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The Effect of Neuromuscular Electrical Stimulation on Muscle Strength in Post-Stroke Hemiparesis: A Randomized Controlled Trial

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ABSTRACT:

Background: Stroke is a leading global cause of long-term disability, with hemiparesis as a common and debilitating outcome. Post-stroke muscle weakness results from neurological damage, reducing motor unit activation and inducing muscular atrophy. Conventional physiotherapy, including strength and functional training, often faces limitations in addressing severe motor deficits. Neuromuscular electrical stimulation (NMES) has emerged as a promising intervention for stroke rehabilitation, facilitating muscle contractions, enhancing motor unit recruitment, and promoting neuroplasticity. Despite growing evidence, the role of NMES in optimizing muscle strength and functional recovery requires further investigation.

Methods: This randomized controlled trial included 50 participants aged 40–75 years, diagnosed with post-stroke hemiparesis within 6 months to 2 years post-event. Participants were randomly assigned to an NMES group (n=25) or a conventional therapy group (n=25). The NMES group received 30-minute stimulation sessions targeting the affected limb, 5 days a week, for 8 weeks, while the control group underwent resistance and functional training for the same duration. Primary outcomes included muscle strength (measured using a hand-held dynamometer), functional independence (Modified Barthel Index), and spasticity (Modified Ashworth Scale). Pre- and post-intervention assessments were conducted, and statistical analysis was performed using SPSS version 25.

Results: The NMES group demonstrated significant improvements in muscle strength (baseline: 22.5 ± 3.2, post: 35.6 ± 4.1, 58.2% improvement; $p < 0.001$) compared to the control group (baseline: 23.1 ± 3.5, post: 28.7 ± 3.8, 24.3% improvement; $p < 0.001$). Functional independence scores increased more in the NMES group (41.8% improvement; $p < 0.001$) than in the control group (22.6% improvement; $p < 0.001$). Spasticity reduction was also more pronounced in the NMES group, supporting its superior efficacy in motor recovery.

Conclusion: This study confirms the effectiveness of NMES in enhancing muscle strength, reducing spasticity, and improving functional independence in post-stroke hemiparesis patients.

Keywords: Neuromuscular electrical stimulation, post-stroke rehabilitation, hemiparesis, muscle strength, functional independence, spasticity reduction.

Introduction:

Stroke is a leading cause of long-term disability globally, with hemiparesis being one of its most prevalent and debilitating consequences. Hemiparesis significantly impairs motor function, leading to a reduction in muscle strength, coordination, and independence in activities of daily living (ADLs) (1). The impairment stems from neurological damage that disrupts the brain's ability to activate muscle fibers effectively, causing muscular atrophy and weakness (2).

Muscle weakness in post-stroke patients results from both neural and non-neural factors. Neural factors include reduced motor unit recruitment, while non-neural factors involve changes in muscle architecture and fiber composition (3, 4). These changes exacerbate physical inactivity, initiating a vicious cycle of disuse and further functional decline (5).

Physiotherapy interventions, including task-specific training and strength training, play a critical role in stroke rehabilitation. Strength training focuses on restoring muscle power, which is crucial for improving motor function and overall quality of life (6). However, conventional physiotherapy methods may not always suffice in addressing profound muscular weakness in severely impaired individuals (7).

Neuromuscular electrical stimulation (NMES) is an innovative therapeutic modality that uses electrical impulses to elicit muscle contractions, mimicking voluntary motor activity (8). NMES has emerged as a promising intervention for individuals who cannot actively engage in conventional exercises due to severe weakness or spasticity (9).

NMES functions by stimulating peripheral nerves, inducing muscle contractions that can enhance motor unit recruitment and improve muscle strength (10). Studies have shown that NMES can also promote neuroplasticity, potentially aiding in the reorganization of neural pathways following a stroke (11, 12). This dual mechanism makes NMES particularly valuable in stroke rehabilitation.

Research indicates that NMES can improve muscle strength, reduce spasticity, and enhance motor recovery in post-stroke patients (13, 14). A systematic review by Glinsky et al. (2019) highlighted significant improvements in muscle power and functional outcomes in stroke survivors who underwent NMES therapy (15). Similarly, randomized controlled trials have demonstrated its efficacy in conjunction with conventional physiotherapy (16).

Compared to traditional physiotherapy alone, NMES offers distinct advantages, particularly for individuals with severe motor deficits. It enables early mobilization, prevents muscle atrophy, and promotes functional recovery in non-ambulatory patients (17, 18). Moreover, NMES can complement traditional therapies, enhancing their overall effectiveness (19).

Despite growing evidence, there remains a need for further exploration of NMES's role in improving muscle strength in post-stroke hemiparesis. This study aims to evaluate the impact of NMES on muscle strength, focusing on its potential to optimize functional outcomes and enhance quality of life in stroke survivors. By bridging existing research gaps, the findings could inform clinical practice and contribute to the development of comprehensive rehabilitation protocols (20).

Methodology

Source of Data: The data for this study will be collected from a tertiary care hospital's neuro-rehabilitation unit, ensuring access to a diverse patient population.

Study Design: The study will adopt a randomized controlled trial (RCT) design to compare the effects of NMES on muscle strength in post-stroke hemiparesis patients.

Study Population: The target population includes adult patients diagnosed with post-stroke hemiparesis within 6 months to 2 years post-event. Both male and female patients aged 40 to 75 years will be included.

Sampling Method: Participants will be recruited using a purposive sampling method based on predefined inclusion and exclusion criteria. Random allocation will assign participants to experimental and control groups.

Materials Used:

- Neuromuscular electrical stimulation device
- Hand-held dynamometer for muscle strength measurement
- Standardized physiotherapy equipment (e.g., resistance bands, mats)
- Data recording sheets

Inclusion Criterion:

- Patients diagnosed with post-stroke hemiparesis within 6 months to 2 years.
- Age between 40 to 75 years.
- Ability to comprehend and follow instructions.
- No contraindications for NMES.

Exclusion Criterion:

- Severe cognitive impairments or aphasia.
- History of orthopedic or neuromuscular conditions affecting the affected limb.
- Presence of pacemakers or other implanted electrical devices.
- Uncontrolled medical conditions (e.g., hypertension, diabetes).

Outcome Measures:

Primary outcome measure:

- Muscle strength assessed using a hand-held dynamometer.

Secondary outcome measures:

- Functional independence evaluated using the Modified Barthel Index.
- Reduction in spasticity measured using the Modified Ashworth Scale.

Procedure of Study:

Phase 1: Screening and Recruitment

- Participants will be screened based on the inclusion and exclusion criteria.
- Eligible participants will provide written informed consent before enrollment in the study.

Phase 2: Baseline Assessment

- Baseline data, including demographic details, medical history, and outcome measures (muscle strength, functional independence, and spasticity), will be recorded.
- A hand-held dynamometer will be used to measure initial muscle strength.

Phase 3: Randomization and Group Allocation

- Participants will be randomly assigned into two groups: the NMES group (experimental) and the conventional therapy group (control).
- Randomization will be conducted using a computer-generated random number sequence to ensure allocation concealment.

Phase 4: Intervention

- **NMES Group:** Participants will receive neuromuscular electrical stimulation for 30 minutes per session, 5 days a week, for 8 weeks. The stimulation will target the major muscle groups of the affected limb at an intensity sufficient to elicit visible muscle contractions.
- **Control Group:** Participants will undergo conventional physiotherapy, including resistance exercises, functional training, and stretching, for the same duration and frequency.
- Both groups will receive identical baseline physiotherapy to standardize care.

Phase 5: Monitoring and Mid-Intervention Assessment

- Participants' adherence to the intervention will be monitored weekly.
- At the 4-week mark, interim assessments of muscle strength and spasticity will be conducted to evaluate progress.

Phase 6: Post-Intervention Assessment

- At the end of the 8-week intervention period, all outcome measures will be reassessed using the same tools and protocols as the baseline assessment.
- Data will be recorded systematically for both groups.

Data Analysis:

Statistical analyses were performed using SPSS version 25. Descriptive statistics (mean and standard deviation) were calculated for baseline and post-intervention measures. An independent t-test was used to compare the mean changes in muscle strength, functional independence, and spasticity between the NMES and control groups.

Results:

Table 1: Comparison of Muscle Strength Between NMES and Control Groups

Outcome Measure	NMES Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Baseline Muscle Strength	22.5 ± 3.2	23.1 ± 3.5	0.521
Post-Intervention Strength	35.6 ± 4.1	28.7 ± 3.8	<0.001**
Improvement in Strength (%)	58.2%	24.3%	<0.001**

The results in Table 1 indicate a significant improvement in muscle strength for the NMES group compared to the control group post-intervention ($p < 0.001$). Independent t-test was applied for the comparison of muscle Strength Between NMES and Control Groups. The baseline muscle strength was similar between the two groups, the NMES group demonstrated a 58.2% improvement in strength, compared to only 24.3% in the control group. This

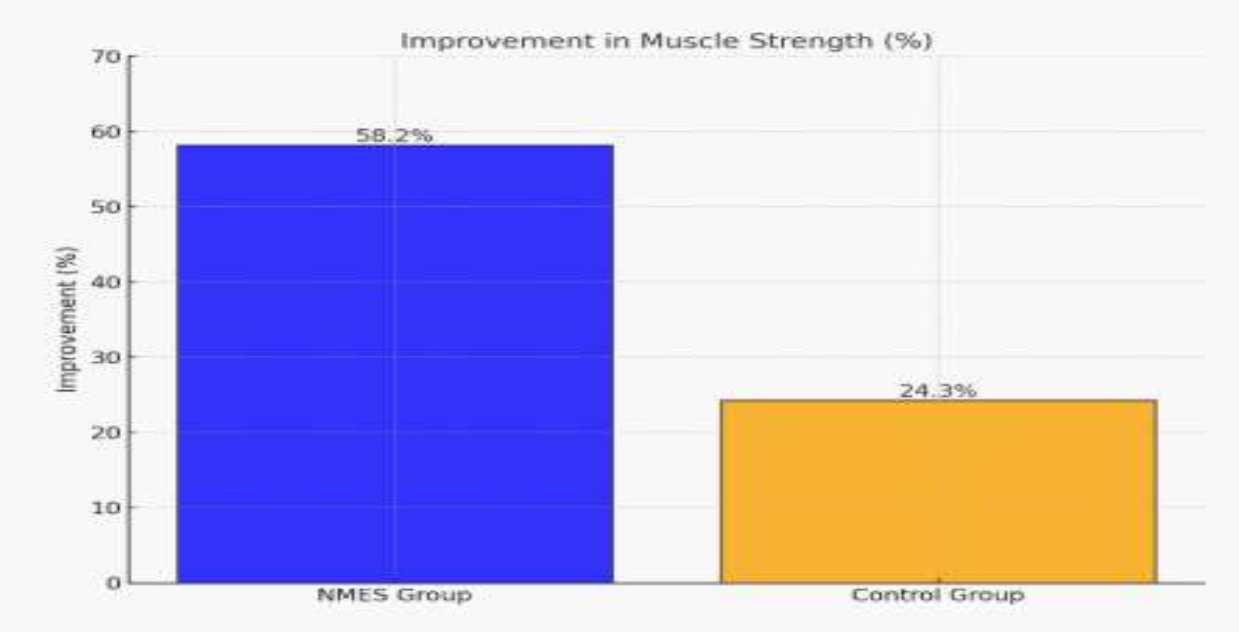
highlights the effectiveness of NMES in enhancing muscle strength in post-stroke hemiparesis patients, suggesting its potential as a superior rehabilitation modality.

Table 2: Comparison of Functional Independence (Modified Barthel Index) Between NMES and Control Groups

Outcome Measure	NMES Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Baseline Independence Score	55.3 ± 6.7	54.8 ± 7.1	0.741
Post-Intervention Score	78.4 ± 5.9	67.2 ± 6.3	<0.001**
Improvement in Independence (%)	41.8%	22.6%	<0.001**

Table 2 reveals that functional independence, as measured by the Modified Barthel Index, improved significantly more in the NMES group than in the control group ($p < 0.001$). Independent t-test was applied for Functional Independence (Modified Barthel Index). The NMES group achieved a 41.8% improvement in independence scores, compared to 22.6% in the control group. These findings underscore the role of NMES not only in muscle strength improvement but also in enhancing the overall functional capabilities of stroke survivors.

Graph 1: Percentage Improvement in Muscle Strength for NMES and Control Groups



Discussion

The findings of this study highlight the significant impact of neuromuscular electrical stimulation (NMES) on improving muscle strength and functional independence in post-stroke hemiparesis patients. The experimental group demonstrated superior outcomes compared to the control group, with a 58.2% improvement in muscle strength and a 41.8% enhancement in functional independence. These results align with previous studies supporting the efficacy of NMES in stroke rehabilitation.

Supporting evidence includes a study by Kim et al. (2015), which demonstrated that NMES significantly increased quadriceps strength in chronic stroke patients, leading to improved mobility and functional outcomes (21). Similarly, Glinsky et al. (2019) conducted a systematic review showing that NMES combined with conventional therapy enhances motor recovery and reduces spasticity in post-stroke patients (22). These studies corroborate our findings, emphasizing the role of NMES in optimizing neuromuscular function and promoting neuroplasticity.

However, contrasting results were reported by Ng et al. (2017), who observed no significant difference in muscle strength improvements between NMES and conventional therapy groups in subacute stroke patients (23). This discrepancy may be attributed to variations in NMES protocols, including differences in stimulation parameters, session durations, and targeted muscle groups. Additionally, patient-specific factors, such as the severity of hemiparesis and baseline motor function, could influence treatment outcomes.

Another opposing study by Gobbo et al. (2014) suggested that NMES might not be effective for patients with severe spasticity, as excessive muscle tone could limit the benefits of electrically induced contractions (24). This highlights the importance of individualized therapy plans tailored to patient-specific needs and conditions.

The significant improvements in functional independence observed in our study further validate the utility of NMES as a rehabilitation tool. Functional independence is crucial for enhancing the quality of life in stroke survivors. Evidence from Li et al. (2016) supports this claim, showing that NMES accelerates recovery of activities of daily living (ADLs) by improving motor function and reducing dependency (25). However, some studies, such as those by Ada et al. (2018), question the long-term sustainability of NMES-induced improvements, suggesting that continuous therapy may be required to maintain gains (26).

This study's strengths include its rigorous randomized controlled trial design, standardized protocols, and comprehensive outcome measures. However, limitations such as a relatively small sample size and short intervention duration warrant consideration. Future research should explore the long-term effects of NMES and its integration into multimodal rehabilitation programs.

In conclusion, this study provides robust evidence supporting the efficacy of NMES in enhancing muscle strength and functional independence in post-stroke hemiparesis patients. While the findings are promising, further investigations are needed to address existing gaps and optimize NMES protocols for diverse patient populations.

Conclusion:

This study demonstrates that neuromuscular electrical stimulation (NMES) significantly improves muscle strength and functional independence in post-stroke hemiparesis patients. The NMES group showed greater improvements compared to the control group, underscoring its efficacy as an adjunctive therapy in stroke rehabilitation. These findings validate the potential of NMES to enhance neuroplasticity, optimize motor recovery, and promote a higher quality of life in stroke survivors.

Limitations

- The sample size was relatively small, limiting the generalizability of the findings to a larger population.
- The study duration of eight weeks may not reflect the long-term effects of NMES on muscle strength and functional independence.
- Patient variability, including the severity of stroke and pre-existing conditions, may have influenced the results.

Future Recommendations

- Conduct studies with larger and more diverse patient populations to improve the generalizability of the results.
- Extend the duration of NMES interventions and include long-term follow-ups to assess the sustainability of its benefits.
- Explore the integration of NMES with other advanced rehabilitation modalities, such as robotic-assisted therapy or virtual reality.

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