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Effects of myofascial release with tennis ball on spasticity and motor functions of upper limb in patients with chronic stroke

A randomized controlled trial

Rutu J. Parikh, MPTh[a], Jayshree M. Sutaria, PhD[a], Mohammad Ahsan, PhD[b], Shibili Nuhmani, PhD[b], Ahmad H. Alghadir, PhD[c], Masood Khan, MPTh[c,*]

Abstract

Background: Impaired motor function and upper extremity spasticity are common concerns in patients after stroke. It is essential to plan therapeutic techniques to recover from the stroke. The objective of this study was to investigate the effects of myofascial release with the tennis ball on spasticity and motor functions of the upper extremity in patients with chronic stroke.

Methods: Twenty-two chronic stroke patients (male-16, female-6) were selected to conduct this study. Two groups were formed: the control group (n=11) which included conventional physiotherapy only and the experimental group (n=11) which included conventional physiotherapy along with tennis ball myofascial release – in both groups interventions were performed for 6 sessions (35 minutes/session) per week for a total of 4 weeks. The conventional physiotherapy program consisted of active and passive ROM exercises, positional stretch exercises, resistance strength training, postural control exercises, and exercises to improve lower limb functions. All patients were evaluated with a modified Ashworth scale for spasticity of upper limb muscles (biceps brachii, pronator teres, and the long finger flexors) and a Fugl-Meyer assessment scale for upper limb motor functions before and after 4 weeks. Nonparametric (Mann–Whitney *U* test and Wilcoxon signed-rank test) tests were used to analyze data statistically. This study has been registered on clinicaltrial.gov (ID: NCT05242679).

Results: A significant improvement ($P < .05$) was observed in the spasticity of all 3 muscles in both groups. For upper limb motor functions, significant improvement ($P < .05$) was observed in the experimental group only. When both groups were compared, greater improvement ($P < .05$) was observed in the experimental group in comparison to the control group for both spasticity of muscles and upper limb motor functions.

Conclusion: Myofascial release performed with a tennis ball in conjunction with conventional physiotherapy has more beneficial effects on spasticity and motor functions of the upper extremity in patients with chronic stroke compared to conventional therapy alone.

Abbreviations: MCID = minimal clinically important difference, MMSE = mini-mental state exam, PNF = proprioceptive neuromuscular facilitation, ROM = range of motion

Keywords: chronic stroke, Fugl–Meyer assessment scale, modified Ashworth scale, motor functions, myofascial release, spasticity

1. Introduction

Stroke is a rapid onset of neurological dysfunction caused by abnormalities in the cerebral circulation, with signs and symptoms corresponding to the involvement of specific areas of the brain.[1] After a stroke, the most common primary impairments are altered sensations, pain, visual changes, motor dysfunction, postural instability, speech and language dysfunction, perception, and cognition defects.[2] Many individuals experience chronic unilateral upper-extremity motor dysfunction, significantly restricting their functional movements.[3] Motor dysfunctions are the major factors that make an individual incapable to participate in many activities of daily living. Only 5% to 20% of stroke survivors have been reported to have made a near-complete functional recovery.[4] Approximately 50% of stroke survivors have significant functional problems in their

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[a] Government Physiotherapy College, Government Spine Institute, Civil Hospital, Ahmedabad, Gujrat, India, [b] Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia, [c] Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia.

* Correspondence: Masood Khan, Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, P.O. Box. 10219, Riyadh-11433, Saudi Arabia (e-mail: raomasood22@gmail.com, mkhan4.c@ksu.edu.sa).

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hands and arms[5] and remain with reduced arm functions even after 6 months of stroke incidence.[6] These reduced upper limb functions restrict the activities of daily living of the patient, reduce their productivity, make social integration difficult, and cause an economic burden.[7] Stroke causes motor disorders such as spasticity, which is caused by an imbalance of brain activity. Spasticity is high resistance to passive muscle stretching influenced by velocity.[8] Spasticity prevalence after stroke varies from 18% to 60%.[9,10] Spasticity affects the upper extremities more frequently than the lower extremities. This regional inclination adds to the slower recovery of upper limb functions while there is a near-permanent disability in hand and wrist function.[11] Spasticity delays stroke recovery because it interferes with the ability to move normally and perform everyday tasks, including grooming, clothing, and bathing. According to several researchers, dysfunctional reflexes linked to spasticity are the primary determinants of motor dysfunction.[12,13] Spasticity is considered one of the factors that contribute to a motor and functional impairment after stroke. However, it is not an autonomous agent because other primary factors, such as muscle weakness, may also be present.[14,15]

Myofascial release is a therapeutic technique that aims to improve flexibility and sliding between layers of soft tissues, reduce the severity of muscle activity pain, and improve functional performance.[16] The tissue will become softer and more flexible after a few releases. Restoration of length and health of myofascial tissues reduces pressure on pain-sensitive tissues such as nerves and blood vessels and restores joint alignment and mobility.[17] This approach requires the application of an external force to reduce fibrous tissue adhesion in muscles and a long-duration low-load stretch to return the myofascial complex to its original length, resulting in pain relief and improved function.[18]

A study by Grieve et al reported significant differences in muscle length between the control and intervention groups after performing self-myofascial release with a tennis ball.[19] Wilke et al reported that the myofascial release technique enhances muscular properties, functional capacity, and activities of daily living in patients with chronic stroke due to changes in myofascial chains.[20] This is a form of manual therapy of soft tissue release and muscle stretching to increase muscle length, soft tissue flexibility, and joint range of motion (ROM).[21] Several physiological benefits of myofascial release have been reported, such as capillary dilation, and metabolic and cutaneous temperature changes.[22] These changes are reflected in individuals in the form of decreased pain, muscle spasms, muscle tone, edema, increased extensibility of soft tissues, ROM, and improved biomechanics of the joint.[22]

A previous study included myofascial release with a tennis ball in the lower extremity in patients with chronic stroke and reported improved balance.[23] Different other unique therapeutic interventions have been proposed over the past 2 decades for stroke management; however, myofascial release with a tennis ball has not been included in them.[24] To the best of our knowledge, no study has been performed that examined the effects of myofascial release of the upper extremity with a tennis ball on spasticity and motor functions. Therefore, the present study aimed to examine the effects of myofascial release with a tennis ball on spasticity and motor functions of the upper limb in patients with chronic stroke. Generally, the term chronic stroke refers to the period of recovery that occurs after 6 months after the initial stroke incident.[25]

2. Methods

2.1. Study design and setting

A 2-arm parallel pretest–posttest experimental design was used. This study was conducted in the outpatient physiotherapy department of B.J. Medical College & Civil Hospital, Ahmedabad. All patients were referred from the outpatient department. Each participant was treated 6 days a week for a total of 4 weeks.

2.2. Participants

Due to the lack of availability of enough stroke (hemiplegic) patients, a convenient sampling method was performed and a total of 22 (16 male and 6 female) participants were recruited according to the exclusion and inclusion criteria. Participants were equally divided into 2 groups viz. experimental and control, with 11 participants in each group. Random allocation of participants was performed by the examiner using the lottery method and randomization.com. The control group comprised 7 males and 4 females, while the experimental group comprised 9 males and 2 female participants. The allocation of participants into 2 groups is shown in Figure 1. Participants and outcome assessors were kept blinded to the allocation. In the control group, 5 participants had a left affected side and 6 participants had a right affected side. In the experimental group, 3 participants had the left affected side and 8 participants had the right affected side. The mean duration of the stroke in the control group was 13.45 ± 4.41 months and in the experimental group, it was 15.63 ± 5.76 months. Participants (age: 40–65 years,) suffering from unilateral stroke, hemiplegia with upper extremity dysfunctions of more than 6 months and less than 2 years of duration were selected for the study. The participants younger than 40 years and older than 65 years were not recruited because younger people tend to recover faster than the older people, which could have affected the outcome of our interventions.[26,27] Selected participants had grades 1–3 according to the modified Ashworth scale, MMSE (Mini-Mental State Exam) score >24 suggesting intact cognition, 3–5 level of recovery of voluntary control according to Brunnstrom stages for shoulder, elbow, and wrist joints, and full passive ROM of the shoulder, elbow, wrist, and hand joints. Participants having circulatory problems (e.g., deep vein thrombosis), complex regional pain syndrome, sensory aphasia, severe cognitive impairment, severe visual impairment, impaired sensation over the affected upper limb, recently injured area/open wounds, arthritic or any other musculoskeletal condition of the upper extremity, shoulder instability based on the posterior or anterior apprehension test, and positive sulcus test, history of brain surgery after stroke, Botox injection in the past 4 months, medically unstable patients and patients who had multiple strokes were excluded from the study. Before conducting the study, ethical approval was obtained from the institutional ethics committee, B.J. Medical College & Civil Hospital (File id: GSTIESC/23/16). This study was in accordance with "The Code of Ethics of the World Medical Association (Declaration of Helsinki)". All participants were informed in detail about the study procedure, potential risks, and benefits. All participants signed informed consent. This study has been registered on clinicaltrial.gov (ID: NCT05242679) on 2/16/2022.

2.3. Outcome measures

2.3.1. Modified Ashworth scale. The scale is used to determine severe hypertonia. This scale has been proven to have strong reliability (0.84 for interrater and 0.83 for intrarater comparisons).[28] It is considered a "gold standard" test by which other tests are validated.[29] The modified Ashworth scale was used to measure the spasticity of the biceps brachii, pronator teres, and long finger flexor muscles.

2.3.2. Fugl-Meyer assessment scale for upper extremity functions. The Fugl-Meyer assessment is a performance-based impairment assessment test for stroke patients. The overall reliability of the Fugl-Meyer assessment tool has a very high interclass correlation coefficient (ICC) of 0.96.[30] This

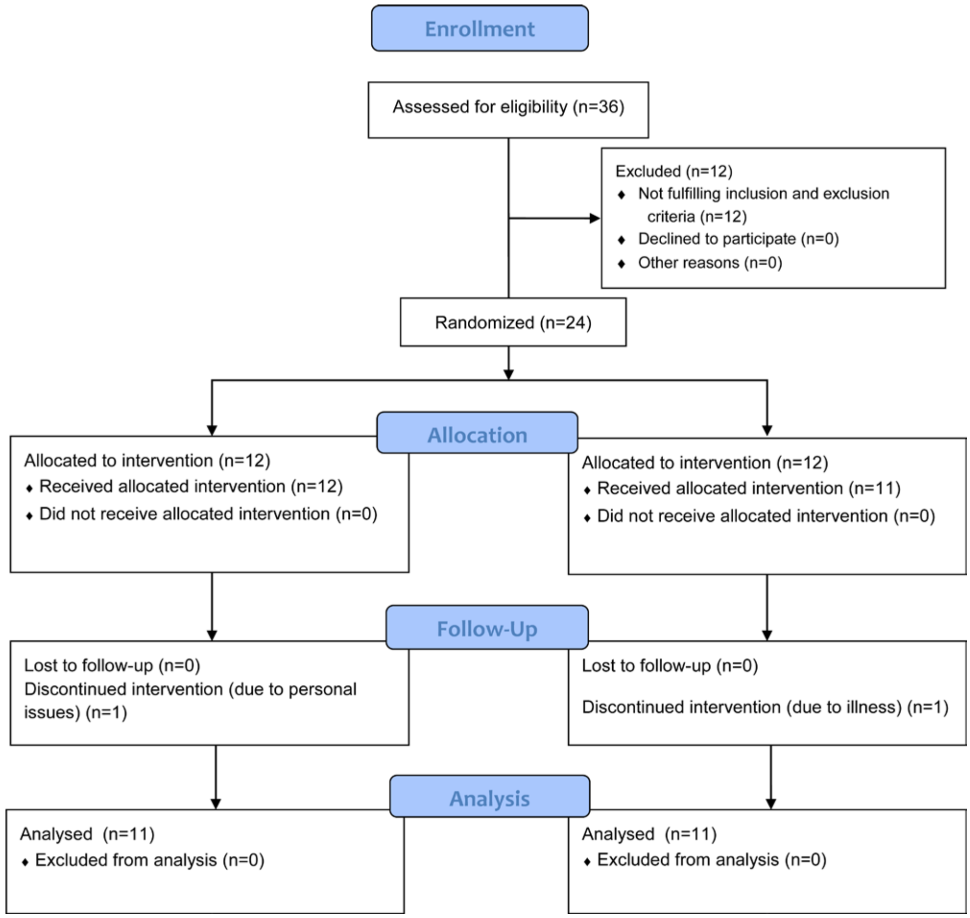

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) chart showing recruitment and allocation of participants.

evaluation was performed in a quiet area when the patient was maximally alert. Clear and precise instructions were provided. Each movement was repeated 3 times on the affected side and the best performance was recorded down for baseline measurement. No motor assistance was provided during the testing.

2.4. Study procedure

Before starting the intervention, a pre-participation evaluation was performed to find demographic data, history, main complaints, and stroke duration. Before inclusion, participants were evaluated for the modified Ashworth scale, MMSE (mini-mental state exam), Brunnstrom stages of recovery, and passive ROM of the shoulder, elbow, wrist, and hand joints. Once inclusion and exclusion criteria were satisfied then participants were evaluated for baseline measurement of the modified Ashworth scale and Fugl Meyer Assessment Scale for Upper Extremity Functions. Similarly, after 4 weeks of intervention, participants were evaluated for the modified Ashworth scale and Fugl-Meyer assessment scale. All participants were assessed and treated in the same room with an optimal temperature of 30°C.

2.4.1. Intervention. Participants were divided into 2 groups: the experimental and control group. The experimental group included myofascial release along with a conventional physiotherapy program and the control group included only a conventional physiotherapy program. In both groups, the intervention was performed for 4 weeks.

1. Myofascial release with tennis ball: A chair was placed beside the plinth and the participant was made to sit on the chair so that the affected arm faces the plinth side. The affected upper limb was placed on the plinth. Myofascial release was applied to the patient keeping the ball below the patient's limb. The therapist rolled the patient's limb over the tennis ball passively. Tolerable pressure was applied to the limb so that it presses the tennis ball. One session of this therapy was given to the patient for about 2 minutes to biceps brachii, pronator teres, and long finger flexor muscles, for a total of 6 minutes per day.
2. Conventional Physiotherapy Protocol: The conventional physiotherapy intervention for both groups aimed to improve the movement of the affected upper and lower limbs. Therapy sessions were tailored according to the patient's needs. Both groups received conventional intervention for approximately 30–40 minutes per session for 4 weeks (6 days a week).[30]

(i). To improve ROM/flexibility and manage spasticity: Active and passive ROM movements were performed with terminal stretch to maintain joint integrity and prevent contractures.
   - (a). *Positional stretching:* Different positional stretch like a modified plantigrade, kneeling, quadruped, and sitting with extended arm support was used. Reach-outs were added to the above positions to get a better effect.
   - (b). *Static stretching:* The targeted muscle was gradually lengthened to the end position (maximum tolerable length) and held for at least 20–30 seconds, depending on the patient's tolerance. The number of repetitions was also adjusted depending upon the patient's compliance. Positions such as quadruped and kneeling were performed to inhibit spasticity in the quadriceps through prolonged pressure and weight-bearing exercises.

(ii). To improve force production: Strength training was provided to the participants as the force was exerted on the weakened muscle to work against it. Manual resistance was applied according to the capacity of the participants. Some of the proprioceptive neuromuscular facilitation (PNF) techniques, such as adding resistance and reversal of the antagonist, were used. D1 extension (extension-abduction-internal rotation) and D2 flexion patterns (Flexion-abduction-external rotation) were used.

(iii). To improve postural control and functional mobility: The following exercises were used: Walking on different surfaces (flat surface, foam), PNF patterns to enhance movement, supine-to-sit, and sit-to-supine with an emphasis to rise from the affected side. Compensatory training strategies to compensate for the balance deficit were also used. Bridging to develop trunk and hip extensor control. It also facilitated early weight-bearing through the feet. Participants were made to sit on a therapy ball to promote pelvic alignment and mobility and were asked to perform gentle bouncing on the therapy ball to enhance upright alignment of the trunk. Gradually challenges were added.

(iv). To improve lower limb functions and gait: PNF for lower extremity (D1 extension pattern), gait training in the parallel bar, and dual-task training were also provided to the participants.

2.4.2. Statistical analysis. *IBM* Statistical Package for Social Sciences (IBM SPSS) version 24 for Windows was used for statistical analysis. The data were checked for missing data, outliers, and normal distribution. Normal distribution was assessed using the Shapiro-Wilk test of normality. Data were identified as not normally distributed. As a result, nonparametric tests were performed for further data analysis. The within-group comparison was determined using the Wilcoxon signed-rank test, while the between-group comparison was determined using the Mann–Whitney *U* test. The effect size was calculated using Cohen's *d*, with d=0.2 considered as small-, d=0.5 as a medium-, and d=0.8 as a large effect size. The significance level was established at 0.05, with a 95% confidence interval.

3. Results

The present study was conducted to assess myofascial release with the tennis ball on spasticity and upper extremity motor function in patients with chronic stroke. A total of 22 participants completed the study. The mean and standard deviation of all anthropometric characteristics of participants in the control and experimental group are presented in Table 1.

3.1. With-in group analysis (Wilcoxon signed-rank test)

Table 2 shows there were significant reductions in spasticity of Biceps brachii [control group (z=–2.27, P=.02), experimental group (z=-2.59, P=.01)], pronator teres [control group (z=-2.12, P=0.03), experimental group (z=-2.46, P=.01)], and long finger flexor muscles [control group (z=-2.42, P=.01), experimental group (z=-2.88, P=.00)] in both groups. A significant increase in motor functions was observed in the experimental group (z=–2.95, P=.00), however, in the control group (z=–1.95, P=.051) no significant difference was observed.

3.2. Between-group analysis (Mann–Whitney U test)

Table 3 revealed that there were significant differences between the control and the experimental group for spasticity of the Biceps brachii (U=32.50, P=.046), the pronator teres (U=25.50, P=.012), and the long finger flexor (U=29.00, P=.026). Spasticity was reduced more in the experimental group compared to the control group. Also, a significant difference was observed in upper limb motor functions between the control and experimental group (U=27.00, P=.026). Motor functions of the upper extremity increased more in the experimental group compared to the control group.

4. Discussion

This study aimed to investigate the effects of tennis ball myofascial release on spasticity and upper limb motor functions in patients with chronic stroke. Twenty-two participants were randomly allotted into an experimental group (n=11) and a control group (n=11). In the control group, participants were treated with conventional physiotherapy, while in the experimental group, participants were treated with conventional physiotherapy along with tennis ball myofascial release to the biceps brachii, the pronator teres, and the long finger flexor muscles. The results of the within-group analysis of this study revealed significant improvements in spasticity for the biceps brachii, the pronator teres, and the long finger flexor muscles in both groups. However, motor functions of the upper extremity improved only in the experimental group. The experimental group showed a greater improvement in motor functions of the upper extremity (P=.026), spasticity for Biceps brachii (P=.04), Pronator Teres (P=.012), and long finger flexors (P=.026) than the control group.

In this study, the approach adopted to increase flexibility was the same as proposed in case of somatic dysfunction, i.e., repeat the stretch procedure until an end sensation is achieved. Long-term disability in people who have had a stroke is caused by sensory and motor deficits, such as weakness in voluntary movements, spasticity, and poor coordination. These altered structures result in decreased joint ROM and soft tissue extensibility, resulting in deformities and loss of function. Wilke et al reported in a systematic review that myofascial release at the superficial muscle improves muscular flexibility. The myofascial release approach can enhance muscle characteristics, function capacity, and activities of daily living in patients with chronic stroke.[20] Other benefits were also reported in previous studies, such as improved joint biomechanics, increased muscle flexibility,[22] and reduced fascial adhesion.[31] Park and Hwang conducted a pilot study and found that myofascial release using a tennis ball improved balance function in patients with chronic stroke who had spasticity in the lower extremity.[23] Timothy et al investigated the effects of myofascial release on physical performance and discovered that myofascial release interventions help restore normal resting muscle electrical activity.[32] They indicated that while the muscle is at rest, it is locally hyperactive, causing pain, which may prompt people to compensate by intentionally decreasing their ROM.[32] According to a study

Table 1

Anthropometrical characteristics among the control and experimental groups.

Parameters	Control group Mean ± SD	Experimental group Mean ± SD
Age (y)	51.81 ± 5.54	50.27 ± 6.71
Height (cm)	162.47 ± 5.34	165.42 ± 6.24
Weight (kg.)	66.54 ± 4.61	68.74 ± 5.37
BMI (kg/m^2)	25.34 ± 6.47	24.87 ± 5.57
Duration of stroke (months)	13.45 ± 4.41	15.63 ± 5.76
Gender, (male/female) (n)	7/4	9/2
Handedness(right/left)	(10/1)	(11/0)
Affected side(right/left)	(6/5)	(8/3)

SD = standard deviation.

Table 2

Baseline and postintervention values (mean±SD) for spasticity and upper limb motor functions in both groups, Shapiro–Wilk test results for baseline values, and with-in group analysis results (*P* values).

		Group	BaselineMean±SD	*P* value for Shapiro-Wilk Test	df	Post-intervention Mean±SD	*z*-value	*P* value for Wilcoxon-signed rank test
Spasticity	Biceps brachii	Control	2.136 ± 0.63	.018*	11	1.681 ± 0.40	−2.27	.022*
		Experimental	2.045 ± 0.56	.008*	11	1.363 ± 0.45	−2.588	.014*
	Pronator teres	Control	1.95 ± 0.65	.001*	11	1.65 ± 0.47	−2.12	.034*
		Experimental	1.94 ± 0.65	.009*	11	1.25 ± 0.49	−2.460	.014*
	Long finger flexor	Control	1.83 ± 0.32	.000*	11	1.36 ± 0.39	−2.42	.015*
		Experimental	1.77 ± 0.34	.000*	11	1.13 ± 0.49	−2.88	.004*
Motor Function	Fugl-Meyer assessment	Control	24.63 ± 7.33	.043*	11	27.72 ± 11.65	−1.95	.051
		Experimental	23.18 ± 7.88	.012*	11	32.81 ± 10.12	−2.95	003*

df = degree of freedom, SD = standard deviation.
*Significant.

Table 3

Results of between-group comparison for spasticity and motor functions of the upper extremity, mean difference±SD, *U*-, *P*- and Cohen's *d* values.

		Control groupmean difference±SD	Experimental groupmean difference±SD	*U* value	*P* value	Cohen's d
Spasticity	Biceps brachii	0.45 ± 0.47	0.86 ± 0.39	32.50	.046*	0.94
	Pronator teres	0.45 ± 0.52	1.04 ± 0.56	25.50	.012*	1.09
	Long finger flexor	0.36 ± 0.39	0.72 ± 0.26	29.00	.026*	1.08
Motor Function	Fugl-Meyer assessment	6.27 ± 3.46	9.63 ± 5.50	27.00	.026*	0.73

SD = standard deviation.
*Significant.

conducted by Akta et al on the short-term effect of myofascial release on calf muscle spasticity in patients with spastic cerebral palsy, myofascial release reduces spasticity by inhibiting motor neuron excitability through prolonged stretch and compression on muscle spindles, Golgi tendon organ, joint and cutaneous receptors.[33] As a result, muscle relaxation with myofascial release may improve inhibition of spasticity.

According to Luomala et al, movement dysfunction may be caused by changes in connective tissue, which result in a disorganization of the structure of the surrounding fascia, jeopardizing the sliding system between layers.[34] Loi et al have shown that myofascial structural integration therapy is a unique and complementary approach to loosening and realigning muscles and improving motor functions.[35]

Chandan et al suggested that the most likely mechanism for improving spasticity is the neuroreflexive modification that occurs when manual force is applied to the musculoskeletal system when performing myofascial release.[36] The hands-on method provides afferent stimulation via receptors, then processed centrally at the spinal cord and brain levels.[36] Myofascial release combined with the external force of manual traction and sustained stretching exercises causes the breakdown of the fibrous adhesive tissues in the muscle. Low load and extended time are also required for this treatment, which helps stretch the myofascial complex and restore its ideal length, increasing muscular flexibility and function.[18,37] Self-induced myofascial release can mechanically break down cross-links and scar tissue, remobilizing the fascia to its gel-like condition. Soft-tissue compliance improves as the fascia becomes more gel-like, allowing for a larger ROM after just 2 minutes of myofascial release.[35] Therefore, all this may explain the improvement observed in our study after adding myofascial release to the conventional physiotherapy program.

In addition to statistical significance, clinical relevance is also important in deciding the prognosis of the intervention. In the present study, both groups produced statistically significant results. The Minimal clinically important difference (MCID) is defined as "the smallest variation in the domain of interest that patients perceive as favorable, and that would demand a change in patients' care in the absence of bothersome side effects and high cost". MCID was observed in the Fugl-Meyer assessment score for motor functions of the upper extremity in the experimental group with a mean difference of 9.63. Page et al determined that the expected MCID of the Fugl-Meyer scores for the upper extremity ranged from 4.25 to 7.25 points, depending on the different aspects of the movements of the upper extremities.[38] Therefore, myofascial release along with the conventional physiotherapy program was statistically and clinically effective in our study.

There were a few limitations in this research that need to be addressed. To begin with, the study sample size was small. As a result, the study's findings cannot be applied to the entire stroke population. Second, the application of tennis ball myofascial release in stroke patients was for a short period of time and there was no long-term follow-up after 4 weeks. The improvements observed in spasticity and motor functions may be short-lived. Future studies are needed with larger sample size and long-term follow-up to assess whether the observed improvements are sustained even after discontinuation of treatment. Third, this study determined only 2 outcome measures, ie, spasticity, and motor function in patients with chronic stroke. Further investigation should also confirm the effectiveness of tennis ball myofascial release treatment in pain reduction, balance, and walking patterns.

5. Conclusion

The present study concluded that the addition of tennis ball myofascial release to the conventional physiotherapy program caused a clinically and statistically significant improvement in upper limb motor functions as tested by the Fugl-Meyer assessment scale and spasticity of the biceps brachii, pronator teres, and long finger flexor muscles as measured by the modified Ashworth scale in patients with chronic stroke. Myofascial release using a tennis ball can be combined with a conventional physiotherapy program for better improvement in chronic stroke patients.

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Author contributions

R.J.P., J.M.S., M.A., S.N., A.H.A., and M.K. conceptualized the study, and its methodology and were involved in data collection and curation. R.J.P. and M.K. performed the data analysis and wrote and edited the manuscript. J.M.S., M.A., S.N., and A.H.A., were involved in supervision. All authors reviewed and approved the manuscript.

References

[1] Aho K, Harmsen P, Hatano S, et al. Cerebrovascular disease in the community: results of a WHO collaborative study. Bull World Health Organ. 1980;58:113–30.
[2] Pandian JD, Sudhan P. Stroke epidemiology and stroke care services in India. J Stroke. 2013;15:128–34.
[3] De Oliveira CB, de Medeiros IRT, Ferreira NA, et al. Balance control in hemiparetic stroke patients: main tools for evaluation. J Rehabil Res Dev. 2008;45:1215–26.
[4] Geiger RA, Allen JB, O'Keefe J, et al. Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. Phys Ther. 2001;81:995–1005.
[5] Weiss PL, Rand D, Katz N, et al. Video capture virtual reality as a flexible and effective rehabilitation tool. J Neuroeng Rehabil. 2004;1:1–12.
[6] Kwakkel G, Kollen BJ, van der Grond J, et al. Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke. Stroke. 2003;34:2181–6.
[7] Bertani R, Melegari C, Maria C, et al. Effects of robot-assisted upper limb rehabilitation in stroke patients: a systematic review with meta-analysis. Neurol Sci. 2017;38:1561–9.
[8] Urban PP, Wolf T, Uebele M, et al. Occurence and clinical predictors of spasticity after ischemic stroke. Stroke. 2010;41:2016–20.
[9] Lundström E, Terént A, Borg J. Prevalence of disabling spasticity 1 year after first-ever stroke. Eur J Neurol. 2008;15:533–9.
[10] Wallesch CW, Maes E, Lecomte P, Bartels C. Feasibility Study on Pharmacoeconomics of Botulinum Toxin A (Botox) in Spasticity Following Stroke. Paper presented at: 3rd European Botulinum Toxin Symposium Abstracts. Rapid Science, London: 1997;1:4.
[11] Sommerfeld DK, Gripenstedt U, Welmer A-K. Spasticity after stroke: an overview of prevalence, test instruments, and treatments. Am J Phys Med Rehabil. 2012;91:814–20.
[12] Foley N, Pereira S, Salter K, et al. Treatment with botulinum toxin improves upper-extremity function post stroke: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2013;94:977–89.
[13] Brunnstrom S. Movement therapy in hemiplegia. A Neurophysiological Approach. 1970:113–22.
[14] Sommerfeld DK, Eek EU-B, Svensson A-K, et al. Spasticity after stroke: its occurrence and association with motor impairments and activity limitations. Stroke. 2004;35:134–9.
[15] Ada L, O'Dwyer N, Ada L, et al. Relation between spasticity, weakness and contracture of the elbow flexors and upper limb activity after stroke: an observational study. Disabil Rehabil. 2006;28:891–7.
[16] Ożóg P, Weber-Rajek M, Radzimińska A, et al. Analysis of muscle activity following the application of myofascial release techniques for low-back pain—a randomized-controlled trial. J Clin Med. 2021;10:4039.
[17] Barnes MF. The basic science of myofascial release: morphologic change in connective tissue. J Bodyw Mov Ther. 1997;1:231–8.
[18] Ajimsha M, Al-Mudahka NR, Al-Madzhar J. Effectiveness of myofascial release: systematic review of randomized controlled trials. J Bodyw Mov Ther. 2015;19:102–12.
[19] Grieve R, Goodwin F, Alfaki M, et al. The immediate effect of bilateral self myofascial release on the plantar surface of the feet on hamstring and lumbar spine flexibility: a pilot randomised controlled trial. J Bodyw Mov Ther. 2015;19:544–52.
[20] Wilke J, Krause F, Vogt L, et al. What is evidence-based about myofascial chains: a systematic review. Arch Phys Med Rehabil. 2016;97:454–61.
[21] Meltzer KR, Cao TV, Schad JF, et al. In vitro modeling of repetitive motion injury and myofascial release. J Bodyw Mov Ther. 2010;14:162–71.
[22] Kain J, Martorello L, Swanson E, et al. Comparison of an indirect tri-planar myofascial release (MFR) technique and a hot pack for increasing range of motion. J Bodyw Mov Ther. 2011;15:63–7.
[23] Park D-J, Hwang Y-I. A pilot study of balance performance benefit of myofascial release, with a tennis ball, in chronic stroke patients. J Bodyw Mov Ther. 2016;20:98–103.
[24] Winstein CJ, Stein J, Arena R, et al. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2016;47:e98–e169.
[25] Rehab F. Understanding Chronic Stroke: What It Means & How to Recover. Available at: https://www.flintrehab.com/chronic-stroke/#:~:text=Generally%20speaking%2C%20%E2%80%9Cchronic%20stroke%E2%80%9D,even%20decades%20after%20a%20stroke. [access date May 11, 2022].
[26] Akinwuntan A, Hu X, Terrill AL, et al. Young stroke: resources for patients, their families, and caregivers for long-term community living. Arch Phys Med Rehabil. 2021;102:1035–9.
[27] Michael KM, Shaughnessy M. Stroke prevention and management in older adults. J Cardiovasc Nurs. 2006;21:S21–6.
[28] Gregson JM, Leathley M, Moore AP, et al. Reliability of the tone assessment scale and the modified Ashworth scale as clinical tools for assessing poststroke spasticity. Arch Phys Med Rehabil. 1999;80:1013–6.
[29] Rw B, Smith M. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther. 1987;67:206–7.
[30] O'Sullivan SB, Schmitz TJ, Fulk G. Physical Rehabilitation. Pennsylvania, US: F.A. Davis Company is headquartered in Philadelphia; 2019.
[31] Liptan G, Mist S, Wright C, et al. A pilot study of myofascial release therapy compared to Swedish massage in fibromyalgia. J Bodyw Mov Ther. 2013;17:365–70.
[32] Mauntel TC, Clark MA, Padua DA. Effectiveness of myofascial release therapies on physical performance measurements: a systematic review. Athl Train Sports Health Care. 2014;6:189–96.
[33] Bhalara A, Talsaniya D. Short term effect of myofascial release on calf muscle spasticity in spastic cerebral palsy patients. Int J Health Sci Res. 2014;4:188–94.
[34] Luomala T, Pihlman M, Heiskanen J, et al. Case study: could ultrasound and elastography visualized densified areas inside the deep fascia? J Bodyw Mov Ther. 2014;18:462–8.
[35] Loi EC, Buysse CA, Price KS, et al. Myofascial structural integration therapy on gross motor function and gait of young children with spastic cerebral palsy: a randomized controlled trial. Front Pediatr. 2015;3:74.
[36] Kumar C, Vaidya S. Effectiveness of myofascial release on spasticity and lower extremity function in diplegic cerebral palsy: Randomized controlled trial. Int J Phys Med Rehabil. 2014;3:2.
[37] Meltzer KR, Cao TV, Schad JF, et al. Stroll, and Paul R. Standley.". Vitro Modeling of Repetitive Motion Injury and Myofascial Release". J Bodyw Mov Ther. 2010;14:162–71.
[38] MacDonald GZ, Penney MD, Mullaley ME, et al. An acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. J Strength Cond Res. 2013;27:812–21.