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Research

Comparison of the Effects of Extracorporeal Shock Wave Therapy and Dry Needing on Spasticity in Poststroke Patients: A Randomized Controlled Trial

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Abstract

Introduction: The effective treatment of spasticity following a stroke is a critical and pressing concern. Various therapeutic approaches, such as physiotherapy (7, 8) and medication (9, 10), have been employed. In recent years, external corporeal shockwave therapy (ESWT) and dry needling (DN) have gained popularity for managing spasticity and post-stroke pain. This study aims to conduct a comparative analysis of the effectiveness of ESWT and DN in addressing spasticity, pain, as well as upper limb function and sensation in individuals with hemiplegia.

Methods: In this study, individuals with hemiplegia were randomly assigned in a 1:1 ratio to either the External Corporeal Shockwave Therapy (ESWT) group (n = 10) or the Dry Needling (DN) group (n = 10). We assessed Upper Extremity Functions, Sensation, Spasticity, and Pain. All measurement indicators were evaluated before treatment and immediately after a single treatment session. To determine the presence of a group *time interaction effect on the treatment's impact for each outcome variable, we used mixed-model repeated-measures ANOVAs. The between-subjects variable was the group, and time served as the within-subjects variable.

Results: Both Dry Needling (DN) and External Corporeal Shockwave Therapy (ESWT) demonstrated significant reductions in spasticity within the biceps brachii muscle, along with notable improvements in upper extremity function tests. Moreover, both DN and ESWT led to significant enhancements in the forearm, arm, and finger; however, the same level of improvement was not observed for the hand. Tactile sensitivity, pain sensation, and light touch did not show significant improvements in either treatment group. Nonetheless, both groups experienced a significant reduction in pain levels. When we conducted a comparative analysis between these two treatment groups across all measures, no significant differences were observed ($p > 0.05$).

Conclusion: In individuals with hemiplegia, both External Corporeal Shockwave Therapy (ESWT) and Dry Needling (DN) have demonstrated the ability to effectively reduce pain and spasticity while enhancing upper extremity function. As a result, these treatments may be regarded as viable alternative methods for addressing the needs of individuals with hemiplegia.

***Keywords:** Hemiplegia, external corporeal shockwave therapy, dry needling, spasticity*

1. Introduction

Stroke is a prevalent neurological condition that can result in permanent disabilities, particularly in developed societies, with 13.7 million new cases occurring worldwide each year. Stroke and its associated disabilities can significantly impact daily activities and lead to various effects on daily life.

One common consequence of stroke is the development of pain and spasticity, which frequently occur following a stroke (1). Spasticity is a characteristic feature of the upper motor neuron syndrome (2).

Spasticity can lead to limitations in activities and may restrict participation, particularly affecting hand function and fine motor skills. This dependency on others for daily tasks can subsequently result in higher direct care costs after a stroke (3, 4). An alarming 48% to 77% of stroke survivors experience upper limb impairments, which significantly impact their overall function, quality of life, and overall well-being. This is primarily due to the presence of spasticity in the limbs. Notably, Wissel et al. observed that spasticity most commonly manifests in the elbow region, affecting approximately 79% of cases (5). Therefore, reducing spasticity in upper limb muscles, particularly in elbow flexors like the biceps brachii, holds paramount importance.

Effective treatment of spasticity after a stroke is of paramount importance. Some therapeutic approaches include physiotherapy (6, 7) and medication (8, 9). In recent years, External Corporeal Shockwave Therapy (ESWT) and Dry Needling (DN) have gained popularity for managing spasticity and pain following a stroke (1, 10-14). According to a systematic review, ESWT has demonstrated the ability to reduce upper limb spasticity, both as a standalone therapy and in combination with other treatments (15). Shockwaves, composed of sound waves, exert a physical effect on tissues due to the energy imparted by these sounds. These waves are characterized by their nonlinearity, high peak pressure, low tensile amplitude, short rise time, and brief duration (10 μs) (16). Studies conducted by Li et al. and Guo et al. have shown significant reductions in upper limb spasticity following shockwave therapy (17, 18).

Studies have suggested that Dry Needling (DN) can significantly reduce upper limb spasticity (13). The mechanisms underlying DN's effectiveness in decreasing spasticity, as indicated by research, involve alterations in fascial length and pennation angle. These changes can influence the properties of spastic muscles and result in reduced noise at dysfunctional endplates. Furthermore, DN has been shown to have a positive impact on regional brain activity (14).

Despite the numerous studies conducted on the effectiveness of External Corporeal Shockwave Therapy (ESWT) and Dry Needling (DN) in addressing spasticity, there is a notable absence of research comparing these two modalities concerning their impact on pain, upper extremity function, and spasticity, particularly in the biceps brachii muscle (BBM). The selection of a more effective treatment modality is essential for achieving a significant reduction in upper limb spasticity, thereby enhancing the quality of life and promoting independence in daily activities. Therefore, the primary objective of this study is to conduct a comparative analysis of the effectiveness of ESWT and DN in addressing upper limb spasticity, function, and pain.

2. Method

2.1. Study design

This study was structured as a single-blind, randomized, 1:1 parallel trial. Twenty individuals experiencing post-stroke spasticity in the biceps brachii muscle (BBM) were randomly assigned to one of two groups: the group receiving External Corporeal Shockwave Therapy (ESWT) or the group receiving Dry Needling (DN) treatment. Randomization was executed using Microsoft Excel, and the procedure was developed by a researcher uninvolved in other aspects of the protocol. The study received approval from the Local Ethics Committee (permission number: 560), and written informed consent was obtained from all participants.

2.2. Participant

This study aimed to compare the effectiveness of External Corporeal Shockwave Therapy (ESWT) and Dry Needling (DN) in addressing spasticity, function, and pain in the biceps brachii muscle (BBM) among individuals with hemiplegia. The study involved 20 individuals with hemiplegia between the ages of 25 to 65 years who willingly accepted treatment.

Inclusion criteria consisted of:

Age between 25 and 65 years.

Diagnosis of stroke by a specialist.

First-time occurrence of stroke.

Presence of BBM spasticity.

Ability to comprehend and follow verbal instructions.

Stable vital signs.

Unchanged drug doses that might affect muscle spasticity (18).

No current use of antispastic medication (19).

Modified Ashworth Scale (MAS) score between 1 and 4 for upper limb flexor tension (17).

Exclusion criteria included:

Prior receipt of Botox, alcohol, or phenol block treatments.

Previous orthopedic elbow joint surgery.

History of epilepsy.

Severe mental disorders.

Malignant tumors.

Limb venous thrombosis (18).

Sensory disturbances.

Presence of any other neurological disorders.

Ongoing concurrent treatments.

Contraindications to ESWT (19).

Fear of needles or contraindications to DN (20).

Following the selection of participants based on the inclusion criteria, the data collection process commenced. Each participant who voluntarily participated in this study completed a demographic information questionnaire. Subsequently, the examiner conducted a series of tests, proceeding systematically from sensory tests to functional assessments. Prior to each test, the examiner provided participants with detailed information about the procedures.

2.3. Assessment

The individuals included in the study were assessed using the following tools. All measurement indicators were evaluated before the treatment and immediately after a single session of treatment.

2.3.1.Demographic information

Demographic information and other background variables such as age, sex, height, weight, and Body Mass Index (BMI) were recorded.

2.3.2. Evaluatıon of Upper Extremity Functions

Jebsen Taylor Test of Hand Function (JTHF):

To conduct the Jebsen-Taylor Hand Function Test (JTHF), participants were seated in a chair in front of a table. The test comprised seven parts:

Writing Task: Participants were provided with a blank A4 sheet of paper and a pen, and they were instructed to write a sentence displayed to them.

Page Turning Task: An A4-sized booklet with pages was given to the individual, and they were asked to turn five pages as quickly as possible.

Collecting and Dropping Small Objects: This segment involved the use of two covers, two book clips, and two coins. These materials were placed on a plate, spaced apart, right in front of the individual's hand on the table. The individual was tasked with collecting these items in a specified order and placing them on an empty plate.

Stacking Task: In this part, participants were instructed to stack four backgammon pieces, positioned at intervals, in front of them.

Feeding Simulation: For this segment, five large bean grains were used to simulate a feeding task. Individuals were asked to take one bean grain at a time from a plate, using a spoon, and place them onto an empty plate.

Carrying Light Objects: Five empty cans were used for this task.

Carrying Heavy Objects: For this section, five full tin cans were employed. Participants were required to move the cans forward in a specific order.

Each test was thoroughly explained to the participants, and they practiced each task to ensure a complete understanding. To score each test, we utilized a stopwatch to record the time taken to complete each task. To calculate the total score, we summed the times recorded in each subtest (21).

Purdue Pegboard Test (PPT): To conduct the Purdue Pegboard Test (PPT), participants were seated in a chair in front of a table with the pegboard placed on it. Nails and washers were positioned in the holes above the pegboard. After providing an explanation of the test and allowing participants to practice, the test commenced. In the first three subtests, participants were required to insert the nails into the holes within a 30-second time frame. The recorded test result was the maximum number of nails inserted. These subtests were performed first with the non-affected hand, then with the other hand, and finally with both hands simultaneously, working from top to bottom. In the final subtest, individuals used both hands to assemble sets of nails and washers within a 60-second period. The composite score was calculated based on the total number of sets comprising nails and washers successfully completed (22, 23).

9 Hole Peg Test: To conduct the 9-Hole Peg Test (9-HPT), participants were seated in a chair in front of a table with the pegboard placed on the table. The sticks were positioned on the affected hand side of the individuals, while the holes were on the non-affected hand side. Participants were instructed to place the sticks into the holes and then remove them as swiftly as possible. After providing a detailed explanation of the test and allowing participants to practice, the test commenced. Test results were recorded by measuring the time with a stopwatch, starting from the moment individuals touched the first stick until the last stick was inserted into the board (21).

2.3.3 Evaluation of the Sensation of the Upper Extremity

Light Touch: For the Light Touch Test, a cotton swab was employed to gently touch various areas, including the arm, forearm, hand, and finger. During each test, the patient, positioned in a supine posture with the upper limb at their side and eyes closed, was asked to respond with "yes" or "no" to indicate whether they could sense the swab. If there was no loss of light touch sensation, a score of "0 points" was assigned; however, if there was any loss of sensation, a score of "1 point" was recorded. To calculate the total score, the grades assigned to each tested area were summed together (24).

Tactile Sense: The patient assumed a supine position with the upper limb at their side and eyes closed. The sensory examination began with the thickest filament (6.65), which was pressed against the skin at a 90º angle until it began to bend to half its length. The patient was then asked if they could sense the filament or not. If the patient could sense this filament, the process continued with a thinner filament (5.58), and this process was repeated until the patient could no longer sense a filament. The thickness of the first filament that the patient could not feel was recorded. This test was conducted on the arm, forearm, hand, and finger (25).

Pain Sensation: For the Pain Sensation Test, the patient was positioned in a supine posture with the upper limb at their side and eyes closed. A discriminator with both a sharp and blunt head was utilized. Sharp and blunt pressure were randomly alternated, and the patient was instructed to respond with "blunt" if they sensed bluntness and "sharp" if they felt sharpness. This test was conducted on the arm, forearm, hand, and finger. A score of "0 points" was assigned if there was no loss in the sense of pain, whereas a score of "1 point" was given if there was any loss of sensation. To calculate the total score, the grades assigned to each tested area were summed together (24).

2 Point Discrimination: For the Two-Point Discrimination (2PD) test, the patient assumed a supine position with the upper limb at their side and eyes closed. To start, the examiner employed the widest discriminator gap, which measured 100 millimeters (mm). The patient was then asked whether they sensed one point or two points. If the patient indicated feeling only one point, the test concluded. However, if the patient could sense two points, the distance was reduced, and the question was repeated. This process continued, with the distance progressively decreasing until reaching the narrowest gap, which measured 1mm. The narrowest gap at which the patient felt a single point was recorded as the measurement value. This test was conducted on the arm, forearm, hand, and finger (26).

2.3.4 Spasticity: We utilized the Modified Ashworth Scale to assess spasticity in the elbow flexors while participants were lying in a supine position. The Modified Ashworth Scale is graded as follows:

0: No resistance to passive movement or no increase in muscle tone.

1: Slight increase in resistance to passive movement or a slight increase in muscle tone, characterized by a release or minimal resistance at the end range during passive flexion or extension.

1+: Slight increase in resistance to passive movement or an increase in muscle tone, manifesting as a catch, with minimal resistance throughout the remaining (less than half) range of motion.

2: Marked increase in resistance to passive movement or muscle tone throughout most of the range of motion, although the limb can still be moved easily through the range.

3: Considerable increase in muscle tone or resistance to passive movement.

4: The limb is rigid in flexion or extension, and it cannot be moved through the range of motion.

Spasticity was assessed both before and immediately after one treatment session (17).

2.3.5. Pain: To assess pain, we employed the Visual Analog Scale (VAS). We administered the VAS both before and immediately after one treatment session (27).

Treatment Procedure

After obtaining informed consent from the subjects, they underwent an examination by the examiner to determine eligibility based on the inclusion criteria. Eligible patients were then randomly assigned to one of two groups: those receiving shock wave therapy on the biceps brachii muscle of the affected arm (ESWT-group) and those receiving dry needling therapy on the biceps brachii muscle of the affected arm (DN-group). In the ESWT-group, subjects received a single session of shock wave therapy, consisting of 6,000 impulses delivered at 0.06–0.07 mJ/mm^2 (1.2–1.4 bar) and a frequency of 18 Hz, targeting the biceps brachii muscle (17). Subjects in the DN-group underwent dry needling using disposable stainless steel sterilized needles sized 0.25×0.30. Dry needling was performed with patients in the supine position, the arm positioned away from the trunk, and the forearm in supination. The fast-in and fast-out cone-shaped technique was adopted, with each muscle being needled for one minute (28).

Statistical analysis

Mean and standard deviation were employed to describe quantitative variables, while frequency and percentage were used for qualitative variables. To assess the homogeneity of demographic variables and baseline measurements between the two groups, independent sample t-tests, Chi-square tests, and Fisher's exact tests were applied. A two-way mixed analysis of variance (ANOVA) was utilized to examine the primary and interaction effects of the group and time. All analyses were conducted using SPSS 24 software, with a significance level set at 5%.

3. Results

Baseline measurements were compared between the two groups, and the results are summarized in Table 1. According to the data presented in Table 1, there were no significant differences between the two groups in terms of baseline measurements. It is noteworthy that individuals in both the ESWT and DN groups exhibited similarity in their demographic characteristics, including age, height, weight, body mass index, gender, affected side, and spasticity status ($p>0.05$, as indicated in both Table 1 and Table 2).

Table 1: Average and standard deviation values of age, height, weight, body mass index of individuals in ESWT and DN groups.

Parameters	ESWT (n=10)		DN (n=10)		p
	Average	Standard Deviation	Average	Standard Deviation	
Height (m)	167.90	10.04	166.80	10.32	0.812
Age (yıl)	77.70	15.25	72.40	12.47	0.710
Weight (kg)	56.00	13.68	57.90	8.08	0.406

$p<0.05$ n: Number of individuals, ESWT: Extracorporeal shock wave therapy, DN: Dry needling

Table 2: Examination of gender, affected side and spasticity parameters of individuals in ESWT and DN groups.

Parameters		ESWT (n=10)		DN (n=10)		
		n	%	n	%	p
Gender	Male	8	57.14	6	42.86	0.329
	Female	2	33.33	4	66.67	
Affected Side	Right	4	44.44	5	55.56	0.651
	Left	6	54.55	5	45.45	
Modified Ashworth Scale	1	-	-	2	100	0.17
	2	2	100	-	-	
	3	2	66.67	1	33.33	
	1+	6	54.55	5	45.45	
	2+	-	-	2	100	

p<0.05 n: Number of individuals, ESWT: Extracorporeal shock wave therapy, DN: Dry needling

The analysis revealed that individuals in both the ESWT and DN groups exhibited similarity in sensory parameters, measurement values of upper extremity functions, and pain values (p>0.05, as presented in Table 3). Detailed information regarding sensory parameters and the measurement values of upper extremity functions, as well as the pain status of individuals, can be found in Table 3.

Table 3: Investigation of sensory parameters, functional parameters and pain values of individuals in ESWT and DN groups.

Parameters	ESWT (n=10)		DN (n=10)		P
	Average	Standard Deviation	Average	Standard Deviation	
JTEFT- Writing	45.70	21.79	28.80	13.41	0.051
JTEFT- Page-Turning	41.00	39.16	24.90	11.41	0.228
JTEFT- Lifting and Dropping Small Objects	31.70	26.63	27.40	12.74	0.651
JTEFT- Feeding	36.60	29.51	22.10	5.34	0.144
JTEFT- Lifting Lightweight	20.50	14.80	24.00	8.93	0.530
JTEFT- Lifting Heavy Objects	24.40	20.10	18.80	7.91	0.423
JTEFT- Stacking The Checkers	26.60	21.38	21.20	12.52	0.499
Light Touch Sense	2.70	1.89	1.80	1.81	0.291
Tactile Sense	9.90	7.81	15.80	5.03	0.060
Pain Sense	0.80	1.69	0.50	1.27	0.658
2PD- Hand	14.75	10.77	17.80	10.41	0.551
2PD- Finger	13.75	8.50	15.00	10.10	0.784
2PD- Forearm	28.75	9.72	28.10	6.59	0.868

Table continued...

2PD- Arm	33.88	11.33	30.90	9.67	0.556
Purdue Peg Board Test	20.56	5.25	17.90	5.97	0.320
9-HPT- Right	89.70	72.98	90.60	80.48	0.979
9-HPT- Left	98.70	76.79	79.90	62.75	0.556
JTHFT (Total)	202.00	105.62	167.00	50.25	0.357
VAS	1.56	1.59	1.80	.92	0.683

p<0.05 n: Number of individuals, ESWT: Extracorporeal shock wave therapy, DN: Dry needling, JTHFT: Jebsen Taylor Hand Function Test, 9-(HPT): 9-Hole Peg Test, VAS: Visual Analog Scale, 2PD: 2-Point Discrimination.

3.1. Statistical Analysis Results of Upper Extremity Functions

3.1.1. Jebson Taylor Hand Function Test: The statistical analysis of the study revealed several key findings. Firstly, it was demonstrated that the factor of time had a significant effect (p=0.004), indicating that there were significant differences between the results of the two measurements in terms of the Jebsen-Taylor Hand Function Test (JTHFT) score. Secondly, no significant difference was observed between the two groups concerning the JTHFT score (p=0.307). Lastly, the interaction between time and group was found to be non-significant (F=0.47, p=0.502, $\eta^2 = 0.025$). This suggests that there were no significant differences between the two groups regarding the initial measurement and post-intervention measurement, as detailed in Table 4.

Writing: Based on the results of the statistical analysis in this study, it was found that the effect of time had a significant impact (p=0.004). In simpler terms, there were significant differences between the results of the two measurements, indicating changes over time. Additionally, it was observed that the two groups did not exhibit significant differences (p=0.051) in the studied parameters. Furthermore, the interaction between time and group was not deemed significant (F=1.4, p=0.252, $\eta^2 = 0.07$). This suggests that there were no notable distinctions between the two groups concerning the baseline measurement and post-intervention measurement, as outlined in Table 4.

Page-Turning: The statistical analysis results of the study indicate that the effect of time was significant (p=0.002), signifying significant differences between the results of the two measurements. Furthermore, it was established that the two groups did not display significant differences from each other (p=0.252). The interaction between time and group was not deemed significant, and there were no noteworthy differences between the two groups concerning the initial measurement and post-intervention measurement (F=2.43, p=0.136, $\eta^2 = 0.12$), as detailed in Table 4.

Lifting and Dropping Small Objects: The results of the statistical analysis in the study revealed that the effect of time was significant (p=0.002), indicating that there were significant differences between the results of the two measurements. However, it was determined that the two groups were not significantly different from each other (p=0.635). Furthermore, the interaction between time and group was not found to be significant, and the two groups did not exhibit significant differences in terms of the initial measurement and post-intervention measurement (F=0.07, p=0.793, $\eta^2 = 0.004$), as summarized in Table 4.

Feeding: According to the results of the statistical analysis in the study, it was determined that the effect of time was not significant in the "Feeding" item, which is one of the sections of the Jebsen-Taylor Hand Function Test (JTEFT) for the patients (p=0.56). This indicates that there were no significant differences between the results of the two measurements. Additionally, it was found that there were no significant differences between the two groups (p=0.092). Furthermore, the interaction between time and group was not deemed significant (F=2.25, p=0.151, $\eta^2 = 0.111$). In other words, the two groups did not exhibit significant differences in terms of the initial measurement and post-intervention measurement, as presented in Table 4.

Lifting Lightweight: According to the results of the statistical analysis in the study, it was determined that the effect of time was not significant in the "Lifting Lightweight" component, which is one of the sections of the Jebsen-Taylor Hand Function Test (JTEFT) for the patients (p=0.66). This indicates that there were no significant differences between the results of the two measurements in the "Lifting Lightweight" section.

Furthermore, it was observed that the ESWT group and the DN group were not significantly different from each other (p=0.86). Interestingly, the interaction between time and group was found to be significant (F=9.47, p=0.006, η^2 = 0.345). However, the two groups did not exhibit significant differences in terms of baseline measurement and post-intervention measurement, as presented in Table 4.

Lifting Heavy Objects: Based on the results of the statistical analysis in the study, it was established that the effect of time was significant in the "Lifting Heavy Objects" section, which is one of the components of the Jebsen-Taylor Hand Function Test (JTEFT) for the patients (p<0.001). This implies that there were significant differences between the results of the two measurements in the "Lifting Heavy Objects" section.

Furthermore, it was determined that the effect of the group was not significant, and there were no significant differences between the two groups in terms of their performance in lifting heavy objects (p=0.489). However, it was notable that the interaction between time and group was not significant, and there was a significant difference between the two groups in terms of their initial measurement and post-intervention measurement (F=8.62, p=0.009, η^2 = 0.324), as shown in Table 4.

Stacking The Checkers: Based on the results of the statistical analysis in the study, it was observed that the effect of time was significant in the "Stacking Checkers" item, which is one of the sections of the Jebsen-Taylor Hand Function Test (JTEFT). This indicates that there were significant differences between the results of the two measurements in the "Stacking Checkers" section (p=0.04). Furthermore, it was determined that the effect of the group was not significant, and there were no significant differences between the ESWT group and the DN group (p=0.684) in terms of their performance in stacking checkers. Additionally, it was noted that the interaction between time and group was not significant in the scores obtained by the patients for stacking checkers. This suggests that the two groups did not exhibit significant differences in terms of their initial measurement and post-intervention measurement (F=1.53, p=0.23, η^2 = 0.078), as displayed in Table 4.

3.1.2. Purdue Pegboard Test: According to the results of the statistical analysis in the study, it was established that the effect of time was significant (p=0.001). This indicates that there were significant differences between the results of the two measurements in terms of the Purdue Pegboard test score. Furthermore, it was determined that the effect of the group was not significant (p=0.403), and there were no significant differences between the two groups in terms of their performance in the Purdue Pegboard test. Additionally, it was found that the interaction between time and group was not significant (F=1.57, p=0.226, η^2 = 0.085). This demonstrates that the two groups did not exhibit significant differences in terms of their initial measurement and post-intervention measurement, as presented in Table 4.

3.1.3. 9-Hole Peg Test: Right Extremity: According to the results of the statistical analysis in the study, it was established that the effect of time was not significant (p=0.085). This suggests that there were no significant differences between the results of the two measurements for the 9-HPT right extremity score. Furthermore, it was determined that the effect of the group was not significant (p=0.855), indicating that there were no significant differences between the two groups in terms of their performance in the 9-HPT right extremity score. Additionally, it was found that the interaction between time and group was not significant (F=0.684, p=0.419, η^2 = 0.037). This demonstrates that there was no significant difference between the ESWT group and the DN group in terms of their initial measurement and post-intervention measurement, as presented in Table 4.

Left Extremity: Based on the results of the statistical analysis in the study, it was revealed that the effect of time was not significant (p=0.092). This indicates that there were no significant differences between the results of the two measurements for the 9-HPT left extremity score. Furthermore, it was determined that the effect of the group was not significant (p=0.33), suggesting that there were no significant differences between the two groups in terms of their performance in the 9-HPT left extremity score. Additionally, it was found that the interaction between time and group was not significant (F=1.29, p=0.27, η^2 = 0.067). This demonstrates that the two groups did not exhibit significant differences in terms of their initial measurement and post-intervention measurement, as presented in Table 4.

3.2. Statistical Analysis Results of the Sense of the Upper Extremity

3.2.1. Light Touch Sense: According to the results of the statistical analysis in the study, it was determined that the effect of time was not significant for the light touch sense, and there were no significant differences between the results of the two measurements (p=0.09). Furthermore, it was found that there was no significant difference between the two groups in terms of light touch sense, and the effect of the group was not significant (p=0.084).

Additionally, it was observed that the interaction between time and group was not significant, and there were no significant differences between the ESWT group and the DN group in terms of their initial measurement and post-intervention measurement (F=1.97, p=0.17, η^2 = 0.1), as presented in Table 4.

3.2.2. Tactile Sense: According to the results of the statistical analysis in the study, it was observed that the effect of time was not significant in terms of the Touch Sense Score, and there were no significant differences between the results of the two measurements (p=0.053). Furthermore, it was determined that there was no significant difference between the two groups in terms of the tactile sense score, and the effect of the group was not significant (p=0.05). Additionally, it was established that there was no significant difference between the ESWT group and the DN group in terms of their initial measurement and post-intervention measurement. Moreover, the interaction between time and group was not significant (F=1, p=0.33, η^2 = 0.054), as presented in Table 4.

3.2.3. Pain Sense: Based on the statistical analysis results of the study, it was determined that there were no significant differences between the results of the two measurements in terms of the pain sensation score, and the effect of time was not significant (p=0.55). However, it was observed that the two groups were significantly different in terms of the pain sensation score, and the effect of the group was found to be significant (p=0.016). Furthermore, it was noted that the interaction between time and group was not significant, and there were no significant differences between the two groups in terms of their initial measurement and post-intervention measurement (F=1, p=0.35, η^2 = 0.053), as shown in Table 4.

3.2.4. 2-Point Discrimination

Regarding the hand, the statistical analysis results of the study indicated that the effect of time was not significant, and there were no significant differences between the results of the two measurements (p=0.39). Furthermore, it was observed that the effect of the group was not significant (p=0.47). Additionally, it was determined that the interaction between time and group was not significant (F=2.13, p=0.16, η^2 = 0.118). In other words, the two groups showed no significant differences in terms of their initial measurement and post-intervention measurement, as presented in Table 4.

Fingers: Based on the statistical analysis results of the study, it was found that the effect of time was significant (p=0.046), indicating that there were significant differences between the results of the two measurements in terms of the finger score. However, the effect of the groups was not significant (p=0.77), suggesting that there was no significant difference between the two groups. Furthermore, it was determined that the interaction between time and group was not significant (F=0.13, p=0.911, η^2 = 0.001). Consequently, the two groups did not exhibit significant differences in terms of their initial measurement and post-intervention measurement, as outlined in Table 4.

Forearm: According to the statistical analysis results of the study, it was observed that the effect of time was significant (p<0.001), indicating that there were significant differences between the results of the two measurements in terms of the 2PD score of the forearm. However, the effect of the group was not significant (p=0.835), suggesting that there was no significant difference between the two groups in terms of the 2PD score of the forearm. Furthermore, it was determined that the interaction between time and group was not significant (F=0.056, p=0.816, η^2 = 0.003), and it was observed that there was no significant difference between the ESWT group and the DN group in terms of initial measurement and post-intervention measurement, as outlined in Table 4.

Arm: According to the statistical analysis results of the study, it was found that the effect of time was significant (p=0.004), indicating that there were significant differences between the results of the two measurements in terms of the 2PD score of the arm. However, the effect of the group was not found to be significant (p=0.801), suggesting that there was no significant difference between the two groups in terms of the 2PD score of the arm. Furthermore, it was determined that the interaction between time and group was not significant (F=2.42, p=0.139, η^2 = 0.13), and there was no significant difference between the ESWT and DN groups in terms of initial measurement and post-intervention measurement, as shown in Table 4.

3.3. Statistical Analysis Results for Pain: According to the results of the statistical analysis in the study, it was found that the effect of time was significant (p=0.001), indicating that there were significant differences between the results of the two measurements for VAS (Visual Analog Scale) scores. However, the effect of the group was not significant (p=0.745), suggesting that there was no significant difference between the two groups in terms of VAS scores, indicating pain levels. Furthermore, it was determined that the interaction between time and group was not significant (F=0.26, p=0.62, η^2 = 0.015), indicating that there was no significant difference between the ESWT group and the DN group in terms of initial measurement and post-intervention measurement for pain levels, as shown in Table 4.

3.4. Statistical Analysis Results for Spasticity: According to the results of the statistical analysis in the study, it was found that the effect of time was significant (p=0.003), indicating that there were significant differences between the results of the two measurements for the MAS (Modified Ashworth Scale) scores, which assess spasticity. However, the effect of the group was not significant (p=0.449), suggesting that there was no significant difference between the two groups in terms of MAS scores, indicating spasticity levels. Furthermore, it was determined that the interaction between time and group was not significant (F=0, p=1, η^2 = 0), indicating that there was no significant difference between the ESWT group and the DN group in terms of initial measurement and post-intervention measurement for spasticity levels, as shown in Table 4.

Table 4: Comparison of first and last measurement scores using 2-way mixed ANOVA.

Parameters	Groups	First Measurement		Final Measurement		Within-Group Change Scores*	Main Effect (time) p	Main Effect (Group) p	Group*Time Interaction F/p value	η^2_p (effect size)
		Mean	SD	Mean	SD					
JTEFT- Writing	ESWT	45.70	21.79	38.70	15.61	-7(-9.28,-4.71)	0.004	0.051	1.4/0.252	0.072
	DN	28.80	13.41	25.50	13.62	-3.3(-5.58,-1.01)				
JTEFT- Page-Turning	ESWT	41.00	39.16	32.70	30.59	-8.3(-14.76, -1.83)	0.002	0.252	2.43/0.136	0.12
	DN	24.90	11.41	21.50	10.61	-3.4(-6.34,-0.45)				
JTEFT- Lifting and Dropping Small Objects	ESWT	31.70	26.63	27.40	20.45	-4.3(-8.87,0.275)	0.002	0.635	0.07/0.793	0.004
	DN	27.40	12.74	23.70	10.22	-3.7(-5.96,-1.43)				
JTEFT- Feeding	ESWT	36.60	29.51	37.90	29.40	1.3(-4.95,4.75)	0.56	0.092	2.25/0.151	0.111
	DN	22.10	5.34	19.10	5.04	-3(-4.68,-1.31)				
JTEFT- Lifting Lightweight	ESWT	20.50	14.80	24.40	20.10	3.9(-0.29,8.09)	0.66	0.86	9.47/0.006	0.345
	DN	24.00	8.93	18.80	7.91	-5.2(-10.41,-0.01)				
JTEFT- Lifting Heavy Objects	ESWT	24.40	20.10	21.50	18.98	-2.9(-4.04,-1.76)	<0.001	0.489	8.62/0.009	0.324
	DN	18.80	7.91	17.70	7.82	-1.1(-1.88,-0.31)				
JTEFT- Stacking The Checkers	ESWT	26.60	21.38	20.00	18.83	-6.6(-15.18,1.98)	0.04	0.684	1.53/0.23	0.078
	DN	21.20	12.52	19.40	12.69	-1.8(-3.61,0.01)				
Light Touch Sense	ESWT	2.70	1.88	2.85	1.88	0.15(-0.33, 0.34)	0.099	0.084	1.97/0.17	0.10
	DN	1.80	1.81	1.5	1.77	-0.30(-0.65, 0.046)				
Tactile Sense	ESWT	9.90	2.47	15.80	1.59	0(-1.65,1.65)	0.053	0.05	1/0.331	0.054
	DN	9.90	2.64	16.60	1.64	0.80(0.061, 1.54)				
Tactile Sense	ESWT	0.8	1.68	0.8	1.69	0(-0.33,0.28)	0.55	0.016	1/0.35	0.053
	DN	0.5	1.27	0.4	0.96	-0.1 (-0.39,0.36)				
2PD- Hand	ESWT	14.75	10.77	12.63	11.16	-2.12(-4.33,0.084)	0.394	0.476	2.13/0.16	0.118
	DN	17.80	10.41	17.00	10.77	-0.8(-1.53,-0.06)				
2PD- Finger	ESWT	13.75	8.50	12.75	8.58	-1(-2.48,0.48)	0.046	0.77	0.013/0.911	0.001
	DN	15.00	10.10	14.10	10.41	-9(-2.27,0.47)				
2PD- Forearm	ESWT	28.75	9.72	25.50	10.84	-3.25(-6.56,0.057)	<0.001	0.835	0.056/0.816	0.003
	DN	28.10	6.59	24.50	6.29	-3.60(-5.22,-1.97)				
2PD- Arm	ESWT	33.88	11.33	28.25	12.81	-5.62(-10.73,-0.51)	0.004	0.801	2.42/0.139	0.13
	DN	30.90	9.67	28.80	7.22	-2.1(-4.52,0.32)				
Purdue Peg Board Test	ESWT	20.56	5.25	21.67	4.92	-1.11(0.3,1.92)	0.001	0.403	1.57/0.226	0.085
	DN	17.90	5.97	20.10	5.47	2.2(0.49,3.91)				
9-HPT- Right	ESWT	89.70	72.98	73.20	68.70	-16.5(-44.31,11.30)	0.085	0.855	0.684/0.419	0.037
	DN	90.60	80.48	84.40	74.84	-6.2(-10.7,-1.69)				
9-HPT- Left	ESWT	98.70	76.79	107.90	67.55	9.2(-30.07,48.47)	0.920	0.33	1.29/0.27	0.067
	DN	79.90	62.75	68.90	56.38	-11(-19.35,-2.65)				
Jebsen Taylor Hand Function Test (Total)	ESWT	202.00	105.62	189.60	105.05	-12.4(-33.29,8.49)	0.004	0.307	0.47/0.502	0.025
	DN	167.00	50.25	148.00	47.42	-19(-25.12,-12.87)				
VAS	ESWT	1.56	1.59	.44	1.01	-1.11(-1.82,-0.39)	<0.001	0.745	0.26/0.62	0.015
	DN	1.80	.92	.50	.53	-1.3(-1.78,0.817)				
MAS	ESWT	1.60	.84	1.20	.42	-0.4(-0.77,-0.03)	0.003	0.449	0/1	0
	DN	1.40	.70	1.00	.47	-0.4(-0.77,-0.03)				

p<0.05 05 n: Number of individuals, ESWT: Extracorporeal shock wave therapy, DN: Dry needling, JTHFT: Jebsen Taylor Hand Function Test, 9-(HPT): 9-Hole Peg Test, VAS: Visual Analog Scale, 2PD: 2-Point Discrimination, 9-HPT: 9 Hole Peg Test, VAS: Visual Analog Scale, MAS: modified ashworth scale.

Discussion

This study is the first to compare the effects of DN and ESWT on spasticity, pain, and upper limb function and sensation. The findings reveal that both DN and ESWT can significantly reduce spasticity in the biceps brachii muscle, as well as improve upper extremity function tests. The study also determined that both DN and ESWT led to significant improvements in the forearm, arm, and finger, although they did not yield significant improvements in hand function. Additionally, no significant enhancements were observed in tactile sense, pain sensation, or light touch in either group. However, VAS scores decreased significantly in both groups. When comparing these two treatment groups across all measures, no significant differences were observed.

Selecting the most effective treatment modalities for spasticity is a challenging task due to the complex interaction of spasticity with various components of upper motor neuron syndrome, the diversity of the patient population, and the absence of definitive criteria for spasticity management (1). In recent years, both ESWT and DN treatments have gained popularity for managing post-stroke spasticity and associated pain (1, 10-14). However, research on the use of these treatments specifically for upper extremity spasticity remains limited (15).

In our study, we observed that ESWT treatment significantly reduced spasticity as indicated by the MAS score. While Li et al. (29) suggested in their study that multiple sessions of ESWT might be more effective, previous research has shown that a single session of ESWT can lead to an immediate reduction in spasticity, with a sustained but weaker effect over time (29). Park et al. also reported the effectiveness of ESWT in reducing spasticity in wrist flexor muscles (12), and Leng et al. documented a decrease in spasticity following ESWT treatment (30). Radinmehr et al. similarly found that a single session of radial ESWT reduced spasticity scores (31). The potential mechanism behind the reduction of spasticity through ESWT therapy involves the physical effects of both negative and positive phase-forming shockwaves. The positive phase results from direct mechanical compression of the tissue, while the negative phase arises from cavitation events that occur at high velocities and generate a secondary shockwave during the shockwave transmission (16). This physical effect can decrease muscle stiffness and impact connective tissue stiffness, particularly by influencing fibrotic tissue, as demonstrated in various studies (32).

Another possible mechanism contributing to the reduction of spasticity involves the secretion of Nitric Oxide (NO). NO plays a role in stimulating neuromuscular junction formation and affects the peripheral nervous system. It also has physiological effects on the central nervous system, such as inducing synaptic plasticity and influencing neurotransmission (11). Continuous or intermittent pressure on tendons or muscles, as applied in ESWT, can lead to a reduction in action potential at the neuromuscular junction and affect the function of Golgi tendon organs (GTOs). GTOs are encapsulated muscle receptors that sense changes in muscle tension, located at the muscle-tendon junction and in direct contact with tendon collagen. Muscle contraction, due to the collagen fibers containing these receptors, is a potent stimulus for the tendon organ. Golgi tendon organs transmit signals via Ib fibers to various areas in the spinal cord and the cerebellum through the spino-cerebellar pathway (33). The inhibitory interneurons in the spinal cord receive input from GTOs and result in muscle inhibition. When muscle force increases, Ib afferent inputs inhibit motor neurons, and GTOs reduce tension through autogenic inhibition. ESWT can enhance GTO activity, leading to muscle inhibition after treatment and ultimately decreasing spasticity (18).

Another mechanism through which ESWT may reduce spasticity involves alterations in neuromuscular transmission, particularly concerning acetylcholine (34). Acetylcholine is a neurotransmitter that plays a crucial role in various physiological processes, including blood vessel dilation, increased bodily secretions, and the contraction of smooth muscles. Within motor neurons, acetylcholine is stored in vesicles, and when a nerve impulse reaches the end of a motor neuron, acetylcholine is released from these vesicles into the neuromuscular junction. Acetylcholine's primary function is to open sodium channels, leading to muscle cell contraction (35). Therefore, by reducing the levels of acetylcholine, which is typically secreted during muscle contractions, ESWT may indirectly modulate sodium channels involved in impulse transmission from motor neurons, ultimately contributing to a reduction in spasticity. This potential mechanism aligns with our study's findings, which are consistent with previous research demonstrating a decrease in spasticity following ESWT treatment.

In our study, it was observed that dry needling (DN) significantly reduced both pain and spasticity. This aligns with previous research findings. For example, Mila et al. reported a reduction in spasticity among post-stroke patients after DN treatment (20). Additionally, Fakhari et al. found that DN could significantly reduce spasticity in the wrist flexor muscles of post-stroke patients (25).

One possible mechanism underlying the reduction in pain in the DN group is its neurophysiological effect. DN may impact pain intensity by reducing both peripheral and central effects. Peripherally, DN may help clear nociceptive substances, while centrally, it may induce changes in spinal cord activity and activate central inhibitory pathways, ultimately leading to a reduction in spasticity (36).

DN may also induce intrinsic changes by causing local tissue stretching, reducing the overlap between actin and myosin in the muscles, and subsequently decreasing muscle stiffness and spasticity (37). This hypothesis is supported by previous research (38).

Moreover, local twitch responses can occur during DN when applied to trigger points, leading to a reduction in spasticity and pain. This response is characterized by the rapid depolarization of muscle fibers. When the twitching ends, spontaneous electrical activity decreases, resulting in muscle hypertonicity and pain relief. DN at the endplate region can also reduce the storage of acetylcholine (ACH). Furthermore, DN may cause muscle fiber unloading, leading to changes in fascicle length, muscle thickness, and the angle of pennation of muscle fibers. DN may also increase blood flow while reducing ACH, opioid, or analgesic secretion, thereby boosting metabolism in the area and accelerating the repair process (38).

Dry needling (DN) can also affect pain inhibition mechanisms. In the skin and various tissues, there are two types of pain receptors: Aδ and C fibers. Aδ fibers are stimulated by strong mechanical stimuli, while C fibers respond to various stimuli, including chemical ones. DN acts as a stimulus for Aδ fibers. Both A and δ fibers are connected to the periaqueductal gray region in the brain. Descending neurons pass through this area and terminate in the enkephalin-containing gelatinosa areas in the posterior horn of the spinal cord. On the other hand, C fibers act as enkephalin inhibitors, signaling the transmission of pain signals to the central nervous system (39). This complex interplay between different types of nerve fibers and pain receptors highlights the multifaceted nature of pain modulation and how DN can impact these processes.

Dry needling (DN) also plays a role in inhibiting C fibers, thereby preventing pain. When Aδ pain receptors are activated by DN, they generate impulses in the midbrain. These impulses travel through the spinal cord and lead to the inhibition of sensory neurons at specific levels. This process is known as diminished pain inhibition. Within this system, the secretion of enkephalin by interneurons in the dorsal horn, activated by the stimulation of Aδ pain receptors, results in the inhibition of C fibers and a reduction in pain (40). DN's ability to modulate pain perception through these mechanisms demonstrates its potential as a therapeutic intervention for managing pain associated with various conditions.

The pain-spasm-pain theory provides another possible mechanism for the reduction of pain and spasticity following DN and ESWT treatments. According to this theory, muscle pain can intensify spasms because it increases the concentration of sodium chloride, ultimately leading to muscle spasms. These contractions can, in turn, compress nerves and restrict blood flow, creating a cycle of pain leading to spasms, which then exacerbate the pain.

During muscle activity, certain nociceptive substances are generated, contributing to pain. These substances can also be produced during episodes of spasticity. Reduced blood flow in spastic muscles leads to an accumulation of these pain-inducing substances, increasing the stimulation of pain receptors. The constant contraction of spastic muscles further contributes to the presence of these substances, resulting in increased pain.

In our study, both DN and ESWT treatments reduced both pain and spasticity, consistent with findings from previous research. Consequently, these treatments may have an impact on interrupting the pain-spasm-pain cycle, addressing both pain and spasticity in the process. This mechanism suggests that these therapies can offer comprehensive relief by breaking the cycle that perpetuates pain and spasms.

Post-stroke patients' independence is closely related to upper extremity function and dexterity function, which involve grasping, pinching, and manipulating objects requiring coordinated finger and hand movements. Stroke patients often struggle to perform these dexterity functions, such as grasping or manipulating small objects, in a coordinated manner. Therefore, finding an effective treatment to improve upper extremity function is crucial.

There are few studies examining the effect of ESWT and DN therapy on upper extremity function, which is crucial for stroke patients. Previous studies on ESWT and DN therapy in stroke patients have primarily used the Fulg Meyer assessment (FMD) to evaluate upper extremity function. In our study, we employed the 9-hole peg test, Jebsen-Taylor Hand Function Test (JTHFT), and Purdue Pegboard Test to assess upper extremity functions, including finer motor functions. Simpson et al. have indicated that FMD scores may lack sensitivity to detect differences and changes after treatment. Troncati et al., on the other hand, reported a significant improvement in upper extremity function assessed by FMD scores following one session of ESWT treatment in post-stroke patients (41). In a study by Li et al., significant improvements in upper extremity function, as evaluated by FMD scores, were observed after three sessions of ESWT treatment. They suggested that ESWT could effectively reduce hand and wrist spasticity while enhancing wrist control and hand function in patients with chronic stroke (29).

In our study, we observed significant improvements in upper extremity function tests after just one session of treatment. Notably, our study stands out in the literature due to its use of different tests to evaluate upper extremity function. Specifically, we found significant improvements in upper extremity function, as assessed by the Purdue Pegboard Test and Jebsen-Taylor Hand Function Test (JTHFT), following a single session of both DN and ESWT treatments. These findings underscore the effectiveness of these treatments in enhancing upper extremity function and highlight the value of our study in contributing to the existing body of research.

The observed improvement in upper extremity function in our study is likely attributable to the reduction in spasticity and pain. Post-stroke patients commonly face challenges such as spasticity, pain, and muscle weakness on the hemiplegic side, all of which hinder coordinated and efficient movement. By reducing spasticity, we can increase the range of motion in affected limbs, which in turn contributes to the enhancement of upper extremity function. This mechanism highlights the interconnectedness of these factors and underscores the importance of addressing spasticity and pain for the overall improvement of upper extremity function in post-stroke patients (25).

The results of our study indicate that there was no significant difference in terms of improving function between the DN and ESWT groups. Since both groups demonstrated a similar reduction in spasticity and pain, it is possible that the decrease in pain and spasticity contributed to the increase in upper extremity function.

Another possible reason for the improvement in upper extremity function is the theory of proximal stability or the core stability concept. Proximal muscle stability is crucial for distal mobility, coordination, and strength. This proximal stability is essential for better hand functioning and activities of daily living. The lack of proximal stabilization may limit the patients' ability to exert maximum effort (42). One of the important muscles for shoulder stability is the biceps brachii. This muscle can stabilize the proximal part of the upper extremity. The reduction of spasticity leads to better performance of the biceps brachii and better stabilization of the proximal part of the upper extremity, ultimately resulting in an improvement in functional tests.

Somatosensory impairment can negatively impact motor control, upper extremity function, and the ability to perform selective and goal-directed movements. Accurate sensory input and sensory function are essential for optimal motor performance. Impairments in sensory input and processing can disrupt the interaction between an individual and their environment. When sensory disorders are present, the quality of upper extremity movements can also deteriorate.

Conclusion

Our study demonstrated that both DN and ESWT treatments led to significant improvements in 2-point discrimination in the finger, forearm, and arm. However, there were no significant improvements in tactile sensation, pain sensation, and light touch in either treatment group. The only significant difference between the two groups in the sensory test was related to pain sensation. The substantial improvement in 2-point discrimination in the fingers may be attributed to the test's higher sensitivity in this area, while the improvement in the arm may be linked to the treatment's focus on the arm and elbow flexors.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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