ORIGINAL ARTICLE

Improvement of Hand Motor Function after Radial Shock Wave Therapy in Chronic Stroke Patients

M. Kamaluddin K, Erna Setiawati, Tanti Ajoe Kesoema

Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Diponegoro University, Kariadi General Hospital, Semarang, Indonesia

ABSTRACT

Introduction: The Radial Shock Wave Therapy (RSWT) expected could improve spasticity and hand function in chronic stroke patients. This study aimed to find out the improvement of hand function after RSWT as an additional therapy in chronic stroke patients.

Methods: Design study was a randomized controlled trial, in December 2018. The patients were assigned randomly to the experimental group (Infrared, Stretching, and RSWT) and control group (Infrared and Stretching) for six weeks. Hand motor function was measured using Fugl-Meyer Motor Assesment (FMA) before and after intervention.

Results: The median values of wrist FMA scores in the experimental and control group before and after intervention were 2 vs 5 ($p=0.001$) and 3 vs 4 ($p<0.001$) respectively. The median values of hand FMA scores in the experimental and control group before and intervention were 4 vs 6 ($p=0,.001$) and 4 vs 5 ($p<0.001$). However, the delta between before and after intervention was higher in experimental group.

Conclusion: The improvement of wrist and hand FMA scores after added treatment by RSWT was tend to higher.

Keywords: *Spasticity, Hand Function, Stroke, Radial Shock Therapy, Fugl-Meyer Motor Assesment*

ABSTRAK

Pendahuluan: Terapi Gelombang Shock Radial (*Radial Shock Therapy* - RSWT) diharapkan dapat memperbaiki spasisitas dan fungsi tangan pada pasien dengan stroke kronis. Penelitian ini bertujuan untuk mendapatkan keterangan mengenai perbaikan kualitas fungsi tangan setelah RSWT dilakukan sebagai terapi tambahan pada pasien dengan stroke kronis.

Metode: Desain penelitian adalah uji acak terkontrol. Pasien ditempatkan secara acak pada kelompok uji coba (Infrared, Peregangan, dan RSWT) dan kelompok kontrol (Infrared dan Peregangan) selama enam minggu. Fungsi motorik tangan diukur menggunakan *Fugl-Meyer Motor Assesment* (FMA) sebelum dan sesudah intervensi.**Hasil:** Nilai tengah dari skor FMA pergelangan tangan pada kelompok perlakuan dan kontrol sebelum dan sesudah intervensi adalah 2 dibanding 5 ($p=0.001$) dan 3 dibanding 4 ($p<0.001$). Nilai tengah skor FMA tangan pada kelompok perlakuan dan kontrol sebelum dan sesudah intervensi adalah 4 dibanding 6 ($p<0.001$) dan 4 dibanding 5 ($p<0.001$). Selisih nilai FMA pergelangan tangan dan tangan pada kelompok perlakuan lebih tinggi.

Kesimpulan: Nilai FMA pergelangan tangan dan tangan pada kelompok yang mendapat terapi tambahan RSWT memiliki skor yang cenderung lebih tinggi.

Kata kunci: Spasisitas, Fungsi Tangan, Stroke, Terapi Radial Syok, *Fugl-Meyer Motor Assesment*

Correspondent Detail:

M. Kamaluddin K
Email: kamaluddin.kacaribu@gmail.com
Phone: 089507055841
Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Diponegoro University, Kariadi General Hospital,
Semarang, Indonesia

INTRODUCTION

Spasticity is one of many consequences after stroke. It is characterized by a velocity-dependent increase in resistance during passive stretch, resulting from hyperexcitability of the stretch reflex. It is a common complication of stroke, but is only one of the many consequences of the UMN (Upper Motor Neuron) syndrome. It is considered a "positive" UMN sign since it represents excessive muscle tone and stretch reflex. Other so-called positive consequences include clonus and spasms. "Negative" consequences of the UMN syndrome, on the other hand, include weakness, impaired coordination, impaired motor control/ planning, and easy fatigability.[1]

Spasticity in this broader sense may interfere with motor function, and is a common reason for clinical interventions such as by physiotherapy, use of orthoses or other technical devices or drugs.[2] Spasticity should be appropriately treated because it inhibits normal movements and causes pain or postural

abnormality, thereby hindering patients' ability for daily living and affecting the quality of life of patients.[3,4] In particular, spasticity of the wrist and hand is a serious disabling and troublesome problem for stroke patients. Therefore, proper and active management of spasticity of the wrist and hand is necessary for successful stroke rehabilitation in terms of spasticity itself and motor function.[5]

In the clinical situation, superficial heat in the form of infrared (IR)[4,6] and stretching[7], are used for reduction of spasticity[4] and one of technique in the physical management of spasticity respectively.[7] The application of infra-red superficial heat may have a mechanical benefit within the spastic muscle as indicated by an increase in post-treatment passive range of motion (PROM). The visco-elastic properties of the muscles may improve post treatment. It has been suggested that combining superficial heat with passive stretches may maximise PROM benefits in spastic muscles.[8] There are numerous methods of applying the modality of stretching to a person, but historically, it is provided by clinicians in a hands-on manual fashion. Manual stretching techniques are heavily utilized as an adjunct to other therapeutic interventions.[9] Moreover, stretching exercise has been used as a basic modality for a long time in the rehabilitation field because of easy availability, fewer side effects, and cost-effectiveness.[3]

The necessity of new noninvasive treatment methods for spasticity has been raised because spasticity cannot be controlled sometimes even with diverse treatment methods as well as due to the existing side effects of oral drugs and the invasiveness of local treatment methods.[3,4,7]

Extracorporeal shock wave therapy (ESWT) is a new technology using a ballistic source to generate pressure waves. It has been used in diverse musculoskeletal diseases, such as plantar fasciitis, patellar tendinopathy, calcifying and non-calcific tendonitis of the shoulder.[4] Recently, Radial Shock Wave Therapy (RSWT) has been advised as a non-invasive alternative treatment for decreasing spasticity [4,7,10,11] which may lead to improvement in hand fuction.

Different types of ESWT modalities either radial ESWT[4] or focused ESWT[4,12] has been used in treatment of spasticity. Radial ESWT compared with conventional focused ESWT, is a low- to medium-energy shock wave generated when a projectile is accelerated by compressed air (1– 5 bar) with a low penetration power (less than 5 cm).[4,13,14] Tsung-Ying Li et al. in their study suggested that rESWT may be valuable in decreasing flexor spasticity of the hand and wrist with accompanying enhancement of hand function and wrist control in patients with chronic stroke. In addition, repetitive sessions of rESWT result in a longer-lasting and more noticeable effect, and are necessary for improving functional motricity.[4]

Radial ESWT was recommended over focused ESWT for treating of musculoskeletal disease due to its better effectiveness in clinical practice, no anesthesia or analgesics required and lower cost of the unit.[4,15,16] Effect of radial shock wave therapy which is good in clinical practice, no anesthesia or analgesics required, lower cost of the unit and only few studies investigating the effect of radial shock therapy on spasticity in stroke patients are background to investigate the effect of RSWT as an additional therapy in chronic stroke

patients getting infrared therapy and stretching exercises to hand function.

METHODS

Design study was a simple randomized controlled trial in chronic stroke patients with onset more than and equal to 1 year conducted from November to December 2018. Participants were recruited from medical rehabilitation outpatients of KRMT Wongsonegoro Hospital in Semarang.

Thirty consecutive stroke patients (13 males, 17 females; 40 to 65 years of age, 1 intracranial hemorrhage and 29 cerebral infarcts; 1 to 3.4 years of stroke onset) according to the following criteria: 1) Age: 18-70 years; 2) More than and equal to 1 year after stroke onset; 3) Motoric function ≥ 3 of grade; 4) Spasticity of the affected wrist and finger flexors Modified Ashworth Scale (MAS) ≥ 2 of scores;[5] 5) No contracture of the affected wrist or fingers; 6) No history of peripheral nerve injury or musculoskeletal disease (*e.g.*, arthritis, musculotendinous injury or bone fracture) in the affected upper extremity; and 7) No history of any invasive procedure (Botox, alcohol or phenol) for treatment of spasticity for at least 6 months before the start of this study. Patients with apraxia, somatosensory problems or cognitive problems (Mini-Mental State Examination Score of < 24) were excluded.[5]

The patients were assigned randomly to the experimental group (Infrared, Stretching, and RSWT) and control group (Infrared and Stretching). Patients assigned to the experimental group underwent six weeks of RSWT, once a week for six consecutive weeks, according to the treatment protocol but not conducted RSWT therapy for control group. Both the experimental and control group underwent six weeks of Infrared and stretching.

RSWT was applied by 1500 Shots of dose, 3.5 Bar of pressure and 5 Hz of frequency at midbelly of wrist flexor. Four thousand of shots, 3 bar of pressure, 5 Hz of frequency were applied at intrinsic muscles group of hand and tendon of flexor digitorum. They were conducted by applying gel as a coupling agent between skin and probe and performed once a week for six consecutive weeks.

Infrared therapy and stretching exercise of upper extremities were conducted in 3 times a week for 6 consecutive weeks. They were conducted in both the experimental and control group. Infrared therapy was applied in perpendicular direction to affected wrist, hand and conducted in distance between lamp and therapy 50 cm of area for 15 minutes. Stretching was conducted by therapist to muscles group of upper extremities which stretched and held for 10 seconds in each movement, 10 times of repetition and 3 set in each session.

Wrist and hand Fugl-Meyer Motor Assessment (FMA) Scores were used for evaluation of motor function.[5] The wrist and hand subsection of the FMA, consisting of 12 tasks scored using a 3-point ordinal scale (0 to 2; maximum score of 24), were used to evaluate motor function in affected wrist and hand. Motor function of affected wrist and hand were assessed two times. The first assessment was performed

before intervention and the second assessment were performed after intervention.

Data were analyzed using Statistical Package for the Social Sciences (SPSS) software (version 24.0) for Windows. Minimal sample for confidence interval of 95% and power test of 90% were 13 participants. The normality distributions were checked using Shapiro-Wilk Test. Mann Whitney and Wilcoxon Test were used to compare scores (Median Wrist FMAs, Median Hand FMAs) before and after intervention and also compare differences of increase in wrist and hand FMA scores between the experimental and control group. P value < 0,05 is considered statistically significant. Ethical approval was obtained from Health Research Ethic Committee of Medical Faculty of Diponegoro University.

RESULTS

Mean of age in the experimental and control group were 56.4 ± 6.03 and 54.9 ± 4.50 years respectively. Male in the experimental and control group were 7 and 6 respectively whereas female were 8 and 9 respectively. Stroke patients with infarct in the experimental and control group were 14 and 15 respectively whereas one stroke patient with intracranial hemorrhage was only in the experimental group. Mean of stroke duration in the experimental and control group were 1.8 ± 0.81 and 1.9 ± 0.79 years respectively. Hemiparetic left side in the experimenatal and control group were 5 and 6 respectively whereas hemiparetic right side were 10 and 9 respectively (Table 1).

Table 1. Characteristics of subjects

Variable	Percentage	
	Experimental Group (n=15)	**Control Group (n=15)**
Age (year) **(Mean ± SD)**	56.4 ± 6.03	54.9 ± 4.50
Sex		
Male	7 (46.7%)	6 (40.0%)
Female	8 (53.3%)	9 (60.0%)
Type of stroke		
Infarct	14 (93.3%)	15 (100%)
*ICH**	1 (6.7%)	0 (0.0%)
Stroke Duration (year) **(Mean ± SD)**	1.8 ± 0.81	1.9 ± 0.79
Hemiparetic affected side		
Left	5 (33.3%)	6 (40.0%)
Right	10 (66.7%)	9 (60.0%)

* ICH: Intra-cerebral Hemorrhage

Median of wrist FMA scores in the experimental and control group before intervention were 2 and 3 respectively whereas median of wrist FMA scores in the experimental and control group after intervention were 5 and 4 respectively. Both wrist FMA scores in the experimental and control group after intervention were increased significantly p = 0.001 and p = 0.001 respectively. However, difference of increased wrist FMA scores in the experimental group after intervention was more significant when compared with difference of increased wrist FMA scores in the control group after intervention p < 0.001 (Table 2, Figure 1).

Table 2. Wrist FMA scores in the Both Group Before and After Intervention

Wrist	Group		p
	Experimental	Control	
Pre	2	3	0.929‡
Post	5	4	0.009‡*
p	0.001†*	0.001†*	
Difference	3	1	<0.001‡*

* Significant (p < 0.05); ‡ Mann Whitney; † Wilcoxon

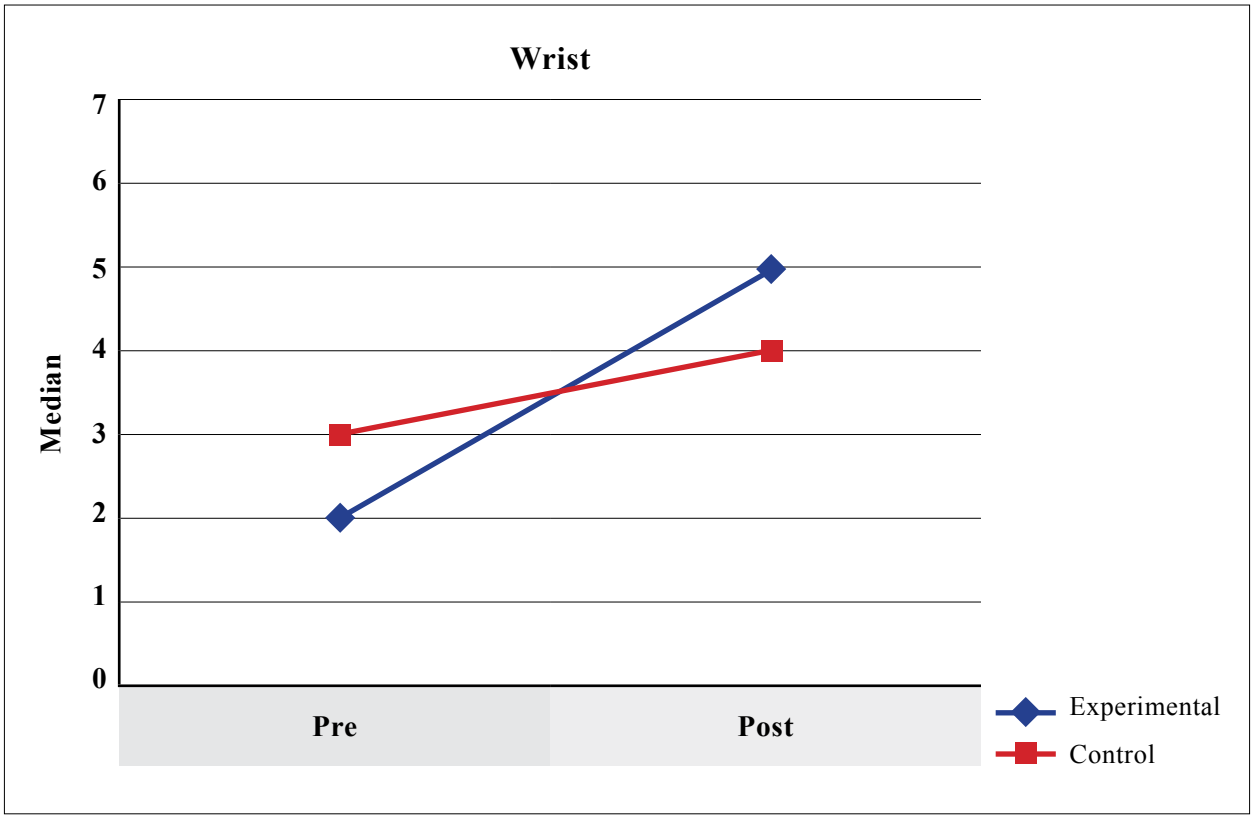

Figure 1. Median of Wrist FMA scores in the Both Group Before and After Intervention

Median of hand FMA scores in the experimental and control group before intervention were 4 and 4 respectively whereas median of hand FMA scores in the experimental and control group after intervention were 6 and 5 respectively. Both hand FMA scores in the experimental and control group after intervention were increased significantly $p < 0.001$ and $p < 0.001$ respectively. However, difference of increased hand FMA scores in the experimental group after intervention was more significant when compared with difference of increased hand FMA scores in the control group after intervention $p < 0.001$ (Table 3, Figure 2).

Table 3. Hand FMA scores Before and After Intervention

Hand FMA	Group		p
	Experimental	Control	
Pre	4	4	0.931‡
Post	6	5	0.012‡*
p	<0.001†*	<0.001†*	
Difference	2	1	<0.001‡*

* Significant ($p < 0.05$); ‡ Mann Whitney; † Wilcoxon

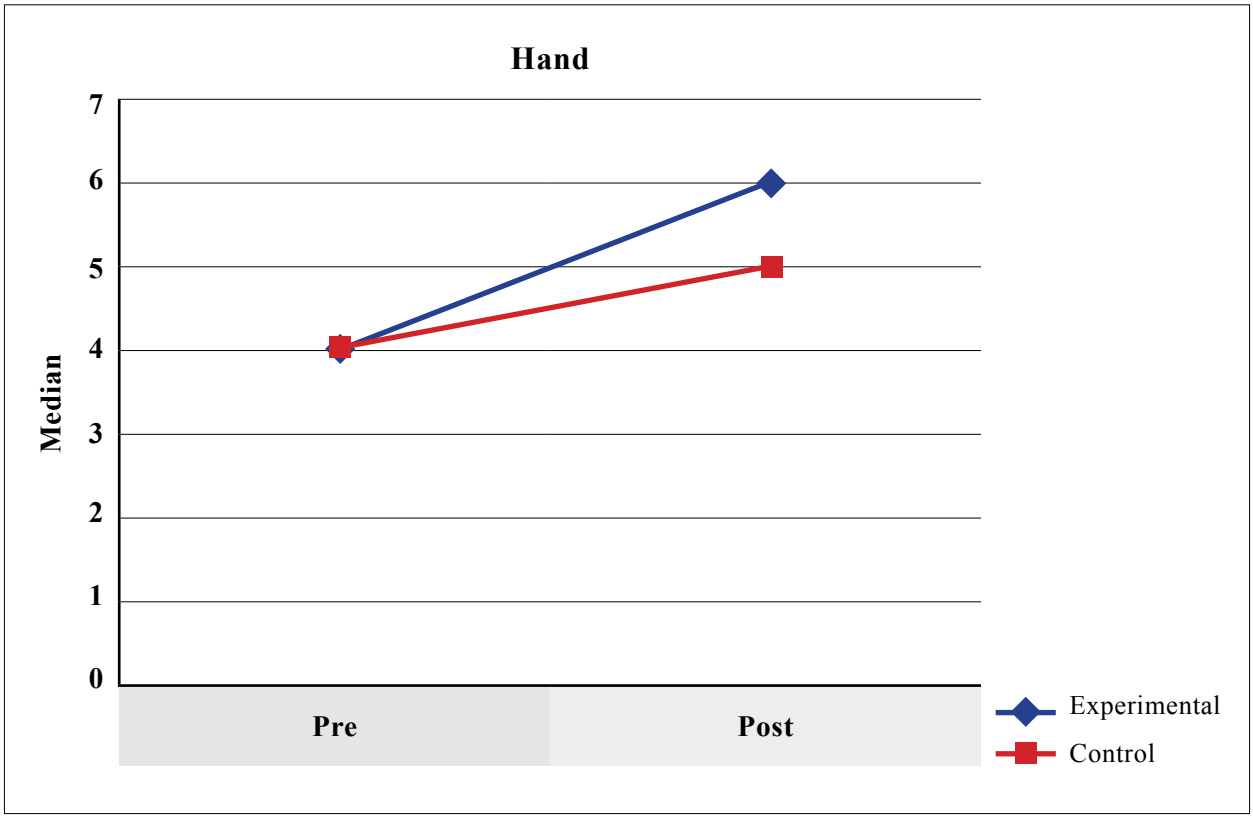

Figure 2. Median of Hand FMA scores in the Both Group Before and After Intervention

DISCUSSION

In this study, we investigated the effect of RSWT as an additional therapy in chronic stroke patients getting infrared therapy and stretching exercises. Our results were as follows: first, both wrist and hand FMA scores in the experimental and control group after intervention were increased significantly; second, difference of increased wrist and hand FMA scores in the experimental group after intervention were more significant when compared with difference of increased wrist and hand FMA scores in the control group over six weeks.

Based on this study we suggested that the affected wrist and hand in the experimental group improved better in wrist and hand FMA scores than the control group because decrease of spasticity in wrist and hand were more significant.

These findings were in agreement with Yoo et al. (2008), Bae et al. (2010), Kim et al., (2013) and Moon et al. (2013) who showed that lower limb spasticity significantly improved immediately after the ESWT treatment for total 3 sessions. The investigators suggested that the effect produced by ESWT depends on the mechanisms of shock wave generation, energy per unit area and the number of application.[4,5]

Yah Ting Wu et al. reported that there were increase in upper extremity Fugl-Meyer Motor Assessment scores significantly after using ESWT for spasticity therapy of upper extremity.[7] Tsung-Ying Li et al. also reported that there were improvement in upper extremity MAS and FMA scores significantly after using rESWT for spasticity therapy of upper extremity.[4] They were regarding to our study that showed increase of wrist and hand FMA scores.

In this study, we also found that the use of RSWT was proven safe for patients with chronic spastic stroke. Not noted any pain or side effects as mentioned in the literature can occur. High effectiveness with minimal side effects of RSWT can be the basis for consideration of the selection of RSWT as an additional therapy in the management of spasticity in stroke patient.

The mechanism of how ESWT relieves spasticity has not yet been clearly determined however suggested variable mechanisms have been proposed, including; 1) Induce nitric oxide (NO) synthesis which involved in the formation of neuromuscular junctions in the peripheral nervous system and play important roles in neurotransmission, memories, and synaptic plasticity in the central nervous system.[4,17] Neuromuscular transmission was hindered by ESWT in neuromuscular junctions.[4,18] 2) Shock waves would directly act on the golgi tendon organ to suppress motor nerve excitability.[4,11] 3) Stimulation effect of mechanical vibrations.[4] 4) Decreasing the stiffness of connective tissue by directly acting on the fibrosis of chronic hypertonic muscles.[4,19] 5) Localized ischemia in the areas of abnormal shortening of the muscles could improve, in turn inhibiting an increase in metabolism, reducing secretion of various pain inducing substances, inhibiting the induction of pain due to excessive stimulation of nociceptors of muscles, and increase the ROM.[4,20]

Limitation in this study, authors could not rule out the effect of physical activity that involved

the movement of the wrist and fingers joints, because there were no measuring devices that could provide limits on joint movements that could affect spasticity.

CONCLUSION

We concluded that application of RSWT combined with infra red and exercise therapy could improve hand function in chronic stroke patients.

REFERENCES

1. Li S, Francisco G.E. New insights into the pathophysiology of post-stroke spasticity. Frontier in Human Neuroscience 2015; 9 (192): 1-9. Available at: https://www.frontiersin.org/articles/10.3389/fnhum.2015.00192/full. Accessed July 16th, 2018.
2. Undström, E., Smits, A., Terént, A., & Borg, J.Time-course and determinants of spasticity during the first six months following first-ever stroke. Journal of Rehabilitation Medicine. 2010; 42(4): 296–301. Available at: https://www.ncbi.nlm.nih.gov/pubmed/20461330. Accessed July 23th, 2018.
3. Mori F, Koch G, Foti C, Bernardi G, Centonze D. The use of repetitive transcranial magnetic stimulation for the treatment of spasticity. Prog Brain Res 2009; 175: 429-39. Available at:https://www.ncbi.nlm.nih.gov/pubmed/19660671. Accessed July 27th, 2018.
4. Li Tsung-Ying, Chang Chih-Ya, Chou Yu-Ching, Chen Liang-Cheng, Chu Heng-Yi, Chiang Shang-Lin, et all. 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 (Baltimore) 2016; 95(18): 1-8. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4863782/. Accessed August 10th, 2018.
5. Jang Woo H., Kwon Hyuk C. , Yoo Kyong J., Jang Sung H. The effect of a wrist-hand stretching device for spasticity in chronic hemiparetic stroke patients. European Journal of Physical and Rehabilitation Medicine 2016; 52 (1): 65-71. Available at:https://www.minervamedica.it/en/journals/europamedicophysica/article.php?cod=R33Y2016N01A0065. Accessed August 14th, 2018.
6. Nakhostin Ansari N, Naghdi S., Hasson S., and Rastgoo M. Efficacy of therapeutic ultra sound and infrared in the management of muscle spasticity. Brain Injury 2009; 23(7-8): 632–8. Available at: https://www.ncbi.nlm.nih.gov/pubmed/19557566. Accessed August 18th, 2018.
7. Moon SW, Kim JH, Jung MJ, Son S, Lee JH, Shin H, et. al. The effect of extracorporeal shock wave therapy on lower limb spasticity in subacute stroke patients. Ann Rehabil Med 2013; 37 (4): 461-70. Available at: https://www.ncbi.nlm.nih.gov/pubmed/24020026. Accessed August 22th, 2018.
8. Monaghan Kenneth, Horgan Frances, Blake Catherine, Cornall Catherine, PM

Paula Hickey, E Lyons Bernadette, et. al. Physical treatment interventions for managing spasticity after stroke. The Cochrane Library. 2011; 7: 1-26. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6472515/. Accessed August 23th, 2018.

9. Naro A, Leo A, Russo M, Casella C, Buda A, Crespantini A, et.al. Breakthroughs in the spasticity management: Are non-pharmacological treatments the future? J Neurosci. 2017;39:16-27. doi: 10.1016/j.jocn.2017.02.044.

10. Sohn MK, Cho KH, Kim YJ, Hwang SL. Spasticity and electrophysiologic changes after extracorporeal shock wave therapy on gastrocnemius. Ann Rehabil Med. 2011; 35:599-604. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22506181. Accessed August 27th, 2018.

11. Bae H, Lee JM, Lee KH. The effects of extracorporeal shock wave therapy on spasticity in chronic stroke patients. J Korean Acad Rehabil Med. 2010; 34: 663-9. Available at: https://www.e-arm.org/journal/view.php?number=1038. Accessed August 27th, 2018.

12. Amelio E, Manganotti P. Effect of shock wave stimulation on hypertonic plantar flexor muscles in patients with cerebral palsy: a placebo-controlled study. J Rehabil Med. 2010; 42: 339-43. Available at: https://www.medicaljournals.se/jrm/content/html/10.2340/16501977-0522. Accessed August 28th, 2018.

13. Galasso O, Amelio E, Riccelli DA, Gasparini G. Short-term outcomes of extracorporeal shock wave therapy for the treatment of chronic non-calcific tendinopathy of the supraspinatus: a double-blind, randomized, placebo-controlled trial. BMC Musculoskeletal Disorders. 2012; 13(86): 1-9. Available at: https://bmcmusculoskeletdisord.biomedcentral.com/track/pdf/10.1186/1471-2474-13-86. Accessed August 25th, 2018.

14. Frassanito Paolo, Cavalieri Carlo, Maestri Roberto, Felicetti Guido. Effectiveness of Extracorporeal Shock Wave Therapy and kinesio taping in calcific tendinopathy of the shoulder: a randomized controlled trial. European Journal of Physical and Rehabilitation Medicine 2018; 54 (3): 333-40. Available at: https://www.minervamedica.it/en/journals/europamedicophysica/article.php?cod=R33Y2018N03A0333. Accessed August 26th, 2018.

15. Moon SW, Kim JH, Jung MJ, et. Al. The effect of extracorporeal shock wave therapy on lower limb spasticity in subacute stroke patients. Ann Rehabil Med. 2013; 37 (4): 461-70. Available at: https://www.e-arm.org/journal/view.php?doi=10.5535/arm.2013.37.4.461. Accessed August 29th, 2018.

16. Dymarek R, Taradaj J, Rosinczuk J. The effect of radial extracorporeal shock wave stimulationon upper limb spasticity in chronic stroke patients: a single-blind, randomized, placebo-controlled study. Ultrasound in Med. & Biol. 2016; pp: 1-14. Available at: https://www.umbjournal.org/article/S0301-5629(16)00145-9/fulltext. Accessed August 29th, 2018.

17. Mariotto S, de Prati AC, Cavalieri E,

Amelio E, Marlinghaus E, Suzuki H. Extracorporeal shock wave therapy in inflammatory diseases: molecular mechanism that triggers anti-inflammatory action. Curr Med Chem. 2009; 16: 2366-72. Available at: https://www.ncbi.nlm.nih.gov/pubmed/19601786. Accessed August 30th, 2018.

18. Kenmoku T, Ochiai N, Ohtori S, Saisu T, Sasho T, Nakagawa K, et al. Degeneration and recovery of the neuromuscular junction after application of extracorporeal shock wave therapy. J Orthop Res. 2012; 30: 1660-5. Available at: https://onlinelibrary.wiley.com/doi/full/10.1002/jor.22111. Accessed August 30th, 2018.
19. Vidal X, Morral A, Costa L, Tur M. Radial extracorporeal shock wave therapy in the treatment of spasticity in cerebral palsy: a randomized, placebo-controlled clinical trial. Neuro Rehabil. 2011; 29: 413-9. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22207070. Accessed August 30th, 2018.
20. Jeon JH, Jung YJ, Lee JY, Choi JS, Mun JH, Park WY, et al. The effect of extracorporeal shock wave therapy on myofascial pain syndrome. Ann Rehabil Med. 2012; 36: 665-4. Available at: https://www.e-arm.org/journal/view.php?doi=10.5535/arm.2012.36.5.665. Accessed August 30th, 2018.