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Combined effects of dry needling and exercises therapy on muscle spasticity and motor function in chronic stroke: a pretest-posttest pilot study

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Abstract

Aim: Spasticity is one of the most common symptoms in post-stroke patients. Dry needling (DN) is a relatively new method for the management of muscle spasticity. A multimodal treatment may be more effective in spasticity management. The purpose of this study was to explore the short-term combined effects of DN and exercise therapy on wrist flexor spasticity, motor function, and motor neuron excitability in patients with chronic stroke.

Methods: Ten patients with stroke and a mean age of 52 ± 4.9 years participated in this pretest-posttest pilot study. Patients received four sessions of DN and exercise therapy. Affected flexor carpi radialis and flexor carpi ulnaris muscles were needled each for 1 min. Patients underwent exercise therapy for about 30 min, once a week after DN. The outcome measures were the Modified Modified Ashworth Scale (MMAS), the maximal amplitude of H wave/maximal amplitude of M wave ratio (H_{max}/M_{max} Ratio), H-reflex latency, wrist extension active and passive range of motion (ROM), Action Research Arm Test (ARAT), and Fugl-Meyer Assessment (FMA). Assessments were performed at baseline, after four sessions of treatment, and three weeks after treatment.

Results: After treatment, significant improvements in MMAS, wrist passive ROM, ARAT, and FMA were obtained ($P \leq 0.05$).

Conclusions: DN combined with exercise therapy improved muscle spasticity and motor function in patients with chronic stroke. Further investigations with a randomized controlled trial design with a comparator group of DN only are warranted (https://www.irct.ir/ identifier: IRCT20180611040061N1).

Keywords

Stroke, spasticity, dry needling, exercise therapy, Hoffmann reflex

Introduction

Spasticity is one of the most common symptoms of stroke, which occurs in about 60% of these patients [1]. It is an upper motor neuron disorder characterized by a velocity-dependent increase in stretch reflex and resistance to passive movement [2]. Many stroke patients suffer from upper extremity spasticity, which can result in contracture, pain, limitation in function, and social participation [3]. Various treatment methods such as medication, physiotherapy, electrical stimulation, and botulinum toxin injection are used to improve spasticity [4]. Dry needling (DN) has been demonstrated to be effective to manage spasticity in chronic and subacute stroke [5, 6]. Moreover, DN has also been shown to be a cost-effective treatment method [7].

A combination of DN with other treatments may have better effects on spasticity management and rehabilitation of patients with chronic stroke [8]. Previous studies have demonstrated the positive effects of exercise therapy on functional improvement and increased range of motion (ROM) in patients with stroke [8, 9]. There is only one case study that investigated the positive effects of DN with exercise therapy in improving spasticity and upper-limb motor function in post-stroke patients [10]. We hypothesized that DN combined with exercise therapy have more positive effects on spasticity and motor function after chronic stroke. Therefore, this pilot study aimed to evaluate the short-term combined effects of DN and exercise therapy on spasticity, motor function, and alpha motor neuron excitability in patients with chronic stroke.

Materials and methods

Study design

We conducted a pretest-posttest pilot study with a single intervention group. Assessments and treatments were performed in the Rehabilitation Center of Shafa Yahyaian Hospital, Tehran, Iran. The study protocol was approved by the Ethical Committee of Tehran University of Medical Sciences (TUMS; IR.TUMS.FNM.REC.1399.008). Written informed consent was obtained from all participants before beginning the study. Evaluations were performed at baseline (T1), after four-session treatment (T2), and after three-week follow-up (T3).

Inclusion criteria were: age ≥ 40 years, first-ever stroke, stroke onset of ≥ 6 months, spasticity grade ≥ 1 for the wrist flexor muscles according to the Modified Modified Ashworth Scale (MMAS), and ability to understand and follow the instructions. Exclusion criteria were any contraindications to DN (e.g., needle phobia, vascular disease, and lymphedema among others), presence of diabetic neuropathy and other neurological disorders, fixed contracture at the wrist joint, and recent history of botulinum toxin A injection.

Outcome measures

The primary outcome measures were MMAS, the maximal amplitude of H wave/maximal amplitude of M wave ratio (H_{max}/M_{max} Ratio), and the Hoffmann reflex (H-reflex) latency. Secondary outcome measures were active and passive wrist extension ROM, Action Research Arm Test (ARAT), and Fugl-Meyer Assessment (FMA).

Procedure

Patients' demographic information including age, gender, duration since stroke onset, weight, height, and body mass index (BMI) was recorded. An experienced physiotherapist performed all measurements. Another trained physiotherapist performed the DN and exercise therapy. Measurements were taken at baseline (T1), after four-session treatment (T2), and after three-week follow-up (T3). Treatment consisted of four sessions of DN and exercise therapy performed once a week.

Measurements

MMAS

MMAS is a valid and reliable test for measuring the wrist flexor spasticity that grades the level of spasticity from the "0" to "4". A score of "0" indicates no increase in muscle tone, and a score of "4" indicates that the affected limb is rigid in flexion or extension [11, 12]. To perform the test, the patient was in a supine position with the upper limb slightly away from the body. The assessor moved the wrist passively from the maximum flexion to the maximum extension and scored the level of spasticity based on the resistance to passive stretching.

H-reflex

The H-reflex of the flexor carpi radialis (FCR) muscle was used for electrophysiological measurement of spasticity. The method used in a previous study was followed [13]. Briefly, patients were positioned supine with the forearm in supination. The cathode was placed on the FCR muscle bulk and the anode 4 cm distal in the direction of the muscle fibers. To stimulate the median nerve, a bipolar surface electrode was placed in line with the median nerve in the cubital fossa. The ground electrode was placed between the recording and stimulation electrodes on the forearm. An electromyography (EMG) machine (EBNeuro Myto II, B9700020100, Italy) set with a bandpass filter at 5 Hz to 3 kHz, sweep speed at 5 ms/div, and sensitivity at 200 μv/div to 500 μv/div was used. To stimulate the median nerve, a rectangular pulse with 1 ms division, and a frequency of 0.2 Hz with an interval between two stimuli of at least 5 s was used. The current intensity gradually increased to record the maximum M wave. The H-reflex latency was calculated from the onset of the stimulation to the start of the initial deflection from the baseline. The H_{max}/M_{max} ratio was calculated by dividing the maximum amplitude of the H-reflex by the maximum amplitude of the M wave.

ROM

A standard goniometer was used to measure the active and passive ROM of the wrist extension. The forearm was in the neutral position on a table, arm next to the trunk and elbow at 90° flexion. The assessor then placed the goniometer axis at the anatomical snuff box, the stationary arm parallel to the longitudinal axis of the forearm, and the movable arm along with the second metacarpal. To measure active ROM, the patients were asked to actively extend their wrists. For passive ROM, the assessor extended the patient's wrist and recorded the maximal end position [14].

ARAT

The ARAT is a valid and reliable test to assess upper limb performance (coordination, dexterity, and function). This test consists of 4 subscales of grasp, grip, pinch, and gross movement, and includes 19 items that are arranged in order of difficulty. Each item is scored from "0" to "3", and the total score is 57 [15, 16].

FMA

The FMA measures the limb function based on the International Classification of Functioning, Disability, and Health (ICF). In this study, the upper limb section consisting of 33 tasks was used. In total, each task is scored "0" (no active movement), "1" (partial active movement), or "2" (full active movement) [17].

DN

Dong Bang AcuPrime Ltd, Korea acupuncture needle (0.25 mm × 20 mm) was used for DN. We used the fast in-fast out cone shape technique. Patients were in a supine position with the forearm in supination. DN was performed on the affected FCR and flexor carpi ulnaris muscles, each for one min. The FCR muscle was needled 1cm medial and 4cm below the midpoint of the elbow crease. The flexor carpi ulnaris muscle was needled at the middle of the proximal third segment of the line connecting the medial epicondyle to the ulnar styloid process [5].

Exercise therapy

The exercises were delivered by a physiotherapist in three levels of structure, function, and activity according to the ICF [18]. The exercises were performed for about 30 min, once a week after DN.

Statistical analysis

All statistical analyzes were performed by statistical package for social science (SPSS) software (version 23, SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were used to describe patients' demographic information and other variables. Kolmogorov-Smirnov (KS) test was used to assess the normal distribution of the variables. One way repeated measure analysis of variance (ANOVA) test was applied, followed by the Bonferroni test for post hoc analyses. The greenhouse-Geisser test was used if the sphericity condition was not met. The effect size was calculated by partial eta^2 (η^2_p; low = 0.25, medium = 0.40, large > 0.40) [19]. Friedman test was used for ordinal variables and variables that were not normally distributed. Then Wilcoxon signed rank test was used for pairwise comparisons. The significance level was set at $P \leq 0.05$.

Results

Ten patients with chronic stroke (5 females and 5 males) with a mean age of 52 ± 9.4 years and a mean time since the stroke of 8.6 ± 5.5 years participated in this study.

MMAS

Before treatment, four patients were graded "3" on MMAS, one patient was scored "4", and no patient was scored "0". After treatment, five patients were graded "2", no patient was graded "4", and one patient was graded "0". At follow-up, four patients were graded "2", no patient was scored "4", and two patients were scored "0" (Table 1). The median MMAS before treatment was "2.5", which improved significantly to "2" after treatment (T2, T3). Wilcoxon signed rank test showed a statistically significant improvement of MMAS at T2 and T3 compared to T1 (both $P = 0.05$).

Table 1. Frequency (percentage) of MMAS scores before and after treatment ($n = 10$)

MMAS	T1	T2	T3
0	0 (0)	1 (10)	2 (20)
1	3 (30)	2 (20)	1 (10)
2	2 (20)	5 (50)	4 (40)
3	4 (40)	2 (20)	3 (30)
4	1 (10)	0 (0)	0 (0)

H-reflex

Repeated measures ANOVA showed that changes in the H_{max}/M_{max} ratio and the H-reflex latency were not statistically significant ($P > 0.05$) (Table 2).

Table 2. Mean (standard deviation) of H-reflex measures before and after treatment ($n = 10$)

	T1	T2	T3
H_{max}/M_{max} ratio	0.67 (0.21)	0.49 (0.20)	0.51 (0.19)
H-reflex latency (ms)	16.37 (1.40)	16.95 (1.31)	17.07 (1.33)

Passive and active ROM

Repeated measures ANOVA indicated a significant increase in wrist extension passive ROM after treatment ($P = 0.008$). Pairwise comparisons with the Bonferroni test showed a significant increase only at T2 compared to T1 ($P = 0.0\ 41$) (Table 3). The effect size was 0.42. However, the Friedman test showed that DN and exercise therapy had no significant effect on increasing the wrist extension active ROM ($P = 0.074$) (Table 3).

Table 3. Mean (standard deviation) of clinical variables (n = 10)

	T1	T2	T3
Passive ROM (degree)	62.66 (13.0)	71.83 (11.25)	68.43 (10.67)
Active ROM (degree)	11.49 (18.19)	17.49 (21.27)	18.43 (25.23)
ARAT	14.9 (16.98)	17.9 (17.85)	15.9 (17.75)
FMA	30.9 (16.54)	34.9 (17.73)	33.5 (17.62)

ARAT

Repeated measures ANOVA indicated significant improvement in ARAT scores (P = 0.004). Pairwise comparisons with the Bonferroni test showed a significant increase at T2 compared to T1 (P = 0.04) and a significant decrease at T3 compared to T2 (P = 0.035) (Table 3). The effect size was 0.46.

FMA

Repeated measures ANOVA indicated significant improvement in FMA score after treatment at only T2 (P = 0.005) (Table 3). The effect size was 0.44.

Discussion

The results of this pilot study showed that four sessions of DN and exercise therapy improved wrist flexors spasticity, passive ROM, and upper limb motor function in patients with chronic stroke. However, changes in these outcomes occurred immediately after treatment, at T2, but not at follow-up T3 except for the MMAS improvements in spasticity remained at follow-up. As far as we know, this is the first study that investigated the short-term combined effects of DN and exercise therapy on electrophysiological and functional outcomes in the upper extremity of patients with chronic stroke.

MMAS

In this study, wrist flexor spasticity based on MMAS improved after treatment (median score 2.5 to 2) and lasted after a three-week follow-up. This improvement in the MMAS was more than the minimal clinically important difference (MCID; MCID = 0.48) [20], which indicates the clinical effectiveness of DN and exercise therapy in reducing spasticity. This clinically meaningful decrease in spasticity could be due to the mechanical manipulation by DN and additional effects of therapeutic exercises that resulted in the maintenance of improvement at follow-up [21, 22]. This meaningful change may be due to the reducing actin and myosin overlap and a decrease in resistance to passive stretch after DN [5, 14].

A recent study reported the existence of latent trigger points in spastic muscles which may contribute partly to spastic hypertonia in chronic stroke [23]. Dysfunctional endplates associated with trigger points translate to muscle contraction and localized sarcomere shortenings. Moreover, the presence of nociceptive and sensitizing substances (e.g., bradykinin, substance P, interleukins, serotonin, and norepinephrine) cause pain and acetylcholine release. Hence, another mechanism for the improvements in spasticity found in this study might be the disruption of dysfunctional motor endplate [24]. Other possible mechanisms for the improvements might be enhanced oxygen supply and blood circulation as well as the extracellular signal-related kinase and focal adhesion kinase mechanotransduction pathways triggered after DN intervention which helped to reduce the muscle spasticity [25, 26].

Our findings are consistent with a previous study that DN combined with Bobath exercises was more effective than Bobath exercises alone in reducing lower limb spasticity [27]. These findings indicate that regardless of limb treated, the combination of DN and exercise therapy have a clinically meaningful impact on muscle spasticity after stroke.

H-reflex

In the present study, H-reflex measures did not improve after DN and exercise therapy. The lack of improvements in H-reflex measures following treatment may indicate that the changes resulting in improvements might have occurred at the biomechanical level after DN and exercise therapy [5]. Our

findings are not consistent with previous reports that found improvements in alpha motor neuron excitability after DN intervention [5, 14]. The inconsistencies could be due to the small sample size in this pilot study. Further study with a sufficient sample of patients is suggested to clarify if the DN and exercise therapy will affect the spasticity at the neural level.

Passive ROM

In the present study, DN and exercise therapy had a large effect on the wrist passive ROM, in line with previous studies that have shown significant improvements in passive ROM after DN [5, 14, 28]. However, in our study, the mean increase in passive ROM after treatment, though statistically significant, was about 9˚ which may not be clinically relevant to a previous study, the mean increase in the wrist passive ROM with post-stroke patients (n = 29) was about 19˚ [14]. The inconsistency could be due to the small sample size in the present study. Further, in the present study, 7 patients had a spasticity score of ≥ 2 (Table 1) which indicates the high-level spasticity of the patients included in this study. This could have had a role in the small changes in wrist passive ROM. Considering that DN applied as a single intervention has been shown to have significant effects in improving the passive wrist ROM [5, 14], a further study with two groups of DN only and DN plus exercise therapy is needed to clarify whether the exercise therapy has an additional effect on passive ROM.

Active ROM

In this study, consistent with previous works [28, 29], we did not find a significant effect of DN and exercise therapy on active ROM. However, some studies found improvements in active wrist extension ROM after DN [14, 30]. Although the patients were in the chronic stage and had inconsistencies in the motor tracts after stroke [31–34], we expected improvements in active ROM after a combination of DN and exercise therapy [14]. Reasons for our findings might be the small sample size as well as the insufficient duration of exercise therapy. Further studies with a large sample size and the DN combined with the same exercises for a longer period may be required to assess if such protocol will improve the active wrist extension ROM.

Function

We found significant improvements in the upper limb function in terms of ARAT and FMA after four sessions of DN and exercise therapy in line with previous works that used DN only [5, 14, 30, 35]. Despite the large effect sizes found for both measures at T2, the improvements observed in these patients with chronic stroke did not reach the MCID of ARAT and FMA [36, 37]. The ARAT and FMA require sufficient active ROM to implement the functions [38, 39]. The lack of clinical improvement in the present study could be due to the lack of a significant increase in active wrist ROM. In a recent non-randomized study, the effectiveness of DN plus standard multimodal physiotherapy on affected arm functionality was compared with standard multimodal physiotherapy only in eight sessions for 8 weeks in patients with subacute stroke [6]. While there were no significant differences between the groups on the FMA score, the significantly larger increases in total score (12.6 points in the DN group *vs.* 6.08 points in the standard physiotherapy group) were noted in the needling group [6]. The large improvements in motor skills in terms of FMA found in our study at T2 were in line with those reported for patients with subacute stroke [6]. However, DN did not show lasting changes in motor function at T3 follow-up. The reasons could be the small sample size and insufficient dose of treatment program in our study protocol. Further trials with a larger number of patients and quality design are needed to determine the optimal doses for arm function in patients with stroke.

In conclusion, this pilot study showed that the DN combined with exercise therapy improved wrist flexor spasticity and motor function in patients with chronic stroke. Studies with a randomized controlled trial design and longer follow-up are required to evaluate the effects of DN combined with exercise therapy in patients with stroke.

Limitations

The limitations of this study must be noted. First, the number of participants was small. Second, there was no isolated DN intervention as a comparator group. Third, the long-term effects of our treatment were not

investigated to evaluate the potential sustainability of the effects. Therefore, a study with a large sample size and a comparator group of DN in the context of a blinded randomized controlled trial is warranted.

Abbreviations

ANOVA: analysis of variance

ARAT: Action Research Arm Test

DN: dry needling

FCR: flexor carpi radialis

FMA: Fugl-Meyer Assessment

H-reflex: Hoffmann reflex

MMAS: Modified Modified Ashworth Scale

ROM: range of motion

Declarations

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Author contributions

SSBZ, NNA, NG, and SN contributed to the conception and design of the study. MK and KM contributed to data collection. SSBZ and NNA performed the statistical analyses. SSBZ and SMJH wrote the first draft of the manuscript that was revised by NNA and NG for important intellectual content. All authors read and approved the final submitted version.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Ethical approval

This study was approved by the ethical committee of the Tehran University of Medical Sciences (IR.TUMS.FNM.REC.1399.008).

Consent to participate

The informed consent to participate in the study was obtained from all participants.

Consent to publication

Not applicable.

Availability of data and materials

It is available upon reasonable request. (Nastaran Ghotbi, nghotbi@sina.tums.ac.ir).

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