Journal of Physical Medicine & Rehabilitation Studies
Volume 1 | Issue 1

Review Article Open Access

Novel Evidences of Extracorporeal Shockwave Therapy for Spasticity

Suputtitada A*

Physiatrist, Department of Rehabilitation Medicine, Faculty of Medicine, Chulalongkorn University & King Chulalongkorn Memorial Hospital, Bangkok, Thailand

***Corresponding author:** Suputtitada A, Professor, Physiatrist, Department of Rehabilitation Medicine, Faculty of Medicine, Chulalongkorn University & King Chulalongkorn Memorial Hospital, Bangkok, Thailand, Tel: 66814888549, E-mail: sareerat1111@gmail.com; areerat.su@chula.ac.th; prof.areerat@gmail.com

Citation: Suputtitada A(2018), Novel Evidences of Extracorporeal Shockwave Therapy for Spasticity. J Physic Med Rehabilita Stu 1(1): 101

Abstract

Spasticity is defined as 'a disorder of sensorimotor control, resulting from an upper motor neuron (UMN) lesion, presenting as intermittent or sustained involuntary activation of muscles'. It is characterized by increased involuntary velocity-dependent tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper-excitability of the stretch reflex. In the recent years, a range of non-pharmacological interventions has been used to manage spasticity. Among the novel of all therapies, extracorporeal shock wave therapy (ESWT) is attractive for many researchers since the noninvasive, easy application after well training and safety property. Moreover, the evidences of regeneration of musculoskeletal tissues made ESWT more interesting than other novel therapies. This article will show the evidences, practical clinical use and precaution to guide treating for the clinicians in the novel therapy of ESWT for spasticity. The review of the scientific evidences including methodology components and main results of ESWT treatment on upper limb and lower limb muscles affected by post-stroke spasticity are demonstrated. However, reducing spasticity alone without addressing the negative components of the upper motor neuron syndrome will limit meaningful recovery. A combination of rehabilitation techniques is needed to facilitate functional improvements.

Keywords: Spasticity, Extracorporeal Shock Wave Therapy (ESWT), Rehabilitation

Introduction

Spasticity is defined as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper excitability of the stretch reflex, as one component of the upper motor neuron syndrome [1]. It can be associated with a variety of signs and symptoms of the upper motor neuron syndrome. These symptoms include the neural components and the biomechanical components. The neural components consist of positive phenomena as clonus, dystonia (involuntary muscle contraction resulting in abnormal posturing of a joint or limb), extensor or flexor spasms, spastic co-contraction (contraction of both the agonist and antagonist muscles caused by an abnormal pattern of commands in the descending supraspinal pathway), abnormal reflex responses (exaggerated deep tendon reflexes and associated reaction), and negative phenomena as the loss of dexterity, muscle fatigue, weakness, and loss of limb control. The biomechanical components consist of stiffness, contracture, fibrosis, and atrophy [2-7]. Many disease conditions of the central nervous system, including stroke, cerebral palsy, traumatic brain injury, multiple sclerosis, and spinal cord injury, can provoke spasticity.

Pathophysiology, spasticity results from an abnormal intraspinal processing of primary afferent inputs due to the dissociation of the motor and sensory components of the diastaltic arch [8]. This dissociation is caused by lesions in the brainstem, the cerebral cortex (in the primary, secondary, and supplementary motor areas) or the spinal cord (pyramidal tract), which leads to an inhibitory/excitatory imbalance in the spinal network with a consequent segmental hyperexcitability, including increased muscle activity and exaggerated spinal reflex responses to a peripheral stimulation [9-16]. Furthermore, multiple sclerosis induced spasticity is believed to be due to the occurrence of either axonal degeneration or demyelination within the specific descending tracts in the central nervous system. The inhibitory/excitatory imbalance results from damage-induced dysfunction and maladaptive connectivity among several brain structures such as the supplementary motor, cingulate motor, premotor, posterior and inferior parietal areas, and the cerebellum [9].The spasticity treatments available can be categorized as pharmacological and nonpharmacological treatments. The pharmacological treatment includes oral (eg, baclofen, tizanidine, benzodiazepine, etc) and injectable (eg, botulinum toxins, alcohol and phenol). In recent years, a range of non-pharmacological interventions has been used

to manage spasticity, include: physical interventions (stretching, passive movements); transcutaneous electric nerve stimulation (TENS); transcranial direct current stimulation (tDCS); extracorporeal shock wave therapy (ESWT); vibratory stimulation (whole body vibration); electromyography biofeedback; repetitive transcranial magnetic stimulation (TMS); therapeutic ultrasound; acupuncture; orthotics (splints, casts), thermotherapy, cryotherapy and others. In practice, these categories can be implemented in a neurorehabilitation program, either as a stand-alone therapy or in a combination of 2 or more treatment modalities. Among the novel of all therapies, extracorporeal shock wave therapy (ESWT) is attractive for many researchers since the noninvasive, easy application after well training and safety property. Moreover, the evidences of regeneration of musculoskeletal tissues made ESWT more interesting than other novel therapies. However, reducing spasticity alone without addressing the negative components of the upper motor neuron syndrome will limit meaningful recovery. A combination of rehabilitation techniques is needed to facilitate functional improvements.

What is extracorporeal shockwave therapy (ESWT)

ESWT uses biphasic acoustic energy that goes from positive high peak pressures (10-100 MPa (mega pascals) for fESWT; 0.1-1 MPa for rESWT) to negative phase (10 MPa); short rise times (10-100 μs for F-ESWT; 0.5-1 μs for rESWT), short duration (0.2-0.5 μs for fESWT; 0.2-0.5 μs for rESWT). Focused and radial shockwaves are generated in different ways. Focused shockwaves are generated electrically, either within the applicator (electrohydraulic technique), or externally to it in the focal zone (electromagnetic or piezoelectric techniques), and then propagate to a designated focal point in order to treat it. rESWT are ballistic pressure waves generated at lower pressures over a longer time and propagate divergently within the tissue [17-23]. The induced energy is propagating in the tissue and converges into a focal or radial area, depending on the equipment used and the settings selected for intensity, angle and other parameters [17]. The energy of fESWT decreased within the target tissue consists of bone, calcifications, water, etc., more than 50% in occasionally, whereas consistent energy flux density was found in Reswt [17-39].

The current status of knowledge about ESWT from can be shortly summarized as follows: (i) ESWT is effective. (ii) ESWT is safe. (iii) For certain conditions such as plantar fasciopathy or calcifying tendonitis of the shoulder, randomized controlled trials (RCTs) on ESWT have become the predominant type of RCT listed in the highly prestigious Physiotherapy Evidence Database (PEDro*; www.pedro.org.au), and/or obtained the highest PEDro quality scores among all investigated treatment modalities. (iv) among those RCTs listed in the PEDro database, there is no difference in the "quality" of RCTs with positive or negative outcome. (v) Application of local anesthesia adversely affects outcome of ESWT. (vi) Application of insufficient energy adversely affects outcome of ESWT. (vii) There is no scientific evidence in favor of either rESWT or fESWT with respect to treatment outcome. (viii) The frequently used distinction between rESWT as "low-energy ESWT" and fESWT as "high-energy ESWT" is not correct and should be abandoned. (ix) ESWT has become an attractive alternative for treating newly diagnosed tendinopathies and myofascial pain syndrome. (x) An optimum treatment protocol for ESWT appears to be three treatment sessions at one-week intervals, with 2000 impulses per session and the highest energy flux density that can be applied [17-39].

The advantage for treatment with ESWT are as the follows;17,27,28,37,38 (1) effectively relieves pain in more than 80 percent of patients even after just three treatments, (2) can replace surgery in many cases of diseases of the musculoskeletal system, (3) requires compliance by the patient that can easily be achieved (three times five to ten minutes treatment, usually once a week), (4) can be fully performed on an outpatient basis, (5) can be combined with other PRM treatments ,(6) No medication ,and (7) Gentle and effective.

Potential biological and neuronal mechanisms of ESWT

The mechanism of shock wave therapy on spastic muscles is still are still unclear and require further investigation. There are studies investigated the mechanisms of the shock waves as the following hypotheses follows; (1) can induce non-enzymatic and enzymatic nitric oxide (NO) synthesis [40-43]. NO is involved in neuromuscular junction formation in the peripheral nervous system 44 and in important physiological functions of the CNS, including neurotransmission, memory and synaptic plasticity [45]. NO synthesis has been suggested as an important mechanism to explain the effectiveness of shock waves in the anti-inflammatory treatment of different tendon diseases [41-43]. However, the reduction in hypertonia in patients after stroke after shock wave therapy is not produced by denervation or lesion of the peripheral nerve, as shown by neurophysiological findings in a previous study [46].; (2) A direct effect of shock waves on fibrosis and on the rheological properties of the chronic hypertonic muscles should be considered together with the documented therapeutic effect on bone and tendon diseases [47-53].; (3) possible tixotrophy effects of shock waves on tissues and vessels of the treated muscles [41,42].; (4) The effect of mechanical stimuli of shock waves on the muscle fibers next to the tendon cannot be excluded; (5) pain itself may be contributing to increased muscle tone. Therefore, treating the pain may reduce muscle tone [54,55]. (6) the effect of rESWT on muscle fibrosis and non-reflex hypertonia. The reduced extensibility, due to soft tissue changes, causes pulling forces to be transmitted more readily to the muscle spindles. In this condition, an exaggerated spindle discharge in response to muscle stretch might lead to an increased stretch reflex. Thus, the reduction of non-reflex hypertonia could modify muscle spindles' excitability, leading to a secondary reduction of spasticity [46,56].; (7) a neuroregenerative properties of the ESWT characterized by strong growth in the rate of axonal regeneration, connected with the removal of degenerated axons initially and obtaining a greater capacity for the creation of new axons as a result of partial destructive impact of ESWT [57].; (8) low-energy ESWT enhances the neuroprotective effect in reducing secondary injury and leads to better

locomotor recovery following spinal cord injuries [58].; (9) early application of ESWT facilitated the activity of macrophages and Schwann cells, which affect the survival and regeneration of neurons [59,60]. 10) ESWT treatment is effective in improving the function of peripheral nerves and also show a positive effect on the prevention of atrophy associated with denervation [61].

Evidences from the searched articles

Review of the scientific evidences including methodology components and main results of ESWT treatment on upper limb and lower limb muscles affected by post-stroke spasticity are as in the Table 1 and Table 2, respectively.

	Santamato *et al.* [62]	**Daliri *et al.* [63]**	**Manganotti *et al* [64]**	**Troncati *et al.* 65]**	**Li TY *et al* [66]**
Evidence level	Randomized Controlled Trial, Double blinded	Clinical Controlled Trial, Single blinded	Clinical Controlled Trial, Single blinded	Clinical Case Report	A prospective, randomized, placebo-controlled, single-blind study
Included patients (n)	32	15	20	12	60
Patients in the ESW and control group (n)	16,16	15	20	12 No control	Group A: 20 Group B: 20 Group C: 20
Mean age in ESWT and control group	64.4±6.09 yrs 63.1±7.03 yrs	54.4±9.4 yrs	63.0 (38 ±76) yrs	68.0 (34 ± 86) yrs	Group A: 55.35±3.05 (33–74) Group B: 56.80±3.00 (26–73) Group C: 55.95±2.64 (26–75)
Gender in the ESWT and control group	9 F/7 M 10 F/6 M	3 F/12 M	9 F/11 M	1 F/11 M 10 F/6 M	Group A: 8F/12M Group B: 5F/15M Group C: 6F/14M
Treatment in the ESWT and control group	BTA±ESWT BTA±ES	Active ESW Sham ESW	Active ESW Sham ESW	Active ESW No control	Group A : 3 rESWT Group B : 1 rESWT Group C: 3 sham rESWT
Type of Stroke in the ESWT and Control Group	N/A	13 IS/2 HS Healthy	15 IS/5 HS No control	6 IS/6 HS No control	Group A: 10 IS/10 HS Group B: 10 IS/10 HS Group C: 12 IS/8 HS
Onset of stroke in the ESW and control group	2.5±1.5 mo.	53.4±23.9 mo.	17.6±2.36 mo.	24.9±11.9 mo.	Group A: 61.70±9.73 (9–144) mo. Group B: 66.65±9.56 (16–168) mo. Group C: 66.95 ± 10.04 (11–168) mo.
Involved muscles	Superficial fingers flexors	Carpal flexors	1)Flexor muscles of the forearm mainly in the middle of the belly 2)Each interosseous muscle of the hand	1) Flexor muscles of the forearm mainly in the middle of the belly 2)Each interosseous muscle of the hand	1) Flexor carpi ulnaris and Flexor carpi radialis, mainly in the middle of the belly. 2) Intrinsic muscles and flexor digitorum tendon
Type of ESWT source	Focus, Electromagnetic	Radial Pneumatic	Focus, Electromagnetic	Focus, Electromagnetic	Radial
Brands of ESWT	Minilith SL1; Storz Medical, Switzerland	BTL Industries Ltd, United Kingdom	Modulith SLK® by Storz Medical AG	Modulith SL by Storz Medical	Physio Shock Wave Therapy (Pagani Elettronica, Milano, Italy)
Number of ESWT pulse	2000	1500	1) 1500 2) 3200 (800 each)	1) 1600 2) 800	3) 1500 4) 4000
Parameter of ESWT	0.03 mJ/mm2 1.5 bar, 4Hz	0.03 mJ/mm2 1.5 bar, 4Hz	0.03 mJ/mm2 1.5 bar, 4Hz	1) 0.105 mJ/mm2 2) 0.08 mJ/ mm2 N/A bar N/A Hz	1) 3.5 bar 5 Hz 2) 3 bar 5 Hz
Period of ESWT	1 x day during a period of 5 days (5 sessions)	1 x sham ESW (I stage), 1 wk. "wash-out"period, 1x active ESW (II stage)	1x sham ESW (I stage), 1 wk. "wash-out"period, 1x active ESW (II stage)	1x wk. for 2 wk. (2 sessions)	Group A: 1x wk. for 3 wks. Group B: 1 session Group C: 1x wk. for 3 wks.
FU analysis	2, 4 and 12 wk.	1 and 5 wk.	1, 4 and 12 wk.	3, 6 mo.	1, 4,8,12 and 16 wk.
F/U analysis	Reduction of the spasticity level in MAS ($p<0.05$) Diminishment of the spasm frequency in Spasm frequency score ($p<0.05$) Significant decrease of painful episodes in VAS ($p<0.05$)	Reduction of the spasticity level in MAS ($p<0.05$) Significant alterations of parameters in the nag examination ($p<0.05$) Non-significant changes on the level of limb paresis in BRS ($p>0.05$)	Reduction of the spasticity level in MAS ($p<0.001$) Significant improvement with in the prom ($p<0.001$) Non- significant alterations in the nEMG examination ($p>0.001$)	Reduction of the spasticity level in MAS ($p<0.05$) Decrease on the level of limb paresis in FMS ($p<0.05$) Non-significant changes of painful episodes in VAS ($p>0.05$)	rESWT decreases spasticity in the flexor muscles of the wrist and hand in patients with chronic stroke. This effect persists at least 16 weeks and 8 to 12 weeks after 3 sessions and 1 session of rESWT, respectively.

	Santamato *et al.* [62]	**Daliri *et al.* [63]**	**Manganotti *et al* [64]**	**Troncati *et al.* 65]**	**Li TY *et al* [66]**
Clinical appraisals	The efficacy of combined treatment of BTX-A with ESWT, has greater efficacy than with ES. Given the clinical use of these combined interventions.	The Brunnstrom recovery stage did not improve after either sham or active ESWT. The possible reason could be that a single session ESWT was administered or the small number of patients included in the study.	At 12 weeks after therapy, 10 of the 20 patients showed persistent reduction in muscle tone. There were no adverse events associated with ESWT. No changes were observed in either the amplitude or latency of distal motor action potential and late responses, excluding a significant effect of shock wave therapy on peripheral nerves and spinal excitability.	The use of the MAS in the assessment of spasticity has been questioned because it measures a combination of spasticity and mechanical resistance, related to the viscoelastic properties of soft tissues and joints. However, since ESWT seems to have effects mainly on muscular mechanical resistance, MAS may be considered suitable for the assessment of the effects of this therapy. 2 sessions of ESWT seem to have long-term effects in reducing muscle tone and in enhancing motor impairment.	Whether rESWT therapy is superior to fESWT in reducing spasticity is still uncertain. rESWT is characterized by having a larger therapeutic area compared with fESWT, and specific focusing is less important. Hence, rESWT seems more suitable for treating spasticity because it can be applied to the whole muscle belly rather than a small spot in the muscle. To confirm this hypothesis, further study is needed in the future.

Table 1: Review of the scientific evidences including methodology components and main results of ESWT treatment on upper limb muscles affected by post-stroke spasticity

	Moon *et al.* [67]	**Sohn *et al.* [68]**	**Kim *et al.* [69]**	**Santamato *et al.* [70]**	**Taheri *et al* [71]**
Evidence level	Clinical Controlled Trial, Open label, cross over study	Clinical Controlled Trial, Open label study	Prospective Clinical Trial, Open label study	Prospective Clinical Trial, Open label study	Prospective randomized controlled trial
Included patients (n)	30	20 20	10	23	25
Patients in the ESW and control group (n)	30 (I+II stage)	10	10	23	13,12
Mean age in ESWT and control group	52.6+ +14.9 yrs.	54.4+9.4 yrs.	63.0 (38+76) yrs.	68.0 (34+86) yrs.	ESWT: 56.5±11.6 Control: 54.9±9.4
Gender in the ESWT and control group	13 F/17 M	6 F/4 M 4 F/6 M	5 F/5 M No control	8 F/15 M No control	4F/9M 4F/8M
Treatment in the ESWT and control group	Active ESW Sham ESW	Active ESW Sham ESW	Active ESW No control	Active ESW No control	ESWT: plus ESWT Both groups: Oral Tizanidine hydrochloride daily 2 mg for first 4 day then 4 mg till end + Stretching exercises included 30 min/day, 5 days per week
Type of Stroke in the ESWT and Control Group	16 IS/14 HS	2 IS/8 HS	5 IS/5 HS No control	12 IS/11 HS No control	ESWT: 11 IS/2 HS Control: 11 IS/1 HS

	Moon *et al.* [67]	**Sohn *et al.* [68]**	**Kim *et al.* [69]**	**Santamato *et al.* [70]**	**Parameter of ESWT**
Gender in the ESWT and control group	13 F/17 M	6 F/4 M 4 F/6 M	5 F/5 M No control	8 F/15 M No control	4F/9M 4F/8M
Treatment in the ESWT and control group	Active ESW Sham ESW	Active ESW Sham ESW	Active ESW No control	Active ESW No control	ESWT: plus ESWT Both groups: Oral Tizanidine hydrochloride daily 2 mg for first 4 day then 4 mg till end + Stretching exercises included 30 min/day, 5 days per week
Type of Stroke in the ESWT and Control Group	16 IS/14 HS	2 IS/8 HS	5 IS/5 HS No control	12 IS/11 HS No control	ESWT: 11 IS/2 HS Control: 11 IS/1 HS
Onset of stroke in the ESW and control group	2.5+1.5 mo.	53.4+23.9 mo.	17.6+2.36 mo.	24.9+11.9 mo.	ESWT: 33±21.4 mo. Control: 25.8±9.9 mo.
Involved muscles	Gastrocnemius (both bellies)	Gastrocnemius (medial belly) at the middle of the belly	Gastrocnemius (medial belly)	Gastrocnemius (both bellies)+soleus	Gastrocnemius (both bellies) at musculotendinous junction
Type of ESWT source	Focus, Piezoelectric	Focus, Electrohydraulic	Radial Pneumatic	Focus, Electromagnetic	Focus, Electromagnetic
Brand of ESWT	a PiezoWave (Richard Wolf GmbH, Knittlingen, Germany)	Evotron® (SwiTech, Kreuzlingen, Switzerland)	The ShockMaster 500 (APSUN Inc., GymnaUniphy, NV, Belgium)	EvoTron RFL0300 (Sanuwave AG, Lengwil, Switzerland).	Dornier AR2 machine (Dornier MedTech GmbH, Wessling, Germany).
Number of ESWT pulse	1500	1500	1500	1500	1500
Parameter of ESWT	0.089 mJ/mm2 1.5 bar, 4Hz	0.10 mJ/mm2 N/A bar N/A Hz	0.089 mJ/mm2 N/A bar, 4 Hz	0.10 mJ/mm2 N/A bar N/A Hz	0.10 mJ/mm2 N/A bar, 4 Hz
Period of ESWT	1 x sham ESW (I stage), 1 wk. "wash-out" period, 3 x active ESW (II stage)	Single ESW session	1 x day during a period of 3 days (3 sessions)	1x wk. during a period of 2 wk. (2 sessions)	1x wk. for 3 wk.
FU analysis	1 and 4 wk.	None	1.5 and 6 mo.	1 mo.	1,3,12 wk.
F/U analysis	Reduction of the spasticity level in MAS ($p<0.05$) Short-term improvement of the peak eccentric torque (PET) and torque threshold angle (TTA) parameters in isokinetic tests ($p<0.05$) Non-significant Changes on the level of limb paresis in FMS ($p>0.05$) Non-significant improvement within the prom ($p>0.05$)	Reduction of the spasticity level in MAS ($p<0.05$) Non-significant alterations in the nEMG examination ($p>0.05$)	Reduction of the spasticity level in MAS ($p<0.001$) Significant decrease of painful episodes in VAS ($p<0.001$ Significant improvement in gait function in FGA ($p<0.001$) Diminishment of the plantar fascia thickness ($p<0.001$)	Reduction of the spasticity level in MAS ($p<0.01$ or $p<0.05$) Significant improvement within the prom ($p<0.01$ or $p<0.05$) Non-significant alterations in the nEMG examination ($p>0.05$)	Pain score, MAS, ROM and LL functional score are significantly improvement since the first treatment session, and the effect persisted until the end of the study period at 12 wk.

	Moon *et al.* [67]	**Sohn *et al.* [68]**	**Kim *et al.* [69]**	**Santamato *et al.* [70]**	**Taheri *et al* [71]**
Clinical appraisals	PET is known to primarily reflect the intrinsic stiffness at low angular speeds as well as the entire spasticity, including both intrinsic stiffness and stretch reflex at high angular speeds. TTAs tend to primarily reflect the stretch reflex element of spasticity rather than the stiffness of joints themselves. The TTA statistically significantly increased only immediately after the treatment at all angular speeds probably because the ESWT affects the intrinsic stiffness element more than the stretch reflex element of spasticity. The musculotendinous junction of the medial and lateral gastrocnemius were stimulated once a week for a total of 3 weeks, the spasticity significantly relieved immediately after the treatment but the treatment effects decreased with time and became not statistically significant at four weeks after the treatment.	Results showed no significant changes in F wave minimal latency, H-reflex latency, or H-M ratio after treatment. Therefore, can be eliminated as the mechanism by which ESWT reduces spasticity by decreasing spinal excitability. Another possible mechanism which can be rule out is mechanical vibratory stimulation, which reduces excitability of motor neurons and induces the change of F wave since no significant change of F wave or H-reflex were detected. Considering the clinical anti-spastic effect observed up to 4 weeks after treatment, mechanical vibratory stimulation, which is transitory and short lasting, could also be excluded as a major effect.	The application of ESWT to stroke patients with plantar fasciitis has a positive effect on the thickness of the plantar fascia, spasticity, degree of pain, and gait ability. ESWT helps in improving expansibility in the plantar fascia and spasticity and helps to relieve pain and enhance gait ability.	ESWT is safe and effective for the treatment of post stroke plantar-flexor muscles spasticity, reducing muscle tone and improving passive ankle dorsiflexion motion. The effect was long lasting in subjects with echo intensity of calf muscles graded I, II, or III but was brief for echo intensity graded IV on the Heckmatt scale. The ESWT effect did not appear to be related to spinal excitability.	ESWT combined with oral antispasticity and stretching exercises can decrease spasticity and improve lower extremity function.

Table 2: Review of the scientific evidences including methodology components and main results of ESW treatment on lower limb muscles affected by post-stroke spasticity

Guo P, *et al* conducted a meta-analysis to combine the results of previous studies to arrive at a summary conclusion. The pooled data immediately after ESWT and 4 weeks after ESWT compared with baseline date all suggested that ESWT had a significant effect on relieving spasticity caused by stroke measured by MAS grades. Moreover, no serious adverse effects were observed in any patients after shock wave therapy. But the differences in the subtype of shock wave, therapeutic energy, treatment sessions, and tested muscles might lead to the varied effects reported in selected studies, leading to a significant level of heterogeneity among the studies [72].

Conclusion

ESWT is effective in treating spasticity and improving some parameters, although the improvement more significant immediately after apply ESWT and diminished with time. The non-invasive nature of ESWT and its much fewer adverse effects, it can be a useful alternative for treating spasticity especially in stroke patients or combined with other therapies as botulinum toxin injection, oral antispasticity drugs and stretching exercises. The various mechanisms are evidenced for ESWT in decreasing spasticity and enhance functions. However, the neurorehabilitation treatment as strengthening exercises for the antagonist muscles, endurance exercises, balance and coordination training are also need for enhancement the movement ability and the functional outcome of the patients.

References

1. Lance JW (1980) The control of muscle tone, reflexes, and movement: Robert Wartenberg lecture. Neurol 30: 1303-13.

2. Trompetto C, Marinelli L, Mori L, Pelosin E, Curra A, et al. (2014) Pathophysiology of spasticity: Implications for neurorehabilitation. Biomed Res Int 2014: 354906.

3. Mullick AA, Musampa NK, Feldman AG, Levin MF (2013) Stretch reflex spatial threshold measure discriminates between spasticity and rigidity. Clin Neurophysiol 124: 740-51.

4. Tardieu G, Tardieu C, Colbeau-Justin P, Bret MD (1982) Effects of muscle length on an increased stretch reflex in children with cerebral palsy. J Neurol Neurosurg Psychiatry 258: 348-52.

5. Rymer WZ, Houk JC, Crago PE (1979) Mechanisms of the clasp-knife reflex studied in an animal model. Exp Brain Res 37: 93-113.

6. Kamper DG, Schmit BD, Rymer WZ (2001) Effect of muscle biomechanics on the quantification of spasticity. Ann Biomed Eng 29: 1122-34.

7. Mukherjee A, Chakravarty A (2010) Spasticity mechanisms for the clinician. Front Neurol 1: 149.

8. Kheder A, Nair KP (2012) Spasticity: Pathophysiology, evaluation and management. Pract Neurol 12: 289-98.

9. Lim JS, Kang DW (2015) Stroke connectome and its implications for cognitive and behavioral sequelae of stroke. J Stroke 17: 256-67.

10. Thibaut A, Chatelle C, Ziegler E, Bruno MA, Laureys S, et al. (2013) Spasticity after stroke: Physiology, assessment and treatment. Brain Inj 27: 1093-105.

11. Reinkensmeyer DJ, Guigon E, Maier MA (2012) A computational model of use-dependent motor recovery following a stroke: Optimizing corticospinal activations via reinforcement learning can explain residual capacity and other strength recovery dynamics. Neural Netw 30: 60-9.

12. Berg HE, Larsson L, Tesch PA (1997) Lower limb skeletal muscle function after 6 weeks of bed rest. J Appl Physiol 82:182-8.

13. Ferretti G, Berg HE, Minetti AE, Moia C, Rampichini S, et al. (2001) Maximal instantaneous muscular power after prolonged bed rest in humans. J Appl Physiol 90: 431-5.

14. Tizard JP (1980) Cerebral palsies: Treatment and prevention. The Croonian Lecture 1978. J R Coll Physicians Lond 14: 72-80.

15. Hefter H, Jost WH, Reissig A, Zakine B, Bakheit AM, et al. (2012) Classification of posture in post-stroke upper limb spasticity: A potential decision tool for botulinum toxin A treatment? Int J Rehabil Res 35: 227-33.

16. Marciniak C (2011) Post-stroke hypertonicity: Upper limb assessment and reatment. Top Stroke Rehabil 18: 179-94.

17. Schmitz C, Császár NB, Rompe JD, Chaves H, Furia JP (2013) Treatment of chronic plantar fasciopathy with extracorporeal shock waves (review). J Orthop Surg Res 8: 31-41.

18. Ioppolo F, Rompe JD, Furia JP, Cacchio A (2014) Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. Eur J Phys Rehabil Med 50: 217-30.

19. Speed C (2014) A systematic review of shockwave therapies in soft tissue conditions: focusing on the evidence. Br J Sports Med 48: 1538-42.

20. Cacchio A, Giordano L, Colafarina O, Rompe JD, Tavernese E, et al. (2009) Extracorporeal shock-wave therapy compared with surgery for hypertrophic long-bone nonunions. J Bone Joint Surg Am 91: 2589-97.

21. Rompe JD, Furia JP, Maffulli N (2009) Eccentric loading versus eccentric loading plus shock-wave treatment for midportion Achilles tendinopathy: a randomized controlled trial. Am J Sports Med 37: 463-70.

22. Lee SS, Kang S, Park NK, Lee CW, Song HS, et al. (2012) Effectiveness of initial extracorporeal shock wave therapy on the newly diagnosed lateral or medial epicondylitis. Ann Rehabil Med 36: 681-7.

23. Vetrano M, Castorina A, Vulpiani MC, Baldini R, Pavan A, et al. (2013) Platelet rich plasma versus focused shock waves in the treatment of jumper's knee in athletes. Am J Sports Med 41: 795-803.

24. Rompe JD, Furia J, Weil L, Maffulli N (2007) Shock wave therapy for chronic plantar fasciopathy. Brit Med Bul 81-82: 183-208.

25. Gleitz M (2011) Shockwave Therapy in Practice: Myofascial Syndrome and Trigger Points, Level 10 Book, (1st edn) Germany.

26. Schmitz C, Nikolaus BM, Stefan M, Matthias S, Nicola M, et al. (2015) Efficacy and safety of extracorporeal shock wave therapy for orthopedic conditions: a systematic review on studies listed in the PEDro database. Br Med Bull 116: 115-38.

27. Suputtitada A, Schmitz C (2016) Extracorporeal Shock Wave Therapy (ESWT) in Musculoskeletal Disorders. 10th ISPRM Congress.

28. Suputtitada A (2016) Novel approaches for chronic pain. Int J Phys Med Rehabil 4: 350.

29. Saggini R, Di Stefano A, Saggini A, Bellomo RG (2015) Clinical application of shock wave therapy in musculoskeletal disorders: part II related to myofascial and nerve apparatus. J Biol Regul Homeost Agents 29: 771-85.

30. Ramon S, Gleitz M, Hernandez L, Romero LD (2015) Update on the efficacy of extracorporeal shockwave treatment for myofascial pain syndrome and fibromyalgia. Int J Surg 24: 201-6.

31. Wang CJ (2012) Extracorporeal shockwave therapy in musculoskeletal disorders. J Orthop Surg Res 7: 11.

32. Notarnicola A, Moretti B (2012) The biological effects of extracorporeal shock wave therapy (eswt) on tendon tissue. Muscles Ligaments Tendons J 2: 33-7.

33. Speed C (2014) A systematic review of shockwave therapies in soft tissue conditions: focusing on the evidence. Br J Sports Med 48: 1538-42.

34. Zhang D, Kearney CJ, Cheriyan T, Schmid TM, Spector M (2011) Extracorporeal shockwave-induced expression of lubricin in tendons and septa. Cell Tissue Res 346: 255-62.

35. Romeo P, Lavanga V, Pagani D, Sansone V (2014) Extracorporeal shock wave therapy in musculoskeletal disorders: a review. Med Princ Pract 23: 7-13.

36. Hausdorf J, Lemmens MA, Heck KD, Grolms N, Korr H, et al. (2008) Selective loss of unmyelinated nerve fibers after extracorporeal shockwave application to the musculoskeletal system. Neuroscience 2008; 155:138-44.

37. Suputtitada A (2017) Myofascial pain syndrome and sensitization. Physic Med Rehabilita Res 10.15761/PMRR.1000127.

38. Suputtitada A (2017) Novel PMR approaches to MYOPAIN conditions. In: Sharan D,Samuel RJ eds. MYOPAIN2017 Breakthroughs in muscle pain research & practice, (1st edn) 2017: 69-74.

39. Kearney CJ, Prevost T, Socrate S, Spector M (2010) Pressure-time profiles of a focused and a radial shockwave device:measurements in tissue, ex vivo, and in a water bath. J Acoust Soc Am 128: 2364.

40. Gotte G, Amelio E, Russo S, Marlinghaus E, Musci G, et al. (2002) Short-time non-enzymatic nitric oxide synthesis from L-arginine and hydrogen peroxide induced by shock waves treatment. FEBS Lett 520: 153-5.

41. Suzuki H, Amelio E, Cavalieri E, Mariotto S, Galasso O, et al. (2003) Effect of shock wave on the catalytic activity of endothelial nitric oxide synthase in umbilical vein endothelial cells. Ital J Biochem 52: 16-20.

42. Mariotto S, Cavalieri E, Amelio E, Campa AR, Carcereri de Prati A, et al. (2005) Extracorporeal shock waves: from lithotripsy to anti-inflammatory action by NO production. Nitric Oxide 12: 89-96.

43. Ciampa AR, Carcereri de Prati A, Amelio E, Cavalieri E, Persichini T, et al. (2005) Nitric oxide mediates anti-inflammatory action of extracorporeal shock waves. FEBS Lett 579: 6839-45.

44. Blottner D, Luck G (2001) Just in time and place: NOS/NO system assembly in neuromuscular junc formation. Micros Res Tech 55: 171-80.

45. Molina JA, Jimenez Jimenez FJ, Ortì Paregja M, Navarro JA (1998) The role of nitric oxide in neurodegeneration. Potential for pharmacological intervention. Drugs Aging 12: 251-9.

46. Manganotti P, Amelio E (2005) Long term effect of shock wave therapy on upper limb hypertonia in patients affected by stroke. Stroke 36: 1967-71.

47. Russo S, Marlinghaus E, Amelio E, Corrado B, Galasso O, et al. (2000) The ESWT in the treatment of pseudoorthtosis: The osteoangiogenetic response. Giornale Italiano di Ortopediae Trumatologia 26: 6-12.

48. Siebrt W, Buch M (1998) Extracorporeal shock wave in orthopaedics. Heidelberg: Springer-Verlag Berlin, Germany.

49. Valchanov VD, Michailov P (1991) High energy shock waves in the treatment of delayed and nonunion of fractures. Int Orthop 15: 181-4.

50. Rompe JD, Burger R, Hopf C, Eysel P (1998) Shoulder function after extracorporeal shock wave therapy for calcific tendinitis. J Shoulder Elbow Surg 7: 505-9.

51. Loew M, Deacke W, Kusnierczak D, Rahmanzadeh M, Ewerbeck V (1999) Shock-wave therapy is effective for chronic calcifying tendinitis of the shoulder. J Bone Joint Surg 81: 863-7.

52. Rompe JD, Hopf C, Kullmer K, Heine J, Burger R (1996) Analgesic effect of ESWT on chronic tennis elbow. J Bone Joint Surg 78: 233-7.

53. Rompe JD, Decking J, Schoellner C, Nafe B (2003) Shock wave application for chronic plantar fasciitis in running athletes: a prospective, randomized, placebo-controlled trial. Am J Sports Med 31: 68-75.

54. Leone JA, Kukulka CG (1988) Effects of tendon pressure on alpha motoneuron excitability inpatients with stroke. Phys Ther 68: 475-80.

55. Ward AB and Kadies M (2002) The management of pain in spasticity. Disabil Rehab 24: 443-53.

56. Gonkova MI, Ilieva EM, Ferriero G, Chavdarov I (2013) Effect of radial shock wave therapy on muscle spasticity in children with cerebral palsy. Int J Rehab Res 36: 284-90.

57. Hausner T, Pajer K, Halat G, Hopf R, Schmidhammer R, et al. (2012) Improved rate of peripheral nerve regeneration induced by extracorporeal shock wave treatment in the rat. Exp Neurol 236: 363-70.

58. Yamaya S, Ozawa H, Kanno H, Kishimoto KN, Sekiguchi A, et al. (2014) Low-energy extracorporeal shock wave therapy promotes vascular endothelial growth factor expression and improves locomotor recovery after spinal cord injury. J Neurosurg 121: 1514-25.

59. Lee JH, Kim SG (2015) Effects of extracorporeal shock wave therapy on functional recovery and neurotrophin-3 expression in the spinal cord after crushed sciatic nerve injury in rats. Ultrasound Med Biol 41: 790-6.

60. Schuh CM, Heher P, Weihs AM, Banerjee A, Fuchs C, et al. (2014) In vitro extracorporeal shock wave treatment enhances stemness and preserves multipotency of rat and human adipose-derived stem cells. Cytotherapy 16: 1666-78.

61. Kenmoku T, Ochiai N, Ohtori S, Saisu T, Sasho T, et al. (2012) Degeneration and recovery of the neuromuscular junction after application of extracorporeal shock wave therapy. J Orthop Res Off Publ Orthop Res Soc 30:1660-5.

62. Santamato A, Notarnicola A, Panza F, Ranieri M, Micello MF, et al. (2013) SBOTE study: Extracorporeal shock wave therapy versus electrical stimulation after botulinum toxin type A injection for post-stroke spasticity – A prospective randomized trial. Ultrasound Med Biol 39: 283-91.

63. Daliri SS, Forogh B, Emami Razavi SZ, Ahadi T, Madjlesi F, et al. (2015) A single blind, clinical trial to investigate the effects of a single session extracorporeal shock wave therapy on wrist flexor spasticity after stroke. NeuroRehabilitation 36: 67-72.

64. Manganotti P, Amelio E (2005) Long-term effect of shock wave therapy on upper limb hypertonia in patients affected by stroke. Stroke J Cereb Circ 36: 1967-71.

65. Troncati F, Paci M, Myftari T, Lombardi B (2013) Extracorporeal Shock Wave Therapy reduces upper limb spasticity and improves motricity in patients with chronic hemiplegia: A case series. NeuroRehabilitation 33: 399-405.

66. Li TY, Chang CY, Chou YC, Chen LC, Chu HY, et al. (2016) Effect of Radial Shock Wave Therapy on Spasticity of the Upper Limb in Patients with Chronic Stroke: A Prospective, Randomized, Single Blind, Controlled Trial. Medicine 95: e3544.

67. Moon SW, Kim JH, Jung MJ, Son S, Lee JH, et al. (2013) The effect of extracorporeal shock wave therapy on lower limb spasticity in subacute stroke patients. Ann Rehabil Med 2013 37: 461-70.

68. Sohn MK, Cho KH, Kim YJ, Hwang SL (2011) Spasticity and electrophysiologic changes after extracorporeal shock wave therapy on gastrocnemius. Ann Rehabil Med 35: 599-604.

69. Kim TG, Bae SH, Kim GY, Kim KY (2015) The effects of extracorporeal shock wave therapy on stroke patients with plantar fasciitis. J Phys Ther Sci 27: 523-6.

70. Santamato A, Micello MF, Panza F, Fortunato F, Logroscino G, et al. (2014) Extracorporeal shock wave therapy for the treatment of poststroke plantar-flexor muscles spasticity: a prospective open-label study. Top Stroke Rehabil 1: S17-24.

71. Taheri P, Vahdatpour B, Mellat M, Ashtari F, Akbari M (2017) The Effect of Extracorporeal Shock Wave Therapy on Lower Limb Spasticity in Stroke. Patients. Arch Iran Med 20: 338-43.

72. Guo P, Gao F, Zhao T, Sun W, Wang B, et al. (2017) Positive effects of extracorporeal shock wave therapy on spasticity in poststroke patients: A meta-analysis. J Stroke Cerebrovasc Dis 26: 2470-6.