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# Physiotherapy Efficiency in Post-stroke Upper Extremity Spasticity: TENS *vs.* Ultrasound *vs.* Paraffin

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**Abstract.** *Background/Aim: Post-stroke spasticity is a significant debilitating condition with negative consequences on individual functional independence and quality of life. This study aimed to identify the differences between transcutaneous electrical stimulation (TENS), ultrasound therapy and paraffin procedures on post-stroke upper extremity spasticity and dexterity. Patients and Methods: Twenty-six patients were enrolled in the study, divided into three therapy groups: TENS (n=9), paraffin (n=10) and ultrasound therapy (n=7). For 10 days, the patients received specific group therapy and conventional physical therapy exercises for upper extremities. Modified Ashworth Scale, Functional Independence Measure, Functional Coefficient, Stroke Specific Quality of Life Scale, Activities of Daily Living score and ABILHAND questionnaire were used to assess the participants before and after therapy. Results: The results of the group comparisons by analysis of variance showed no significant difference between outcomes by the applied treatments. In contrast, one-way analysis of variance suggested significant improvements in patients in all three groups after therapy. Step-wise regression results on functional independence measure and quality-of-life scales suggested that functional range of motion values for elbow and wrist influence individual independence and quality of life. Conclusion: TENS, ultrasound, and paraffin therapy bring equal benefits in the management of post-stroke spasticity.*

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Stroke has become one of the most severe neurological conditions in developed countries and the third leading cause of death after heart disease and cancer; it is considered a significant cause of long-term disability and cognitive impairment (1, 2). Since the risk of death from stroke has been reduced, the number of stroke survivors with motor and cognitive impairments has risen. Stroke survivors are at increased risk of developing spasticity, a significantly debilitating impairment. The burden is more remarkable in stroke survivors who have spasticity than in those without spasticity, in terms of the costs of treatment, quality of life, and caregiver burden (3, 4).

In addition to spasticity that causes hypertonia and alteration of segment muscle equilibrium, post-stroke motor weakness may arise. Motor deficit depicts a reduced muscle strength, ranging from total lack of muscle contraction to mild paresis (5, 6). In time, the muscle structure is altered by a decrease in the number of motor units and atrophic abnormalities of fast-twitch fibres (7).

Spasticity is characterized by a marked increase in muscle tone and muscle resistance, which limits joint motions and leads to exaggeration of the stretch reflex, gamma system hyperactivity, and flexion reflex hyperactivity (8-10). The mechanism underlying spasticity is still debated but it has been shown that the pyramidal system has an inhibitory action on myotatic medullary reflexes *via* the gamma loop. Hyperactivity of the gamma loop leads to increased excitability of tonic alpha motoneurons, and the exaggeration of the myotatic reflex leads to spasticity (11).

Spasticity can manifest more pronounced increased muscle tone at the beginning of a movement and possibly a decrease in tone during movement execution. As a predominant disability characteristic in the distal segments, the mobilized spastic extremity is inclined to return to its initial position. Spasticity usually predominates in the flexor muscles of upper limbs and extensor muscles of the lower limbs. However, in the upper extremity, five different patterns of muscle spasticity have been identified, while in the lower extremity, inversion and equinovarus have been detected (12, 13).

In the manifestation of motor deficits, spasticity 'sets' within 1 to 3 months after stroke onset, although muscle overactivity may increase in time (14). As a result, spasticity occurring due to vascular incidents and subsequent dysfunction has become the focus of attention in the discovery of new techniques and treatment methods that can help rehabilitate and restore patients' quality of life. Thus, several physical strategies have been developed to deal with this problem, including conventional physiotherapy, proprioceptive facilitation techniques, transcutaneous electrical stimulation (TENS), local heat or diathermy, transcranial direct current stimulation, functional electrical stimulation, and biofeedback methods (15-22).

For patients, post-stroke rehabilitation encompasses physical therapy, electrotherapy, massage, hydrotherapy, thermotherapy, occupational therapy, immersive or augmented virtual reality therapy, robotic training, speech therapy, and psychotherapy. The main goal of rehabilitation post stroke is to restore motor capacity for ambulation, activities of daily living (ADLs), and social and professional reintegration (23-26).

TENS is a method of combating acute and chronic pain states of various cases or muscle contraction stimulation, using low-frequency current, rectangular pulses, and one or two output channels using electrodes applied to the patient's skin. Previous research suggested that TENS therapy may positively affect post-stroke rehabilitation by stimulating weak muscles (27, 28).

Although widely known as a diagnostic tool, ultrasound, high-frequency currents produce capacitive phenomena that can easily cross the barriers which low-frequency currents cannot, and they are frequently used in rehabilitation. In the high-frequency electromagnetic field produced, electrical energy is transformed into caloric energy. The heat produced is directly proportional to the intensity, resistance, and duration square. This caloric effect is frequently used in therapy, alongside micro-vibration mechanical ultrasound property, which proved to have a muscle-relaxation effect (29, 30).

Paraffin therapy has been widely used as a physical modality in treating patients with various conditions such as joint stiffness or muscle spasticity. Paraffin therapy provides superficial heat to the skin, which has an analgesic and hyperaemic effect. Previous studies have shown that paraffin therapy reduces pain and increases joint range of motion in patients with joint spasticity or stiffness. After receiving combined paraffin and ultrasound treatments, improvements in the symptoms of patients with spasticity have been observed (31, 32).

This study aimed to identify whether there was a difference between TENS, ultrasound therapy and paraffin therapy in treatment of spasticity in patients post-stroke and compare the effects of physiotherapy procedures on post-stroke spasticity.

## Patients and Methods

The prospective study was conducted at the Brașov Neurology and Psychiatry Hospital for 6 months, from 01.11.2021 to 30.04.2022. The inclusion criteria for the study were: Age between 18-80 years, with post-stroke sequelae and spasticity evaluated by MAS of 2 or more. The exclusion criteria were: Sensitive aphasia, sensitivity disorders, more than 5 years post stroke, blood pressure higher than 90 mmHg (diastolic) and 150 mmHg (systolic), anticoagulant therapy, skin injuries, diabetes, and thermally sensitive diseases. All patients provided informed consent, and the research was performed according to the Helsinki declaration. Informed written consent was obtained under European legislation statements. The Research and Ethics Committee approved the study of the Clinical Hospital of Psychiatry and Neurology in Brașov (no. 12534/18 July 2019).

A total of 26 patients participated. The patients were divided into ultrasound (n=7), TENS (n=9) and paraffin (n=10) therapy groups after the initial assessment. They were initially and finally assessed using the following assessment scales: Modified Ashworth Scale (MAS), Functional Independence Measure (FIM) Functional Coefficient (based on range of motion in functional tasks), Stroke Specific Quality of Life Scale (SS-QOL), ADL score and ABILHAND questionnaire.

The MAS is most often used for spasticity assessment. The scale has been proven reliable when the same therapist assessed spasticity before and after intervention (33). Functional coefficient assesses the range of motion of joint mobility, determined by examining the degree of joint and segment motion in daily activities (34).

Although both the ADL score and FIM assess individual independence or the degree of disability, through ADL, transfers, bed mobility, toileting and eating are investigated, whereas with FIM, besides motor assessment, cognition is also evaluated, its scoring being more complex (0 to 7) as compared to the ADL score (0 to 2) (35, 36).

The SS-QOL provides correlations between psychological status and illness, investigating energy, roles in the family, language, mobility, mood, personality, personal care, roles in society, and cognitive capacities. The scale is convergent with the Barthel Index, Beck Depression Inventory, and subscales of the Short Form 36 Health Survey (37, 38).

The ABILHAND questionnaire was designed to measure the patient's dexterity and hand ability. It assesses the most representative tasks of the hand and investigates self-perception regarding the difficulty of daily tasks which require hand dexterity. The questionnaire was validated regarding item difficulty, as well as being found to have a high item reliability index and content validity for manual ability (39).

*Therapy*. The TENS therapy protocol lasted for 20 minutes, with the negative electrode on the spastic belly muscles, using a frequency of 100 Hz, a pulse phase of 50 μs, and the threshold at intense vibration. For the ultrasound therapy, 0.8 W/cm$^2$ was applied, pulsed 50% for 10 min on the spastic muscles. Paraffin was applied at a temperature of 42˚C for 20 min to the hypertonic muscles.

All patients underwent physical therapy exercises – 20 min daily for every spastic muscle group – stretching, proprioceptive facilitation relaxation techniques, passive analytical motions, selfpassive motions, and bed positioning for 30 min daily. No splints were used. The treatment therapy was for 2 weeks, comprising 10 working days.

*Statistical analysis*. Analysis of variance (ANOVA) was conducted to determine if the different therapy approaches, namely paraffin, ultrasound, and TENS, have different results on muscle spasticity in patients post stroke. Data are presented as the mean±standard deviation.

One-way repeated measures ANOVA was conducted to determine whether there was a statistically significant difference in muscle overactivity amongst the three different types of procedures before and after the intervention. No outliers were identified when checking data assumptions, and the data were normally distributed at each time point. The normality of data distribution was performed by boxplot examination and Shapiro–Wilk test ($p>0.05$), respectively. Although the assumption of sphericity was not met, as assessed by Mauchly's test of sphericity ($p<0.05$), Greenhouse and Geisser adjustments were used for data interpretation.

Step-wise multiple regressions were run to determine which elements from initial assessments improved the prediction of disability (FIM), quality of life (SS-QOL) and daily living performance (ADL) in patients with post-stroke spasticity. The confidence interval was set to 95%, with alpha <0.05. Pearson correlation coefficient between the dependent variable and the independent variable is reported as R-squared, and the standard error of estimates is given.

For all three regressions, scatterplots were created, and the assumption of linearity was checked. Secondly, for the independence of the observations, the Durbin Watson value was verified to be very close to 2, so the independence of errors or residuals can be accepted.

Pearson correlation was used to identify possible correlations between applied assessment scales. Data were analysed using IBM SPSS statistics (version 26.0; IBM Corp., Armonk, NY, USA). G*Power 3.1.9.7 version (RRID:SCR_013726) (40) was used to compute the effect size and identify the power analysis. Posteriori ANOVA parameters were identified for the 26 participants in the three groups, with an effect size of 0.8, alpha of 0.001 and power of 0.99.

## Results

The mean age of the participants was 65.12 years (standard deviation=6.80 years) and there 13 men. Eleven (42.31%) participants had right hemiparesis, while 15 (57.69%) were affected on the left side. Of the 26 participants, five had an ischemic stroke, and 21 had a haemorrhagic stroke. The average time since stroke was 2.12 years (SD=0.36 years). No differences were found in the baseline group comparison at the first assessment.

In Table I, the results of group comparison regarding the therapy effect within the three groups can be found. None of the therapies suggested better outcomes than others.

In Table II, the results of applied therapies before and after treatment are summarized. As can be seen from the table, all three types of treatment improved patients' functional and motor status.

The ADL score was highly correlated with the FIM assessment, clearly showing that both scales genuinely assess similar tasks. In Table III, results for regression analysis of FIM scale influences are depicted. Durbin Watson's value was 2.290, suggesting that shoulder and wrist functional range of motion influence individual functional independence.

The results for SS-QOL regression from Table IV suggest that functional independence and hand dexterity are essential predictors of patients' post-stroke quality of life. Durbin Watson's value was 1.858, showing that the available range of motion of the shoulder and wrist also influence the quality of life.

Pearson correlation results suggest a high correlation of FIM with ADL scores (r=0.817 and $p<0.001$) and SS-QOL (r=0.618 and $p<0.001$). MAS values for elbow flexors correlated negatively with elbow functional range of motion (r=–0.445, $p=0.023$) and positively with MAS wrist flexors (r=0.504 and $p=0.009$). The functional shoulder and elbow coefficients were highly correlated (r=0.728 and $p<0.001$). Wrist functional coefficient was positively correlated with functional elbow coefficient (r=0.707) and shoulder functional range of motion (r=0.652) ($p<0.001$) whereas wrist MAS was negatively correlated with (r=–0.509 and $p=0.008$).

## Discussion

This study aimed to identify the potential benefits of paraffin, TENS, and ultrasound therapy in management of post-stroke spasticity. Although none of these therapies proved to have better efficiency than the others, the research results suggest that each of these therapies brings significant improvement in post-stroke upper-extremity spasticity and individual independent functioning.

Parks *et al*. in 2014 (41) demonstrated the beneficial effects of TENS therapy, showing a decrease in spasticity by 0.80 points in the TENS-treated group compared to the TENS placebo group. A change in static and dynamic balance was also observed in the TENS-treated group, and the speed and cadence of movement also improved significantly with TENS. In addition, static balance improved significantly in the patients in this group; in the walking test, an increase in velocity, cadence and step length was observed, while in the TENS placebo group, only the velocity changed. Thus, the study's results suggest that a recovery programme that combines TENS applications and an exercise programme reduces spasticity and improves walking and balance in patients in the chronic stage post stroke.

Wang *et al*. (20) showed the beneficial effect of paraffin therapy in reducing upper extremity spasticity; although no favourable evidence was found for the range of motion, significant differences were identified in MAS and Visual Analog Scale pain, suggesting a decrease of pain and spasticity. Previous studies also suggested that TENS and other conventional physiotherapy interventions reduce spasticity (19, 42).

Table I. *Analysis of variance: Between-group comparisons.*

| Measure | Therapy group | | N | Mean difference | SD | 95% CI | F | *p*-Value |
|---|---|---|---|---|---|---|---|---|
| FIM | Paraffin | | 10 | 2.40 | 1.51 | 1.3230-3.4770 | 0.397 | 0.677 |
| | Ultrasound | | 7 | 2.14 | 1.77 | 0.5033-3.7824 | | |
| | TENS | | 9 | 2.89 | 1.90 | 1.4282-4.3496 | | |
| SS_QOL | Paraffin | | 10 | 13.00 | 5.94 | 8.7478-17.2522 | 0.310 | 0.737 |
| | Ultrasound | | 7 | 13.43 | 8.28 | 5.7675-21.0897 | | |
| | TENS | | 9 | 15.89 | 10.65 | 7.7048-24.0730 | | |
| ABILHAND | Paraffin | | 10 | −5.30 | 3.97 | −8.14-−2.46 | 0.997 | 0.384 |
| | Ultrasound | | 7 | −6.57 | 4.72 | −10.94-−2.21 | | |
| | TENS | | 9 | −8.22 | 4.89 | −11.98-−4.46 | | |
| ADL | Paraffin | | 10 | 0.10 | 0.32 | −0.13-0.33 | 0.786 | 0.467 |
| | Ultrasound | | 7 | 0.00 | 0.00 | 0.00-0.00 | | |
| | TENS | | 9 | 0.00 | 0.00 | 0.00-0.00 | | |
| Functional correlation | Shoulder | Paraffin | 10 | 4.50 | 4.53 | 1.26-7.74 | 1.174 | 0.327 |
| | | Ultrasound | 7 | 2.93 | 8.69 | −5.10-10.96 | | |
| | | TENS | 9 | .17 | 5.53 | −4.09-4.42 | | |
| Functional correlation | Elbow | Paraffin | 10 | 6.60 | 10.97 | −1.25-14.45 | 0.243 | 0.786 |
| | | Ultrasound | 7 | 3.29 | 10.42 | −6.35-12.92 | | |
| | | TENS | 9 | 4.67 | 7.86 | −1.37-10.71 | | |
| Functional correlation | Wrist | Paraffin | 10 | 7.05 | 4.92 | 3.53-10.57 | 0.455 | 0.640 |
| | | Ultrasound | 7 | 7.57 | 5.03 | 2.92-12.22 | | |
| | | TENS | 9 | 5.33 | 5.16 | 1.37-9.30 | | |
| MAS | Elbow | Paraffin | 10 | −0.45 | 0.50 | −0.81-−0.09 | 0.354 | 0.705 |
| | | Ultrasound | 7 | −0.57 | 0.45 | −0.99-−0.16 | | |
| | | TENS | 9 | −0.61 | 0.33 | −0.87-−0.35 | | |
| MAS | Wrist | Paraffin | 10 | −0.50 | 0.41 | −0.79-−0.21 | 0.646 | 0.533 |
| | | Ultrasound | 7 | −0.43 | 0.45 | −0.84-−0.01 | | |
| | | TENS | 9 | −0.28 | 0.44 | −0.62-0.06 | | |

ABILHAND: Hand dexterity questionnaire; ADL: Activities of Daily Living; CI: confidence interval; MAS: Modified Ashworth Scale; SD: standard deviation; SS_QOL: Stroke Specific Quality of Life Scale; TENS: transcutaneous electrical stimulation.

Table II. *One way analysis of variance of repeated measures before and after therapy (N=26).*

| Measure | Mean difference | SE | 95% CI | F | *p*-Value | Partial eta squared |
|---|---|---|---|---|---|---|
| FIM | 2.50 | 0.33 | 1.82-3.18 | 57.62 | <0.001 | 0.697 |
| SS-QOL | 14.12 | 1.61 | 10.80-17.43 | 77.06 | <0.001 | 0.755 |
| ABILHAND | 6.65 | 0.88 | 4.83-8.47 | 56.66 | <0.001 | 0.694 |
| ADL | 0.04 | 0.04 | 0.04-0.12 | 1.00 | 0.327 | 0.038 |
| Functional correlation | | | | | | |
| Shoulder | 2.58 | 1.22 | 0.06-5.10 | 4.44 | 0.045 | 0.151 |
| Elbow | 5.04 | 1.87 | 1.19-8.89 | 7.25 | 0.012 | 0.225 |
| Wrist | 6.60 | 0.97 | 4.61-8.58 | 46.67 | <0.001 | 0.651 |
| MAS | | | | | | |
| Elbow | 0.54 | 0.08 | 0.37-0.71 | 42.24 | <0.001 | 0.628 |
| Wrist | 0.40 | 0.08 | 0.23-0.58 | 23.51 | <0.001 | 0.485 |

ABILHAND: Hand dexterity questionnaire; ADL: Activities of Daily Living; CI: confidence interval; FIM: Functional Independence Measure; MAS: Modified Ashworth Scale; SE: standard error; SS_QOL: Stroke Specific Quality of Life Scale.

Previous research results are ambiguous on ultrasound therapy as a potential treatment for post-stroke spasticity. Ansari *et al*. (43) showed no significant improvement in spasticity, but their pilot study was performed on only four patients; therefore, the results cannot be extrapolated. The research results of Choi *et al*. (44) suggested that ultrasound therapy used as an adjunct treatment may reduce spasticity and improve gait and function in patients post stroke. Furthermore, recent clinical trial research showed that ultrasound therapy reduced post-stroke spasticity compared

Table III. *Step-wise regression on Functional Independence Measure (FIM) predictability.*

| Model | R Squared | SE | F | B Coefficient | 95% CI | *p*-Value |
|---|---|---|---|---|---|---|
| 1 | 0.621 | 7.35 | 39.278 | 0.79 | 5.72-11.34 | <0.001 |
| 2 | 0.755 | 6.03 | 12.654 | 0.63 | 4.34-9.36 | 0.002 |
| 3 | 0.818 | 5.32 | 7.532 | 0.63 | 4.62-9.06 | 0.012 |
| 4 | 0.872 | 4.57 | 8.818 | 0.66 | 5.24-9.09 | 0.007 |

Dependent Variable: FIM. Predictors: Model 1: (Constant), ADL; Model 2: (Constant), ADL, SS-QOL; Model 3: (Constant), ADL, SS-QOL, Shoulder Functional coefficient; Model 4: (Constant), ADL, SS-QOL, Shoulder Functional coefficient, Wrist Functional coefficient. ADL: Activities of Daily Living; SS_QOL: Stroke Specific Quality of Life Scale.

Table IV. *Step-wise regression on Stroke Specific Quality of Life Scale (SS-QOL) predictability.*

| Model | R Squared | SE | F | B Coefficient | 95% CI | *p*-Value |
|---|---|---|---|---|---|---|
| 1 | 0.411 | 16.97 | 16.738 | 0.64 | 0.61-1.86 | 0.000 |
| 2 | 0.553 | 15.09 | 7.339 | 0.60 | 0.60-1.71 | 0.013 |
| 3 | 0.634 | 11.75 | 4.817 | 0.73 | 0.83-1.97 | 0.039 |
| 4 | 0.753 | 13.98 | 10.155 | 0.66 | 0.78-1.76 | 0.004 |

Dependent Variable: SS-QOL. Predictors: Model: 1: (Constant), FIM; Model 2: (Constant), FIM, ABILHAND; Model 3: (Constant), FIM, ABILHAND, Shoulder Functional coefficient; Model 4: (Constant), FIM, ABILHAND, Shoulder Functional coefficient, Wrist Functional coefficient. ABILHAND: Hand dexterity questionnaire; FIM: Functional Independence Measure; MAS: Modified Ashworth Scale.

with shockwave therapy. The results are linked to ultrasound vibration properties which seem to influence proprioception and reduce muscle hyperexcitability, rather than with the thermal effect (45, 46).

Moreover, previous guidelines and research point out the complexity of post-stroke management, and the suggestions on possible therapies are vast, from neural prosthesis to physical modalities (ultrasound therapy, thermotherapy, functional electrical stimulation), shockwave therapy and robot-assisted therapy (47-50). Furthermore, experts in treating post-stroke spasticity have concluded that clinical and functional diagnosis is essential for correctly identifying the true cause of spasticity and should not be confused with structural changes in muscle, or soft or joint tissue (51).

FIM assessment was linked in previous research to upper extremity functionality. Our research results also suggest that FIM is influenced by upper limb functionality, especially concerning distal segment and hand ability, which also previously proved crucial in reducing disability and increasing functional independence (52-54).

Post-stroke quality of life was also linked to upper extremity ability and functioning, suggesting that it is increased by upper extremity motor rehabilitation and daily activities (55-57). Therefore, the findings of our research regression analysis are similar to that from previous studies.

For further research and therapy practice, information on management of time, personnel and material resources is significant since all three therapies studied bring the same benefit and can be used separately.

One of the limitations of this study is related to the small and uneven number of participants, determined in particular by the inclusion criteria for the research, which requires a precise approach and a clear delimitation of the functional status to measure the therapeutic effects objectively. The results on elbow and wrist mobility should be further investigated on a larger scale to identify future therapy guidelines focusing on the best outcomes for post-stroke patients. Another significant limitation is the need for follow-up at 3 or 6 months post-treatment, which is often difficult due to healthcare systems and policies. Therefore, future studies should consider researching a large sample of subjects but with adequately defined groups of patients without heterogeneity. Furthermore, since the post-stroke condition is degenerative, follow-up of therapeutic effects should be considered for both medical practice and research purposes.

## Conclusion

Functional range of motion values for the wrist and elbow influence independence and quality of life in patients after stroke. TENS, ultrasound therapy and paraffin procedures provide equal benefits in management of post-stroke spasticity, although none of them had superior efficiency.

## Conflicts of Interest

The Authors declare that they have no competing interests.

## Authors' Contributions

Conceptualization, N.R., R.S.M. and RN; methodology, N.R. and R.S.M.; validation, A.D.; formal analysis C.C; investigation, N.R., RN. and O.D.G.; data curation, N.R., R.N and O.D.G; writing – original draft preparation, N.R. and R.S.M.; writing – review and editing, N.R. and R.S.M., visualisation, C.C., and A.D.; supervision, R.S.M. All Authors have read and agreed to the published version of the article.

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