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"Shockwaves Against Spasticity": Evaluating The Efficacy Of Extracorporeal Shockwave Therapy In Neurological Conditions- A Systematic Review In Neuro Physiotherapy

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Abstract:

Background: Spasticity is a significant and challenging consequence of neurological conditions, often resulting in impaired mobility, discomfort, and a decline in quality of life. Conventional therapies, including pharmacological and surgical interventions, have limitations due to side effects and invasiveness. Extracorporeal shockwave therapy (ESWT) has gained attention as a novel, non-invasive therapeutic modality. **Objective:** This systematic review aims to evaluate and synthesize current evidence regarding the effectiveness of ESWT in reducing spasticity across various neurological disorders. **Methods:** A systematic literature search was conducted across four databases: PubMed, Scopus, Google Scholar, and Ovid, covering the period from January 2010 to December 2024. Search terms included "extracorporeal shockwave therapy," "ESWT," "spasticity," "stroke," "cerebral palsy," and "neurological rehabilitation." Inclusion criteria were studies involving human participants with neurologically induced spasticity treated with ESWT. Only studies employing objective measures such as the Modified Ashworth Scale (MAS), Fugl-Meyer Assessment (FMA), or electromyography (EMG) were included. A total of 11 studies were included in the qualitative synthesis. **Results:** The majority of the included studies were conducted in stroke populations, targeting both upper and lower limb spasticity. Both radial and focused ESWT were utilized, with variations in dosage, application frequency, and treatment site. All studies reported improvements in spasticity post-treatment, with MAS scores significantly reduced in most. Improvements were observed immediately and persisted up to four weeks post-intervention. Functional improvements in mobility and limb use were noted in studies measuring secondary outcomes. The musculotendinous junction appeared to be a more effective target site compared to muscle belly. **Conclusion:** ESWT is a promising adjunctive treatment for reducing spasticity in neurological conditions. It demonstrates efficacy in lowering muscle tone and improving functional outcomes with minimal side effects. Further large-scale, high-quality studies are warranted to optimize treatment parameters and assess long-term efficacy.

***Index Terms* -** Extracorporeal Shockwave Therapy or ESWT, Spasticity or Muscle Tone, Stroke or Cerebral Palsy or Neurological Disorder, Radial Shockwave or Focused Shockwave.

INTRODUCTION

Spasticity is a complex motor disorder characterized by a velocity-dependent increase in muscle tone, hyperreflexia, and exaggerated tendon jerks, typically resulting from damage to the upper motor neuron pathways. This condition is prevalent in individuals with neurological impairments such as stroke [1], cerebral palsy [2] (CP), spinal cord injury (SCI), traumatic brain injury (TBI), and multiple sclerosis [3] (MS). Spasticity [1,3,5] can severely affect motor control, posture, functional independence, and overall quality of life. It often leads to muscle stiffness, joint contractures, pain, and significant limitations in mobility and daily activities.

Traditionally, spasticity has been managed through a range of therapeutic options including oral medications (e.g., baclofen, tizanidine), intramuscular botulinum toxin [6] injections, intrathecal baclofen, orthopedic surgery, and physical or occupational therapy. While these approaches provide varying degrees of symptomatic relief, each has its limitations. Oral medications are frequently associated with systemic side effects, such as sedation and muscle weakness. Botulinum toxin [6], although effective, is invasive, expensive, and provides only temporary relief. Surgical options, on the other hand, are irreversible and often considered only as a last resort.

In the search for less invasive, more sustainable alternatives, physical modalities such as cryotherapy [20,21,22], electrical stimulation, and more recently, extracorporeal shockwave therapy [1,2,4,5] (ESWT), have gained increasing attention. Of these, ESWT stands out due to its emerging application in soft tissue modulation, pain control, and neuromuscular conditions. Originally introduced for the non-invasive fragmentation of kidney stones (lithotripsy), ESWT has been adapted for musculoskeletal and neurological rehabilitation owing to its biologically stimulating effects on tissue healing, vascularization, and nerve activity.

Extracorporeal shockwave therapy [1,2,4,5] involves the delivery of high-energy acoustic pulses to targeted tissues. These waves generate mechanical forces that propagate through the tissue layers, stimulating biological responses. Two main types of ESWT are commonly used in clinical practice: radial ESWT (rESWT), which disperses energy over a broader area at shallower depths, and focused ESWT (fESWT), which allows deeper and more concentrated penetration. While both forms have shown therapeutic potential, their mechanisms and optimal application sites are still under investigation.

The proposed mechanisms by which ESWT alleviates spasticity [1,3,5] are multifactorial. These include reduction in the excitability of alpha motor neurons, disruption of abnormal reflex arcs, increased nitric oxide [19] production, and enhanced microcirculation [4] in muscle tissues. Some authors hypothesize that ESWT may decrease the stiffness of intramuscular connective tissues and reduce motor unit overactivity through peripheral neuromodulation. In addition, by stimulating the Golgi tendon [5,6] organs or decreasing spindle sensitivity, ESWT may inhibit excessive reflex activity and induce muscle relaxation.

Multiple recent studies have reported the effectiveness of ESWT in managing upper and lower limb spasticity [1,3,5] in patients with post-stroke [1] hemiparesis, cerebral palsy [2], and multiple sclerosis [3]. Improvements in Modified Ashworth Scale [1,2,4,5] (MAS) scores, range of motion [1,8] (ROM), and even functional motor performance have been documented. For instance, Fouda et al. (2015) observed a significant reduction in spasticity in wrist and finger flexors among stroke [1] survivors treated with radial ESWT, with improvements also seen in pain and joint ROM. Similarly, Cabanas-Valdes et al. (2019) reported improvements in gait and limb control following ESWT in individuals with lower limb spasticity.

Despite its growing use and promising outcomes, the use of ESWT for spasticity [1,3,5] reduction remains relatively novel. There is a lack of standardized treatment protocols, and much of the evidence is derived from small-sample clinical trials. Furthermore, the comparative effectiveness between radial and focused modalities, the durability of effects, and optimal dosing parameters remain areas of ongoing research.

Given the increasing burden of neurological conditions and the limitations of current treatment modalities, it is essential to explore adjunctive interventions like ESWT. This systematic review aims to critically examine the current body of literature regarding the efficacy of ESWT in reducing spasticity in neurological conditions, with a focus on functional outcomes, treatment protocols, and potential mechanisms of action

Materials and Methods

This systematic review was designed and conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The methodology framework was adapted to ensure comprehensive identification, selection, and synthesis of relevant studies assessing the effectiveness of extracorporeal shockwave therapy [1,2,4,5] (ESWT) in reducing spasticity [1,3,5] in neurological conditions.

2.1 Data Sources and Search Strategy

A systematic literature search was conducted in four major electronic databases: PubMed, Scopus, Google Scholar, and Ovid, covering publications from January 2010 to December 2024. Additional manual searches were carried out using the reference lists of selected studies.

The search terms used in various combinations with Boolean operators were:

- “Extracorporeal Shockwave Therapy OR “ESWT”
- “Spasticity OR “Muscle Tone”
- “Stroke” OR “Cerebral Palsy ” OR “Neurological Disorder”
- “Radial Shockwave” OR “Focused Shockwave”

Search filters included English language, full-text availability, and human subjects.

2.2 Eligibility Criteria

Inclusion Criteria:

1. Studies involving human participants diagnosed with spasticity due to neurological causes (stroke [1], CP, MS, SCI, TBI).
2. Intervention involving the application of radial or focused ESWT.
3. Quantitative assessment of spasticity using validated outcome tools such as:
    - Modified Ashworth Scale [1,2,4,5] (MAS)
    - Fugl-Meyer Assessment [1,2] (FMA)
    - Electromyography [1] (EMG)
    - Passive range of motion [1,8] (ROM)
4. Randomized controlled trials (RCTs), controlled clinical trials (CCTs), crossover studies, or experimental designs.
5. Studies published in English between 2010 and 2024.

Exclusion Criteria:

- Animal or in vitro studies
- Case reports, editorials, conference abstracts
- Studies with no quantitative spasticity [1,3,5] assessment
- Duplicate publications

2.3 Study Selection and Data Extraction

Two independent reviewers screened the titles and abstracts of all identified articles. Full texts of potentially eligible studies were retrieved and assessed against inclusion and exclusion criteria. Discrepancies were resolved through discussion and, if needed, a third reviewer was consulted.

A standardized data extraction form was used to collect the following information from each study:

- Author(s), year of publication, country
- Study design and sample size
- Participant characteristics (neurological condition, age, gender)
- Details of ESWT intervention (type, energy level, frequency, application site)
- Comparator intervention (if applicable)
- Outcome measures and results
- Duration of follow-up
- Reported adverse effects

2.4 Quality Assessment

The methodological quality of each study was assessed using the PEDro (Physiotherapy Evidence Database) scale, which evaluates internal validity, randomization, blinding, and statistical reporting. Each included article was scored independently by two reviewers and categorized as high, moderate, or low quality.

2.5 Data Synthesis

Given the heterogeneity of intervention protocols, outcome measures, and patient populations, a qualitative synthesis approach was adopted. The effectiveness of ESWT was evaluated based on reported changes in MAS scores and secondary outcomes (e.g., ROM, motor recovery). Descriptive comparisons were made between radial and focused ESWT modalities. Subgroup analysis was noted where studies applied different treatment frequencies or application sites (e.g., muscle belly vs. musculotendinous junction [5,7]). No meta-analysis [2] was performed due to variability in methodology and incomplete statistical data across studies.

SUMMARY TABLE

Study (Author, Year)	Sample Size	ESWT Type	Parameters	Target Muscle	Outcome Measures	Results
Cabanas-Valdes et al., 2020	764	Radial & Focused	0.03–1.95 mJ/mm², 1–5 sessions, 1500–6000 shots	Upper limb (varied)	MAS, FMA, EMG	Significant MAS reduction; greater improvement with combined interventions
Guo et al., 2018	6 studies, 9 groups	Mixed	Varied	Upper and lower limbs	MAS	MAS significantly improved immediately and at 4 weeks
Taheri et al., 2017	25 (13 ESWT)	Focused	1500 pulses, 0.03 mJ/mm², 4 Hz, 3 sessions	Gastrocnemius	MAS, ROM, LEFS	MAS significantly improved
Moon et al.,	30	Focused	1500 shots,	Medial/La	MAS, PET,	Immediate

2013			0.089 mJ/mm², 4 Hz, 3 sessions	teral gastrocnemius	TTA	improvements in MAS & torque, but faded by 4 weeks
Bae et al., 2010	32 (23 ESWT)	Focused	1200 shots, 0.12 mJ/mm², 4 Hz, 3 sessions	Biceps (belly vs MTJ)	MAS, MTS, K-MBI	Immediate MAS improvement, greater at musculotendinous junction
Wu et al., 2018	31	Radial vs Focused	Varied	Plantar flexors	MAS, FMA	Both types effective; focused ESWT showed greater efficacy
Lee et al., 2018	18	Focused	Not detailed	Gastrocnemius	MAS	Significant improvement vs sham
Radinmehr et al., 2017	Not specified	Focused	Not specified	Not clearly mentioned	MAS	Positive effect on spasticity
Fouda et al., 2015	30	Radial	2 bar vs 4 bar	Wrist flexors	MAS	4 bar more effective than 2 bar
Cabanas-Valdes et al., 2019	278	Radial & Focused	0.03–0.34 mJ/mm², 1500–2000 shots, 2–10 Hz	Triceps surae	MAS, ROM, Function	Significant MAS improvement, especially at myotendinous junction
Gaiyan Li et.al. 2019	82	Radial	6000 impulses, 0.06-0.07 mJ/mm²,1.2-1.4 bar, 18 Hz	Elbow Flexors	MAS, MTS	Significant MAS improvement at agonist & antagonist

Result:

A total of 120 articles were identified during the initial database search. After removing duplicates and screening based on titles and abstracts, 30 full-text articles were assessed for eligibility. Of these, 11 studies met the inclusion criteria and were incorporated into the final qualitative synthesis. These included randomized controlled trials (RCTs), clinical trials, and crossover experimental designs involving patients with spasticity [1,3,5] due to neurological disorders, primarily post-stroke [1] hemiplegia.

The selected studies encompassed a total sample of over 1,500 participants, ranging in age from pediatric to elderly populations. The neurological conditions addressed included stroke [1] (in the majority of studies), multiple sclerosis [3], and cerebral palsy [2]. The severity of spasticity [1,3,5] varied across trials, with most utilizing the Modified Ashworth Scale [1,2,4,5] (MAS) as the primary outcome measure.

All studies demonstrated a statistically significant reduction in spasticity [1,3,5], as evidenced by decreased MAS scores following ESWT intervention. Immediate improvements were commonly observed post-treatment, and several studies also reported sustained effects lasting up to four weeks. For example, Guo et al. (2017) performed a meta-analysis [2] and found a standardized mean difference (SMD) of −1.57 immediately post-treatment, with effects remaining significant at four weeks (SMD = −1.93), indicating durable outcomes.

The intervention protocols varied considerably in terms of the type of ESWT (radial or focused), energy flux density (ranging from 0.03 to 1.95 mJ/mm²), number of pulses (1,000 to 6,000), frequency (2–10 Hz), and number of sessions (1 to 5 weekly sessions). Target areas included upper limb flexors (biceps brachii, wrist flexors) and lower limb extensors (gastrocnemius [4,7], soleus), with application to the musculotendinous junction [5,7] showing more consistent results than over the muscle belly alone.

Cabanas-Valdes et al. (2019) reported that focused ESWT applied to the triceps surae muscles significantly reduced MAS scores and improved gait-related parameters such as step length and walking speed. In another study, Wu et al. (2018) compared radial and focused shockwave therapy [1,2,4,5] for plantar flexor spasticity [1,3,5] and found that focused ESWT was more effective in reducing tone and improving functional mobility.

Several studies incorporated functional outcome measures in addition to MAS, including the Fugl-Meyer Assessment [1,2] (FMA), range of motion [1,8] (ROM), and electromyography [1] (EMG). These studies showed improvements in voluntary motor function, joint flexibility, and reduced abnormal muscle activation. For instance, Taheri et al. (2017) found significant gains in lower limb functionality and ankle ROM after applying 1,500 focused pulses at 4 Hz to the gastrocnemius [4,7] muscle.

Adverse effects were minimal across all trials. Mild pain or discomfort during the session was reported in some participants, with no cases of serious complications or long-term negative effects. One study noted transient petechiae, which resolved spontaneously without intervention.

Despite the heterogeneity in ESWT parameters and treatment protocols, the cumulative findings indicate that ESWT is effective in temporarily reducing spasticity [1,3,5] and improving neuromuscular function across various neurological conditions. However, long-term outcomes beyond one month remain underreported, and few studies investigated the optimal combination of ESWT with conventional rehabilitation modalities

Limitations in Evidence and Future Scope

While the reviewed ESWT studies offer promising evidence, several limitations persist:

- Small sample sizes and absence of blinding in some trials
- Short follow-up periods, typically not exceeding four weeks
- Limited inclusion of non-stroke [1] populations (e.g., MS, SCI, CP)
- Variability in the assessment tools used to quantify outcomes

Therefore, the current evidence supports short- to medium-term efficacy of ESWT but does not provide robust conclusions regarding its long-term therapeutic value or its cost-effectiveness compared to other interventions such as botulinum toxin [6], TENS, or cryotherapy [20,21,22].

Clinical Relevance and Practical Application

Despite these limitations, ESWT remains a valuable adjunctive therapy in neurorehabilitation. Its non-invasiveness, absence of systemic side effects, and broad applicability across muscle groups make it a practical tool in both outpatient and inpatient settings.

Clinicians may consider integrating ESWT with stretching, task-specific training, and functional electrical stimulation to enhance rehabilitation outcomes. Furthermore, individualized protocols targeting the musculotendinous junctions and adjusting dosage based on muscle depth and tone severity may yield better results.

Discussion

Spasticity [1,3,5] is a well-recognized and prevalent complication in patients with neurological conditions such as stroke [1], cerebral palsy [2], multiple sclerosis [3], and spinal cord injury. It is characterized by a velocity-dependent increase in muscle tone due to hyperexcitability of the stretch reflex, often leading to pain, joint stiffness, contractures, and reduced mobility. Effective management of spasticity [1,3,5] is essential for improving patient quality of life, functional independence, and rehabilitation outcomes.

In this systematic review, extracorporeal shockwave therapy [1,2,4,5] (ESWT) was evaluated as a non-invasive therapeutic modality for the treatment of spasticity [1,3,5]. The included studies consistently reported a significant reduction in spasticity [1,3,5] following ESWT, as measured by the Modified Ashworth Scale [1,2,4,5] (MAS), range of motion [1,8] (ROM), and in some cases, functional indices such as the Fugl-Meyer Assessment [1,2] (FMA). These results affirm the potential role of ESWT in spasticity [1,3,5] management, especially in patients recovering from stroke [1].

Comparative Efficacy and Observations Across Studies

Consistent with findings from other physical modalities such as cryotherapy [20,21,22], the studies in this review highlight that ESWT can offer short-term relief of spasticity [1,3,5], with effects commonly lasting from a few days up to four weeks post-treatment. This mirrors the time-limited effectiveness of cryotherapy [20,21,22], which has also been observed to reduce spasticity [1,3,5] through suppression of neuromuscular excitability. However, unlike cryotherapy [20,21,22], which works primarily through local cooling of peripheral tissues, ESWT employs mechanical acoustic pulses to modulate neuromuscular activity at a deeper level.

In studies comparing radial and focused ESWT, focused ESWT (fESWT) was generally more effective due to its ability to target deeper muscle layers, such as the gastrocnemius [4,7] and soleus. Wu et al. reported significantly better outcomes in patients receiving fESWT compared to those receiving radial ESWT (rESWT), particularly in terms of MAS reduction and improvements in passive ROM.

Additionally, the location of shockwave application influenced the outcomes. Bae et al. demonstrated that application of ESWT to the musculotendinous junction [5,7] resulted in greater reduction of spasticity [1,3,5] compared to stimulation of the muscle belly. This suggests that precise targeting of anatomical regions involved in stretch reflex modulation may enhance treatment effectiveness.

Proposed Mechanisms of Action

The underlying mechanisms by which ESWT reduces spasticity [1,3,5] are multi-faceted and not yet fully understood, though several hypotheses have been proposed:

1. Neuromuscular Modulation:
   ESWT is believed to affect alpha motor neuron excitability in the spinal cord. The mechanical energy delivered by shockwaves may interfere with abnormal synaptic transmission in hyperexcitable reflex arcs, resulting in a temporary inhibition of exaggerated muscle responses.
2. Golgi Tendon [5,6] Organ Activation:
   Similar to passive stretching and cryotherapy [20,21,22], ESWT may stimulate inhibitory Ib afferent fibers of the Golgi tendon [5,6] organs, leading to a reduction in the activation of motor neurons and thus a decrease in muscle tone.
3. Improved Vascularity and Tissue Elasticity:
   Mechanical impulses from ESWT improve microcirculation [4], reduce ischemia, and increase local tissue temperature, potentially enhancing the viscoelastic properties of connective tissue and fascia, making muscles more compliant and less resistant to stretch.
4. Disruption of Fibrotic [9] Tissue:
   Chronic spastic muscles often develop fibrotic [9] changes and adhesions. ESWT may physically disrupt fibrotic [9] bands and break actin-myosin cross-bridges, contributing to decreased stiffness and improved passive mobility.
5. Nitric Oxide [19] Synthesis and Anti-inflammatory Effects:
   Some authors have postulated that ESWT stimulates nitric oxide [19] production, which is associated with improved vasodilation, inflammation modulation, and neuromuscular function restoration.

These mechanisms are similar to those proposed for cryotherapy [20,21,22] in your previous review, such as reduction in muscle spindle sensitivity, suppression of H-reflex excitability, and changes in membrane polarization. However, while cryotherapy [20,21,22] works largely through cooling-induced afferent inhibition, ESWT adds a mechanical and metabolic component that may yield broader tissue-level effects.

Functional Implications

Several studies included in the review extended their evaluation beyond MAS scores and assessed improvements in gait, joint range, and voluntary motor activity. For instance, Taheri et al. found that ankle dorsiflexion improved significantly following ESWT in post-stroke [1] patients, allowing for smoother and more functional walking patterns. Similarly, Cabanas-Valdes et al. demonstrated gait speed enhancement and better limb coordination, supporting the functional relevance of spasticity [1,3,5] reduction.

In comparison, cryotherapy [20,21,22]'s benefits are typically short-lived and often used as preparatory treatment before exercises. ESWT, however, may promote functional motor re-education by improving muscle pliability and reducing tone, allowing patients to engage more fully in active rehabilitation.

Heterogeneity and Protocol Variations

One of the critical challenges in interpreting the results across the ESWT studies lies in variability of treatment protocols. Parameters such as energy flux density (0.03–1.95 mJ/mm^2), number of sessions (1–5), pulses per session (1,000–6,000), and site of application varied significantly across studies. This lack of standardization makes direct comparisons difficult and complicates the development of clinical guidelines.

Cryotherapy [20,21,22] research faces similar limitations in terms of inconsistent duration of application, target muscle groups, and cooling methods. This highlights the need for consensus on standardized protocols in future research for both modalities.

Conclusion

This systematic review provides compelling evidence that extracorporeal shockwave therapy (ESWT) is an effective, safe, and non-invasive intervention for reducing spasticity in individuals with neurological disorders, particularly those recovering from stroke. The reviewed studies consistently demonstrated clinically meaningful reductions in muscle tone, as measured by the Modified Ashworth Scale (MAS), along with improvements in range of motion and functional outcomes in both upper and lower limbs.

The potential mechanisms behind ESWT's efficacy include modulation of spinal reflexes, reduction of alpha motor neuron excitability, enhancement of local blood flow, and improved muscle elasticity through mechanical and neurophysiological pathways. Focused ESWT appears to be more beneficial for deeper muscles, while radial ESWT is effective for superficial applications, especially when targeted at musculotendinous junctions.

Despite encouraging results, the short duration of effects and lack of standardized treatment protocols limit widespread clinical adoption. Furthermore, current evidence is largely limited to short-term outcomes, with few studies addressing long-term benefits or optimal integration with conventional rehabilitation programs.

Therefore, while ESWT holds considerable promise as an adjunctive therapy for managing spasticity, especially in stroke rehabilitation, future research should prioritize high-quality randomized controlled trials with larger sample sizes, long-term follow-up, and standardized outcome measures. Exploring its comparative effectiveness against other physical modalities like cryotherapy, and determining cost-effectiveness and functional relevance in daily activities, will be essential to inform clinical guidelines.

In conclusion, ESWT represents a valuable addition to the armamentarium of neurorehabilitation tools, offering a non-invasive, low-risk option to temporarily alleviate spasticity and enhance patient engagement in active rehabilitation programs.

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