Acute effect of shockwave therapy on plantar pressure distribution and balance in hemiparetic individuals

Efeito agudo da terapia por ondas de choque na pressão plantar e equilíbrio de indivíduos hemiparéticos

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Abstract

Introduction: Cerebral vascular accident (CVA) is the second leading cause of death and is one of the diseases that most generate disability Hemiparesis is the most common motor deficit, and one of its characteristics is asymmetry in weight bearing and in the plantar sup-port area, leading to balance deficits. extracorporeal shock-wave therapy (ESWT) has been shown to be effective in reducing post-stroke spasticity. **Objective:** To evaluate the effect of a ESWT session on the distribution of plantar pressure and on the static and dynamic balance of hemiparetic individuals after stroke. **Methods:** Twelve individuals with hemiparesis as a result of stroke in the chronic stage participated in the study. Data collection was divided into two days. On the first day, anamnesis and tests were performed: timed up and go (TUG), four square step test (FSST), and short physical performance battery (SPPB). After carrying out the tests, the distribution of plantar pressure was evaluated using baropodometry. Also on the first day, participants received ESWT in the muscle belly of the gastrocnemius muscle on the hemiparetic side. At the end of the ESWT session and after 7 days, the individuals were reassessed. **Results:** The results referring to the static and dynamic balance and baropodometry evaluations performed before, im-mediately after and one week after the application of ESWT did not show a significant difference between the three evaluations in any of the tests and in any of the moments performed. **Conclusion:** One ESWT session did not affect plantar pressure distribution and static and dynamic balance of hemiparetic individuals after stroke.

Keywords: Extracorporeal shockwave therapy. Postural balance. Stroke.

Resumo

Introdução: *O acidente vascular cerebral (AVC) é a segunda principal causa de morte e é uma das doenças que mais gera incapacidade. A hemiparesia é o déficit motor mais comum e tem como uma das características assimetrias na sustentação do peso e na área de apoio plantar, acarretando déficits de equilíbrio. A terapia por ondas de choque extracorpórea (TOCE) tem se mostrado eficaz na redução da espasticidade pós-AVC.* ***Objetivo:*** *Avaliar o efeito de uma sessão de TOCE na distribuição de pressão plantar e no equilíbrio estático e dinâmico de indivíduos hemiparéticos pós-AVC.* ***Métodos:*** *Participaram da pesquisa 12 indivíduos com hemiparesia em estágio crônico. A coleta de dados foi dividida em dois dias. No primeiro dia, realizaram-se anamnese e os testes* timed up and go *(TUG),* four square step test *(FSST) e* short physical performance battery *(SPPB). Após a realização dos testes, avaliou-se a distribuição da pressão plantar por meio da baropodometria. Ainda no primeiro dia, os participantes receberam a TOCE no ventre mus-cular do músculo gastrocnêmio do lado hemiparético. Ao término da sessão de TOCE e após 7 dias, os indivíduos foram reavaliados.* ***Resultados:*** *Os resultados referentes às avaliações do equilíbrio estático e dinâmico e da baropodometria realizados nos momentos antes, imediatamente após e uma semana após a aplicação da TOCE não apontaram diferença significativa entre as três avaliações em nenhum dos testes e em nenhum dos momentos realizados.* ***Conclusão:*** *Uma sessão de TOCE não afetou a distribuição de pressão plantar e o equilíbrio estático e dinâmico de indivíduos hemiparéticos pós-AVC.*

Plavras-chave: *Tratamento por ondas de choque extracorpórea. Equilíbrio postural. Acidente vascular cerebral.*

Introduction

In 2019, stroke was the second leading cause of death (6.6 million deaths) and ranked third in the cause of disability in 2019, according to global data.[1,2] As stroke incidence increases, and without improvements in prevention and rehabilitation programs, global deaths and disabilities are expected to increase.[3] The long-term effects of stroke can reduce independence and quality of life, requiring ongoing support from family members or health professionals. Early identification and treatment improves outcomes and reduces the severity of disabilities. Rehabilitation, which may include physiotherapy, occupational therapy and speech therapy, is crucial to recovery, helping to improve physical and cognitive abilities.[4,5]

Hemiparesis, characterized by motor impairment, spasticity and muscle weakness on the side of the body contralateral to the injury, is the most common motor deficit after a stroke. Approximately 20-40% of people who have had a stroke develop spasticity,[6] a movement disorder that increases muscle tone[7] and can limit the use of the affected limb, cause pain, contractures, and falls and impair gait.[8] Spasticity is usually accompanied by signs such as loss of selective motor control, weakness and dexterity, as well as slow movements and lack of coordination.[9] Proper management of spasticity can improve motor function during the chronic phase of stroke. In hemiparetic individuals, weight bearing and plantar support area are asymmetric and decreased on the paretic side.[10] This is due, in part, to plantar flexion contracture, known as "drop foot," which results in an inability to dorsiflex the affected ankle during the swing phase of gait.[11] With the foot in plantar flexion, there is a decrease in plantar support area and, consequently, a decrease in cutaneous afferentation of plantar mechanoreceptors that provide spatial and temporal information about foot contact pressures,[12] affecting balance and increasing the risk of falls.

Balance, the ability to maintain the body within the support base, is essential both at rest and in movement[13] and it depends on the integration of the vestibular, visual and somatosensory systems. Changes in balance, reduced plantar pressure area, and muscle weakness associated with hemiparesis decrease functional mobility and independence in post-stroke individuals.

Extracorporeal shockwave therapy (ESWT) consists of a sequence of modified acoustic pulses to transmit mechanical energy, characterized by high peak pressure, rapid pressure increase and short duration.[14] According to Taheri et al.,[15] ESWT is a noninvasive and effective treatment in reducing post-stroke spasticity. The most common sites of application are the wrist and plantar flexors, due to the fact that these muscles are the most affected by spasticity.[16] The mechanisms of action of ESWT in reducing spasticity are not yet fully elucidated, but there are some hypotheses. One of them suggests that ESWT increases the production of nitric oxide, which acts on vasodilation, neoangiogenesis and regulation of inflammation in the central nervous system.[17] Another hypothesis is that ESWT influences the non-neural component of spasticity, improving muscle fibrosis and the rheological properties of the spastic muscle.[18]

Therefore, the aim of this study was to evaluate the effect of a ESWT session on the distribution of plantar pressure and on the static and dynamic balance of hemiparetic individuals after stroke..

Methods

The study was approved by the Research Ethics Committee of the Universidade Estadual Paulista (UNESP), under protocol No. 5.541.259. Twelve individuals participated in the study, nine males and three females (Figure 1). Data collection was performed at the Center for Education and Health Studies of the School of Philosophy and Sciences of UNESP. Participants with hemiparesis due to stroke (ischemic or hemorrhagic) in the chronic stage (after 6 months of injury), aged 18 years or older, and who could walk independently or use assistive devices were included. Individuals with psychiatric and/or cognitive disorders that would prevent them from understanding and performing the required activity were not included.

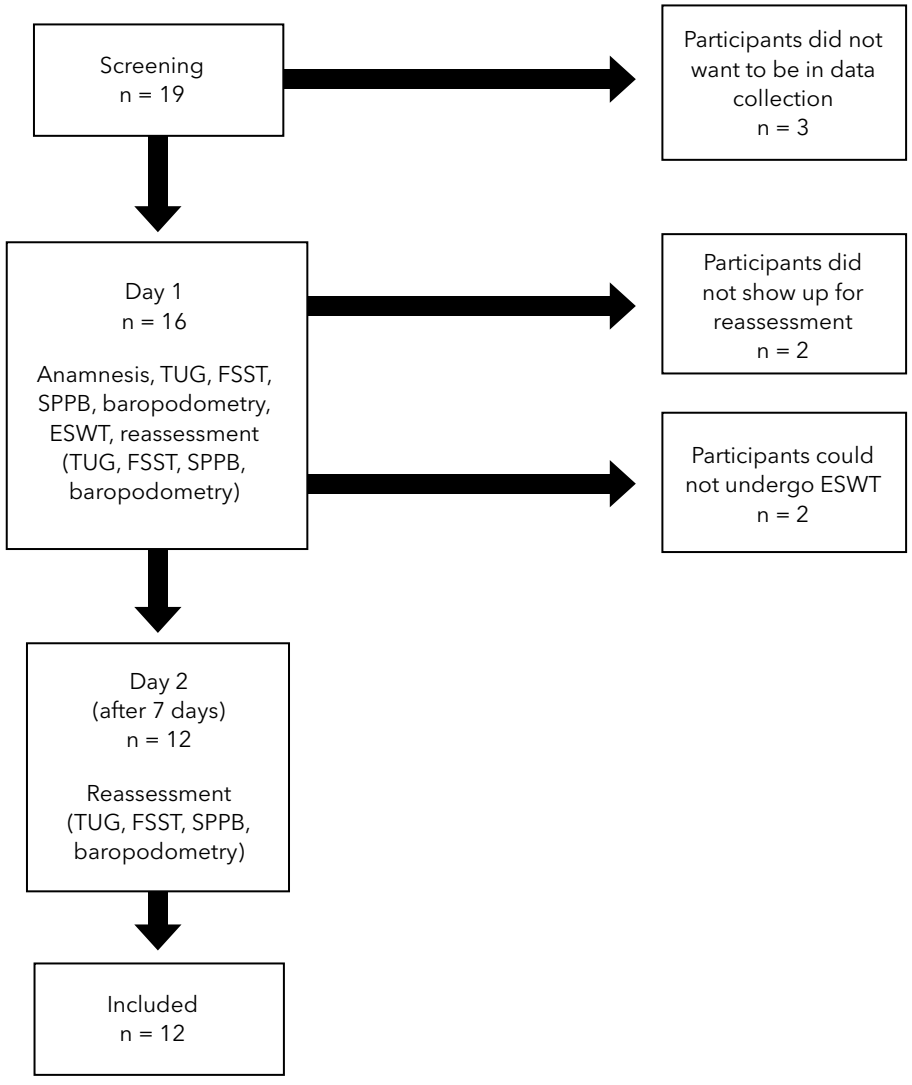

Figure 1 - Flowchart of inclusion and non-inclusion of participants.

Note: TUG = timed up and go; FSST = four square step test; SPPB = short physical performance batery; ESWT = extracorporeal shockwave therapy.

Procedures

Data collection was divided into two days. On the first day, anamnesis was performed with questions about name, age, time since stroke, most affected side, medications being used and times, body weight measurement and history of falls, among others. Subsequently, participants were assessed for balance (static and dynamic) using the timed up and go (TUG), four square step test (FSST) and short physical performance battery (SPPB). After the tests, plantar pressure distribution was assessed using baropodometry. Also on the first day, participants received ESWT on the belly of the gastrocnemius muscle on the hemiparetic side. At the end of the ESWT session and after seven days, individuals were reassessed.

TUG is to assess mobility and functional balance. The test quantifies functional mobility (in seconds) by measuring the time it takes an individual to get up from a chair, walk three meters, turn around, return to the chair and sit down again.[19] Bischoff et al.[20] consider that completing the test in up to 10 seconds is considered normal for healthy, independent adults with no risk of falls; values of 11 to 20 seconds are expected for older individuals with disabilities or frail individuals, with partial independence and low risk of falls; values above 20 seconds suggest that the older person has a significant deficit in physical mobility and risk of falls. The same authors determine a performance of up to 12 seconds as the normal time to complete the test for community-dwelling older individuals.

The FSST, described by Dite and Temple,[21] is a clinical test that assesses dynamic balance and mobility. It consists of four 90-cm long sticks resting on the floor, forming a square; the squares are numbered from 1 to 4. The test measures the time it takes the participant to step as quickly as possible on each square in the following sequence: 2, 3, 4, 1, 4, 3, 2 and 1 without touching the sticks and with both feet making contact with the floor of each square. The test is repeated if the individual is unable to complete the sequence successfully, loses balance or makes contact with a stick during the sequence. Participants with scores greater than 15 seconds are considered multiple fallers and those with scores ≤ 15 are considered non-fallers.[21]

The SPPB was used to assess static and dynamic balance and lower limb strength. To assess static balance, the participant is instructed to remain for 10 seconds in the feet together, semi-tandem and tandem stance, and the score for this task is calculated based on the time the individual remains in these positions. The assessment of lower limb strength is calculated from the time it takes the participant to stand up and sit down from a chair five times, and the assessment of dynamic balance is obtained by the time it takes the individual to complete a 3-m walk. The score for the last two tests is given by the ability to complete the task and the time it takes the participant to perform it. The scores for the three tasks are added together, ranging from 0 to 12 points. Higher scores suggest greater functional capabilities and lower scores suggest lesser functional capabilities.[22]

Extracorporeal shockwave therapy protocol

To apply ESWT, the participant was placed in the prone position, and the device was kept aligned throughout the application so that it remained perpendicular to the participant's skin. The equipment used to apply extracorporeal shock waves was the Thork Shock Wave (Ibramed, São Paulo, Brazil), with a diameter of 15 mm², made of stainless steel, and a penetration depth of 20 to 30 mm.[23] The application was performed on the belly of the gastrocnemius muscle on the paretic side, with the following parameters: 1500 pulses, energy flux density = 0.1 mJ/mm², frequency = 5 Hz and pressure = 1 bar.

Baropodometry

For the baropodometric assessment, all individuals stood on the platform in a static, bipedal position, with their arms hanging at their side, with their eyes open and looking at a fixed point on the wall of the examination room. Initially, the participants gathered on the platform for 10 seconds to conduct the baropodometer, which was calibrated by weight before each measurement following the procedure recommended by the manufacturer. After separating the equipment, the participants underwent a test to familiarize themselves with the equipment; immediately afterwards, three collections of 10 seconds each were performed. All participants were assessed on the same baropodometer (EPS R-1-KINETEC®). The baropodometer records images of plantar pressure points, anteroposterior sway and lateral sway (both in cm), that is, on the Y and X axes, and sway of the center of pressure measured on the surface per cm². The following clinically relevant stabilometric and plantar pressure parameters were measured: surface pressure

of the paretic side (Sur-P), in cm²; surface pressure of the non-paretic side (Sur-NP), in cm²; center of pressure of the paretic side (CP-P), in cm; center of pressure of the non-paretic side (CP-NP), in cm; laterolateral sway amplitude (A_LL), in mm; laterolateral sway velocity (V_LL), in mm/s; laterolateral sway standard deviation (SD_LL), in mm; anteroposterior sway amplitude (A_AP), in mm; anterior-posterior sway velocity (V_AP), in mm/s; anteroposterior sway standard deviation (SD_AP), in mm.

Statistical analysis

Data were presented as mean and standard deviation values. Statistical analysis was performed using the PASW statistics 18.0® software (SPSS). Repeated measures ANOVA with Bonferroni post hoc was used to compare the evaluations. A significance level of $p < 0.05$ was used for all statistical tests.

Results

Twelve individuals of both sexes participated in the study, with a mean age of 61.41 ± 15.32 years. Table 1 shows the data regarding the characterization of the sample regarding age, weight, height, paretic side, time since diagnosis and number of falls. Table 2 shows the results of the static and dynamic balance assessments performed using the FSST, TUG and SPPB tests before, immediately after and one week after the application of ESWT. The statistical analysis did not indicate any significant difference between the three assessments in any of the tests performed.

Table 3 shows the results regarding the variables analyzed in baropodometry. The statistical analysis (repeated measures ANOVA) did not indicate a significant difference between the three moments analyzed (before, immediately after and one week after) for any of the variables.

Table 1 - Characterization of sample

Variable	Mean ± SD*
Sex (female/male)	3/9
Age (years)	61.41 ± 15.32
Height (m)	162.25 ± 12.18
Weight (kg)	67.41 ± 12.18
Paretic side (right/left)	6/6
Time since stroke (months)	69.50 ± 46.46
Number of falls	0.88 ± 1.20

Note: *Except for sex and paretic side. SD = standard deviation.

Table 2 - FSST, TUG and SPPB assessments performed before, immediately after and one week after ESWT

Test	Before	Immediately after	One week after	p-value	F
FFST	37.31 ± 6.07	34.69 ± 5.85	33.83 ± 5.70	0.45	0.81
TUG	24.12 ± 0.32	25.37 ± 4.98	22.63 ± 4.31	0.32	1.18
SPPB	7.58 ± 0.87	7.50 ± 0.73	7.63 ± 0.66	0.91	0.09

Note: FSST = four square step test; TUG = timed up and go; SPPB = short physical performance battery; ESWT = extracorporeal shock wave therapy. Values presented as mean ± standard deviation of the mean. Analysis – repeated measures ANOVA. Significance level $p < 0.05$.

Discussion

The objective of this study was to evaluate the effect of an ESWT session on plantar pressure distribution and static and dynamic balance in post-stroke hemiparetic individuals. Improvements in plantar pressure distribution and balance were expected immediately after and seven days after the application of ESWT. Statistical analysis, performed using repeated measures ANOVA, did not indicate a significant difference between the three moments analyzed (before, immediately after, and one week after) for any of the variables.

Table 3 - Baropodometry assessments

Parameter	Before	Immediately after	One week after	p-value	F
Sur-P	62.62 ± 4.11	59.66 ± 4.02	65.13 ± 6.43	0.38	0.990
Sur-NP	73.99 ± 5.65	74.72 ± 4.86	74.95 ± 5.79	0.94	0.061
CP-P	13.40 ± 1.05	12.91 ± 1.21	14.32 ± 1.61	0.54	0.062
CP-NP	7.42 ± 0.85	8.73 ± 1.19	7.33 ± 1.19	0.12	2.258
A_LL	7.35 ± 1.46	8.58 ± 2.14	7.88 ± 1.42	0.61	0.497
V_LL	2.62 ± 0.35	3.06 ± 0.62	2.71 ± 0.44	0.66	0.411
SD_LL	1.86 ± 0.37	2.13 ± 0.57	2.07 ± 0.39	0.69	0.366
A_AP	10.89 ± 1.66	10.73 ± 1.51	11.00 ± 2.30	0.98	0.012
V_AP	5.09 ± 0.81	4.48 ± 0.71	5.11 ± 0.97	0.76	0.297
SD_AP	2.46 ± 0.40	2.98 ± 0.47	2.71 ± 0.61	0.58	0.549

Note: Sur-P = surface of paretic side (cm²); Sur-NP = surface of non-paretic side (cm²); CP-P = center of pressure of paretic side (cm); CP-NP = center of pressure of non-paretic side (cm); A_LL = amplitude of laterolateral oscillation (mm); V_LL = velocity of lateral oscillation (mm/s); SD_LL = standard deviation of laterolateral oscillation (mm; A_AP = amplitude of anteroposterior oscillation (mm); V_AP = velocity of anteroposterior oscillation (mm/s); SD_AP = standard deviation of anteroposterior oscillation (mm).

The ESWT intervention on balance, assessed by the TUG, SPPB, and FSST tests, did not show a significant difference in the present study. Similar results, in relation to the TUG, have been previously reported. The systematic review by Mihai e et al.[24] found that TUG did not show significant changes after the application of ESWT in the studies included in the review that used this test.[25,26] It is worth mentioning that the studies analyzed had the following dosage: pulses of 1,500 to 2,000, frequency of 4 and 10 Hz, with 4 Hz and 5 Hz being the most used, and pressure energy levels between 0.03 and 0.340 mJ/mm².[24]

This result may be due to the fact that, as in the present study, only one ESWT session was used. Taking into account the difficulties of the activities proposed by the, which involve, in addition to the gait pattern and its complexity, the functions of standing up, returning and sitting down, it is possible to suggest, in addition to a greater number of ESWT sessions, that they be performed together with conventional and/or task-specific physiotherapy exercises.

In addition to the complexity of the tasks, it is important to emphasize that the action of sitting and standing up, present in both the SPPB and the TUG, requires adequate muscle strength. Muscle weakness, resulting from neural factors and muscle changes,[27,28] is one of the main sequelae after stroke. Intrinsic changes in muscles, such as changes in muscle fiber phenotype, hyperelongated sarcomeres, proliferation of connective tissue, changes in muscle length and muscle atrophy,[27,29-32] require specific training to be reversed. In the present study, patients in the chronic phase of stroke were included, which suggests that musculoskeletal changes were already established. It is recommended that studies be carried out using ESWT in the subacute phase of stroke, when the musculoskeletal changes secondary to stroke are not yet fully consolidated.

No studies were found in the literature that used SPPB and FSST as an assessment method after the use of ESWT in hemiparetic individuals or in other populations with or without neurological impairments, which leads to the suggestion that new studies be conducted with ESWT as an adjuvant in rehabilitation. According to Stookey et al.,[33] SPPB is a very relevant test for the post-stroke population and can be used as a predictor of functional capacity after stroke because of its relationship with the 6-minute walk test and peak oxygen consumption (VO_2 peak). In turn, FSST is related to the risk of falls in post-stroke individuals.[34] Therefore, it is suggested that new studies be conducted, with a greater number of ESWT sessions associated with other physical therapy interventions, to verify whether they will result in important functional changes reflected by better performance in the SPPB, FSST and TUG tests.

Lee and Kim[35] also suggested, after conducting a study that summarized the evidence on the effects of ESWT in stroke patients, focusing on balance, pain reduction, improvement in spasticity and muscle control, that ESWT should be used as an effective addition to conventional rehabilitation. The mechanical stimulation induced by ESWT promotes tissue repair and neuromuscular reeducation,[35] providing better conditions for training specific tasks to be performed.

Regarding the area of plantar pressure distribution, represented by the variables Sur_A and Sur_NA, and the body sway measurements analyzed by the baropodometer (Table 3), no significant changes were observed after the application of ESWT. In the study conducted by Wu e et al.,[36] a significant difference was found in the plantar contact area, passive ankle mobilization and spasticity; however, unlike the present study, the authors performed three ESWT sessions with a one-week interval between them. The use of three ESWT sessions was recommended by Silveira[37] in an integrative review study. According to the author, three sessions showed more effective results for the treatment of lower limb spasticity and variables such as plantar contact, skills and difficulties in some activities of daily living and the 10-m walk test.[35]

A relevant factor was verified by Perry et al.,[12] who investigated the level of sensitivity of the plantar surface in older individuals compared to young adults. The findings of the study indicate that older people have a decrease in the sensitivity of the plantar surface compared to young adults. Furthermore, Ruwer et al.[38] state that aging compromises the ability of the central nervous system to process the vestibular, visual and proprioceptive pathways, which are responsible for balance. Thus, the individuals collected in the present study, mostly older persons, show changes in balance and in the distribution of plantar pressure due to the stroke but also due to the aging process. Thus, one ESWT session may not have been enough to significantly influence the variables studied.

The limitations of the study include the small number of sessions, the dose (number of pulses and energy emitted) and the small sample size of participants. This study demonstrated that, at the dose used, one session was not enough to achieve the main objective of the study. However, these results are important as a contribution to the scientific literature, since studies on the subject of ESWT in post-stroke patients are still scarce.

Conclusion

A ESWT session at a dose of 1,500 pulses, energy flux density of 0.1 mJ/mm² and frequency of 5 Hz did not alter the plantar pressure distribution and static and dynamic balance of hemiparetic post-stroke individuals.

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Authors' contributions

BGR and FRFN formulated the research objectives and goals. BGR, MCNSV and LMS conducted the research and investigation process, specifically collecting data, which were analyzed and synthesized by FRFN. DCC actively participated in the discussion, and CRP and FRFN reviewed the manuscript. All authors approved the final version.

References

1. GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol. 2021;20(10):795-820. DOI

2. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396(10258):1204-22. DOI

3. Feigin VL, Owolabi MO; World Stroke Organization–Lancet Neurology Commission Stroke Collaboration Group. Pragmatic solutions to reduce the global burden of stroke: a World Stroke Organization-Lancet Neurology Commission. Lancet Neurol. 2023; 22(12):1160-206. DOI

4. Sohn MK, Cho KH, Kim YJ, Hwang SL. Spasticity and electrophysiologic changes after extracorporeal shock wave therapy on gastrocnemius. Ann Rehabil Med. 2011;35(5):599-604. DOI

5. Larson ST, Ray BE, Wilbur J. Ischemic stroke management: Posthospitalization and transition of care. Am Fam Physician. 2023;108(1):70-7. Link

6. Zorowitz RD, Gillard PJ, Brainin M. Poststroke spasticity: sequelae and burden on stroke survivors and caregivers. Neurology. 2013;80(3 Suppl 2):S45-52. DOI

7. Li S, Francisco GE, Rymer WZ. A new definition of poststroke spasticity and the interference of spasticity with motor recovery from acute to chronic stages. Neurorehabil Neural Repair. 2021;35(7):601-10. DOI

8. Rush R, Kumbhare D. Spasticity. CMAJ. 2015;187(6):436. DOI

9. Cabanas-Valdés R, Calvo-Sanz J, Urrùtia G, Serra-Llobet P, Pérez-Bellmunt A, Germán-Romero A. The effectiveness of extracorporeal shock wave therapy to reduce lower limb spasticity in stroke patients: a systematic review and meta-analysis. Top Stroke Rehabil. 2020;27(2):137-57. DOI

10. Kim DY, Park CI, Jang YW, Ahn SY, Na SI, Park YS. The relationship between weight-bearing and stiff-knee gait in hemiplegic patients. J Korean Acad Rehabil Med. 2004;28(1): 20-5. Link

11. Ye F, Howatt D, Mullick A, Grahan M, Balakrishnan A, Kooi CV, et al. Megalin regulates angiotensinogen and contributes to atherosclerosis. Arterioscl Throm Vas Biol. 2917;37(Suppl 1): A227. DOI

12. Perry SD, McIlroy WE, Maki BE. The role of plantar cutaneous mechanoreceptors in the control of compensatory stepping reactions evoked by unpredictable, multi-directional perturbation. Brain Res. 2000;877(2):401-6. DOI

13. Ribeiro TV. Estudo do equilíbrio estático e dinâmico em indivíduos idosos [dissertação]. Porto: Universidade do Porto; 2009. Link

14. International Society for Medical Schockwave Treatment. Indications. 2020 [cited 2024 Apr 20]. Available from: https://www.shockwavetherapy.org/abouteswt/indications/

15. Taheri P, Vahdatpour B, Mellat M, Ashtari F, Akbari M. Effect of extracorporeal shock wave therapy on lower limb spasticity in stroke patients. Arch Iran Med. 2017;20(6):338-43. Link

16. Guo P, Gao F, Zhao T, Sun W, Wang B, Li Z. Positive effects of extracorporeal shock wave therapy on spasticity in post-stroke patients: A meta-analysis. J Stroke Cerebrovasc Dis. 2017; 26(11):2470-6. DOI

17. Mariotto S, 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(19):2366-72. DOI

18. Dymarek R, Taradaj J, Rosińczuk J. The effect of radial extracorporeal shock wave stimulation on upper limb spasticity in chronic stroke patients: a single- blind, randomized, placebo-controlled study. Ultrasound Med Biol. 2016;42(8): 1862- 75. DOI

19. Podsiadlo D, Richardson S. The Timed "Up & Go": A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39(2):142-8. DOI

20. Bischoff HA, Stähelin HB, Monsch AU, Iversen MD, Weyh A, von Dechend M, et al. Identifying a cut-off point for normal mobility: a comparison of the timed 'up and go' test in community-dwelling and institutionalised elderly women. Age Ageing. 2003;32(3):315-20. DOI

21. Dite W, Temple VA. A clinical test of stepping and change of direction to identify multiple falling older adults. Arch Phys Med Rehabil. 2002;83(11):1566-71. DOI

22. Treacy D, Hassett L. The Short Physical Performance Battery. J Physiother. 2018;64(1):61. DOI

23. Santamato A, Micello MF, Panza F, Fortunato F, Logroscino G, Picelli A, et al. Extracorporeal shock wave therapy for the treatment of poststroke plantar-flexor muscles spasticity: a prospective open-label study. Top Stroke Rehabil. 2014;21 (Suppl 1):S17-24. DOI

24. Mihai EE, Dumitru L, Mihai IV, Berteanu M. Long-term efficacy of extracorporeal shock wave therapy on lower limb post-stroke spasticity: A systematic review and meta-analysis of randomized controlled trials. J Clin Med. 2020;10(1):86. DOI

25. Radinmehr H, Nakhostin Ansari N, Naghdi S, Olyaei G, Tabatabaei A. Effects of one session radial extracorporeal shockwave therapy on post-stroke plantarflexor spasticity: a single-blind clinical trial. Disabil Rehabil. 2017;39(5):483-90. DOI

26. Radinmehr H, Ansari NN, Naghdi S, Tabatabaei A, Moghimi E. Comparison of therapeutic ultrasound and radial shock wave therapy in the treatment of plantar flexor spasticity after stroke: A prospective, single-blind, randomized clinical trial. J Stroke Cerebrovasc Dis. 2019;28(6):1546-54. DOI

27. McNulty PA, Lin G, Doust CG. Single motor unit firing rate after stroke is higher on the less-affected side during stable low-level voluntary contractions. Front Hum Neurosci. 2014;8: 518. DOI

28. Silva-Couto MA, Prado-Medeiros CL, Oliveira AB, Alcântara CC, Guimarães AT, Salvini TF, et al. Muscle atrophy, voluntary activation disturbances, and low serum concentrations of IGF-1 and IGFBP-3 are associated with weakness in people with chronic stroke. Phys Ther. 2014;94(7):957-67. DOI

29. Huang C, Yao B, Li X, Li S, Zhou P. Muscle fiber diameter and density alterations after stroke examined by single-fiber EMG. Neural Plast. 2021;2021:3045990. DOI

30. Lieber RL, Steinman S, Barash IA, Chambers H. Structural and functional changes in spastic skeletal muscle. Muscle Nerve. 2004;29(5):615-27. DOI

31. Gray V, Rice CL, Garland SJ. Factors that influence muscle weakness following stroke and their clinical implications: a critical review. Physiother Can. 2012;64(4):415-26. DOI

32. Lieber RL. Skeletal muscle structure, function, and plasticity: the physical basis of rehabilitation. Philadelphia: Lippincott Williams & Wilkins; 2010.

33. Stookey AD, Katzel LI, Steinbrenner G, Shaughnessy M, Ivey FM. The short physical performance battery as a predictor of functional capacity after stroke. J Stroke Cerebrovasc Dis. 2014;23(1):130-5. DOI

34. Blennerhassett JM, Dite W, Ramage ER, Richmond ME. Changes in balance and walking from stroke rehabilitation to the community: a follow-up observational study. Arch Phys Med Rehabil. 2012;93(10):1782-7. DOI

35. Lee JH, Kim EJ. A comprehensive review of the effects of extracorporeal shock wave therapy on stroke patients: balance, pain, spasticity. Medicina (Kaunas). 2023;59(5):857. DOI

36. Wu YT, Chang CN, Chen YM, Hu GC. Comparison of the effect of focused and radial extracorporeal shock waves on spastic equinus in patients with stroke: a randomized controlled trial. Eur J Phys Rehabil Med. 2018;54(4):518-25. DOI

37. Silveira RBF. Terapia por ondas de choque extracorpórea no músculo espástico pós-AVE: uma revisão integrativa [trabalho de conclusão de curso]. Marília: Universidade Estadual Paulista; 2021. 24 p. Link

38. Ruwer SL, Rossi AG, Simon LF. Equilíbrio no idoso. Rev Bras Otorrinolaringol. 2005;71(3):298-303. DOI