The effects of extracorporeal shock wave therapy in spasticity due to stroke: a systematic review

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INTRODUCTION
Spasticity, also known as hyperresistance, occurs in 18-38% of patients after a Cerebrovascular Accident (CVA) and negatively impacts their quality of life. Direct costs are higher with hyperresistance. Extracorporeal Shock Wave Therapy (ESWT) is a treatment for hyperresistance involving the administration of a mechanical pressure wave to muscle tissue. The aim of this statement is to provide an overview of the current evidence regarding the physiotherapeutic use of ESWT in patients suffering from the consequences of hyperresistance after a CVA. Due to the recent strengthening evidence on this topic, it remains unaddressed in various Dutch guidelines on spasticity. This underscores the need for a position paper to explore the role of ESWT. This position paper aims to: 1) assess its effects within the domains of the International Classification of Functioning, Disability, and Health, 2) evaluate the evidence, 3) investigate what is known about the duration of effects and side effects, 4) determine optimal parameters, and 5) make recommendations for further research.

METHODS
A literature search was conducted up to February 2022 in the following databases: PubMed, Cochrane, PEDro, and Cinahl using a Domain-Determinant-and-Outcome search string. Selection based on inclusion and exclusion criteria and quality assessment were performed by two authors.

RESULTS
Out of 139 articles found, 14 Randomized Controlled Trials and 4 Clinical Controlled Trials were included. The average PEDro score was 6.4. A total of 465 individuals received ESWT. Significant improvements were found in the Modified Ashworth Scale, Modified Tardieu Scale, range of motion of the ankle and wrist, hand grip strength, and walking distance on the six-minute walk test. Additionally, significant reductions were found in pain scores on the visual analogue scale, muscle electrical activity, and dependency. Effects persist for several weeks with few reported side effects.

DISCUSSION
Limitations of this study include the possibility of missing articles in the search and lack of quality exclusion. Long-term effects, optimal parameters, and number of sessions remain unclear.

CONCLUSION
ESWT is effective in reducing hyperresistance after a Cerebrovascular Accident with positive effects on various domains of the International Classification of Functioning, Disability, and Health.

IMPACT STATEMENT
With ESWT, healthcare professionals can better treat patients with hyperresistance.

INTRODUCTION

The purpose of this statement is to provide an overview of the current evidence regarding the use or non-use of physiotherapeutic intervention with Extracorporeal Shockwave Therapy (ESWT) in patients suffering from the consequences of spasticity following a Cerebrovascular Accident (CVA). Due to the increasingly strong evidence on this subject, it remains unaddressed in various Dutch guidelines concerning spasticity. This underscores the need for a visionary document to explore the positioning of ESWT.

Stroke, or Cerebrovascular Accident (CVA), is the leading cause of disability in adults in the European Union. Approximately 1.1 million residents of Europe suffer from a stroke annually.[1] Spasticity occurs in 18-38% of patients after a stroke.[2] Spasticity affects movement and can cause muscle pain, joint stiffness, and loss of function.[3]
It hinders patients in their daily activities, social participation, and negatively affects their quality of life.[2] Most patients are unable to participate in the labor market at pre-morbid levels.[3] Direct costs in the first year after a stroke are four times higher in patients with spasticity than in patients without spasticity.[4] Treatments to reduce spasticity are therefore desirable.[3]

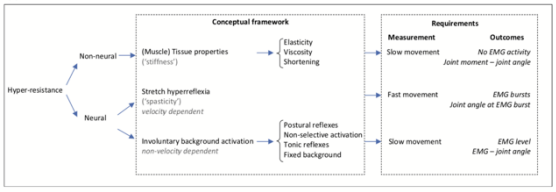
Spasticity is not unequivocally defined. Definitions commonly used are those of Lance[5] and Pandyan[6]. Lance describes spasticity as a phenomenon where a joint of a patient with an Upper Motor Neuron lesion is bent or passively stretched at multiple speeds. Higher-speed stretching results in greater electrical muscle activity.[5]

However, the Dutch guidelines of the Association of Rehabilitation Physicians (VRA)[7,8] adhere to the definition according to Pandyan.[6] Pandyan describes spasm as "impaired sensorimotor control due to an upper motor neuron lesion, which presents as intermittent or sustained involuntary activation of muscles due to the Upper Motor Neuron Syndrome (UMNS)".[6]

In the (outpatient) clinical setting, the term spasticity often refers to the perceived increased resistance during passive movement. Other positive symptoms of UMNS that may occur together are often also categorized under the term spasticity, which can lead to confusion in terms of diagnosis and treatment strategy. Despite spasticity still being the most commonly used term in clinical practice, the term does not encompass all aspects of increased resistance experienced by the practitioner during passive movement. For this reason, European consensus was reached in 2017 on consistent terminology and measurements regarding pathophysiological neuromuscular responses to passive muscle stretching. In a European context, the term "hyper-resistance" was proposed instead of spasticity to better describe the phenomenon

of disturbed neuromuscular reaction to passive stretching.[9] A conceptual framework of pathophysiological neuromuscular responses to passive muscle stretching, over which recent European consensus has been reached, is depicted in figure 1.[9]

Figure 1. Conceptual framework of pathophysiological neuromuscular responses to passive muscle stretching



Perceived hyper-resistance to movement can be divided into two main components. A neural component, due to overactive muscle contraction, and a non-neural or biomechanical component due to secondary tissue changes.[10] These tissue changes can occur due to disuse or immobilization affecting the viscous and elastic properties of muscle tissue, such as muscle atrophy, loss of sarcomeres, muscle conversion to connective tissue, and muscle length loss at rest, whether resulting in contractures or not. It is also known that there can be a loss of motor units in a paretic limb, which may be explained by secondary trans-synaptic degeneration[11] Here, motor neurons likely undergo degeneration because the trophic input normally received via descending motor pathways is lost. Further research is needed to better understand how changes in the neural component of hyper-resistance also longitudinally interact with progressive biomechanical tissue changes.[12] Increased tone can lead to shortening and/or stiffening of muscle tissue, while muscle spindles in stiff tissue are more sensitive and lower the threshold of stretch reflexes, theoretically leading to a self-promoting system in which hyper-resistance increases.[13] In this evidence statement, the term hyper-resistance is used in accordance with European consensus to denote impaired neuromuscular response.

Therapeutic interventions to improve resistance to passive movement include 1) pharmacological therapy, 2) physiotherapy (electrostimulation, thermotherapy, exercise therapy), 3) occupational therapy, 4) botulinum toxin injections, 5) chemical neurolysis, and 6) selective neurotomy.3 Recent studies indicate that ESWT can alleviate symptoms of hyper-resistance in spastic cerebral palsy.[14–18] The effects of ESWT are reported to be comparable to treatment with botulinum toxin (BTX).[19–21]

ESWT is a non-invasive treatment. A mechanical pressure wave, or sonic pulse, is administered to the tissue. This shockwave has certain physical characteristics. Initially, there is a high peak pressure in a short time, in some cases exceeding 100 Megapascals within less than 10 nanoseconds. This is followed by a lower pressure of slightly longer duration, for example, 10 Megapascals for 10 microseconds.

The frequency of the pressure wave ranges from 4 to 20 Hz.[22] The intensity of the pressure wave is expressed in bars, Megapascals, or in millijoules per square millimeter (mJ/mm2). ESWT can be divided into two types: focused and radial ESWT. The waves of focused ESWT are generated at the probe of the device and converge on the target area. The waves arrive more targeted in deeper tissue. In radial ESWT, the maximum energy of the wave is developed at the probe tip. This wave is radially distributed over the superficial tissue and reaches less deep.[23]

ESWT causes transient dysfunction of acetylcholine transmission in the neuromuscular junction. Research in rats shows temporary destruction of motor endplates on the muscular side of the neuromuscular junction. This leads to degeneration of acetylcholine receptors. The action potential amplitude in the treated muscle groups remains significantly smaller for up to 8 weeks thereafter.[24,25] A recently published case report on a stroke patient demonstrates the same effect.[3] ESWT may also influence non-neural contributions to hyper-resistance, such as reducing fibrosis of muscle tissue.[26]

By reducing hyper-resistance, the quality of life may increase and direct costs may decrease. The effects of ESWT treatment within the different domains of the International Classification of Functioning, Disability and Health (ICF) are unclear. Currently, there is no clear positioning of ESWT in patients with hyper-resistance due to a stroke in various Dutch guidelines. This underscores the need for a visionary document to explore the positioning of ESWT. The purpose of this statement is to provide an overview of the current evidence regarding the use or non-use of physiotherapeutic intervention with ESWT in patients suffering from the consequences of hyper-resistance after a stroke.

This overview aims to answer the following questions: 1) What is known from the most recent scientific studies about the effects of ESWT on outcome measures within the domains of the ICF? 2) What is the value of this evidence according to the Evidence Based Guideline Development of the quality institute for healthcare (EBRO/CBO)?27 3) 3) What is known about the duration of the effects, side effects, or adverse consequences? 4) What are the optimal treatment parameters? 5) What are recommendations for future research?

Methods

Research Design and Population

The aim of this systematic review is to describe the effects of Extracorporeal Shock Wave Therapy (ESWT) on patients with hyperresistance following a stroke, categorized within the domains of the International Classification of Functioning, Disability and Health (ICF). Other outcome measures include the duration of effects, treatment parameters,

and potential adverse effects of ESWT. The analysis will be conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This perspective adheres to the author guidelines of the Physical Therapy Journal.[29]

Sources and Search Strategies

The literature search was conducted in the following databases: PubMed, Cochrane, PEDro, and Cinahl, using a Domain-Determinant-Outcome (DDO) search string. The search string included the domain of elderly individuals with stroke, the determinant being ESWT, and the outcome comprising at least one item falling under the ICF domains such as body functions, activities, participation, and personal and environmental factors. To obtain the broadest possible overview of the ICF domains, a Patient-Intervention-Comparison-Outcome (PICO) analysis was not utilized. The literature search was carried out by the first author (LvUD) and extended until February 2022. The search was conducted in English. Medical Subject Headings (MeSH) terms, free search terms, and their synonyms were employed, including but not limited to: "Shock-Wave-Therapy," "Spasticity," "Abnormal-reflex," "Spasms," "Clonus," "Range-of-motion," "Muscle-weakness," "Fatigue," "Dystonia," "Myalgia," "Contracture," "Quality-of-life," "Social-problems," "Social-participation," "International-classification-of-functioning-disability-and-health." The entire search string can be found in Appendix 1.

Study Selection

The retrieved articles were screened by the first author based on title and abstract. Exclusion followed if it was already evident that an exclusion criterion applied. The abstracts of the remaining articles were independently reviewed by the first and second authors (AdHL) for inclusion and exclusion criteria. Articles not meeting the inclusion criteria were excluded. Any differences in opinion were discussed until consensus was reached. The subsequently selected articles were all read in full-text by the first two authors. The first author also checked the reference lists of these articles as well as excluded reviews to identify potentially relevant articles not captured in the initial search.

Articles were included if they met the following criteria: 1) the study was conducted on patients post-stroke; 2) ESWT was used to treat hyperresistance; 3) at least one outcome measure aligned with an ICF domain (body functions, activities and participation, personal factors, or environmental factors); 4) the publication language was English. Exclusion criteria applied if: 1) besides ESWT, an invasive treatment was used; 2) the research was conducted on pathologies other than stroke; 3) in Randomized Clinical Trials (RCTs), there was no control group or the control group received

therapy other than conventional therapy, placebo therapy, or no therapy; 5) in Clinical Control Trials (CCTs), there was no control measurement at the research group; 6) in a systematic review, the quality assessment according to the EBRO/CBO was lower than A1.

Data Extraction

Data extraction was performed by the first author and later checked by the second author. Population details such as number of subjects, age, gender, and pathology were recorded. Significant treatment outcomes were categorized according to the ICF domains. The duration of effect, treatment parameters, and any adverse effects of ESWT were noted.

Quality Assessment

Selected articles were independently assessed for methodological quality by the first and second authors. The following study characteristics were examined: study design, available participant information, description of interventions, and reported outcomes. Methodological quality was assessed using the Physiotherapy Evidence Database (PEDro) score.[30] Poor quality corresponded to a PEDro score of 0 to 3, fair quality to a score of 4 to 5, good quality to a score of 6 to 8, and very good quality to a score of 9 to 10. Subsequently, the first two authors evaluated the level of evidence according to the EBRO/CBO.[27] Level A2 indicates a randomized study of good quality and sufficient size. Level B indicates a comparative study with not all features of level A2.

Assessment of Hyperresistance

Hyperresistance is a relatively new term. Internationally, the term spasticity is still used, and the Modified Ashworth Scale (MAS) is the most commonly used measure to assess spasticity.[8] The researcher scores the observed resistance during passive movement on an ordinal scale from zero to four. Reliability and validity of MAS for resistance against passive movement have been demonstrated in several studies.[8,31] However, MAS is not valid and reliable for measuring spasticity because it lacks the velocity-dependent component.[32,33] The resistance against passive movement measured with MAS is a combination of non-neural and neural contributions that cannot be distinguished from each other using this measurement instrument.[9] This makes the suitability of MAS for mapping hyperresistance debatable.[9]

In this perspective, the term hyperresistance is used where the original articles use the term spasticity, and the results of MAS should be related to the body function "resistance against passive movement" and not for the effect on spasticity.

Results

The PRISMA[28] diagram (figure 2) provides a summary of the literature review. Out of the 138 articles found, 100 were excluded based on title and abstract. Of the remaining 38 articles, fourteen RCTs and four CCTs were included. The remaining articles did not meet the inclusion criteria or contained exclusion criteria.

Figure 1

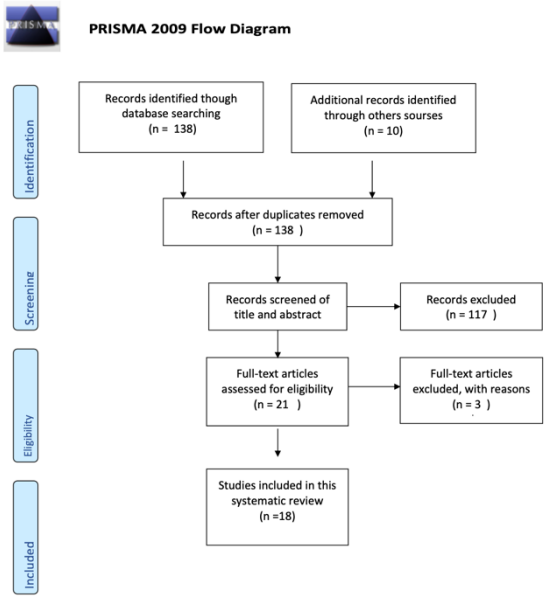


Table 1 presents the quality assessment of the included studies. The PEDro score was poor for one RCT[34] and two CCT's,[35,36] and reasonable for four RCTs [37–40] and two CCT's.[41,42] Six RCTs[43–48] scored well, and three RCTs[49–51] scored very well. The average PEDro score of all included articles was 5.7, indicating moderate to good quality. The level of evidence according to EBRO/CBO criteria classified four studies as level A2[48–51] and 14 studies as level B.[34–38,40–43,45–47,52,53]

A total of 465 out of 781 individuals received ESWT. An overview of included studies with participant characteristics, types of interventions, treated muscle(s), outcome measures, and follow-up moments is provided in Table 2. Table 3 presents the treatment parameters of the ESWT treatment and duration. Significant outcomes of the studies, duration of effect, and side effects are listed in Table 4.

The duration of symptoms was divided into early phase (between 24 hours and 3 months), rehabilitation phase (between 3 and 6 months), and chronic phase (longer than 6 months). Five studies[42,45,49,51,53] included patients from all phases, and eleven studies[34–37,40,42–44,46,48,50] included only patients in the chronic phase. One study[47] included the early and rehabilitation phases, and one study[38] included the rehabilitation and chronic phases.

Five studies[41,42,50,51,53] investigated the lower extremity, twelve studies[34–38,43–49] investigated the upper extremity, and one study investigated both[40]. Twelve studies[35,36,38,40–43,46,48,50,51,51] employed a control group with placebo treatment. Only one study[51] compared three groups: one group with ESWT, one group with placebo treatment, and a control group with conventional therapy.

The outcomes are discussed based on the ICF domains. Duration of effect, side effects, and treatment parameters of ESWT are discussed thereafter.

Body Functions

Resistance to passive movement measured with the MAS

The MAS was used in sixteen studies to express the degree of resistance to passive movement. Two poor quality CCTs[35,36] and one CCT[41] of reasonable quality, three RCTs[39,40,49] of reasonable quality, five RCTs[43–45,47,48] of good quality, and three RCTs[49–51] of very good quality concluded that the MAS showed a significant decrease after ESWT.

Resistance to passive movement measured with the Modified-Tardieu scale (MTS)

One RCT[40] of reasonable quality, one RCT[45] of good quality, and two RCTs[50,51] of very good quality used the MTS to quantify resistance to passive movement. They found a significant improvement favoring ESWT over three placebo groups and two groups with conventional therapy.

Range-of-motion (ROM)

One poor quality CCT,[36] two reasonable CCTs[41,42] van redelijke kwaliteit, two RCTs of reasonable quality[38,53] and two RCTs[50,51] of very good quality found a significant increase in dorsiflexion of the ankle[41,42,50,51,53] and extension of the wrist.[36,38]

Visual-Analogue-Scale (VAS)

Three RCTs, two[38,53] with reasonable quality and one[45] with good quality, investigated pain scores using the VAS. All found a significant reduction in pain scores.

Muscle Properties

To measure muscle properties including muscle tension and stiffness, various studies used MyotonPRO, electromyogram, neuroflexor, an isokinetic dynamometer, and ultrasonographic evaluations. Of the six studies that used electromyogram[35,36,42,43,47] two good quality RCTs[31,36] found a significant decrease in muscle electrical activity. One poor quality CCT[35] and one reasonable quality CCT[42] van redelijke kwaliteit beschreven een significante afname van de H/M-ratio op het elektromyogram. escribed a significant decrease in the H/M ratio on the electromyogram. This is a measure of the excitability of alpha motor neurons. One very good quality RCT[50] showed a significant decrease in Achilles tendon length and an increase in muscle bundle length on ultrasonographic evaluation. This indicates a decrease in pennation angle: the angle made by the muscle fibers with their line of action. One good quality RCT[46] and one very good quality RCT[49] found a significant decrease in muscle tension, stiffness, and improvement in elasticity after ESWT using MyotonPRO. One reasonable quality CCT[41] used an isokinetic dynamometer and found a significant reduction in Peak Eccentric Torque (PET) and

Torque Threshold Angle (TTA). These tests assess the torque, or force, acting on a joint.

Activities and Participation

Fugl-Meyer

Seven RCTs, one poor quality,[34] three good quality[44,45,47] and three very good quality[49,50,54] used the Fugl-Meyer to frame the degree of functional impairment, all showing significant improvement after ESWT.

Walking tests 3, 6, and 10 meters

One reasonable quality CCT[42], one reasonable quality RCT[53] and one very good quality RCT,[51] all found a significant increase in walking distance in walking tests.

Lower extremity funcional score

One reasonable quality RCT[53] used the Lower Extremity Functional Score and found a significantly higher score and therefore better function of the lower extremities after ESWT treatment.

Modified-Barthel-Index

One good quality RCT[47] and one very good quality RCT[51] used the Modified Barthel Index to measure the degree of assistance needed in daily life, both showing a significant improvement after ESWT treatment.

Personal and Environmental Factors

None of the included studies provided information on the influence of personal factors and environmental factors of daily life.

Duration of effect

The assessment of this depends on the chosen follow-up moments. One poor quality CCT,[36] one good quality RCT[45] and two very good quality RCTs[50,51] reported a significant effect on the following points after four weeks: resistance to passive movement,,[36,45,50,51] pain reduction,[45] improved joint mobility,[36,51] increased angle of catch,[45] increased walking distance,[51] decreased need for assistance, and functional impairment.[50,51]

One poor quality CCT[35] described a significant effect on resistance to passive movement and the H/R ratio after five weeks. Another very good quality RCT[54] found significant reduction in resistance to passive movement of the wrist and improved hand function after a single ESWT treatment at eight weeks. At nine weeks, a reasonable quality RCT[53] reported a significant effect on resistance to passive movement, pain reduction, improved joint mobility, and functionality of the lower extremities. At twelve weeks, a poor quality CCT[36] described a significant reduction in resistance to passive movement of the finger flexors. A very good quality RCT[48] found a significant reduction in resistance to passive movement and improvement in hand function after three treatments at twelve weeks. A good quality RCT[44] also found a significant improvement in resistance to passive movement, pain reduction, and improved joint mobility after three ESWT treatments at twelve weeks.

Adverse effects

A very high-quality RCT[51] identifies mild pain complaints as adverse effects. However, a CCT of reasonable quality,[41] two good-quality RCTs[43,44] and one of very good quality[54] report a painless experience. Other studies do not make statements about adverse effects. None of the included studies make a statement about the long-term adverse effects of ESWT.

Parameters

The ESWT treatments in the studies had different characteristics. There were differences in the physical characteristics of the shockwave, such as radial or focused. These differences are partly explained by the nature and location of the treated muscle(s). The number of shocks per treatment and the treatment duration also varied.

Ten of the included studies used radial ESWT.[34,35,38,43,45,47,49–51,54] Six studies had a total of one,[35,43,48–50] three[54] or four[51] treatments with a frequency of one treatment per week. Two studies[38,45] provided five ESWT treatments with a frequency of once every four to seven days. One study[34] provided six treatments with an interval of one session per week. One study[47] provided twenty treatments with a frequency of five times per week.
The number of shocks per treatment varied between 1500,[34,35,38,43,49,51,54] 2000,[50] 3200,[38] 4000[34,54] and 6000.[45] The studies used different intensities: 1.2-1.4 bar,[45] 1.5 bar,[35,49] 2.0 bar,[51] 3.0-3.5 bar,[34,49,54] and 0.03 mJ/mm^2,[35,43] 0.038 mJ/mm^2,[49] 0.06-0.07 mJ/mm^2,[45] 0.1 mJ/mm^2,[50] 0.11 mJ/mm^2 [47] and 0.23 mJ/mm^2.[38] The frequency varied from 4 herz,[47,49,50] 5 herz,[34,43,54] 8 herz,[38] 10 herz[51] to 18 herz.[45]
Eight studies used focused ESWT.[36,37,41,42,44,46,49,53] The number of treatments varied from one,[36] three[37,41,49,53] to six sessions[42] with an interval of one per week. One study[46] provided sixteen treatments with an interval of two sessions per week. Another study[44] provided twenty treatments with an interval of five sessions per week.
The number of shocks per treatment varied between 1200,[37] 1500,[36,40–42,46,53] 2000[44] and 3200.[46] The studies used different intensities ranging from 1.5 bar,[53] 2.0-3.0 bar[44] and 0.03 mJ/mm^2,[36,46] 0.068-0.093 mJ/mm^2,[40,41] 0.1 mJ/mm^2 [53] and 0.12 mJ/mm^2.[37] The frequency varied from 4 herz,[37,41,53] 5 herz[40] to 8 herz.[44]

Level of Evidence According to EBRO/CBO

It has been demonstrated that ESWT reduces resistance to passive movement when treating the triceps surae[50,51] and when treating the flexor carpi ulnaris and radialis.[49,54] It has also been shown that the degree of functional impairment in the upper extremities decreases.[49,54]
It is plausible that when treating the triceps surae, joint mobility increases.[42,51,53] Additionally, it is plausible that when treating the biceps brachii, resistance to passive movement decreases,[37,38,40,45,47] pain decreases[38,45] and functional impairment of

the upper extremities decreases.[45,47] Furthermore, it is plausible that when treating intrinsic hand muscles, resistance to passive movement decreases,[36,38,44,54] pain decreases,[38,54] functional impairment of the upper extremities decreases[34,44,54] and joint mobility increases.[36,38]

Furthermore, it is plausible that walking speed improves[42,51,53] and the need for assistance in daily life decreases.[37,51] Moreover, it is also plausible that MTS scores increase after ESWT treatment.[40,45,51] Finally, it is plausible that the effects of ESWT last for at least four weeks.[36,44,45,50,51,53,54]

Discussion

The aim of this study is to describe the effects of ESWT in patients with hyperresistance due to stroke across the domains of the ICF. The results indicate that passive resistance decreases, suggesting a reduction in pain, an increase in ROM of the wrist and ankle, improvement in walking speed, and a decrease in limitations and dependence in ADL. It is conceivable that these effects persist for several weeks, with few reported side effects. It is plausible that ESWT may reduce direct costs after a stroke, and possibly even alleviate pressure on healthcare systems as patients become more self-reliant.

Several (systematic) reviews have been found on the effects of ESWT on hyperresistance.[55–61] Studies often investigated different underlying conditions, such as multiple sclerosis or cerebral palsy. Some included studies combined ESWT with other treatments such as botulinum toxin injections. The outcomes were not described across the ICF domains, and the maximum follow-up duration was typically four weeks. However, the found results are comparable to the results of this study regarding the reduction in passive resistance,[55–60] improvement in joint mobility,[58,59] pain reduction,[59,61] h motor function improvement [55,58,61] and enhancement of functional independence.[61] Furthermore, it is found that the effect persists for at least 4 weeks[57,59] and few side effects are reported.[55–60]

Nine studies in this study had a follow-up moment up to one week after the last ESWT.[34,38,42,43,46,47,49,62] These studies cannot provide information about long-term effects. Only three studies,[41,44,54] with a total of 102 patients, had a follow-up duration of twelve weeks or longer. Although they demonstrate a sustained significant effect, the limited number of studies precludes a certain conclusion about the long-term effect.

Four studies investigated the effects of a single session. One other study[54] compared a single session with three sessions. Up to sixteen weeks, there was a significant difference in MAS and Fugl-Meyer between the intervention groups and the control group, but there was also a significant difference between the intervention groups, with the single-session group being disadvantaged. This suggests that multiple sessions may be more beneficial in

the long term. Further research is needed to clarify this.

The MAS is the most commonly used measurement instrument, but there is a risk that not all items of hyperresistance are measured. Ten studies[35,36,41–43,46,47,49,50] studies used technical measuring instruments to assess hyperresistance. This may provide more complete information but requires more time, is more expensive, and is less readily available. None of the included studies using the MAS and MTS mentioned a minimal clinically relevant difference. The clinical relevance is important for understanding whether the patient notices any difference. This remains unclear for hyperresistance. The pain score on the VAS decreases by more than 30%, which means a clinically relevant improvement.[63] Clinical relevance is important to determine whether the patient notices any improvement from the treatment and also helps position the treatment within the ICF domains. Further research should absolutely focus on clinical relevance.

Although one RCT[51] mentions mild pain as a side effect, most studies do not discuss side effects. This is a possible reporting bias: patients may have experienced discomforts that were not inquired about. Long-term side effects are also not discussed. Further research should focus on this.

The included studies were conducted in different parts of the world with patients of different ethnicities and different neurorehabilitation standards. Although included in the PEDRO analysis, the external validity of the studies was not further investigated. Most studies were monocentric and had a small sample size.[34,37,50,53,54,38,40,43–47,49] This can give a distorted view of the results. The muscle groups studied were also not homogeneous. All of this can affect the generalizability of the results.

Limitations of our study include that only articles written in English were included and that studies without a control group – or with a control group other than placebo, conventional, or no treatment – were excluded. This choice was made to exclude "confounders" as much as possible. However, this may have resulted in missing articles with information relevant to the research question. One study[64] compared high and low intensity of the mechanical shockwave. This study was excluded because both groups received ESWT, but it might have provided valuable information about the treatment parameters. The same applies to a study[23] that compared focused and radial ESWT. One study[34] was included in which infrared therapy was also used. Since it was used in all groups, the authors reached a consensus to include the study. However, the effect of ESWT may be overestimated due to the combination with infrared therapy.

There is no clarity about the ideal parameters of the mechanical shockwave and the frequency of ESWT. The studies found different – and sometimes contradictory – durations of effect. Only when this is clearer

can one consider with what intervals ESWT treatment can be given. This needs to be further investigated before treatment protocols and guidelines can be established. Besides the purchase and maintenance of the equipment, there are no additional costs. This makes ESWT easily cost-effective.

In conclusion, ESWT is an effective, safe, and non-invasive way to reduce hyperresistance after a stroke and improve range of motion and function. Within the ICF domain "body functions," it has been shown that ESWT reduces resistance to passive movement, it is likely that pain complaints decrease, and the ROM of the wrist and ankle increase. Within the ICF domain "activities and participation," it is likely that walking speed improves, functional limitations decrease, and the need for assistance with ADL decreases. It is likely that the effects last for several weeks and that there are few to no side effects.
The geriatric physical therapist can play a more central role in the treatment of patients with hyperresistance after a stroke by using ESWT. It is even possible that there could be a shift in treatment from other disciplines to the geriatric physical therapist.
Further research is needed before a treatment protocol or guideline can be established. This research should focus on clinical relevance, the ideal parameters of the mechanical shockwave, the frequency, and duration of the effect. Preferably, this should be investigated per extremity or muscle (group). There should also be attention to side effects and long-term effects.

Conflict of interest
The authors have no conflicts of interst to disclose.

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Table 1. Level of evidence

Reference	Year of Publication	Design	PEDro Score	Classification	Level of Evidence
Bae et al.	2010	RCT non-blind	5	Fair	B
Daliri et al.	2015	CCT single-blind	2	Poor	B
Dymarek et al.	2016	RCT single-blind	6	Good	B
Fouda et al.	2015	RCT single-blind	5	Fair	B
Guo et al.	2019	RCT single-blind	6	Good	B
Kamaluddin et al.	2018	RCT non-blind	3	Poor	B
Leng et al.	2021	RCT double blind	9	Very Good	A2
Lee et al.	2019	RCT double blind	9	Very Good	A2
Li et al.	2020	RCT single-blind	7	Good	B
Li et al.	2016	RCT double-blind	6	Good	A2
Manganotti et al.	2005	CCT non-blind	3	Poor	B
Moon et al.	2013	CCT non-blind	4	Fair	B
Park et al.	2018	RCT single-blind	7	Good	B
Sawan et al.	2017	CCT non-blind	5	Fair	B
Taheri et al.	2017	RCT non-blind	5	Fair	B
Xu et al.	2021	RCT non-blind	7	Good	B
Yoldaş Aslan et al.	2021	RCT double-blind	9	Very Good	A2
Yoon et al.	2017	RCT non-blind	5	Fair	B

CCT: Clinical Controlled Trial; RCT: Randomized Controlled Trial

Table 2. Characteristics of the included studies

Author /year	Study type	Participants m/f	Type of stroke	Interventions (ESWT/CG)	Mean age ± SD	Months after stroke	Threated muscle	Anatomic area	Outcome	Follow-up
Bae et al. 2010	RCT	N=32 (21/12) IG: 15/8 CG: 5/4	IG: 13/10 CG: 3/6	IG A (n=12): 3x 1 ESWT/week spierbuik IG B (n=11): 3x 1 ESWT/week spier pees overgang CG: NB	IG: 56.7 ± 12.4 CG: 53.4 ± 16.8	IG: 22.0 ± 8.2 CG: 25.1 ±14.6	Biceps	12 patiënten op de spierbuik 11 patiënten spier pees overgang	MAS MTS K-MBI	To (baseline) T1 (meteen na ESWT) T2 (1 week erna) T3 (4 weken erna)
Daliri et al. 2015	CCT	N=15 12/3	13/2	To-placebo-T1-T2-ESWT-T3-T4-T5	54.4 ± 9.4	30.0 ± 22.5	Flexor carpi ulnaris Flexor carpi radialis	NB	MAS Brunnstrom recovery stage H/M ratio	T0 (baseline) T1(onmiddellijk na placebo) T2 (1 week later vóór de ESWT) T3 (meteen erna) T4 (1 week Na ESWT) T5 (5 weken na ESWT)
Dymarek et al. 2016	RCT	N=60 IG:19/11 CG: 15/15	IG: 30/0 CG: 30/0	IG: 1x ESWT CG: 1x placebo ESWT	IG: 61.43 ±12.74 CG: 60.87 ± 9.51	IG: 51.30 ± 25.46 CG: 51.53 ± 26.13	Flexor carpi radialis en flexor carpi ulnaris	spierbuik	MAS EMG IRT	T0 (baseline) T1: (onmiddellijk na ESWT) T2: (1 na uur) T3: (na 24 uur)
Fouda et al. 2015	RCT	N=30 IG: 15/0 CG: 15/0	IG: 58/10 CG: 6/9	IG: 5x 1/week ESWT en traditionele fysiotherapie CG: 5x 1/week placebo- ESWT en traditionele fysiotherapie	IG: 52.72 ± 5.90 CG: 51.83 ± 6.80	IG: 12.2 ± 8.12 CG: 14.6 ± 9.21	Flexoren onderarm en palmaire interosseus- spieren	NB	MAS ROM VAS	T: (voor behandeling) T1: (na behandeling)
Guo et al. 2019	RCT	N=60 (32/28) IG:16/14 CG:16/14	IG:12/18 CG:13/17	IG: ESWT 20min/dag, 5/week, gedurende 4 weken + conventionele revalidatie therapie 30 minuten/dag, 5x/week gedurende 4 weken CG: conventionele revalidatie therapie 30 minuten/dag, 5x/week gedurende 4 weken	IG: 66.79 ±11.02 CG: 69.72 ± 11.13	IG: 3.23 ± 0.82 CG: 3.49 ±0.93	Intrinsieke spieren en flexor digitorum pees	Spierbuik Intrinsieke spieren flexor digitorum pees	FMA MAS	T0 (baseline) T1 (1 maand na de interventies) T2 (3 maanden na de interventies) T3 (6 maanden na de interventies) T4 (12 maanden na de interventies)
Kamaluddin et al. 2018	RCT	N=30 IG: 7/8 CG: 6/9	IG: 14/1 CG: 15/0	IG: 6x 3/week Infrarood+ stretching+ 6x 1/week ESWT CG: 6x 3/week infrarood+ stretching	IG: 56.4 ± 6.03 CG: 54.9 ± 4.50	IG: 21.6 ± 9.72 CG: 22.8 ± 9.48	-Buik pols flexor -Intrinsieke spiergroep hand -Pees flexor digitorum	Pees en buik	FMA (pols hand)	T0 (voor interventie) T1)na interventies)
Lee et al. 2019	RCT	N=18 IG: 7/2 CG: 9/0	IG: 4/5 CG: 2/7	IG: 1x ESWT +fysiotherapie, ROM oefeningen+ spasmeremmers	IG: 50.89 ± 8.81 CG: 44.11 ± 4.07	IG: 12.89 ± 8.99 CG: 10.44 ± 9.11	Gastrocnemius spier	Spierbuik mediaal	MAS PROM FMA ATL MFL	T) (baseline) T1 (na 30 minuten) T2 (na 1 week) T3 (na 4 weken)

				CG: placebo ESWT+ fysiotherapie, ROM oefeningen+ spasmeremmers					MT PA	
Leng et al. 2021	RCT	N=30 IG: 11/3 CG: 11/2	IG: 8/6 CG: 10/3	IG: 1 sessie + conventionele therapie (5x/week 1,5 uur) CG: conventionele therapie (5x/week 1,5 uur)	IG: 51.14 ± 13.68 CG: 58.92± 10.08	IG: 17.39- 29.18 CG: 24.42- 37.09	Flexor carpi radialis	Spierbuik paretische en niet-paretische kant	NC EC VC F S R X Y MAS FMA	T0 (baseline) T2 (meteen na ESWT) T3 (1 week)
Li et al. 2020	RCT	N=82 IG A: 20/7 IG B: 21/9 CG: 22/3	IG A:24/3 IG B:22/8 CG: 20/5	IG A: 1x/4dagen rESWT op agonist (totaal 5 sessies) + 3x 6/week conventionele fysiotherapie IG B: rESWT op antagonist 1x/4 dagen rESWT (totaal 5 sessies) + conventionele fysiotherapie CG: conventionele fysiotherapie	IG A: 65 ± 10 IG B: 61 ±12 CG: 61 ± 13	IG A: ≤1m:3 ≥1,≤3 m:9 >3,≤6 m: 9 >6m: 6 IG B: ≤1m:1 ≥1,≤3 m:17 >3,≤6 m: 9 >6m: 3 CG: ≤1m:1 ≥1,≤3 m:11 >3,≤6 m: 9 >6m: 4	IG A: spierbuik biceps, brachioradialis, pronator teres en bicepspees IG B: spierbuik en pezen triceps	Spierbuik en perzen	MAS MTS VAS FMA SS	T0 (baseline) T1 (24 uur na 5e behandeling) T2 (na4 weken follow-up)
Li et al. 2016	RCT	N=60 IG A: 12/8 IG B: 15/5	IG A: 10/10 IG B: 10/10	IG A: 3x 1ESWT/week IG B: 1x ESWT CG c: 3x 1placebo ESWT/ week	IG A: 55.35 ± 3.05 IG B: 56.80 ± 3.00	IG A: 61.70 ± 9.73 IG B: 66.65 ± 9.56 CG: 66.95 ± 10.4	Flexoren onder arm intrinsieke spieren flexor digitorumpees	Spierbuik en pees	MAS FMA	T0 (baseline) T1 (meteen na de behandeling of behandelreeks) T2 (na 1 week) T3 (ma 4 weken) T4 (na 8 weken

		CG: 14/6	CG: 12/8		CG: 55.95 ± 2.64					T5 (na 12 weken) T6 (na 16 weken)
Mangannotti et al. 2005	CCT	N=20 (11/9)	15/5	To-placebo-T1-T2-ESWT-T3-T4-T5	Gemiddeld: 63 (38-76)	≥ 9 maanden	Flexoren onderarm Interosseus	spierbuik	MAS ROM EMG	T0 (baseline) T1(onmiddellijk na placebo) T2 (1 week later vóór de ESWT) T3 (meteen erna) T4 (1 week Na ESWT) T5 (4 weken na ESWT) T6 (12 weken na ESWT
Moon et al. 2013	CCT	N 30 (17/13)	16/14	To-placebo-T1-3x ESWT-T2-T3-T4	52.6 ±14.9	Gemiddeld 80.5 ±46.5	Laterale en mediale gastrocnemius	Spier- pees overgang	MAS ROM FMA IDT	T0 (baseline) T1(onmiddellijk na placebo) T2 (meteen na ESWT) T3 (1 week Na ESWT) T4 (4 weken na ESWT)
Park et al. 2018	RCT	N=30 IG (9/6) CG (10/5)	 IG 10/5 CG 9/6	IG: 8x 2/week ESWT CG: 8x 2/week placebo ESWT	IG 64.2 ± 5.1 CG 65.0 ± 4.8	IG 18.1 ± 7.2 CG 16.9 ±7.7	flexor carpi ulnaris en radialis, en over intrinsieke spieren en flexor digitorum pees	Met name de spierbuik	MyotonPRO: -Tone -Stijfheid =S -Elasticiteit =EC	T0 (baseline) T1 (na behandeling)
Sawan et al. 2017	CCT	N=40 IG 20 CG 20	40/0	IG: 6x 1/week ESWT + 6x 3/week conventionele fysiotherapie CG: : 6x 1/week placebo- ESWT + 6x 3/week conventionele fysiotherapie	IG 50.6 ± 6.7 CG: 84.8 ±5.9	6-18 maanden	Plantair flexoren	Met name: Mediale kop gastrocnemius	-H/M Ratio -AROM dorsaalflexie -10 meter looptest	T0 (baseline) T 1 (na behandelsessies)
Taheri et al. 2017	RCT	N=25 IG: 9/4 CG: 8/4	IG: 11/2 CG: 11/1	IG: 3x 1/week ESWT + rekoefeningen 30min/dag 5x/week + orale anti spastische medicatie CG: rekoefeningen 30min/dag 5x/week + orale anti spastische medicatie	IG: 56.5 ± 11.6 CG: 54.9 ± 9.4	IG: 33 ± 21.4 CG: 25.8 ± 9.9	Mediale en laterale kop gastrocnemius	Musculotendineuse kruising mediale en laterale kop gastrocnemius	-VAS -MAS -ROM -clonus score -3 meter looptest -LEFS	T0 (baseline) T1 (eind van week 1) T2 (eind week 3) T3 (eind week 12)
Xu et al. 2021	RTC	N=44 IG(16/6) CG(15/7)	IG: 20/2 CG: 16/6	IG: 4x 5x/week ESWT + Conventionele therapie CG: conventionele revalidatie therapie 4x 5x/week 30 minuten	IG: 68.86 ± 5.82 CG: 68.86 ± 3.09	Allemaal 2 weken tot 6 maanden na infarct	Biceps	Spierbuik en pees	-FMA-UE -iEMG -MAS -MBI	T0 (baseline) T1 (na behandeling)
Yoldaş Aslan	RCT	N=51 IG A: 9/8	-	IG A: 2x 2/week rESWT + conventionele therapie	IG A: 57.5 ± 14.3	IG A: 35.5 ± 70.2 IGB: 28.9 ± 76.5	Plantair flexoren	gastrocnemius-spierbuik en de	MAS Tardieu	T0 (baseline) T1 (meteen erna)

et al. 2021		IG B: 9/7 CG: 9/7		IG B: 2x 2/week placebo ESWT + conventionele therapie CG: conventionele therapie	IG B: 58.8 ± 10.8 CG: 60.6 ± 96	CG: 3.8 ±2.8		musculotendineuze overgang	ROM 6 meter wandeltest Modified Barthel index Stijfheid via strain index (s)	T2 (na 4 weken follow-up/ 6 weken na start)
Yoon et al. 2017	RCT	N=124 elleboog flexor: IG A 26/0 IG B 26/1 CG:23/3 Knie flexor: IG A 13/0 IG B 13/0 CG:16/2	NB	IG A: Belly: 3x 1/week ESWT IG B: junction: 3x 1/week CG 3x 1/week placebo:	elleboog: IG Belly 58.7 ± 15.7 IG Junction 63.1 ± 11.8 CG: 64.4 ± 13.8 knie flexor: IG Belly 61.0 ± 12.2 IG junction: 66.9 ± 4.9 CG: 59.5 ± 16.9	Elleboog: IG Belly: 100.3 ± 98.3 IG Junction: 66.8 ± 51.9 CG: 63.5 ± 94.1 Knie: IG Belly: 99.1 ± 85.1 IG Junction: 51.1 ± 36.0 CG: 38.7 ± 30.2	Biceps brachii Semi tendinosis	Buik of junction	MAS MTS	T0(baseline) T1 (1 week na 1e ESWT) T2 (week2) T3(week 3) T4 (week 4)

ATL: Achilles tendon length; **AROM:** Active Range Of Motion; **CCT:** Clinical Control Trial; **CG:** control group; **EC:** elastic component; **ESWT:** extracorporeal shockwave therapy; **EMG:** Electromyogram; **F:** muscle tension; **fESWT:** focused extracorporeal shockwave therapy; **FMA:** Fugl-Meyer assessment; **FMA-UE:** Fugl-Meyer upper extremity; **H/M ratio:** the ratio between the maximum amplitude of the H-wave (Hmax) and that of the M-wave (Mmax); **IDT:** isokinetic dynamometer; **iEMG:** myoelectric signal time-domain range interval values; **IG:** intervention group; **IG A:** intervention group A; **IG B:** intervention group B; **IRT:** infrared thermal imaging; **K-MBI:** Korean-modified Barthel index; **LEFS:** Lower extremity functional score; **m:** months; **M/V:** male/female; **MAS:** modified Ashworth Scale; **MBI:** modified Barthel index; **MFL:** muscle fascicle length; **MT:** muscle thickness; **MTS:** modified Tardieu Scale; **N:** number of participants; **NB:** not mentioned; **NC:** neural component; **NG:** not described; **PA:** pennation angle; **PROM:** Passive Range Of Motion; **R:** resistance; **ROM:** Range Of Motion; **rESWT:** radial shockwave therapy; **RCT:** Randomized Controlled Trial; **S:** stiffness; **SD:** Standard Deviation; **SS:** swelling scale; **T:** test moment; **VAS:** Visual Analog Scale; **VC:** viscosity component; **X:** reactance; **y:** phase angle.

Table 3. Parameters for extracorporeal shockwave therapy from the included articles

Study	Type of shockwave	Number of sessions	Frequentie	Threatment	Threatment time in weeks	Session duration
Bae et al. 2010	fESWT	3	1/week	1200 shots/sessie 0.12 mJ/mm2 4Hz	4	5 minuten
Daliri et al. 2015	rESWT	1	-	1500 shots 0.030mJ/mm2 1.5 bar	2	-
Dymarek et al. 2016	rESWT	1	-	1500 shots 0.03mJ/mm2 5Hz	0.1	NB
Fouda et al. 2015	rESWT	5	1/week	Flexor onderarm: 1500 shots 0.23mJ/mm2 2.5 bar Palmaire interosseus- spieren van de hand: 3200 shots (800/spier) 8Hz	5	-
Guo et al. 2019	fESWT	20	5/week	2000 shots/sessie 2.0-3.0 bar 8Hz	4	20minuten/ dag
Kamaluddin et al. 2018	rESWT	6	1/week	Buik polsflexor: 1500 shots/ sessie 3.5 bar 5Hz Intrinsieke spiergroepen hand+pees flexor digitorum: 4000 shots 3 bar, 5Hz	6	NB
Lee et al. 2019	rESWT	1	-	0.1 mJ/mm2 2000 shots 4Hz	4	NB
Leng et al. 2021	rESWT	1	-	0.038mJ/mm2 1.5 bar 1500 shots 4Hz	1	NB
Li net al. 2020	rESWT	5	1/ 4 dagen	0.06-0.07 mJ/mm2 6000 shots 1.2-1.4 bar 18Hz	3	NB
Li et al. 2016	rESWT	3 en 1	1/week	Flexor carpi ulnaris en radiales:	3	NB

				1500 shots 3.5 bar 5Hz Intrinsieke spieren+ flexor digitorumpees : 4000 shots 3 bar 5Hz		
Manganotti et al. 2005	fESWT	1	-	Flexoren onderarm: 1500 shots Interosseus: 3200 shots (800 elk) 0.030mJ/mm2	2	geen
Moon et al. 2013	fESWT	3	1/week	1500 shots 0.089mJ/mm2 4Hz	4	geen
Park et al. 2018	fESWT	16	2/week	Flexoren onderarm: 1500 shots Interosseus: 3200 shots (800 elk) 0.030mJ/mm2	8	NB
Sawan et al. 2017	fESWT	6	1/week	1500 shots	6	NB
Taheri et al. 201 7	fESWT	3	1/week	1500shots 0.1mJ/mm2 1.5 bar 4 Hz	3	NB
Xu et al. 2021	rESWT	20	5x/week	0.11mJ/mm2 3 bar 4Hz	4	20 minuten/ sessie
Yoldaş Aslan et al. 2021	rESWT	4	2/week	1500 shots 2 bar 10Hz		-
Yoon et al. 2017	fESWT	3	1/week	1500 shots 0.068-0.093mJ/mm2 5Hz	4	NB

fESWT: focused extracorporeal shockwave therapy; Hz: Hertz; mJ/mm2: millijoules per square millimeter; NB: not described; rESWT: radial extracorporeal shockwave therapy

Table 4. Outcome measures, significant treatment outcomes, and duration of effects

Study	Significant outcome after treatment at t0 -> last measurement (mean ± SD)	Effect duration	Adverse effects
Bae et al. 2010	MAS: IG 2.9 ± 0.3 → T1: 1.6 ±1.0* (onmiddellijk na behandeling) MTS: IG: 40.7 ± 25.4 → T1: 73.4 ± 27.0 * (onmiddellijk na behandeling) verschil IG A en IG B: B> A maar niet significant	Gemeten na 4 weken, 1 week effect	NB
Daliri et al. 2015	MAS: na ESWT →T3,T4,T5 2* H/M ratio → T4,T5*	Effect tot 5 weken na ESWT	NB
Dymarek et al. 2016	MAS radio carpale gewrichten: 1.70 ± 0.70 → T1: 1.30 ± 0.50* MAS vinger gewrichten: 2.10 ± 0.90 → T1: 1.50 ± 0.80* T2: 1.40 ± 0.60* T3: 1.70 ± 0.80 * EMG flexor carpi radialis: IG: 6.35 ± 2.35 → T1: 4.83 ± 1.28** T2: 4.74 ± 1.04** T3: 4.71 ± 1.28** EMG flexor carpi ulnaris: IG: 6.15 ± 2.24 → T1: 4.77 ±1.26* T2: 4.92 ± 1.31* T3: 4.72 ± 1.24*	Na 24 uur	NB
Fouda et al. 2015	IG: MAS pols flexoren: 3.4 ± 0.4 →2.1 ± 0.6** MAS vinger flexoren: 3.2 ± 0.5 → 1.4 ± 0.4** ROM 51.4 ± 4.8 → 75.5 ± 5.5** VAS 5.79 ± 0.8 → 2.63 ± 0.6**	5 weken	NB
Guo et al. 2019	FMA: IG:13.06 ± 3.01 →T1: 16.53 ± 4.13* (na 1 maand) T2: 19.08 ± 3.96 **(na 3 maanden) T3: 20.12 ± 2.21**(na 6 maanden) T4: 23.98 ± 2.91**(na 12 maanden) MAS: IG:3.13 ± 0.81 → T1: 2.87 ± 0.92* T2: 2.19 ± 1.02 * T3:1.49 ± 1.08* T4: 1.07± 0.89*	12 maanden	geen
Kamaluddin et al. 2018	Pols: IG FMA: 2→ 5* CG FMA: 3→4* Hand: IG 4→6* CG 4→5*	Gemeten na 6 weken interventie	geen
Lee et al. 2019	IG: MAS: 2.22 ± 1.09 → T3: 1.56 ± 0.52* FMA: 21.89 ± 6.00 →T2: 23.44 ± 5.81* T3: 25.22 ± 5.82* ALT: 55.53 ± 5.13 → T1: 51.88 ± 4.63* T2: 50.65 ± 4.64* T3: 50.92 ± 6.62* MFL: 44.13 ± 6.32 → T1: 46.73 ± 6.18* T2: 48.13 ± 6.23* T3: 48.85 ± 6.41* MT: 13.58 ± 0.99 → T1: 12.63 ± 0.85* T2: 11.87 ± 1.03* T3: 10.91 ± 0.97* PA: 22.73 ± 1.84 → T1: 21.00 ± 1.37* T2: 19.92 ± 1.74* T3: 18.82 ± 1.76*	MAS na 4 weken pas significant Laatste meting na 4 weken	NB
Leng et al. 2021	F: IG 19.66 ± 2.38 → 16.79 ± 1.81* S: IG 385.50 ± 88.15 → 303.57 ± 42.05* MAS: IG 2.00 ± 0.78 → 1.07 ± 0.73* Fugl- Meyer: IG 22.79 ± 14.37 → 25.50 ± 13.73** CG 30.23 ± 20.73 → 32.76 ± 20.73**	Gemeten 1 week na behandeling	NB
Li et al. 2020	MAS: significante verbetering in beide rESWT groepen na 5 behandelingen, effect op agonist was beter dan op antagonist MTS: na 5 behandelingen significante veranderingen voor R1 en R2, na 4 weken follow-up verbeterde de hoek R1 in de ESWT groepen en bleef R2 onveranderd VAS: In beide ESWT groepen significante verlaging, ook bij follow-up na 4 weken ESWT agonist: T0: 2.5±1.4→ T1:0.7±0.8 T2:0.3±0.5 Antagonist: T0: 2.2±1.4→T1:1.0±0.9 T2: 0.6±0.9 FMA: binnen groepen CG, IGA en IGB significante vooruitgang	na 4 weken follow-up	NB
Li et al. 2016	MAS hand: alle testmomenten: A vs C ** T1,2,3,5: B vs C**, T4 B vs C* T1,T4,T5,T6 A vs B **	MAS: Serie 3x ESWT > 16mnd effect 1x ESWT >8 weken effect	Geen

	MAS pols: alle testmomenten: A vs C ** Tot week 8 B vs C** T4 B vs C * T1,T4, T5, T6 A vs B ** T3 A vs B * FMA: handfunctie: op alle testmomenten: A vs C** T1,2,3,4 A vs B** T5 A vs B* Pols: T1,T2,T3 A vs C** T1,2,3 A vs B** T5 A vs B*	Handfunctie FMA: 16 weken significant effect handfunctie, 8 weken effect pols control	
Manganotti et al. 2005	MAS: vinger flexoren: T1 (P 0.001)** T5 na 4 weken (P 0.02)* en T6=12 weken (P 0.05)* Pols flexoren: T1 =na 1 week (P 0.001)* en T5= vierde week (P 0.05)* ROM: T0: 20 ±7→ T3= meteen erna: 50 ± 6* T4= na 1 week: 50 ± 7 T5= na 4 weken 40 ± 6	Tot 12 weken effec op vinger flexoren, ruim 4 weken effect ROM	NB
Moon et al. 2013	MAS: T0: 2.5 ±0.67 → T2(post ESWT) 1.41 ± 0.67* T3 (na 1 week) 1.67 ± 0.65* PET: T2= post ESWT 60Nm, 180Nm,240Nm * T3= na 1 week 180, 240Nm * TTA: T2 post ESWT 60,180, 240Nm*	Tot 1 week na ESWT significant	geen
Park et al. 2018	flexor carpi ulnaris en radialis, intrinsieke spieren en flexor digitorum : Toon* S= Stijfheid* EC= Elasticiteit*	Gemeten na behandelserie	NB
Sawan et al. 2017	H/M Ratio IG: 2.93 ± 0.64 → 1.79 ± 0.40 ** AROM IG: 9.90 ± 1.74 → 16.40 ± 1.14** 10 meter looptest IG: 36.15 ± 7.79 → 25.95 ± 6.72**	Gemeten eind week 6	NB
Taheri et al. 2017	VAS: IG: alle meetmomenten significante verlaging pijnscore** IG: T0: 4.5±3.4→T1: 3.5±3 T2: 2±1.8 T3: 1.9±2 MAS:IG: alle meetmomenten significante verlaging MAS-score** ROM: IG: alle meetmomenten significante verhoging ROM-score** 3 meter wandelduur: IG: Significante vermindering van duur ** LEFS: IG: Significant beter**	Gemeter eind week 12	NB
Xu et al. 2021	FMA-UE: IG: 9.05 ± 1.25 → 27.14 ± 3.84* CG: 8.27 ± 1.32 → 22.68 ± 3.34* iEMG: IG: 12.8 ± 4.66 → 4.43 ± 1.59* CG: 14.30 ± 4.05 → 8.9 ± 2.62 MAS: IG: 2.46 ± 0.51 →1.36 ± 0.33* MBI: IG: 28.36 ± 1.65 → 38.32 ± 2.77* CG: 27.86 ± 1.32 → 33.55 ± 2.34*	Gemeten eind week 4	NB
Yoldaş Aslan et al. 2021	MAS IG A: meteen na ESWT(week 2) ** Tardieu IG A: meteen na ESWT(week 2) ** ROM: IG A: vanaf week 6* Modified Barthel index verbeterde significant in de 3 groepen** 6 meter looptest: IGA: tijd in week 2 en 6 significant afgenomen* Strain: significante afname in alle groepen in week 2 en 6*	Na 4 weken gemeten	Milde pijn (2)
Yoon et al. 2017	elbow: IG belly: MAS: 2.81 ± 0.69 → 2.62 ± 0.75* MTS: 53.63 ± 16.26 → 64.50 ± 15.87** IG Junction: MAS: 2.86 ± 0.52 → 2.68 ± 0.55* MTS: 49.61 ± 13.74 → 59.71 ± 14.55** Knee: IG Belly: MAS: 2.92 ± 1.03 → 2.38 ± 0.76* MTS: 52.38 ± 25.15 → 66.62 ± 20.41** IG Junction: MAS: 2.85 ± 0.55 → 2.31 ± 0.63* MTS: 55.46 ± 14.87 → 63.46 ± 14.63**	Gemeten eind week 4	NB

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