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Dry needling for the treatment of muscle spasticity in a patient with multiple sclerosis: a case report

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ABSTRACT
Background: Spasticity is a common cause of disability in multiple sclerosis (MS), which can negatively affect the patient's walking and balance.
Objective: To evaluate the immediate effect of dry needling (DN) on spasticity and mobility in a female with MS.
Case Description: In this case, a 38-year-old female with a 4-year history of MS was treated. The hamstring muscles (biceps femoris and semitendinosus) were needled for 1 minute in a single session. The main outcome measures were the Modified Modified Ashworth Scale (MMAS) to evaluate spasticity, the Timed 25-Foot Walk (T25FW) for the assessment of mobility and leg function performance, and stiffness as a biomechanical index of spasticity measured by a dynamometer. The assessments were done before and immediately after DN.
Outcomes: The MMAS scores decreased in the hamstrings (1 to 0) and quadriceps (2 to 1). The mobility improved as the time for T25FW decreased from 16.30 to 9.29 seconds. The stiffness of hamstring decreased after treatment (0.451 to 0.312).
Conclusion: One session of DN for the hamstring muscle decreased spasticity and improved mobility in this patient with MS. Further studies are suggested.

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KEYWORDS
Multiple sclerosis; dry needling; spasticity; muscle stiffness; walking

Introduction

Spasticity is one of the most disabling symptoms in individuals with multiple sclerosis (MS). It is reported that almost 80% of patients with MS experience spasticity (Arroyo, Massana, and Vila, 2013). Spasticity may be more severe in males, elderly patients, and individuals with a long duration of MS (Oreja-Guevara, González-Segura, and Vila, 2013). In the lower limb, it is more than twice as common as spasticity of the upper limb (Bethoux and Marrie, 2016). Since spasticity in MS patients leads to pain, mobility disorders, loss of agility, personal hygiene challenges, and low quality of life (Milinis, Tennant, and Young, 2016a; Milinis and Young, 2016b), its reduction might be helpful for these patients.

Medical and rehabilitation strategies for decreasing spasticity are reported in the literature (Ansari et al., 2015). Pharmacological options have generalized effects on the body and can trigger side effects such as weakness and cognitive problems (Rizzo, Hadjimichael, Preiningerova, and Vollmer, 2004). Rehabilitation strategies used by physical therapists to reduce spasticity may include hydrotherapy, electrical stimulations, vibration, ice therapy, or other interventions (de Sa et al., 2011). Hydrotherapy and ice therapy have temporary effects on muscle spasticity (de Sa et al., 2011). Electrical stimulation did not have an obvious influence on reduction of spasticity in individuals with MS. However, increasing the duration of the application was found to be beneficial to reduce pain and muscle spasm (Miller, Mattison, Paul, and Wood, 2007). Moreover, whole-body vibration has not been found to be effective for spasticity in patients with MS (Schyns et al., 2009).

Dry needling (DN) is a relatively new technique applied by physiotherapists for the treatment of myofascial trigger points and musculoskeletal pain. It likely helps to stretch the muscle fibers to improve the muscle extensibility (Ansari et al., 2015). It may also have a positive impact on local blood flow and pain reduction (Cagnie et al., 2013). Recently, DN has been shown to be effective in decreasing spasticity and improving function

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through a reduction in pain (DiLorenzo et al., 2004; Salom-Moreno et al., 2014), passive motion resistance (Gallego and del Moral, 2007); local muscle stiffness (Calvo, Quintero, and Herrero, 2016), and alpha motor neuron excitability (Fakhari et al., 2017). The effectiveness of DN has also been reported through improvements in the ability to move spastic muscles (Ansari et al., 2015; Gallego and del Moral, 2007; Salom-Moreno et al., 2014), range of motion (Ansari et al., 2015; Ghaffari et al., 2019; Mendigutia-Gómez, Martín-Hernández, Salom-Moreno, and Fernández-de-las-Peñas, 2016; Sánchez-Mila, Salom-Moreno, and Fernández-de-las-Peñas, 2018), dynamic stability, gait speed (Cruz-Montecinos et al., 2020), and balance (Cruz-Montecinos et al., 2020; Sánchez-Mila, Salom-Moreno, and Fernández-de-las-Peñas, 2018). MS is categorized as a neurological disease and has a different pathology than other neurological diseases like stroke. It is a neuroinflammatory autoimmune disease, while stroke occurs due to ischemia (Pinheiro et al., 2016). However, spasticity is a common complaint among most patients suffering from neurological diseases. Based on previous studies, it is expected that DN might also be effective for patients with MS. There are no studies on the effectiveness of DN on the level of spasticity in patients with MS. Therefore, the objective of this case report was to describe the immediate effects of DN on spasticity and mobility in a female with MS.

Case description

The patient was informed about the details of the intervention, and she signed an informed consent. The institutional Research Ethics Committee approved the treatment protocol. A 38-year-old woman with a 4-year history of MS, who was admitted to the outpatient physical therapy clinic of the Iranian MS society, presented with no history of other neurological diseases. She had not experienced a relapse during the past 6 months. Her MS management consisted of taking dalfampridine and receiving physiotherapy once a week. Physical therapy included passive hamstring stretching and gait training exercises. Her main complaints related to balance and mobility issues. She was able to walk independently, but ambulation was slow and with more difficulty than normal, with spasticity in the lower extremities, especially on the left. Her Kurtzke Expanded Disability Status Scale (EDSS) score was 5.5 (which means that she could walk without aid for about 100 m). Her disability was severe enough to prevent full daily activities (Kurtzke, 1983). In addition to restrictions in her ADL, her social participation was limited due to a lack of agility and fear of falling. After 2 years of physiotherapy and exercises (i.e., muscle stretching and strengthening, balance training, and application of electrical stimulations at the clinic), she still complained of pain and spasticity in her lower limb muscles, especially in the hamstring and quadriceps, and decreased balance during walking.

Examination

Timed 25-Foot Walk (T25FW)

Mobility was assessed by the Timed 25-Foot Walk (T25FW) test, which is valid and reliable in individuals with MS (Kaufman, Moyer, and Norton, 2000; Motl et al., 2017; Phan-Ba et al., 2011). The Minimally Important Clinical Difference (MICD) for T25FW is reported to be 17.2% (Coleman, Sobieraj, and Marinucci, 2012). The test was performed in a spacious room. The patient was asked to walk 25 ft. as quickly as possible from one marked end to another, and the time required to walk between these two marked ends was recorded. The second trial was immediately conducted after the first one, and the average of two trials was recorded as the T25FW score. The patient was allowed to use assistive devices during the trials.

Modified Modified Ashworth Scale

The degree of hamstring and quadriceps muscle spasticity was determined using the Modified Modified Ashworth Scale (MMAS) (Ansari, Naghdi, Moammeri, and Jalaie, 2006) which is a valid (Naghdi, Ansari, Mansouri, Asgari, Olyaei, and Kazemnejad, 2008) and reliable (Naghdi, Nakhostin Ansari, Azarnia, and Kazemnejad, 2008) test for spasticity measurements. Approximately one grade decrease in spasticity is considered to be a meaningful clinical improvement (Shaw et al., 2010). The test identifies five grades of muscle spasticity measured by the physiotherapist, where zero indicates no increase in muscle tone and four implies that the affected part(s) are rigid in flexion or extension (Ansari, Naghdi, Moammeri, and Jalaie, 2006). To measure the spasticity of the hamstrings, the patient was in the prone position with her hips in extension and the left knee in full flexion. A pillow was placed under her chest with the head in the mid-position. The physiotherapist stabilized the patient's hip and moved her knee passively from full flexion to full extension. For the quadriceps, the patient was in the side lying position with her hips and knees in extension and the head in the mid-position. Again, the physiotherapist placed one hand proximal to the

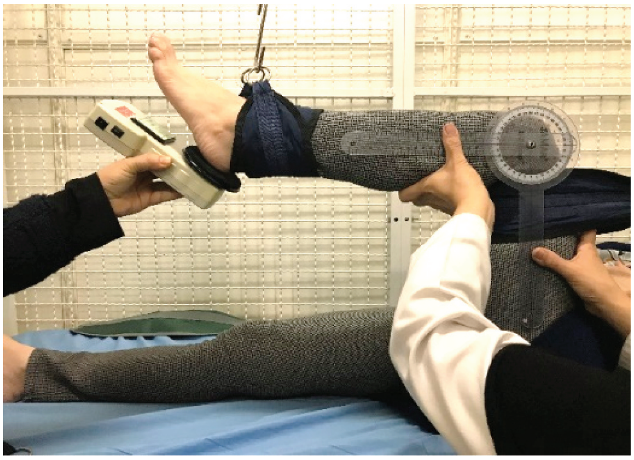

Figure 1. Patient's position to measure stiffness of hamstring.

knee and the other hand around the ankle of the left side. Next, the knee was moved from full extension to full flexion passively.

Hamstring stiffness

To measure hamstring muscle stiffness, the patient was positioned in supine. Her right lower extremity was fixed in extension by a strap over her thigh, while the left lower extremity was positioned in supine position with knee and hip in the 90–90 position (Figure 1).

A hand-held dynamometer (HHD; Micro Manual Muscle Tester, North Coast Medical Inc., USA) was utilized to measure passive force. The HHD was placed under the patient's heel, while a physiotherapist moved the knee passively to maximum extension. Two torque values corresponding to the points where the patient reported the first and the maximum stretch sensation were recorded. Another physiotherapist measured the relevant angles with a goniometer. Stiffness (Δ Torque/Δ Angle) was calculated by accounting for the influence of gravity on the considered leg (W = 6.1% of body weight, L = 28.5% of body height) [Torque (Nm) = Force recorded by HHD (N) × L (m); Gravity force in each angle = Force recorded by HHD (N) × cos α] (Winter, 2009). The reliability and the validity of this method were reported in previous studies (Alaei et al., 2020; Ansari et al., 2020). An experienced physiotherapist, who was blinded to the intervention, performed all the assessments before and after DN.

PT diagnosis/prognosis

The primary examination findings of the patient diagnosed with MS were increased muscle spasticity as assessed by MMAS and pain in lower limb muscles as reported by the patient. In addition, the hamstring muscle was shortened as was noted during the assessment of muscle stiffness. The patient's complaints included muscle stiffness, difficulty in walking, and imbalance which resulted in restrictions in activities of daily living and social participation. The main goal of the treatment was to reduce muscle spasticity and improve her walking and balance. Evidence suggests that the DN is effective in reducing spasticity, increasing joint range of motion, pain, walking, and balance (Fernández-de-Las-Peñas et al., 2021; Ghannadi et al., 2020; Valencia-Chulián et al., 2020). It follows that we used DN for this patient with spasticity post MS.

Table 1. Outcomes pre and post needling.

Outcomes	T1	T2
T25FW (s)	16.30	9.29
MMAS grade (Hamstring)	1	0
MMAS grade (Quadriceps)	2	1
Stiffness	0.451	0.312

T1: before DN; T2: right after DN.

Dry needling intervention

An experienced physiotherapist delivered DN using disposable sterilized steel needles (0.3 × 50 mm; DongBang AcuPrime Ltd, Korea). The patient was positioned in prone. The hips and knees were in extension, and the head was in the mid-position. The long head of the biceps femoris and the semitendinosus muscles were needled. The approximate point needled for the long head of biceps is the point in the middle of the line between the ischial tuberosity and the apex of the fibular head. The midpoint of the line between the ischial tuberosity and the medial epicondyle of the tibia is considered to be the approximate location of the motor point of the semitendinosus muscle (Alaei et al., 2020; Ansari et al., 2020). One minute of deep DN with the fast in-out cone-shaped pattern (Alaei et al., 2020; Ansari et al., 2020, 2015; Fakhari et al., 2017) was administered to each point. One session of dry needling was applied (Ansari et al., 2015; Fakhari et al., 2017).

Outcomes

The outcomes are listed in Table 1. After needling, the T25FW decreased from 16.3 to 9.29 s, which indicates a 43% improvement. The MMAS score of the hamstring, which is an indicator of muscle spasticity, showed an improvement from 1 to 0. There was also an improvement in spasticity grade of the quadriceps (2 to 1) after DN. The calculated stiffness reduced from 0.451 to 0.312 (~31%) after treatment.

Discussion

To the best of the authors' knowledge, this is the first attempt to evaluate the immediate effects of DN on spasticity in a patient with MS. This case report showed the immediate effects of DN on spasticity and mobility in a female with MS. The outcomes suggested that DN was effective in reducing spasticity in this patient, as the MMAS scores of the hamstring and quadriceps muscles decreased. DN is commonly used for managing pain (Dommerholt, 2011). Recently, several studies have investigated the influence of DN on spasticity secondary to different neurological diseases including stroke (Ansari et al., 2015; Calvo, Quintero, and Herrero, 2016; Mendigutia-Gómez, Martín-Hernández, Salom-Moreno, and Fernández-de-las-Peñas, 2016; Salom-Moreno et al., 2014) and hypoxic-ischemic encephalopathy (Gallego and del Moral, 2007). Most researchers confirmed the effectiveness of DN on the reduction of spasticity and reported similar results. Only one study of stroke patients concluded that the application of DN did not cause considerable changes in the degree of spasticity (Mendigutia-Gómez, Martín-Hernández, Salom-Moreno, and Fernández-de-las-Peñas, 2016).

As mentioned earlier, spasticity affects the majority of patients with MS and is considered one of the most disabling symptoms. Spasticity can lead to tissue contractures, which consequently can cause structural changes and pain (Ansari et al., 2015; Gracies, 2005; Lieber, Steinman, Barash, and Chambers, 2004; Patejdl and Zettl, 2017). The manipulation by dry needle could affect muscle contractures by generating local stretching, which may eventually result in less tension in local fibers followed by a decrease in spasticity (Ansari et al., 2015). Ansari et al. (2015) proposed that neural mechanisms are more likely than biomechanical mechanisms to justify the immediate effects of DN.

Pain is a common symptom in MS that can occur as a result of spasticity (Solaro, Trabucco, and Uccelli, 2013). Dry needling may stimulate A-delta and C-fibers, cause segmental inhibition at the spinal cord, and release endogenous opioids, which may assist in controlling pain (Cagnie et al., 2013). Since pain can increase spasticity, it follows that a reduction in pain may reduce spasticity (Ward and Kadies, 2002). It is worth noting that the pain was not included in outcome measures of this case report; however, the patient reported pain reduction.

There is a remarkable correlation between spasticity and gait that might impact mobility in patients with MS (Norbye, Midgard, and Thrane, 2020). Similarly, Sosnoff, Gappmaier, Frame, and Motl (2011) found that spastic muscles in MS patients may have a negative impact on mobility and balance. Different muscle groups in the lower extremity can be affected by spasticity. The quadriceps and hamstring muscles represent different degrees of spasticity in patients with MS (Güner et al., 2015; Kelleher, Spence, Solomonidis, and Apatsidis, 2010), which implies that patients may walk slower than normal and experience difficulties, such as falling (Stevenson, 2010). In the current case, the time of the T25FW test decreased, which reflects improvements in walking, mobility, and affected leg function. The clinical difference improvement of 43% is considered a meaningful outcome exceeding the MICD for the T25FW (Coleman, Sobieraj, and Marinucci, 2012). The reduction of spasticity in both the hamstring and quadriceps, as noted in the results of the MMAS, appears to improve the patient's walking ability and reduced the time needed to perform the T25FW.

In this case, the amount of calculated stiffness of the hamstring muscle was decreased following DN. Muscle stiffness is a spasticity-associated symptom that can be observed in neurological diseases such as MS, stroke, and cerebral palsy (Bethoux and Marrie, 2016; Leonard et al., 2019; Wu et al., 2017; Yamaguchi et al., 2018). The authors have recently demonstrated that using DN may have an impact on hamstring compliance (Alaei et al., 2020; Ansari et al., 2020). Accordingly, the stiffness could also be influenced by DN because stiffness is the reverse of compliance. Since muscle stiffness is related to spasticity (Fridén and Lieber, 2003), a decrease in spasticity in this case with MS might reduce muscle stiffness and improve mobility.

It is worth noting that the findings of the current report cannot be generalized without further rigorous research with a large sample of patients. We applied one single treatment; clinical outcomes may additionally improve if DN is used as an element of multimodal physiotherapy treatment. This case report did not look at the long-term effects. Hence, a long-term follow-up is required to assess the lasting effects beyond immediate response following DN therapy.

Conclusion

In this case report of a female with MS, spasticity of both the hamstring and quadriceps muscles decreased after a single session of DN. The time needed for the T25FW reduced, and the amount of muscle stiffness improved. This report suggests that the treatment using DN had a positive effect on spastic muscles and improved mobility in this patient with MS. The improvement observed in MS-related spasticity and walking is promising.

Further research is required to evaluate the effects of DN in patients with MS with spasticity.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Alaei P, Ansari NN, Naghdi S, Fakhari Z, Komesh S, Dommerholt J 2020 Dry needling for hamstring flexibility: A single-blind randomized controlled trial. Journal of Sport Rehabilitation 30: 452–457. doi:10.1123/jsr.2020-0111.

Ansari NN, Alaei P, Naghdi S, Fakhari Z, Komesh S, Dommerholt J 2020 Immediate effects of dry needling as a novel strategy for hamstring flexibility: A single-blinded clinical pilot study. Journal of Sport Rehabilitation 29: 156–161. doi:10.1123/jsr.2018-0013.

Ansari NN, Naghdi S, Fakhari Z, Radinmehr H, Hasson S 2015 Dry needling for the treatment of poststroke muscle spasticity: A prospective case report. NeuroRehabilitation 36: 61–65. doi:10.3233/NRE-141192.

Ansari NN, Naghdi S, Moammeri H, Jalaie S 2006 Ashworth Scales are unreliable for the assessment of muscle spasticity. Physiotherapy Theory and Practice 22: 119–125. doi:10.1080/09593980600724188.

Arroyo R, Massana M, Vila C 2013 Correlation between spasticity and quality of life in patients with multiple sclerosis: The CANDLE study. International Journal of Neuroscience 123: 850–858. doi:10.3109/00207454.2013.812084.

Bethoux F, Marrie RA 2016 A cross-sectional study of the impact of spasticity on daily activities in multiple sclerosis. Patient 9: 537–546. doi:10.1007/s40271-016-0173-0.

Cagnie B, Dewitte V, Barbe T, Timmermans F, Delrue N, Meeus M 2013 Physiologic effects of dry needling. Current Pain and Headache Reports 17: 348. doi:10.1007/s11916-013-0348-5.

Calvo S, Quintero I, Herrero P 2016 Effects of dry needling DNHS technique on the contractile properties of spastic muscles in a patient with stroke: A case report. International Journal of Rehabilitation Research 39: 372–376. doi:10.1097/MRR.0000000000000185.

Coleman CI, Sobieraj DM, Marinucci LN 2012 Minimally important clinical difference of the Timed 25-Foot Walk Test: Results from a randomized controlled trial in patients with multiple sclerosis. Current Medical Research and Opinion 28: 49–56. doi:10.1185/03007995.2011.639752.

Cruz-Montecinos C, Núñez-Cortés R, Bruna-Melo T, Tapia C, Becerra P, Pavez N, Pérez-Alenda S 2020 Dry needling technique decreases spasticity and improves general functioning in incomplete spinal cord injury: A case report. Journal of Spinal Cord Medicine 43: 414–418. doi:10.1080/10790268.2018.1533316.

de Sa JC, Airas L, Bartholome E, Grigoriadis N, Mattle H, Oreja-Guevara C, O'Riordan J, Sellebjerg F, Stankoff B, Vass K 2011 Symptomatic therapy in multiple sclerosis: A review for a multimodal approach in clinical practice. Therapeutic Advances in Neurological Disorders 4: 139–168. doi:10.1177/1756285611403646.

DiLorenzo L, Traballesi M, Morelli D, Pompa A, Brunelli S, Buzzi M, Formisano R 2004 Hemiparetic shoulder pain syndrome treated with deep dry needling during early rehabilitation: A prospective, open-label, randomized investigation. Journal of Musculoskeletal Pain 12: 25–34. doi:10.1300/J094v12n02_04.

Dommerholt J 2011 Dry needling – Peripheral and central considerations. Journal of Manual and Manipulative Therapy 19: 223–227. doi:10.1179/106698111X13129729552065.

Fakhari Z, Ansari NN, Naghdi S, Mansouri K, Radinmehr H 2017 A single group, pretest-posttest clinical trial for the effects of dry needling on wrist flexors spasticity after stroke. NeuroRehabilitation 40: 325–336. doi:10.3233/NRE-161420.

Fernández-de-Las-Peñas C, Pérez-Bellmunt A, Llurda-Almuzara L, Plaza-Manzano G, De-la-Llave-Rincón AI, Navarro-Santana MJ 2021 Is dry needling effective for the management of spasticity, pain, and motor function in post-stroke patients? A systematic review and meta-analysis. Pain Medicine 22: 131–141. doi:10.1093/pm/pnaa392.

Fridén J, Lieber RL 2003 Spastic muscle cells are shorter and stiffer than normal cells. Muscle and Nerve 27: 157–164. doi:10.1002/mus.10247.

Gallego PH, del Moral OM 2007 A case study looking at the effectiveness of deep dry needling for the management of hypertonia. Journal of Musculoskeletal Pain 15: 55–60. doi:10.1300/J094v15n02_09.

Ghaffari MS, Shariat A, Honarpishe R, Hakakzadeh A, Cleland JA, Haghighi S, Barghi TS 2019 Concurrent effects of dry needling and electrical stimulation in the management of upper extremity hemiparesis. Journal of Acupuncture and Meridian Studies 12: 90–94. doi:10.1016/j.jams.2019.04.004.

Ghannadi S, Shariat A, Ansari NN, Tavakol Z, Honarpishe R, Dommerholt J, Noormohammadpour P, Ingle L 2020 The effect of dry needling on lower limb dysfunction in post-stroke survivors. Journal of Stroke and Cerebrovascular Diseases 29: 104814. doi:10.1016/j.jstrokecerebrovasdis.2020.104814.

Gracies JM 2005 Pathophysiology of spastic paresis II: Emergence of Muscle Overactivity. Muscle and Nerve 31: 552–571.

Güner S, Haghari S, Inanıcı F, Alsancak S, Aytekın G 2015 Knee muscle strength in multiple sclerosis: Relationship with gait characteristics. Journal of Physical Therapy Science 27: 809–813. doi:10.1589/jpts.27.809.

Kaufman M, Moyer D, Norton J 2000 The significant change for the Timed 25-foot Walk in the multiple sclerosis functional composite. Multiple Sclerosis Journal 6: 286–290. doi:10.1177/135245850000600411.

Kelleher KJ, Spence W, Solomonidis S, Apatsidis D 2010 The characterisation of gait patterns of people with multiple sclerosis. Disability and Rehabilitation 32: 1242–1250. doi:10.3109/09638280903464497.

Kurtzke JF 1983 Rating neurologic impairment in multiple sclerosis: An expanded disability status scale EDSS. Neurology 33: 1444–1452. doi:10.1212/WNL.33.11.1444.

Leonard TR, Howard JJ, Larkin-Kaiser K, Joumaa V, Logan K, Orlik B, El-Hawary R, Gauthier L, Herzog W 2019 Stiffness of hip adductor myofibrils is decreased in children with spastic cerebral palsy. Journal of Biomechanics 87: 100–106. doi:10.1016/j.jbiomech.2019.02.023.

Lieber RL, Steinman S, Barash IA, Chambers H 2004 Structural and functional changes in spastic skeletal muscle. Muscle and Nerve 29: 615–627. doi:10.1002/mus.20059.

Mendigutia-Gómez A, Martín-Hernández C, Salom-Moreno J, Fernández-de-las-Peñas C 2016 Effect of dry needling on spasticity, shoulder range of motion, and pressure pain sensitivity in patients with stroke: A crossover study. Journal of Manipulative and Physiological Therapeutics 39: 348–358. doi:10.1016/j.jmpt.2016.04.006.

Milinis K, Tennant A, Young C, TONiC Study Group 2016a Spasticity in multiple sclerosis: Associations with impairments and overall quality of life. Multiple Sclerosis and Related Disorders 5: 34–39. doi:10.1016/j.msard.2015.10.007.

Milinis K, Young C, Trajectories of Outcome in Neurological Conditions (TONiC) Study Group 2016b Systematic review of the influence of spasticity on quality of life in adults with chronic neurological conditions. Disability and Rehabilitation 38: 1431–1441. doi:10.3109/09638288.2015.1106592.

Miller L, Mattison P, Paul L, Wood L 2007 The effects of transcutaneous electrical nerve stimulation TENS on spasticity in multiple sclerosis. Multiple Sclerosis Journal 13: 527–533. doi:10.1177/1352458506071509.

Motl RW, Cohen JA, Benedict R, Phillips G, LaRocca N, Hudson LD, Rudick R, Multiple Sclerosis Outcome Assessments Consortium 2017 Validity of the timed 25-foot walk as an ambulatory performance outcome measure for multiple sclerosis. Multiple Sclerosis Journal 23: 704–710. doi:10.1177/1352458517690823.

Naghdi S, Ansari NN, Mansouri K, Asgari A, Olyaei GR, Kazemnejad A 2008 Interrater reliability of the Modified Modified Ashworth Scale MMAS for patients with wrist flexor muscle spasticity. Physiotherapy Theory and Practice 24: 372–379. doi:10.1080/09593980802278959.

Norbye AD, Midgard R, Thrane G 2020 Spasticity, gait, and balance in patients with multiple sclerosis: A cross-sectional study. Physiotherapy Research International 25: e1799. doi:10.1002/pri.1799.

Oreja-Guevara C, González-Segura D, Vila C 2013 Spasticity in multiple sclerosis: Results of a patient survey. International Journal of Neuroscience 123: 400–408. doi:10.3109/00207454.2012.762364.

Patejdl R, Zettl UK 2017 Spasticity in multiple sclerosis: Contribution of inflammation, auto-immune mediated neuronal damage and therapeutic interventions. Autoimmunity Reviews 16: 925–936. doi:10.1016/j.autrev.2017.07.004.

Phan-Ba R, Pace A, Calay P, Grodent P, Douchamps F, Hyde R, Hotermans C, Delvaux V, Hansen I, Moonen G 2011 Comparison of the Timed 25-Foot and the 100-Meter Walk as performance measures in multiple sclerosis. Neurorehabilitation and Neural Repair 25: 672–679. doi:10.1177/1545968310397204.

Pinheiro MA, Kooij G, Mizee MR, Kamermans A, Enzmann G, Lyck R, Schwaninger M, Engelhardt B, de Vries HE 2016 Immune cell trafficking across the barriers of the central nervous system in multiple sclerosis and stroke. Biochimica et Biophysica Acta 1862: 461–471. doi:10.1016/j.bbadis.2015.10.018.

Rizzo M, Hadjimichael O, Preiningerova J, Vollmer T 2004 Prevalence and treatment of spasticity reported by multiple sclerosis patients. Multiple Sclerosis Journal 10: 589–595. doi:10.1191/1352458504ms1085oa.

Salom-Moreno J, Sánchez-Mila Z, Ortega-Santiago R, Palacios-Ceña M, Truyol-Domínguez S, Fernández-de-las-Peñas C 2014 Changes in spasticity, widespread pressure pain sensitivity, and baropodometry after the application of dry needling in patients who have had a stroke: A randomized controlled trial. Journal of Manipulative and Physiological Therapeutics 37: 569–579. doi:10.1016/j.jmpt.2014.06.003.

Sánchez-Mila Z, Salom-Moreno J, Fernández-de-las-Peñas C 2018 Effects of dry needling on post-stroke spasticity, motor function and stability limits: A randomised clinical trial. Acupuncture in Medicine 36: 358–366. doi:10.1136/acupmed-2017-011568.

Schyns F, Paul L, Finlay K, Ferguson C, Noble E 2009 Vibration therapy in multiple sclerosis: A pilot study exploring its effects on tone, muscle force, sensation and functional performance. Clinical Rehabilitation 23: 771–781. doi:10.1177/0269215508101758.

Shaw L, Rodgers H, Price C, van Wijck F, Shackley P, Steen N, Barnes M, Ford G, Graham L 2010 BoTULS: A multicentre randomised controlled trial to evaluate the clinical effectiveness and cost-effectiveness of treating upper limb spasticity due to stroke with botulinum toxin type. Health Technology Assessment 14: 1–113. doi:10.3310/hta14260.

Solaro C, Trabucco E, Uccelli M 2013 Pain and multiple sclerosis: Pathophysiology and treatment. Current Neurology and Neuroscience Reports 13: 320. doi:10.1007/s11910-012-0320-5.

Sosnoff JJ, Gappmaier E, Frame A, Motl RW 2011 Influence of spasticity on mobility and balance in persons with multiple sclerosis. Journal of Neurologic Physical Therapy 35: 129–132. doi:10.1097/NPT.0b013e31822a8c40.

Stevenson V 2010 Rehabilitation in practice: Spasticity management. Clinical Rehabilitation 24: 293–304. doi:10.1177/0269215509353254.

Valencia-Chulián R, Heredia-Rizo AM, Moral-Munoz JA, Lucena-Anton D, Luque-Moreno C 2020 Dry needling for the management of spasticity, pain, and range of movement in adults after stroke: A systematic review. Complementary Therapies in Medicine 52: 102515. doi:10.1016/j.ctim.2020.102515.

Ward A, Kadies M 2002 The management of pain in spasticity. Disability and Rehabilitation 24: 443–453. doi:10.1080/09638280110108878.

Winter DA 2009 Biomechanics and motor control of human movement. Hoboken, New Jersey: John Wiley and Sons.

Wu CH, Ho YC, Hsiao MY, Chen WS, Wang TG 2017 Evaluation of post-stroke spastic muscle stiffness using shear wave ultrasound elastography. Ultrasound in Medicine and Biology 43: 1105–1111. doi:10.1016/j.ultrasmedbio.2016.12.008.

Yamaguchi T, Petersen TH, Kirk H, Forman C, Svane C, Kofoed-Hansen M, Boesen F, Lorentzen J 2018 Spasticity in adults with cerebral palsy and multiple sclerosis measured by objective clinically applicable technique. Clinical Neurophysiology 129: 2010–2021. doi:10.1016/j.clinph.2018.07.004.