International Journal of Multiphysics
Volume 19, No. 1, 2025
ISSN: 1750-9548

Investigating the Effectiveness of Dry Needling on the Outcomes of Spasticity, Range of Motion, Function, Dynamic, and Static Balance in People with Stroke

Seyed Mehdi Okhravi[1,2], Iraj Abdollahi[1]*, Noureddin Nakhostin Ansari[3,4], Ashraf Mahmoudzadeh[2]

[1]Neuromusculoskeletal Rehabilitation Research Center, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.

[2]Department of Physical Therapy, School of Rehabilitation Sciences, Isfahan University of Medical Sciences, Isfahan, Iran.

[3]Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.

[4]Research Center for War-affected People, Tehran University of Medical Sciences, Tehran, Iran.

*Corresponding author

Abstract: Purpose: This clinical trial evaluated the effectiveness of dry needling on the outcomes of spasticity, range of motion, function, and dynamic, and static balance in people with stroke

Materials and Methods: Twenty-one people with stroke participated in this clinical trial and were randomly assigned to one of two groups real dry needling (intervention group) and sham needling (control group). Subjects of the intervention group received one of dry needling treatment in the gastrocnemius, soleus, and posterior tibialis muscles. Needling was performed conically and for one minute in a fast in-fast out way in the muscles. The study outcomes included spasticity, active and passive ankle dorsiflexion range of motion, dynamic, function, and static balance. Outcomes were measured four times before the intervention, immediately after needling, one week later, and one month later. A repeated-measures analysis of variance was used to analyze the results. The effectiveness of the intervention was calculated using Cohen's D effect size.

Results: The results revealed that the degree of spasticity in the group that received real dry needling for lower limb muscles was significantly reduced immediately after treatment and one week later compared to before treatment. However, dry needling immediately after the intervention led to an increase in active and passive ankle range of motion. No significant difference was observed between the real dry needling and sham groups. There was no statistically significant difference between the two groups in improving the overall condition based on the Brunnstrom Recovery Scale.

Conclusion: The results suggest that real dry needling is effective in reducing spasticity, increasing the active and passive ankle dorsiflexion range, and improving dynamic balance in the short-term intervention.

Keywords: Stroke, Spasticity, Dry Needling

Introduction

Stroke-related disability is multifactorial and can be associated with increased spasticity, post-stroke pain, and muscle weakness (1). Spasticity is one of the most common clinical symptoms after stroke. About 30 to 40% of people experience it after stroke (2). Lance et al. provided the first definition of spasticity was proposed in 1980

(3). It is defined as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) due to increased stretch reflex excitability and as part of the upper motor neuron syndrome. Young et al. (4) stated that spasticity is a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes. It is caused by abnormal processing of primary sensory inputs in the spinal cord. The contribution of the viscoelastic properties of soft tissue to spasticity is not considered in the above-mentioned definitions. Given the viscoelastic properties of soft tissue, the reduction in the range of motion in spasticity is attributed to an increase in tissue resistance rather than spasticity or hypertonicity (reference?).

Post-stroke spasticity can cause pain, changes in limb position, disorder in hand motion, limited range of motion, impaired walking, impaired balance control, and impaired daily activities (5, 6). Impaired balance control is one of the most common complications of spasticity. The rate of falling due to balance disorders has been reported to be up to 65% among people with stroke. Balance control is the result of a complex interaction between the physiological systems of the body. Maintaining proper body alignment in space and body stability during functional activities is one of the most important goals of the postural and balance control system. Proper functioning of sensory-motor systems, including vision, vestibular, somatosensory, and musculoskeletal, is essential for maintaining ideal postural control. Dysfunction in one of the sensory-motor systems can affect the final output of the postural control system (7). Balance disorders cause difficulty in performing daily activities and falling. Correction of muscle activity is a key factor for proper balance (8).

Stroke patients show higher impairment in maintaining standing balance in response to external perturbations. One of them is reduced activity of the ankle muscles on the paralyzed side. Previous studies have revealed that ankle muscles play a key role in controlling postural oscillations during quiet standing by affecting the movements of the center of pressure. Spasticity causes plantar flexion and inversion in the patient's ankle. Recent studies in this area have revealed that standing balance control in a stationary state and temporal coordination between the two limbs are more impaired in stroke patients with spasticity compared to patients without spasticity (7). Impaired standing balance control is directly associated with the degree of ankle spasticity (7). Spasticity causes changes in the activity of the agonist-antagonist chain, dystonia, and soft tissue stiffness. It affects the capability of the muscle to regulate force production, thereby causing impaired postural control (9). Improvement in balance following spasticity treatment also indicates that spasticity is a crucial factor in balance control. The impact of spasticity on balance and postural control has also been confirmed in other neurological diseases such as multiple sclerosis and cerebral palsy (10-12).

Several pharmacological and non-pharmacological interventions are used to reduce spasticity in stroke patients, including botulinum toxin injection, acupuncture, and dry needling (13). Botulinum toxin injection is one of the most common therapeutic techniques in this area. It is effective and can cause some side effects, including allergic reactions (14), muscle weakness (15), and anaphylaxis (16). Moreover, the high cost of this technique and the lack of comprehensive agreement on the type of injection technique, injection dose, and injection site limit its application (17). The dry needling technique is a new treatment introduced to improve spasticity (18). Its mechanism of action in spasticity has not been fully clarified, but it is likely to reduce spasticity through neurophysiological and mechanical mechanisms (19). Dry needling can produce a local stretch in shortened cytoskeletal structures, thereby reducing actin and myosin overlap. Another hypothesis is that dry needling modulates motor neuron activity by altering the transmission of muscle-afferent synapses to the spinal cord, thereby reducing spasticity. Reducing spasticity and central mechanisms can improve balance (18).

No study has investigated the effect of dry needling on balance and postural control despite the balance control importance in stroke patients, the direct correlation between the degree of spasticity and balance impairment in these patients, and the evidence of the positive effect of dry needling in reducing spasticity. Various methods are applied for assessing postural control. Posturography, which records the oscillations and lines of the center of pressure in the standing position, is one of the most common methods of assessment (20). Clinically, posturography is of great importance for the diagnosis, monitoring, and evaluation of interventions (21). This clinical trial examined the impact of dry needling on function, range of motion, and balance in people with a history of stroke due to the limited information on the impact of dry needling on postural control indices and to obtain more evidence on the impact of dry needling on postural control and balance. Dry needling is one of the

therapeutic methods that has been very popular in these patients. In studies investigating the impact of dry needling, the results have revealed that this therapeutic intervention can be effective in reducing spasticity and improving function in these people after stroke. Since the effectiveness of the treatments to reduce disability in patients with central nervous system involvement, including stroke, is often short, therapeutic interventions should be evaluated from many aspects. Thus, this clinical trial was conducted to investigate the impact of dry needling on a range of motion and function.

Methods

The present randomized clinical trial was conducted with two parallel groups. The target population of the present study included male and female stroke patients referring to the Musculoskeletal System Research Center, Faculty of Rehabilitation Sciences, Isfahan University of Medical Sciences. A convenience sampling was used in the present study w from 2023/05/14 to 2024/07/13. Written consent was obtained from the subjects before the test. Twenty-one people with stroke participated in this clinical trial and were randomly assigned to one of two groups real dry needling (intervention group) and sham needling (control group). Subjects of the intervention group received one session of dry needling treatment in the gastrocnemius, soleus, and tibialis posterior muscles.

Needling was performed conically for one minute in the muscles in a fast in-fast out way. The control group received sham needling. In this group, the method was the same as in the intervention group, except that the needle did not puncture the skin. The study outcomes included spasticity, active and passive ankle dorsiflexion range of motion, dynamic, function, and static balance. Spasticity was measured by the modified Ashworth scale, range of motion was measured by a goniometer, dynamic balance was measured by Timed Up and Go (TUG) test, function was measured by Brunnstrom recovery scale, and static balance was measured by force plate and linear indices of center of pressure including mean and velocity of center of pressure oscillations in the anterior-posterior and medial-lateral directions with eyes open and closed.

Treatment

Patients of the experimental group received one session of dry needling treatment in the gastrocnemius, soleus, and tibialis posterior muscles. In this study, a needle measuring 50×0.3 mm was used. The needle was moved conically in the muscles for one minute in a fast in-fast out way. The muscle points where the needle was inserted were within the range of the muscle motor points (22). The treatment points were determined as follows: The medial gastrocnemius muscle was needled in the vertical axis 1.5 cm above the head of the fibula and in the horizontal line 1.7 cm inside the imaginary line of the popliteal fossa with the Achilles tendon and at a depth of 1.1 cm (SD 0.4) from the skin surface (Figure 1) (23). The lateral gastrocnemius muscle was needled in the vertical axis 0.9 cm above the head of the fibula and in the horizontal line 1.8 cm outside the imaginary line of the popliteal fossa with the Achilles tendon and at a depth of 1 cm (SD 0.3) from the skin surface (Figure 1) (23). The soleus muscle is located 1.4 cm below the fibula head and 1.6 cm horizontally outside the imaginary line between the popliteal fossa and the Achilles tendon, and at a depth of 2.8 cm (SD 0.7) from the skin surface (23). The tibialis posterior muscle was needled 4.3 cm below the fibula head and 1.9 cm horizontally outside the imaginary line between the popliteal fossa and the Achilles tendon and at a depth of 2.4 cm (SD 0.8) from the skin surface (Figure 1) (23). The control group received dry needling as a sham. In this group, the method and needling points were the same as in the experimental group, except that the needle did not pierce the skin. For this purpose, special sham needles were used. These needles have a tube similar to standard needles, but the needle was blunt and did not enter the skin.

Results

Twenty-one subjects with a history of stroke were randomly assigned to one of two groups: real dry needling (intervention group) (n = 12) and sham dry needling (control group) (n = 9). Table 1 presents the demographic information of the subjects, including the affected side, type of stroke, and duration of stroke by treatment group. The mean age of the subjects in both the intervention and control groups was 58 years. Additionally, 62% of them were male and the rest were female. The mean duration of stroke in the intervention and control groups was 31 and 28 months, respectively.

Table 1: Demographic characteristics and comparison of baseline variables between the two treatment groups

Variable (unit)		Real dry needling group (12 people)	sham needling group (9 people)	P-value*
		Mean (standard deviation)/number(%)	Mean (standard deviation)/number(%)	
age (years)		58 (9.03)	58.55 (6.21)	0.88
weight (kg)		71.56 (13.44)	14).(1577.89	0.32
height (cm)		166.5 (10.43)	7).(6166.11	0.92
body mass index (kg/m2)		25.83 (4.61)	67).(528.23	0.3
duration of infection (months)		31.25(14.27)	).5(1728	0.64
Stroke type	Hemorrhagic	5 (58.3)	3).(333	0.9
	Ischemic	7 (41.7)	6(66.7)	
Involved side	Right	Right	3).(333	0.9
	Left	Left	7).(666	
Gender	Female	Female	(44/4)4	0.67
	Male	Male	) 5(55.6	

Inter-group and intra-group analysis of anterior-posterior displacement of the center of pressure in the closed position

According to the results of repeated-measures analysis of variance, the effect of time, group, and the interaction of time * group for the anterior-posterior displacement of the center of pressure with closed eyes was not statistically significant (p-value<0.05) (Table 2) (Figure 1).

Table 2-Results of repeated-measures analysis of variance for the outcome of the anterior-posterior displacement of the center of pressure in the closed position

the anterior-posterior displacement of the center of pressure	F index	P-value
Time effect	0.42	0.74
Group effect	0.031	0.87
interaction of time * group	2.55	0.064

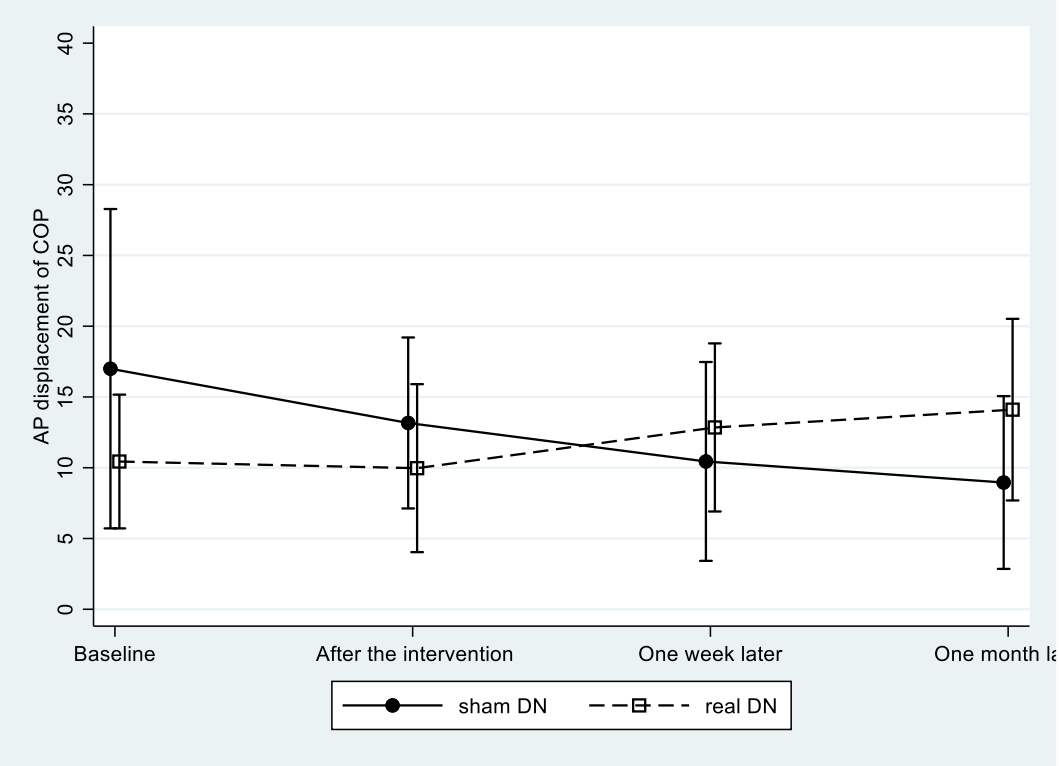

Chart 1- Changes in the anterior-posterior displacement of the center of pressure in the closed-eye position at different times

In this chart, the error bar indicates the 95% CI of the mean. An independent t-test was used to compare the anterior-posterior displacement of the center of pressure between groups at different times. Before the intervention, no statistically significant difference was observed between the two groups in the mean displacement of the center of pressure in the anterior-posterior direction (p-value=0.19) (Table 3). A comparison of the two control and intervention groups based on the test, immediately after the intervention, one week and one month later, did not show a statistically significant difference in the mean displacement of the center of pressure in the anterior-posterior direction in the closed-eye position (p-value>0.05) (Table 3).

Table 3- Results of the independent t-test for the comparison between groups in the anterior-posterior displacement of the center of pressure in the closed-eye position at different times

displacement of the center of pressure in the anterior-posterior direction	F index	p-value	Mean difference (95% CI)	Cohen's D effect size (95% CI)
Before treatment	1.34	0.19	56.6 (-3.67 to 16.78)	-
Immediately after intervention	0.83	0.42	19.3 (-4.88 to 11.27)	-0.35 (-1.23 to 0.51)
One week after intervention	0.59	0.56	-4.2 (-10.95 to 14.6)	0.25 (-0.59 to 0.08)
One month after intervention	1.26	0.22	-15.5 (-13.64 to 3.39)	0.53 (-0.32 to 1.37)

CI= Confidence interval

International Journal of Multiphysics
Volume 19, No. 1, 2025
ISSN: 1750-9548

Inter-group and intra-group analysis of function outcome based on the Brunnstrom recovery scale

The Mann-Whitney test was used to compare inter-group improvement in patients' conditions based on the Brunnstrom recovery scale.

Table 4 presents the results. Based on the results of this test, no statistically significant difference was observed in the improvement of the overall condition between the two groups based on the Brunnstrom recovery scale at any of the outcome measurement times (p-value>0.05). Figures 2 and 34 show the percentage of patients in each phase at different times.

Table 4- Mann-Whitney test for comparing inter-group improvement in patient's condition based on the Brunnstrom recovery scale

	Mean rank		Sum of ranks		p-value
	intervention	Control	intervention	Control	
Before treatment	11.04	10.94	132.5	98.5	0.98
Immediately after intervention	10.79	11.28	129.5	101.5	0.85
One week after intervention	10.67	11.44	128	103	0.75
One month after intervention	10.38	11.83	124.5	106	0.57

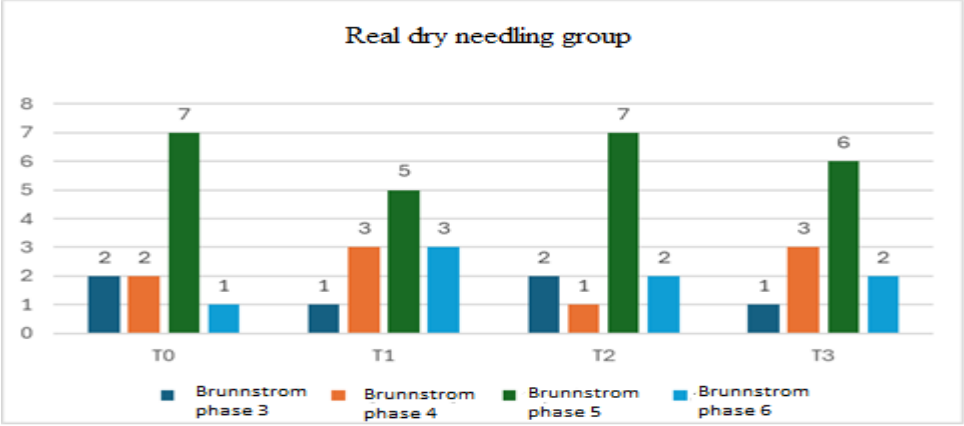

Chart 2 - Number and percentage of subjects by Brunnstrom recovery phases at different times of outcome measurement (intervention group)

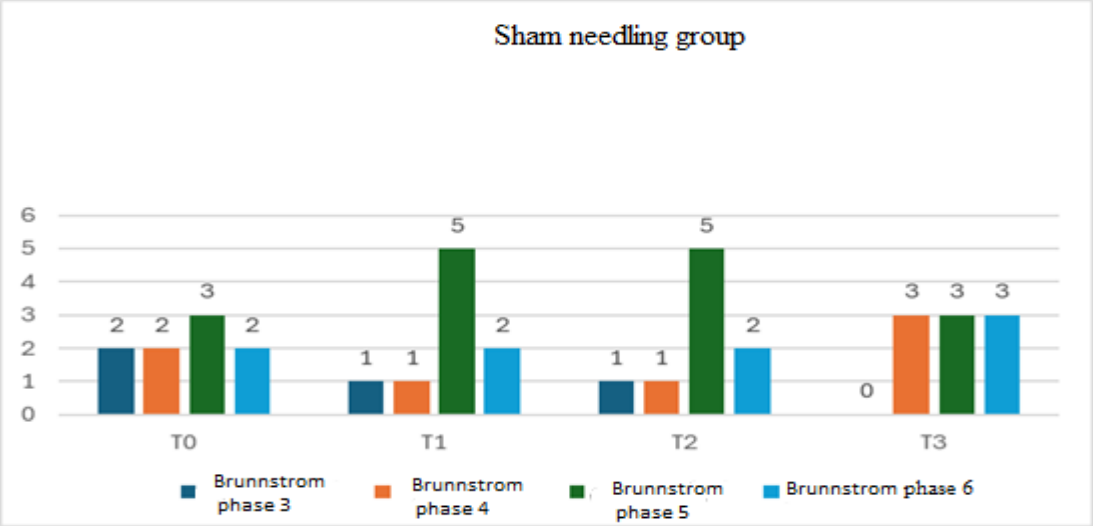

Chart 3 - Number and percentage of subjects by Brunnstrom recovery phases at different times of outcome measurement (control group)

Intragroup comparison

The Wilcoxon test was used to compare intragroup Brunnstrom recovery phases. According to the results of this test, no significant difference was observed between different assessment times in the real dry needling group (p-value>0.05). However, in the control group, the difference between the two times before the intervention and one month after was statistically significant (Table 5).

Table 5 - Results of the Wilcoxon test for intragroup comparison of Brunnstrom recovery phases between different times

Brunnstrom recovery phases		P-value	Negative ranks	Positive ranks	ties
Real dry needling group (n=12)	T0 vs. T1	0.083	0	3	9
	T0 vs. T2	0.16	0	2	10
	T0 vs. T3	0.16	0	2	10
Real dry needling group (n=12)	T0 vs. T1	0.083	0	3	6
	T0 vs. T2	0.083	0	2	6
	T0 vs. T3	0.046	0	4	5

T0 = before intervention, T1 = immediately after intervention, T2 = One week later, T3 = One month later

Positive rank = Number of pairs where the second is larger than the first

Negative rank = Number of pairs where the second is smaller than the first.

Ties = Number of pairs where the first and second are equal.

Discussion

The results revealed that the degree of spasticity in the group that received real dry needling for the lower limb muscles was significantly reduced immediately after treatment and one week later compared to before treatment. However, no significant changes were observed in the control group after treatment compared to before treatment regarding the severity of spasticity. Comparing the two groups also revealed that the severity of spasticity in the intervention group was significantly lower than that in the control group immediately after the intervention. A single-group pre-test and post-test study by Bolhasani et al. proved the short-term effectiveness of a single session of dry needling on reducing spasticity of the ankle plantar flexor muscles in people with a history of stroke (24).

Another clinical trial study revealed that a single session of dry needling on the tibialis anterior and gastrocnemius muscles was effective in reducing spasticity in the short term (10 minutes after needling) compared to sham needling (19). Most studies, including the results of the present study, do not support the durability of the effect of dry needling on spasticity improvement. One reason for this lack of durability could be that only one session of dry needling was performed. Generally, the temporary effects observed with this method may be due to short-term changes in neuromuscular modulation that reduce muscle hyperactivity and reduce spasticity. These changes mostly include temporary inhibition of peripheral nerve signals and improved muscle control, leading to a temporary reduction in muscle tension (25).

Dry needling led to an increase in active and passive ankle range of motion immediately after the intervention, but no significant difference was observed between the real dry needling and sham groups. One reason could be the placebo effect. The sham dry needling may still produce a sham effect, although it does not involve real penetration of the muscle or trigger points. Spasticity in the plantar flexors leads to persistent, involuntary contraction of these muscles, limiting the range of motion of the dorsiflexor muscles and reducing the dorsiflexion capability. Dry needling of the plantar flexors helps reduce these contractions by disrupting abnormal neuromuscular signals, releasing trigger points, and reducing muscle tension (26-28). This reduction in muscle hyperactivity reduces resistance to dorsiflexion and increases the passive range of motion in the ankle joint. Dry needling may also improve local blood flow and reduce the inflammatory response, leading to further inhibition of the spastic muscles (28). Thus, patients experience improved flexibility and ankle movement. In the present study, the active and passive ankle dorsiflexion range increased compared to before treatment immediately after dry needling, while only the passive ankle dorsiflexion range increased after treatment in the control group.

Dry needling may help improve postural stability and reduce center of pressure (COP) oscillations by reducing spasticity and noise in muscle spindle signals (26). Muscle spindles, involved in detecting muscle stretch, may send incorrect or excessive signals due to spasticity. This noise in muscle spindle signals can cause inappropriate muscle responses and increase oscillations (27). Dry needling increases the accuracy of proprioceptive feedback and helps muscles better stabilize their posture, thereby reducing COP oscillations by regulating abnormal muscle spindle activity,. Moreover, dry needling allows muscles to better respond to changes in the body posture by reducing spasticity and releasing trigger points (29), improving muscle control and reducing oscillations.

The effect of dry needling on reducing the oscillations of the center of pressure was observed only in the short term and immediately after needling, and the outcome assessment one week and one month later did not show any difference between the control and intervention groups. Its reason may be that the intervention was a single session. No statistically significant difference was observed between the two groups in improving the overall condition based on the Brunnstrom Recovery Scale. Unlike the results obtained in the present study, in the study by Cuensa et al., using 6 sessions of dry needling along with standard physiotherapy treatment significantly improved upper limb motor function based on the Brunnstrom criteria in patients with subacute phase of stroke (30).

In a case-report study, applying one session of dry needling improved upper limb motor function from phase 3 to 4 based on the Brunnstrom criteria (22). Another study compared one and three sessions of dry needling on the flexor carpi radialis and ulnaris muscles. Its results revealed that motor function improved in both groups from phase three to four, but there was no evidence of the treatment durability (31). The difference between the results

of the present study and those of the mentioned studies is the methodological differences between the studies. These factors include the number of treatment sessions and the combination with other interventions. A higher number of dry needling sessions may have cumulative effects on muscle function and neurological adaptation. Moreover, the combination of dry needling with standard physiotherapy treatment can enhance the effectiveness. Another factor is the phase of the patients. Patients in the subacute phase of stroke may have a higher potential for neurological recovery compared to those in the chronic phase. The target muscles may also be an influential factor. In the mentioned studies that reported dry needling effectiveness (30, 22, 31), the needling was applied to the upper limb muscles, and the motor function of these muscles was assessed, while the gastrocnemius, soleus, and tibialis posterior muscles were needled in our study.

Conclusion

The results of the study revealed that real dry needling is an effective intervention in the short term to reduce spasticity, increase the range of active and passive ankle dorsiflexion, and improve dynamic balance. This indicates its potential as a useful intervention in stroke rehabilitation in the short term. Real dry needling has an immediate impact on reducing spasticity and increasing the range of passive ankle dorsiflexion. Thus, it can be recommended to stroke patients for rapid rather than lasting effectiveness. Applying a single session of dry needling was among the limitations of the study, limiting the effectiveness of the intervention in the long term. Moreover, more diversity in static balance assessment positions could have provided a clearer and broader view of the effect of the intervention on static balance.

References

1. Hernández-Ortíz AR, Ponce-Luceno R, Sáez-Sánchez C, García-Sánchez O, Fernández-de-Las-Peñas C, de-la-Llave-Rincón AI. Changes in muscle tone, function, and pain in the chronic hemiparetic shoulder after dry needling within or outside trigger points in stroke patients: A crossover randomized clinical trial. Pain Medicine. 2020;21(1.47-2939:(1
2. Zorowitz RD, Gillard PJ, Brainin M. Poststroke spasticity: sequelae and burden on stroke survivors and caregivers. Neurology. 2013;80(3 Supplement 2):S45-S52.
3. Lance JW. Symposium synopsis. Spasticity: disordered motor control. 1980:487.9-
4. Young RR. Spasticity: a review. Neurology. 1994;44(11 Suppl 9):S12-20.
5. Harrison RA, Field TS. Post stroke pain: identification, assessment, and therapy. Cerebrovascular diseases. 2015;39(3-4):190-201.
6. Thibaut A, Chatelle C, Ziegler E, Bruno M-A, Laureys S, Gosseries O. Spasticity after stroke: physiology, assessment and treatment. Brain injury. 2013;27(10):1093-105.
7. Rahimzadeh Khiabani R, Mochizuki G, Ismail F, Boulias C, Phadke CP, Gage WH. Impact of spasticity on balance control during quiet standing in persons after Stroke. Stroke research and treatment. 2017;2017.
8. Phadke CP, Ismail F, Boulias C, Gage W, Mochizuki G. The impact of post-stroke spasticity and botulinum toxin on standing balance: a systematic review. Expert review of neurotherapeutics. 2014;14(3):319-27.
9. Singer JC, Nishihara K, Mochizuki G. Does poststroke lower-limb spasticity influence the recovery of standing balance control? A 2-year multilevel growth model. Neurorehabilitation and neural repair. 2016;30.34-626:(7)
10. Sosnoff JJ, Gappmaier E, Frame A, Motl RW. Influence of spasticity on mobility and balance in persons with multiple sclerosis. Journal of Neurologic Physical Therapy. 2011;35(3):129-32.
11. Sosnoff JJ, Shin S, Motl RW. Multiple sclerosis and postural control: the role of spasticity. Archives of physical medicine and rehabilitation. 2010;91(1):93-9.
12. Myhr U, von Wendt L. Reducing spasticity and enhancing postural control for the creation of a functional sitting position in children with cerebral palsy: A pilot study. Physiotherapy theory and practice. 1990;6(2):65-76.
13. Stevenson V. Rehabilitation in practice: spasticity management. Clinical rehabilitation. 2010;24(4):293-304.
14. Careta MF, Delgado L, Patriota R. Report of allergic reaction after application of botulinum toxin. Aesthetic surgery journal. 2015;35(5):NP102-NP5.

15. Gracies J-M, Brashear A, Jech R, McAllister P, Banach M, Valkovic P, et al. Safety and efficacy of abobotulinumtoxinA for hemiparesis in adults with upper limb spasticity after stroke or traumatic brain injury: a double-blind randomised controlled trial. The Lancet Neurology. 2015;14(10):992-1001.
16. Moon I, Chang S, Kim S. First case of anaphylaxis after botulinum toxin type A injection. Clinical and Experimental Dermatology. 2017;42(7):760-2.
17. Núñez-Cortés R, Cruz-Montecinos C, Latorre-García R, Pérez-Alenda S, Torres-Castro R. Effectiveness of dry needling in the management of spasticity in patients post stroke. Journal of Stroke and Cerebrovascular Diseases. 2020;29(11):105236.
18. Sánchez-Mila Z, Salom-Moreno J, Fernández-de-Las-Peñas C. Effects of dry needling on post-stroke spasticity, motor function and stability limits: a randomised clinical trial. Acupuncture in Medicine. 2018;36(6):358-66.
19. Salom-Moreno J, Sánchez-Mila Z, Ortega-Santiago R, Palacios-Ceña M, Truyol-Domínguez S, Fernández-de-las-Peñas C. 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. 2014;37(8):569-79.
20. Van Daele U, Hagman F, Truijen S, Vorlat P, Van Gheluwe B, Vaes P. Differences in balance strategies between nonspecific chronic low back pain patients and healthy control subjects during unstable sitting. Spine. 2009;34(11):1233-8.
21. Lamoth CJ, van Lummel RC, Beek PJ. Athletic skill level is reflected in body sway: a test case for accelometry in combination with stochastic dynamics. Gait & posture. 2009;29(4):546-51.
22. Ansari NN, Naghdi S, Fakhari Z, Radinmehr H, Hasson S. Dry needling for the treatment of poststroke muscle spasticity: a prospective case report. NeuroRehabilitation. 2015;36(1):61-5.
23. Picelli A, Chemello E, Verzini E, Ferrari F, Brugnera A, Gandolfi M, et al. Anatomical landmarks for tibial nerve motor branches in the management of spastic equinovarus foot after stroke: An ultrasonographic study. J Rehabil Med. 2019;51(5):380-4.
24. Bolhasani F, Naghdi S, Ansari N, Fakhari Z. The immediate effects of dry needling for ankle and toe plantar flexors on spasticity and balance in patients with stroke. Tehran University Medical Journal. 2020;78(1):21-7.
25. Fernández-de-Las-Peñas C, Pérez-Bellmunt A, Llurda-Almuzara L, Plaza-Manzano G, De-la-Llave-Rincón AI, Navarro-Santana MJ. 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. 2021;22(1):131-41.
26. .Dommerholt J. Dry needling—peripheral and central considerations. Journal of Manual & Manipulative Therapy. 2011;19(4):223-7.
27. Dommerholt J, Mayoral del Moral O, Gröbli C. Trigger point dry needling. Journal of Manual & Manipulative Therapy. 2006;14(4):70E-87E.
28. Hsieh Y-L, Kao M-J, Kuan T-S, Chen S-M, Chen J-T, Hong C-Z. Dry needling to a key myofascial trigger point may reduce the irritability of satellite MTrPs. American journal of physical medicine & rehabilitation. 2007;86(5):397-403.
29. Falk J, Strandkvist V, Pauelsen M ,Vikman I, Nyberg L, Röijezon U. Increased co-contraction reaction during a surface perturbation is associated with unsuccessful postural control among older adults. BMC geriatrics. 2022;22(1):438.
30. Cuenca Zaldivar JN, Calvo S, Bravo-Esteban E, Oliva Ruiz P, Santi-Cano MJ, Herrero P. Effectiveness of dry needling for upper extremity spasticity, quality of life and function in subacute phase stroke patients. Acupuncture in Medicine. 2021;39(4):299-308.
31. Nakhostin Ansari N, Hasheminasab-Zavareh F-S, Naghdi S, Dommerholt J. Effects of dry needling session frequency on wrist flexor spasticity and motor recovery after stroke: A single-blind randomized clinical trial. Physiotherapy Theory and Practice. 2023:1-12.