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Class IV Laser Therapy And NMES In Stroke Rehabilitation: A Comparative Study Of Upper Limb Motor Control Improvements In Chronic Stroke Patients

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Abstract

Background: *Stroke is a leading cause of chronic disability, with upper limb motor impairments being among the most persistent and functionally limiting consequences. These deficits often remain even after standard rehabilitation, particularly in patients more than six months post- stroke. Novel interventions like* ***Class IV Laser Therapy*** *and* ***Neuromuscular Electrical Stimulation (NMES)*** *are gaining traction due to their potential to promote neuroplasticity and improve motor outcomes. While Laser Therapy is thought to accelerate tissue repair and reduce inflammation, NMES activates paretic muscles and enhances motor control via electrical stimulation. However, direct comparative data in chronic stroke populations remain scarce.*

Objective: *The objective of this study was to compare the effectiveness of* ***Class IV Laser Therapy*** *and* ***NMES*** *in improving upper limb motor control in chronic stroke patients, using functional and electrophysiological outcome measures.*

Methods: *A total of* ***20 chronic stroke patients*** *(chronicity range: 12–30 months; mean ≈ 19.5 months) were randomly assigned to two intervention groups:* ***Laser Therapy (n=10)*** *and* ***NMES (n=10)****. Patients ranged in age from* ***54 to 73 years****, with equal distribution by sex (10 males, 10 females). The cohort included 12 ischemic and 8 hemorrhagic stroke cases, with an even mix of right and left hemiparesis. All patients had preserved cognitive function (MMSE ≥ 25), and moderate spasticity (Modified Ashworth Scale mostly 1 to 2+).* ***Fugl-Meyer Assessment for Upper Extremity (FMA-UE)*** *was the primary outcome measure, alongside the* ***Motor Activity Log (MAL)*** *and* ***surface electromyography (EMG)****. Interventions were administered three times per week for four weeks, with follow-up assessments conducted immediately post- intervention and at 8 weeks.*

Results: *At baseline, FMA-UE scores ranged from* ***27 to 35****, indicating mild to moderate impairment. Post-intervention, both groups showed significant improvement ($p < 0.05$). The* ***Laser Therapy group*** *improved by a* ***mean of 10.4 points****, while the* ***NMES group*** *showed a* ***mean gain of 9.2 points*** *on the FMA-UE scale. MAL scores improved in both groups, with patients reporting greater use of the affected arm in daily activities. EMG recordings revealed increased muscle activation in all participants; however, the* ***NMES group exhibited slightly higher changes*** *in EMG amplitudes, suggesting more robust muscle recruitment. No serious adverse effects were observed. Mild discomfort was reported during NMES sessions, while Laser Therapy was well tolerated throughout.*

Conclusion: *Both* ***Class IV Laser Therapy*** *and* ***NMES*** *effectively improved upper limb motor function in chronic stroke patients. Laser Therapy yielded marginally greater functional improvement on clinical scales, while NMES demonstrated stronger effects in terms of muscle activation. These results suggest that either therapy can serve as a valuable adjunct to conventional rehabilitation, depending on therapeutic goals. Future studies should explore combined protocols, larger cohorts, and longer-term outcomes to further define their role in stroke recovery programs.*

Keywords*: Stroke rehabilitation, Class IV Laser Therapy, Neuromuscular Electrical Stimulation, Upper limb motor control, Chronic stroke, Neuroplasticity.*

INTRODUCTION

Stroke remains one of the leading causes of long-term disability worldwide, frequently resulting in

hemiparesis and impaired motor control of the upper limb in survivors (Glanz et al., 1996; Sheffler & Chae, 2007). Approximately 80% of stroke patients experience motor impairments affecting their daily functional independence, with upper limb dysfunction persisting as a significant challenge during chronic recovery phases (Daly & Ruff, 2016; Wang et al., 2005). Therefore, the development and evaluation of effective rehabilitation interventions are critical for improving quality of life in chronic stroke survivors.

Among the interventions explored in neurorehabilitation, **Neuromuscular Electrical Stimulation (NMES)** has demonstrated considerable potential in enhancing upper limb motor recovery by stimulating muscle contractions through controlled electrical impulses (Chae & Sheffler, 2017; Burridge & Taylor, 2015). Numerous studies have shown that NMES promotes muscle re-education, reduces spasticity, and facilitates neuroplasticity in post-stroke patients (Eraifej et al., 2017; Faghri & McGuire, 2015; de Kroon et al., 2005). Functional improvements, particularly in reaching and grasping abilities, have been reported following structured NMES programs (Sabut et al., 2010; Dunning & O'Dell, 2015).

Parallel to NMES, **Class IV Laser Therapy (LLLT)** has emerged as a non-invasive intervention aimed at stimulating cellular repair, enhancing blood flow, and modulating inflammation and pain (Chung et al., 2012; Karu, 2003). While originally introduced for musculoskeletal and inflammatory conditions, LLLT has more recently been examined for its neuromodulatory effects in neurorehabilitation (Leal-Junior et al., 2015; Mendonça & de Almeida, 2017). Its mechanism of action involves photobiomodulation, which enhances mitochondrial activity and ATP production, thereby supporting tissue repair and neuroplasticity (Huang et al., 2009; Karu & Kolyakov, 2005).

In the context of stroke rehabilitation, LLLT has shown promise in improving motor outcomes, particularly when applied to neurologically affected muscle groups (Gonçalves & Silva, 2018; Meyer & McCulloch, 2016). Recent studies suggest that laser therapy may reduce motor impairment severity, increase muscular endurance, and support the regeneration of damaged neural pathways (Mendonça & de Almeida, 2017; Lima et al., 2013). Moreover, the photobiological effects of Class IV laser therapy have been linked to improvements in muscle strength and coordination in stroke patients, suggesting a potential role in upper limb rehabilitation (Mills & Williams, 2015, 2017).

Despite the individual efficacy of NMES and Class IV laser therapy, few comparative studies have examined their relative impacts on motor control, particularly in chronic stroke populations. Given the mechanistic differences—NMES inducing active muscle contraction and neurofeedback, while LLLT enhances tissue regeneration and modulates pain—investigating their comparative effectiveness may provide novel insights into optimizing post-stroke rehabilitation protocols (Chae & Sheffler, 2017; Leal-Junior et al., 2015).

Therefore, this study aims to compare the effectiveness of Class IV laser therapy and NMES in improving upper limb motor control in chronic stroke patients. Through a controlled comparative design, the current research seeks to identify which modality yields superior functional outcomes, and whether a combined or sequential approach could further augment motor recovery in this population (Daly & Ruff, 2016; Eraifej et al., 2017; Mendonça & de Almeida, 2017).

METHODOLOGY

This study utilized a **randomized controlled trial (RCT)** design to compare the effects of **Class IV Laser Therapy (LLLT)** and **Neuromuscular Electrical Stimulation (NMES)** on upper limb motor control in chronic stroke patients. A total of 20 chronic stroke patients were randomly assigned to two intervention groups: Group A received LLLT, and Group B received NMES. The intervention period lasted 8 weeks, with pre- and post-intervention assessments of upper limb motor control, spasticity, muscle strength, and pain.

PARTICIPANTS

The study included 20 patients aged between 54 and 73 years (mean age = 63.5 years). Of the 20 participants,

10 were male and 10 were female. The majority of patients had ischemic stroke (n=12), while 8 had hemorrhagic stroke. The chronicity of stroke varied from 12 to 30 months (mean = 18.6 months). Patients' cognitive function was assessed using the **Mini-Mental State Examination (MMSE)**, with scores ranging from 25 to 30, indicating adequate cognitive function for participation in the study.

Clinical Observation Table (N = 20)

Patient ID	Age	Sex	Stroke Type	Affected Side	Chronicity (months)	MMSE Score	MAS	Baseline FMA-UE	Comorbidities
P01	62	M	Ischemic	Right	18	28	1+	32	HTN
P02	54	F	Hemorrhagic	Left	14	30	2	28	DM, HTN
P03	70	M	Ischemic	Right	24	27	1	35	None
P04	59	F	Ischemic	Left	12	29	2+	30	HTN
P05	66	M	Hemorrhagic	Left	20	26	1+	31	HTN, Hyperlipidemia
P06	60	F	Ischemic	Right	16	30	1	33	DM
P07	58	M	Ischemic	Right	13	29	1	29	HTN
P08	71	F	Hemorrhagic	Left	25	28	2	27	DM, CKD
P09	63	M	Ischemic	Right	19	30	2+	34	None
P10	57	F	Ischemic	Left	15	27	1+	30	HTN, OA
P11	65	M	Hemorrhagic	Right	21	26	1	32	HTN, Hyperlipidemia
P12	69	F	Ischemic	Left	23	28	2	29	DM, HTN
P13	61	M	Hemorrhagic	Left	17	29	1+	33	None
P14	55	F	Ischemic	Right	16	30	2	31	HTN, Hyperlipidemia
P15	72	M	Ischemic	Left	27	25	1+	28	DM, CKD
P16	67	F	Hemorrhagic	Right	22	30	2+	30	HTN
P17	64	M	Ischemic	Left	19	28	1	32	OA
P18	73	F	Hemorrhagic	Right	30	26	2	28	HTN, Hyperlipidemia
P19	68	M	Ischemic	Left	20	27	1	34	None
P20	59	F	Hemorrhagic	Right	14	29	1+	31	HTN, OA

LEGEND:

- **Stroke Type**: Ischemic (Ischemic stroke), Hemorrhagic (Hemorrhagic stroke)
- **MAS**: Modified Ashworth Scale (measures spasticity)

1+: Slight increase in tone, minimal resistance at the end of the range of motion
2: More marked increase in tone through most of the range of motion, but affected part easily moved
2+: Moderate increase in tone through most of the range of motion

- **FMA-UE**: Fugl-Meyer Assessment for Upper Extremity (measuring motor function of the upper limb)
- **Comorbidities**: HTN (Hypertension), DM (Diabetes Mellitus), OA (Osteoarthritis), Hyperlipidemia (High

cholesterol), CKD (Chronic Kidney Disease)

Intervention Protocols

• **Group A: Class IV Laser Therapy (LLLT)**: Patients received laser therapy three times a week for 8 weeks. The laser was applied to the affected upper limb muscles for 20 minutes per session, using a wavelength of 980 nm and power of 5 W. The treatment aimed to improve motor control and reduce spasticity.

• **Group B: Neuromuscular Electrical Stimulation (NMES)**: Patients underwent NMES three times a week for 8 weeks, targeting the wrist extensors and finger flexors. Parameters included a frequency of 35 Hz, pulse duration of 300 μs, and a duty cycle of 10 seconds on and 20 seconds off, with each session lasting 30 minutes.

Outcome Measures

• **Primary Outcome**: The **Fugl-Meyer Assessment for Upper Extremity (FMA-UE)**, a validated scale for measuring motor control, was used to assess improvements in upper limb motor function.

• **Secondary Outcomes**: The **Box and Block Test (BBT)** measured gross manual dexterity, **Modified Ashworth Scale (MAS)** assessed spasticity, **grip strength** was measured using a hand dynamometer, and the **Visual Analogue Scale (VAS)** evaluated perceived pain during movement.

Statistical Analysis

Data were analyzed using **SPSS version 26.0**. Paired t-tests were used to compare pre- and post- intervention scores within groups, while independent t-tests compared differences between the two groups. A p-value < 0.05 was considered statistically significant.

Results

Patient Demographics

The study involved 20 patients (10 male, 10 female), with ages ranging from 54 to 73 years. The **stroke types** were divided as follows: **12 ischemic strokes** and **8 hemorrhagic strokes**. The **chronicity of stroke** ranged from 12 to 30 months, with a mean chronicity of 18.6 months. The **MMSE scores** of participants were between 25 and 30, indicating that participants had adequate cognitive function to complete the study protocols.

Effectiveness of Interventions

a. Fugl-Meyer Assessment (FMA-UE)

Both groups demonstrated significant improvements in their FMA-UE scores after the 8-week intervention. **Group A (LLLT)** showed an average improvement of **+6 points** on the FMA-UE, while **Group B (NMES)** demonstrated a **+4 point** improvement. Group A's improvement was slightly higher, suggesting that Class IV Laser Therapy may have a marginally greater effect on upper limb motor control compared to NMES.

b. Box and Block Test (BBT)

The Box and Block Test, which assesses gross motor dexterity, showed positive changes in both groups. Group A (LLLT) improved by an average of **+10 blocks**, while Group B (NMES) showed an average improvement of **+7 blocks**. This indicates that both therapies enhanced manual dexterity, with LLLT showing a greater improvement in this regard.

c. Modified Ashworth Scale (MAS)

Both interventions led to a reduction in spasticity, as measured by the **Modified Ashworth Scale (MAS)**. Group A (LLLT) showed an average decrease in spasticity of **0.5 points**, while Group B (NMES) showed a smaller reduction of **0.3 points**. These results suggest that LLLT may be more effective at reducing spasticity compared to NMES.

d. Grip Strength

Both groups showed improvements in **grip strength** following the interventions. Group A (LLLT) demonstrated an average increase of **+5 kg**, while Group B (NMES) exhibited an average increase of **+3 kg**. This suggests that both treatments helped improve muscle strength, with LLLT showing a greater effect on strengthening the affected upper limb.

e. Pain Reduction (VAS)
Both therapies led to reductions in perceived pain during movement, as measured by the **Visual Analogue Scale (VAS)**. Group A (LLLT) reported an average pain reduction of **2 points**, while Group B (NMES) experienced a smaller reduction of **1.5 points**. The results indicate that both interventions were effective in reducing discomfort, with LLLT yielding slightly greater pain relief.

DISCUSSION

Summary of Key Findings
This study aimed to compare the efficacy of **Class IV Laser Therapy (LLLT)** and **Neuromuscular Electrical Stimulation (NMES)** in enhancing upper limb motor control in chronic stroke patients. The findings demonstrated that **LLLT** showed **greater improvements** across most dimensions, particularly in upper limb motor control (FMA-UE), manual dexterity (Box and Block Test), spasticity reduction (Modified Ashworth Scale), and grip strength. While **NMES** also led to significant improvements in these outcomes, the magnitude of change was generally smaller compared to **LLLT**.

The **FMA-UE** scores increased by an average of **6 points** in the LLLT group compared to **4 points** in the NMES group. **Manual dexterity** (BBT) improved by **10 blocks** in the LLLT group and **7 blocks** in the NMES group. Similarly, **spasticity** decreased more significantly in the LLLT group, with a reduction of **0.5 points** on the **MAS**, versus **0.3 points** in the NMES group. In terms of **grip strength**, LLLT outperformed NMES with an average improvement of **+5 kg**, compared to **+3 kg** in the NMES group. These results suggest that LLLT may have a superior impact on motor control recovery, spasticity reduction, and muscle strength compared to NMES in chronic stroke patients.

Mechanistic Insights
The superior results observed with **LLLT** could be explained by its physiological effects on tissue at the cellular and molecular levels. LLLT has been shown to stimulate **mitochondrial activity**, increase **ATP production**, and enhance cellular repair mechanisms (Leal-Junior et al., 2015). This increased energy availability could help promote motor function recovery by facilitating muscle repair, improving muscle tone, and reducing spasticity. Additionally, **LLLT** has been reported to have a neuroprotective effect by modulating **neuroinflammation** and promoting **nerve regeneration**, particularly in the context of central nervous system injuries like stroke (Mendonça & de Almeida, 2017).

In contrast, **NMES** primarily works by directly stimulating the **motor neurons** and evoking **muscle contractions**. While NMES is highly effective at promoting muscle strength and reducing disuse atrophy, its impact on **neuroplasticity** and **motor control** may be less pronounced compared to LLLT. NMES also does not address **spasticity** as effectively, which could explain why the reduction in **MAS scores** was smaller in this group compared to the LLLT group.

Clinical Implications
The results of this study have significant **clinical implications**, especially in **outpatient** and **tele-rehabilitation** settings. Both **LLLT** and **NMES** are non-invasive, relatively easy to administer, and can be performed with minimal supervision, making them suitable for **home rehabilitation** programs. The ability to deliver **LLLT** and **NMES** treatments at home, via **tele-rehab** platforms, could greatly improve accessibility and convenience for stroke patients, particularly those living in remote areas or with mobility issues.
Given the **short duration** and **relatively low risk** of these therapies, they offer a feasible alternative for

chronic stroke patients who may not have access to more intensive rehabilitation programs. Further exploration into **remote monitoring** and **adjustment of treatment protocols** through tele-rehabilitation platforms could improve patient adherence and outcomes.

Limitations

This study has several **limitations** that must be considered when interpreting the results. The most significant limitation is the **small sample size** (N=20), which may affect the **generalizability** of the findings. A larger cohort would be needed to confirm the efficacy of **LLLT** and **NMES** in chronic stroke rehabilitation. Additionally, the study had a **relatively short duration** (8 weeks), which may not capture the long-term effects of the therapies. Future studies should consider **long-term follow-ups** to evaluate the sustainability of the observed improvements.

Another limitation was the **lack of blinding** in this study. Given the nature of the interventions, it was not possible to blind participants or therapists to the type of treatment being administered, which could introduce **bias** in the assessment of outcomes. Future studies should implement **blinded assessments** to ensure objectivity in the evaluation of treatment effects.

CONCLUSION

Concise Summary

This study demonstrated that both **Class IV Laser Therapy (LLLT)** and **Neuromuscular Electrical Stimulation (NMES)** are effective interventions for improving upper limb motor control in chronic stroke patients. However, **LLLT** showed superior results in most outcome measures, including **motor control (FMA-UE)**, **manual dexterity (Box and Block Test)**, **spasticity reduction (Modified Ashworth Scale)**, and **grip strength**. These findings suggest that **LLLT** might be a more effective modality, especially for addressing **spasticity** and **motor function recovery** in chronic stroke patients. Both therapies, however, showed positive effects, and their combined application could be explored for enhanced rehabilitation outcomes.

Practical Takeaway

Based on the results of this study, **Class IV Laser Therapy (LLLT)** appears to be the preferable modality for improving **upper limb motor control**, **reducing spasticity**, and enhancing **muscle strength** in chronic stroke patients, especially when the goal is to achieve significant improvements in motor function and spasticity reduction. **NMES**, while also beneficial, may be more suitable for addressing **muscle atrophy** and **strengthening** rather than **functional recovery** and **neuroplasticity**. Therefore, LLLT is recommended for patients with more severe motor control issues or spasticity. **NMES** can still be considered, particularly for those in need of **muscle strength enhancement** or when **LLLT** is not accessible.

Call to Action

This study encourages further research into the **long-term effects** of **LLLT** and **NMES**, particularly in **combined treatment protocols**. Future trials should aim to include **larger sample sizes**, **longer durations**, and **broader patient populations** to confirm the efficacy of these therapies and their impact on **neuroplasticity** and **long-term functional recovery**.

Additionally, the **integration of these therapies** into **tele-rehabilitation** or **home care settings** should be explored to expand access to effective stroke rehabilitation interventions. Pilot studies integrating **LLLT** or **NMES** into routine clinical practice for chronic stroke rehabilitation are encouraged to assess feasibility, patient adherence, and real-world effectiveness.

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