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PREVENTION & REHABILITATION: RANDOMIZED CONTROLLED CLINICAL TRIAL

The effect of functional stretching exercises on functional outcomes in spastic stroke patients: A randomized controlled clinical trial

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Background: Stroke is the biggest cause of disability in adults. Spasticity is a primary impairment of stroke with a highly variable prevalence. In the present research, we aimed to determine the impact of functional stretching exercises on functional outcomes in stroke patients.

Methods: Thirty stroke patients were randomized into two groups-Experimental group and control group for the purposes of the study. The subjects in the experimental group participated in a functional stretching training program at the rehabilitation center thrice a week for four weeks. The subjects in both groups were evaluated in 3 intervals, once at baseline, once at the end of the program, and once at 2 months following the program. Clinical assessments, such as measuring spasticity, were conducted using the Modified Modified Ashworth Scale (MMAS). Functional outcomes were also evaluated, using the Timed Up and Go (TUG) test, as well as the Timed 10-Meter Walk Test (WTT). Friedman test in SPSS version 22.0 was used to analysis the response variables with respect to each stage of evaluation. Spearman rank correlation was also used to measure correlation among clinical assessments and functional outcomes.

Results: The comparison between two groups showed significant differences only in the Modified Modified Ashworth Scale and Visual Analogue Scale (VAS) post treatment. The experimental group showed significant differences in the MMAS ($p = 0.002$), WTT ($p < 0.001$), and TUG ($p < 0.001$) scores. Nevertheless, the scores of the control group were not significantly different in different stages of evaluation.

Conclusion: The findings of the study suggest that using functional stretching exercises can improve functional outcomes in chronic spastic stroke patients.

1. Introduction

Although stroke is the third-most-common cause of death, it is the most noticeable cause of disability in adults (Carr and Shepherd, 2011). Spasticity is a common motor disorder that sets in following a stroke with a highly variable prevalence, estimated between 4% and 42.6% after a stroke (Wissel et al., 2013). Although spasticity may improve some functional movements, it is still a major impairment that frequently limits motor functions in many stroke patients (Hu et al., 2015). For example, a hemiplegic spastic ankle influences ambulatory quality and decreases the ability to carry out activities of daily life (Wu et al., 2006).

Many stroke patients can walk independently with or without assistance. Nevertheless, only a limited number can maintain an efficient walking speed to have an effective performance and functionality in the society (Dean et al., 2000). The common characteristics of walking after a stroke are decreased gait velocity and asymmetrical gait patterns (Lin et al., 2006). All right ankle control during gait is important for a comfortable gait (Lin et al., 2006). Insufficient plantar flexors power during gait has been vastly perceived and reported for patients with stroke. This has led to decreased gait velocity (Nadeau et al., 1999b; Olney et al., 1991).

Different therapeutic methods are suggested to reduce

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spasticity, including the application of modalities such as biofeedback or complex neurosurgical procedures (Bressel and McNair, 2002). One of these treatments is stretching training. Different stretching methods have been shown to improve ankle joint spasticity in patients with stroke (Bressel and McNair, 2002; Gao et al., 2011; Selles et al., 2005; Yeh et al., 2004, 2005). It should be noted that in previous studies, traditional stretching methods or extra-functional challenges were used for stretching purposes. In functional challenges, the patients use movement patterns that are more familiar (Lederman, 2014). Functional challenges can be practiced anywhere and at any time (Lederman, 2014). In addition, the functional approach promotes the motivational factor and the individualization of management (Lederman, 2014).

In the present research, we aimed to determine the impact of functional stretching exercises on the functional outcomes in spastic stroke patients. To do this we compared the outcome of routine physical therapy and functional stretching exercise in two groups of patients. The secondary aim of the study is to identify the relationship between functional outcomes and clinical findings. We hypothesized that the use of functional stretching training can induce higher improvement in the functional outcomes, and there is a reverse relationship between spasticity and functional outcomes.

2. Materials and methods

2.1. Participants

Fifteen stroke patients (5 men, 10 women; age, 49.67 ± 13.01) as the experimental group and 15 stroke patients (9 men, 6 women; age, 54.87 ± 9.13) as the control group were selected from rehabilitation centers in Isfahan for the purposes of the study. In accordance to our pilot study a power analysis was completed and the sample size of 15 was estimated for each group. In the present study the power was set at 0.8, the alpha error at 0.05 and the effect size was set at 0.5 based on the pilot study. Participants were recruited from rehabilitation centers, in Isfahan, with the use of announcement for inform patients to participate in this study.

The inclusion and exclusion criteria used to determine the eligibility of the participants were as follows: (1) presence of stroke according to the diagnosis of an experienced neurologist; (2) presence of spasticity in the medial gastrocnemius muscle, according to the Modified Modified Ashworth Scale (MMAS≥2) (Nastaran Ghotbi et al., 2011); (3) presence of an appropriate cognitive ability to obey instructions according to the Persian version of the mini-mental status exam (MMSE≥24) (Ansari et al., 2010); (4) ability to go to the rehabilitation center thrice a week for four weeks; (5) ability to walk unaccompanied for 10 m with or without an assistive device; and (6) presence of appropriate general health to do exercises.

The subjects were excluded in case of: (1) deformity or contracture in ankle joint; (2) presence of pain in lower limb; (3) participation in a special training program; (4) usage of anti-spastic drugs or Botox injections; and (5) other central nervous system lesions such as from Parkinson's or multiple sclerosis. All the subjects were outpatients and lived at home. The subjects provided signed informed consents to take part in the study. All procedures were approved by the localethics committee of ShahidBeheshti University of Medical Sciences, Tehran, Iran (Reference number: IR.SBMU.REC.1394.133) and registered in the virtual platform of the Iranian Registry of Clinical Trial (IRCT201610194738N6).

2.2. Design

The present study is a randomized and blinded clinical trial, structuredaccording to the CONSORT recommendations. A randomized approach was applied, and the participants were evaluated before the program, after the program, and at 2 months following the program. The participants with stroke were assessed at baseline for eligibility criteria by a blinded registered physiotherapist. All participants were then randomly allocated to the experimental or control groups. Simple randomization with use of random-number table was used as the randomization tool. All participants in the experimental group completed the stretching training program. But in the control group, two participants did not take part in the two-month follow-up evaluation because they were using anti-spastic drugs or injection. Subjects in control group received their routine physical therapy program including electrical stimulation, gait training exercises and passive stretching exercises for lower extremity. The attrition of the subjects is presented in Fig. 1.

2.3. Intervention

The participants in the experimental group were involved in functional stretching training at theHazratAbolfazl rehabilitation center in Isfahan 3 times a week over a period of 4 weeks. The sessions were arranged and conducted by a trained physiotherapist. The experimental group had a warm-up protocol, including static stretching exercises before the functional exercises. These static stretching exercises were done in the standing position with the use of a wedge. Overall, 2 stretching positions were assumed alternatively by the participants and a total of 5 stretches (30 s for each position) were done (resting duration, 30 s between the stretches) (Guissard and Duchateau, 2004). The participants were asked to perform the stretches at maximum dorsiflexion angle. The following exercises were performed: (1) The patient was positioned in front of the parallel bar, holding the bars with his/her hand. The affected leg was placed on the wedge and the patient moved forward slowly while the knee was held bent (Fig. 2). (2) With the same position as earlier, the normal leg was placed on the wedge and the patient moved forward slowly while the knee was held bent. In this position, the therapist forced the affected knee to a more extended position (Fig. 3).

For functional stretching exercises, we selected three functional challenges (Carr and Shepherd, 2011; Dean et al., 2000): (1) sit-to-stand from chair with an appropriate height (Fig. 4); (2) forward and backward slope walking (Fig. 5); and (3) climbing up from five stairs (Fig. 6). The ability of the patients determined the duration of each training program (Lederman, 2014).

2.4. Evaluation

The subjects in both groups were evaluated in 3 intervals, once before the program (baseline), once at the end of the program (post-training), and once at 2 months following the program (follow-up). A clinical neurological examination was carried out by one of the authors, who is an expert neurologist. The neurological examiner, who only performed clinical examinations, did not attend the subjects. Also, the neurologist was blind to the group assignment of the subjects.

2.5. Clinical evaluation

Muscle tone, Achilles deep tendon reflex, and ankle clonus evaluation in the involved lower limb comprised the neurological assessment. Clinical evaluation of muscle tone was performed at the ankle joint through MMAS(Nastaran Ghotbi et al., 2011). In MMAS, spasticity is graded on a 0–4 scale: 0 = no expansion of the muscle tone; 1 = slight expansion of the muscle tone, characterized by catch and release or minimal resistance at maximum range of

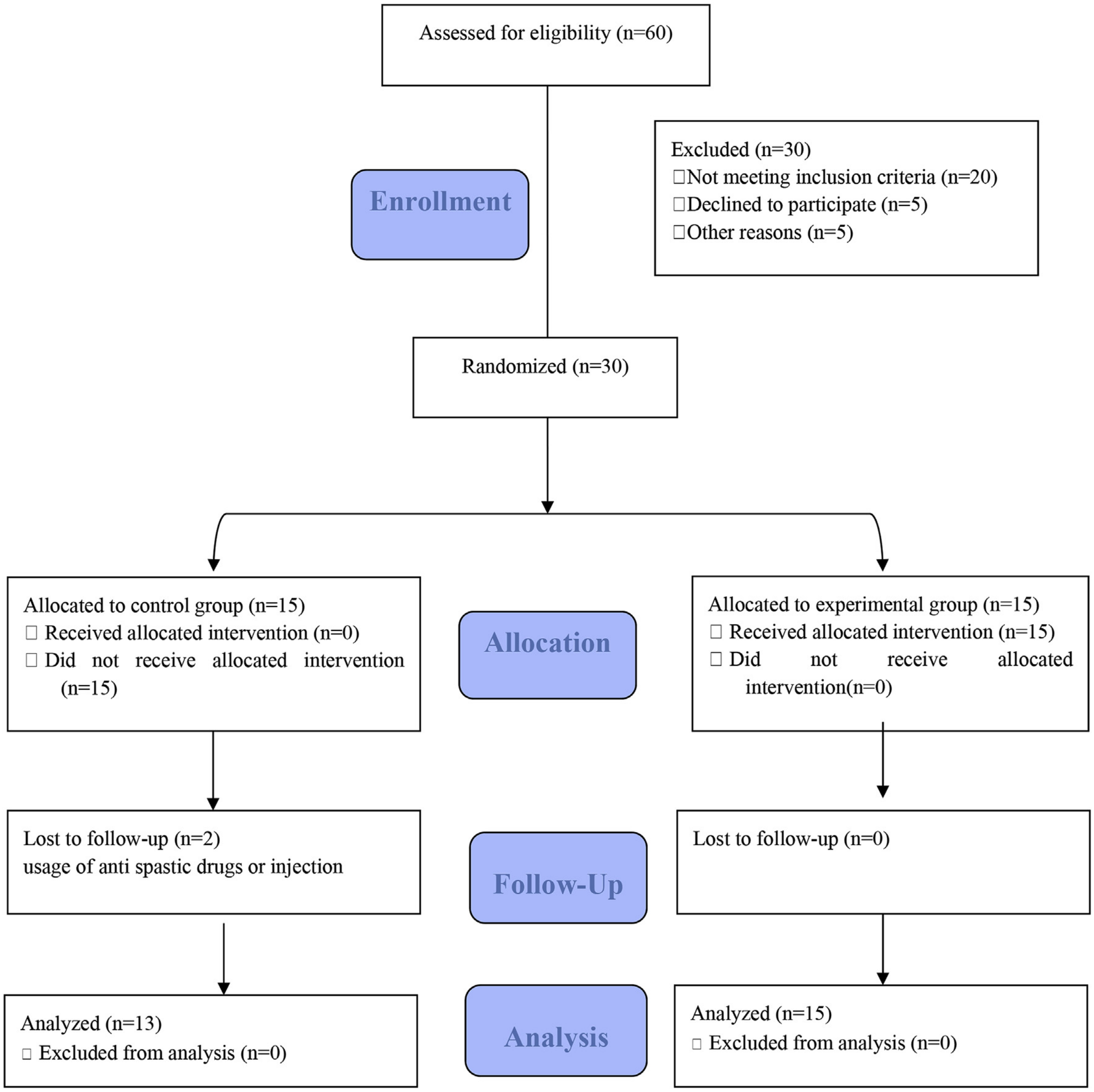

Fig. 1. The CONSORT 2010 diagram for attrition of subjects.

motion (ROM) during flexion or extension of the involved part; 2 = major expansion of the muscle tone, demonstrated by a catch in the middle of ROM and resistance throughout the rest of ROM with effortless movement of the affected part; 3 = substantial expansion of the muscle tone, despite difficult passive movements; and 4 = rigidity in the affected part during flexion or extension.

During the evaluation, the supine position was assumed, with the head in the midline, arms alongside the trunk, and the lower limbs in an extended position (Nastaran Ghotbi et al., 2011). Meanwhile, the examiner put 1 hand beneath the ball of the foot, while placing the other around the ankle joint to stabilize the limb. The ankle was moved from maximum plantar flexion to maximum flexion in a dorsal direction (Nastaran Ghotbi et al., 2011) (Fig. 7).

The Achilles deep tendon reflex, elicited with a clinical hammer, was evaluated using a four-point scale (Walker et al., 1990). Ankle clonus was evaluated using 'Yes' or 'No' options. Dorsiflexion passive range of movement (PROM) of ankle joint was measured with a handheld goniometer. In this evaluation, the patient remained in the supine position with the knee fully extended (Picelli et al., 2014). The axis of the goniometer was fixed on the lateral malleolus. The angle between the fibular shaft and the fifth metatarsal bone was measured. In the assessments, the right angle of the fibular shaft and the fifth metatarsal bone was regarded as 0 degree of dorsiflexion (Tsai et al., 2001). Detailed clinical information about the participants is given in Table 1.

2.6. Functional outcome measurements

Two clinical measures of lower-limb function were achieved. The first lower-limb functional test was a 10-m walking timed test (10-m WTT). In this test, a stopwatch was used to measure the walking speed over 10 m. In order to evade the influence of acceleration or deceleration, calculations were performed at a 10-m walking distance during a 14-m walk (Dean et al., 2000). Overall, one of the standard methods of lower-limb recovery evaluation is the measurement of walking speed. In previous studies, the reliability of this test (via test-retest) has been assessed and an intraclass correlation coefficient of 0.94 was obtained (Stephens and Goldie, 1999; Wu et al., 2006).

Furthermore, the Timed Up and Go (TUG) test was applied to evaluate the lower limb function. TUG is a simple and rapid test, which requires the individual to stand up, walk 3 m, turn, walk

Fig. 2. Static stretching of the calf muscle on the wedge.

Fig. 3. Static stretching of the calf muscle with use of wedge.

back, and sit (Ng and Hui-Chan, 2005); the time required to finish the test is recorded with a stopwatch. Overall, this test is a reliable (intra-class correlation coefficient, 0.99) and valid measure of functional mobility (Podsiadlo and Richardson, 1991). The clinical measurements were administered by an independent rater who was blind to subject assignment.

In addition, the visual analogue scale (VAS) was used to evaluate the participants' subjective experience regarding the impact of

Fig. 4. Sit-to- stand from chair.

Fig. 5. Forward and backward slope walking.

ankle spasticity on ambulation. VAS scores were within a range of 0–10, with 0 representing the maximally intractable spastic intensity that prevented ambulation and 10 representing a spasticity-free status that allows ambulating comfortably. So, subjects rated the intensity of their comfortable in ambulation (0 = No comfortable, 10 = Maximum comfortable).

Fig. 6. Climbing up from stair.

Fig. 7. Assessment of ankle plantar flexor spasticity by Modified Modified Ashworth Scale in Supine position.

2.7. Statistical analysis

For data analysis, SPSS version 22.0 (SPSS Inc., Chicago,USA)was used. Shapiro–Wilk test was used to determine the normality of data. Since some data were not normally distributed they were analyzed by the non-parametric Mann-Whitney *U* test and other data were normally distributed they were analyzed using parametric independent T-tests to measure differences between groups respectively. The Friedman test was also used to analyze the response variables with respect to each stage of evaluation. Because the MMAS and DTR were ordinal variables, the Spearman rank correlation was used to quantify associations among the variables. P-value less than 0.05 was considered statistically significant.

3. Results

3.1. The general features of the subjects

The age ($p = 0.216$), weight ($p = 0.795$), height ($p = 0.088$), and the duration of post-stroke onset ($p = 0.120$) of participants showed a normal distribution and were not significantly different between the experimental and control groups. Other dependant variables had not normal distribution. The mean durations of post-stroke onset ±S. D were 29.13 ± 19.32 (range, 7–60 m) and 18.60 ± 16.50 (range, 3–60 m) months for the experimental and control groups, respectively (Table 2).

All patients in the experimental and control groups showed a clinically enhanced Achilles tendon reflex (DTR>2), and all of the stroke patients had increased medial gastrocnemius muscle tone to passive manual dorsiflexion with the knee in extension (MMAS≥2). The average MMAS and DTR scores were 2.4 and 3.6 in experimental subjects and were 2.47 and 3.33 in control subjects, respectively. Nine patients in the experimental group and five patients in the control group clinically showed clonus in the ankle joint (Table 1).

Comparison of the clinical and functional outcomes:

Between groups comparison shows significant differences only in MMAS at follow-up ($p = 0.048$) and in VAS at post-training and follow up evaluations ($p = 0.01$).

As Table 3 illustrates, there were significant differences in MMAS ($p = 0.002$), DTR ($p = 0.042$), and ROM ($p < 0.001$) in the experimental group and no significant differences in MMAS

Table 1
Clinical measurements of the study population.

Variable	Baseline		Post training		Follow up	
	Experimental (n = 15)	Control (n = 15)	Experimental (n = 15)	Control (n = 15)	Experimental (n = 15)	Control (n = 13)
MMAS	2.40 ± 0.51 2 = 9 3 = 6	2.47 ± 0.52 2 = 8 3 = 7	1.87 ± 0.64 1 = 4 2 = 9 3 = 2	2.27 ± 0.59 1 = 1 2 = 9 3 = 5	1.93 ± 0.46 1 = 2 2 = 12 3 = 1	2.31 ± 0.48 2 = 9 3 = 4
ADTR	3.60 ± 0.51 3 = 6 4 = 9	3.33 ± 0.49 3 = 6 4 = 9	3.40 ± 0.51 3 = 9 4 = 6	3.27 ± 0.59 2 = 1 3 = 9 4 = 5	3.27 ± 0.46 3 = 11 4 = 4	3.46 ± 0.52 3 = 7 4 = 6
AROM	2.33 ± 6.23	5.00 ± 5.00	9.67 ± 7.67	7.27 ± 5.18	9.20 ± 6.00	6.62 ± 5.08
AC	Yes = 9 No = 6	Yes = 5 No = 10	Yes = 6 No = 9	Yes = 5 No = 10	Yes = 5 No = 10	Yes = 6 No = 7

MMAS, Modified Modified Ashworth Scale; ATR, Achilles Deep Tendon Reflex; AROM, AnkleRange of Motion; AC, Ankle Clonus.

Table 2
Stroke subject characteristics.

Group	Age (years)	Weight (Kg)	Height (*Cm*)	Duration of disease (Month)	Stroke Type	Stroke Side	Gender
Experimental	49.67 ± 13.01	65.00 ± 11.44	159.33 ± 6.03	29.13 ± 19.32	H = 10 I = 5	R = 9 L = 6	M = 5 F = 10
Control	54.87 ± 9.13	66.00 ± 9.39	164.33 ± 9.15	18.60 ± 16.50	H = 11 I = 4	R = 7 L = 8	M = 9 F = 6

H, hemorrhagic; I, ischemic; R, right; L, left; M, male; F, female.

Table 3
Matrix for Friedman test for all variables within and between group comparison.

experimental group			control group			
variables	Mean Rank	P- value within-group	variables	Mean Rank	P- value within-group	P-value between-group
MMAS1	2.5		MMAS1	2.15		0.717
MMAS2	1.7	0.002*	MMAS2	1.81	0.097	0.088
MMAS3	1.8		MMAS3	2.04		0.048*
ADTR1	2.27		ADTR1	2		0.15
ADTR2	1.97	0.042*	ADTR2	1.88	0.223	0.562
ADTR3	1.77		ADTR3	2.12		0.292
ROM1	1		ROM1	1.65		0.007*
ROM2	2.57	0.001*	ROM2	2.31	0.054	0.441
ROM3	2.43		ROM3	2.04		0.245
WTT1	3		WTT1	2.15		0.633
WTT2	1	0.001*	WTT2	1.54	0.116	0.191
WTT3	2		WTT3	2.31		0.534
TUG1	2.93		TUG1	2.08		0.917
TUG2	1	0.001*	TUG2	1.62	0.199	0.213
TUG3	2.07		TUG3	2.31		0.596
VAS1	1.23		VAS1	1.81		0.130
VAS2	2.73	0.001*	VAS2	2.27	0.115	0.001*
VAS3	2.03		VAS3	1.92		0.001*

($p = 0.097$), DTR ($p = 0.223$), and ROM ($p = 0.054$) in the control group at different stages of evaluation.

There were also significant differences in WTT ($p < 0.001$), TUG ($p < 0.001$), and VAS ($p < 0.001$) in the experimental group and no significant differences in WTT ($p = 0.116$), TUG ($p = 0.199$), and VAS ($p = 0.115$) at different stages of evaluation in the control group (Figs. 8–10).

3.2. Correlation between the clinical and functional outcomes

As shown in Table 4 (Spearman coefficient), there was no significant correlation between the clinical and functional outcomes. In functional outcomes, a strong significant correlation was observed between WTT and TUG ($r = 0.928$, $p = 0.00$).

4. Discussion

A comparison between the effect of functional stretching exercises and routine physical therapy program in chronic stroke patients showed significant differences only in the MMAS and VAS of the patients. However, using functional stretching exercises led to a significant reduction in the MMAS score, and in the time of the TUG and 10-m walking test after the intervention compared to the baseline. This was not seen in the control group receiving routine

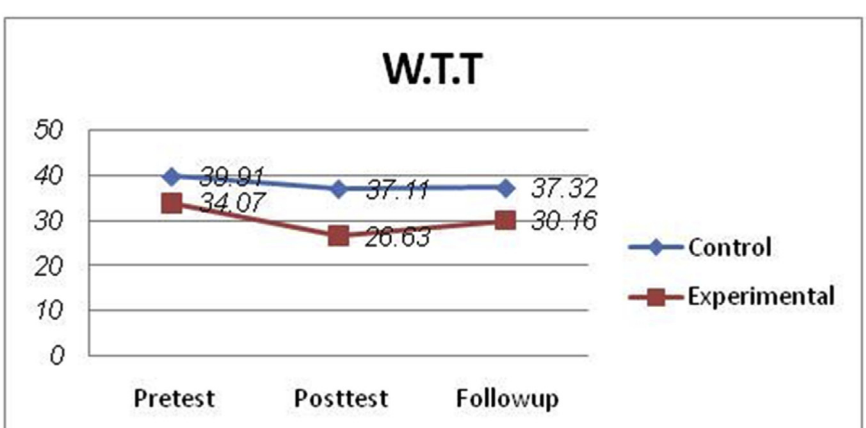

Fig. 8. Time for 10-m walking test in different stages of evaluation.

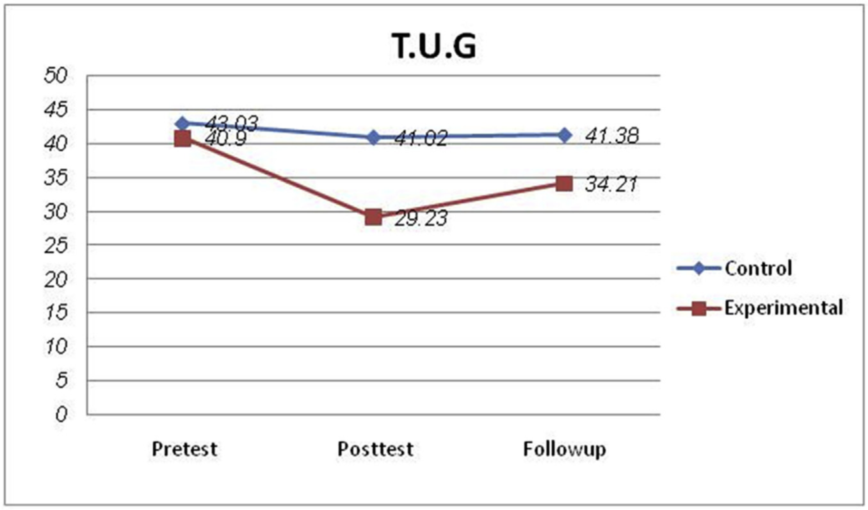

Fig. 9. Time for timed up-and-go-test in different stages of evaluation.

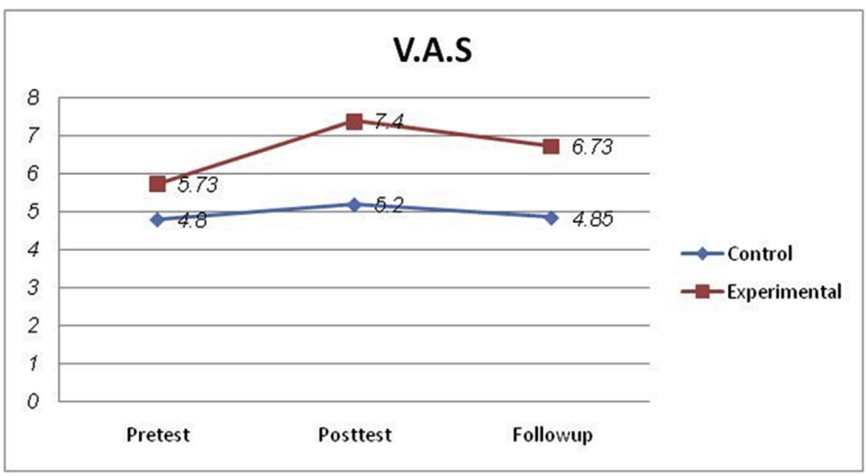

Fig. 10. Visual analogue scale in different stages of evaluation.

Table 4
Correlation matrix for study variables (Spearman).

Outcome measures	Age	Weight	Height	Time	MMAS	ADTR	ROM	TUG	WTT
Age	1.000								
Weight	−0.273	1.000							
Height	−0.059	0.462*	1.000						
Time	−0.165	−0.038	−0.104	1.000					
MMAS	−0.235	0.000	0.227	0.117	1.000				
ADTR	−0.256	−0.116	−0.241	−0.186	0.261	1.000			
ROM	0.070	0.275	0.290	−0.287	0.170	−0.048	1.000		
TUG	0.074	−0.371*	−0.206	−0.162	0.221	0.293	−0.251	1.000	
WTT	0.122	−0.495**	−0.265	−0.123	0.167	0.340	−0.193	0.928**	1.000

*Significant correlation ($p < 0.05$).
**Significant correlation ($p < 0.01$).

physical therapy. The findings of the study suggest that functional stretching exercises improve ankle spasticity and ambulatory ability in chronic stroke patients. VAS also indicated very positive results regarding stretching comfort and personal assessment of the affected ankle.

Although it has been revealed that the highest function recovery occurs in the first three months following strokes (Dean et al., 2000; Duncan et al., 1992), the findings of the study suggest that subjects with chronic stroke, participating in a regular 4-week exercise program (under the supervision of a physiotherapist), demonstrated improved results. Moreover, this improvement was maintained for two months after the cessation of training. This finding was in agreement with other related study (Dean et al., 2000).

Passive stretching, both static and dynamic, plays an important role in the management of spasticity (Wu et al., 2006). An earlier study suggested that stretching the plantar flexor muscles using a tilt table for a period ranging from 30 min to 6 weeks decreased the passive resistance of the ankle joint, enhanced the ROM in the ankle joint, and promoted gait performance (Tsai et al., 2001).

The DTR of the Achilles tendon and ankle clonus was used to determine the reflex features of spastic ankles in the present study. In line with the highly significant reduction in spasticity noted objectively (by MMAS) and subjectively (by VAS), the decrease in both DTR and ankle clonus was significant, which was in contrast with the other study (Wu et al., 2006).

Measurement of walking speed is among standard tools for the assessment of lower limb recovery (Sullivan et al., 2002; Wu et al., 2006). In addition, the TUG reflects not only the subjects' ambulatory function but also the extent of activity in daily life (Ng and Hui-Chan, 2005; Wu et al., 2006). In the present study, after using functional stretching exercises, a significant improvement in ambulatory function (TUG time and 10-m walking speed) and a reduction of MMAS of the spastic ankle was observed in stroke patients. It may be because ankle spasticity affects gait efficacy in chronic stroke patients (Wu et al., 2006). Ankle plantar flexors are necessary in gait. The absence of push-off majorly reduces the forward propel, swing initiation on the same side, and swing phase on the contralateral side (Gao et al., 2011).

Improved outputof muscle force, resulting from repetitive stretching, might help stroke survivors acquire better push-off and swing control. It may also enhance the gait pattern, characterized by improved walking speed and more symmetric gait cycles (Gao et al., 2011). The increase in TUG score is dependent on the symptoms of stroke, including weakness and spasticity of the muscles. On the other hand, muscle limitation and spasticity are indicated by the individual's restrictions in applying timely and adequate muscle force to do a functional task; this can in fact explain the prolonged time of TUG test in stroke patients (Ng and Hui-Chan, 2005).

In disagreement with some previous studies (Eng et al., 2002; Hsu et al., 2003), the present research revealed that ankle spasticity was not correlated with TUG or WTT scores. Insignificant correlations have been also reported in previous studies (Bujanda et al., 2003; Nadeau et al., 1999a). The negative findings in the present study might be attributed to the limited sample size and/or use of compensatory strategy (e.g, increased hip and knee flexion) by the participants to release the involved foot in the swing phase (Ng and Hui-Chan, 2005).

The other reason might be the continuous disability in lots of patients following stoke due to stroke-induceddysfunctions and negative alterations in neural, muscular, psychological, and cardiovascular activities, resulting from the disuse or use of maladaptive behaviors (Dean et al., 2000). Moreover, the correlation between spasticity and gait velocity has not been firmly settled because of the measuring of the static spasticity in place of the dynamic spasticity (Hsu et al., 2003; Lamontagne et al., 2001; Lin et al., 2006). Lamontagne et al. first measured the spasticity of the plantar flexors of subjects with hemiparesis during walking. This method of measuring dynamic spasticity has confirmed its efficiency on gait velocity (Lamontagne et al., 2001). Investigators suggested that gait speed and walked distance might influence cardiovascular performance, muscle weakness, impaired balance, and spasticity (Ng and Hui-Chan, 2005). According to the findings of our study, gait speed was strongly correlated with TUG scores.

5. Limitations of the study

The limitations of this study were the small sample size and lack of a locomotor-specific measure of spasticity during gait. For future studies, we suggest increase in number of participants and use of a locomotor-specific measure of spasticity during gait to reach a good correlation between parameters.

6. Conclusion

The findings of the study demonstrate that using functional stretching training appears to be effective in reducing spasticity and improving gait performance. Furthermore, this simple method is a feasible tool for treating ankle spasticity in chronic stroke patients with use of environmental challenges.

Conflicts of interest

The authors have no conflicts of interest.

Sources of support

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Registration number

Iran Registry for Clinical Trials (IRCT Code: IRCT201610194738N6).

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