. Both tools are validated, sensitive to change, and appropriate for tracking post-stroke rehabilitation progress.

Interventions

All participants received a structured 4-week rehabilitation program (4 sessions/week) combining conventional physiotherapy with NMES. The conventional therapy protocol consisted of 2-hour daily sessions administered 4 days per week, totalling 16 sessions. Each session incorporated patient-specific exercises including stretching of key muscle groups (plantar flexors, hamstrings, and adductors), functional training exercises (sit-to-stand transitions, wall squats, and unilateral stance practice), and gait activities (controlled stepping exercises, stair climbing, side walking, obstacle walking).

The NMES intervention targeted two key muscle groups - the tibialis anterior and hamstrings - with each muscle receiving 10 minutes of stimulation per session. The electrical stimulation parameters included a surged faradic current at 50 Hz frequency with 0.3 ms pulse duration, delivered in 5-second on: off cycles[19,20]. Stimulation intensity was carefully adjusted to produce minimal visible muscle contraction without discomfort, with two rubber electrodes positioned near the origin and insertion points of each target muscle. This NMES protocol was administered concurrently with conventional therapy, 4 days per week for the 4-week intervention period.

Feasibility indicators

- Patient adherence and tolerance
- Ease of NMES administration

No adverse events or dropouts

Statistical Analysis

Data were analysed using SPSS v20. Non-normally distributed outcomes (Shapiro-Wilk test) were compared using the Wilcoxon signed-rank test with significance set at *p* < 0.05. Median and interquartile range (IQR) was reported for WGS and mean and standard deviation for TUG test.

Results

All twenty participants completed the 4-week intervention protocol without any adverse events or dropouts, confirming the safety and tolerability of thecombined NMES and conventional therapy approach.

Quantitative Outcomes

Significant improvements were observed in both gait quality and functional mobility.

Wisconsin Gait Scale

Median scores decreased from 24.5 (IQR: 4.1) at baseline to 18.97 (IQR: 3) post intervention, reflecting a median improvement of 5.53 points ($p<0.001$). The 95% confidence interval for this change was 4.374 to 6.515, exceeding both the minimally clinically important difference (MCID= 2.25) and minimal detectable change (MDC= 4.24), indicating a clinically meaningful and reliably measurable improvement.

Timed Up and Go Test

Mean of time taken to complete the TUG test reduced from 21.05 ± 4.68 seconds to 17.4 ±4.7 seconds, with a mean improvement of 3.65 seconds ($p<0.001$). The 95% confidence interval for this change was 2.483 to 3.487, surpassing the MCID threshold of 10% for stroke populations.

Large effect size (dz=1.73, 95%CI [4.37-6.51]) for WGS confirms robust clinically meaningful gait improvements

Table 1. Changes in gait and mobility outcomes pre- and post- intervention

Outcome Measure	Pre- test scores	Post- test scores	Mean Diff	**Pooled SD**	**Effect size**	**95% confidence interval**	***p*- value**
Wisconsin Gait Scale	24.5 (IQR: 4.1)	18.97 (IQR: 3)	5.53 points	2.61	1.73 [large]	4.375-6.515	<0.001
Timed Up and Go	21.05 (SD: 4.68)	17.4 (SD:4.7)	3.65 seconds	4.69	0.64 [medium-large]	2.483-3.487	<0.001

IQR- interquartile range; SD- standard deviation

Qualitative Gait Improvements

Observational analysis revealed notable enhancements in gait mechanics:

During swing phase of gait cycle:

- Toe Clearance improved in 80% of participants (vs. 35% pre-intervention).
- Knee Flexion during mid-swing increased in 70%.
- Pelvic retraction during terminal swing was reduced.

During stance phase of gait cycle**:**

- 90% of participants achieved full weight transfer to the affected limb.
- Step length symmetry improved between affected and unaffected sides.
- Abnormal stance width reduced in 44% participants.

Additionally, pre-intervention guardedness (hesitation before stepping) resolved in 85% of participants, contributing to smoother gait transitions and reduced fall risk.

Discussion

This case series demonstrates that a 4-week combined intervention of NMES targeting tibialis anterior and hamstrings with conventional physiotherapy produced statistically significant and clinically meaningful improvements. The median WGS score reduction of change of 5.53 points [IQR4.1 to 3, $p<0.001$; 95%CI 4.375-6.515] exceeded both MCID (2.25 points) and MDC (4.25 points) thresholds, confirming reliable detection of true change. TUG improvements averaged 3.65 seconds ($p<0.001$, 95% CI 2.483-3.487), representing 17.3% gain and surpassing stroke-specific MCID benchmarks. Effect sizes were large for WGS (dz=1.73) and medium-large for TUG (dz=0.64), underscoring substantial practical impact.

Qualitative gains- toe clearance (80%).knee flexion (70%), weight shifting (90%)- suggest NMES facilitated neuroplasticity and normalized swing/ stance kinematics[15,16,17,18], addressing foot drop and stiff-knee gait patters characteristics of hemiplegia[15,16].

Findings align with NMES trials demonstrating gait improvements[9,10,12] while extending evidence to low-resource settings. Unlike urban-focused studies or African community models [13,14,] this work validates NMES feasibility in semi-urban Indian outpatients serving rural populations-where stroke rehab access remains <20% due to cost and infrastructure gaps.

Clinical Implications

The protocols brevity (16 sessions), 100% adherence, zero adverse events and minimal equipment needs position MES as a scalable adjunct for low-resource neurorehabilitation units across LMICs. Targeting muscle groups with 5s on-off cycles effectively managed fatigue while enhancing real-world mobility, offering a practical bridge for the urban-rural rehabilitation divide

Limitations

The absence of a control group limits causal inference and small sample size restricts generalizability; data collected 2011-2012 lacks recent validation; no long-term follow-up or blinding.

Future Directions

Randomized controlled trials should isolate NMES effects, optimize parameters (frequency, pulse width), assess cost-effectiveness, and evaluate sustained outcomes. Integration with telerehabilitation could enhance scalability for geographically isolated stroke survivors.

Conclusion

NMES combined with conventional therapy is feasible, effective, and scalable intervention for improving gait and functionalmobility in post-stroke hemiplegia, especially in rural and resource-limited settings. The use of affordable, portable NMES devices alongside simple physiotherapy exercises addresses both muscle impairments and functional limitations, leading to clinically meaningful improvements in gait parameters and daily activities. These findings support NMES as a practical tool to bridge the urban-rural rehabilitation gap and promote neuroplasticity and functional recovery in stroke survivors across diverse contexts.

List of Abbreviations

- NMES- Neuromuscular electrical stimulation
- WGS- Wisconsin Gait Scale
- TUG- Timed Up and Go Test
- MCID- Minimally Clinically Important Difference
- MDC- Minimal Detectable Change
- IQR- Interquartile Range
- SD- Standard Deviation

Declarations

Ethics Approval and Consent to Participate: This study was approved by the Ethics Committee of Seth GS Medical College and KEM Hospital (Approval No.18/2011). Written informed consent was obtained from all participants prior to enrolment

Availability of data and Material: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request

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Conflict of Interest: The authors declare that they have no competing financial interests or personal relationshipsthat could have appeared to influence the work reported in this paper.

Authors' Contributions

Shruti Patil designed the intervention protocol, recruited participants, administered physiotherapy sessions, contributed to data acquisition and

clinical observations, performed statistical analysis, formatted tables and supported manuscript editing.

Archana Gore conceptualized the study, contributed to clinical observations and supported manuscript editing

All authors read and approved the final manuscript.

All authors meet ICMJE authorship criteria: (1) substantial contributions, (2) rafting/revising, (3) final approval, and (4) agreement to be accountable.

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