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TheraSling Therapy (TST) Combined with Neuromuscular Facilitation Technique on Hemiplegic Gait in Patients with Stroke

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Background: TheraSling therapy (TST) is a kind of rehabilitation therapy for patients with stroke in order to improving neural function. The aim of this study was to evaluate the clinical efficacy of TST combined with neuromuscular facilitation technique on hemiplegic gait in patients with stroke.

Material/Methods: Fifty-six patients with abnormal gait after stroke were recruited for this study and assigned randomly to either the control group (n=28) or the TST experiment group (n=28). Patients in the 2 groups all received neuromuscular facilitation technique treatment. In addition, patients in the TST experiment group were received TST. Treatments were 45 minutes a day for 6 weeks.

Result: The functional ambulation category (FAC) score, improved Barthel index, Fugl-Meyer assessment (FMA), Berg balance scale (BBS), and 10 meters walking time and step length were significantly improve in both the TST experiment group and the control group after 6 weeks of treatment with a statistical difference ($P<0.05$). And the aforementioned indices in the TST experiment group after treatment were significantly higher than those of control group ($P<0.05$).

Conclusions: Lower extremity motor function and quality of life were significantly improved by TST combined with neuromuscular facilitation technique. However, the study had a small sample size, thus, further multicenter well-designed prospective randomized controlled trials are needed to confirm our findings.

MeSH Keywords: **Aftercare • Recovery Room • Stroke**

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Background

Stroke is a widespread disease with high death and disability rates [1,2]. Its main complication is abnormal gait, which is often manifested as walking deflection, extension of support phase, decrease of stride length, and slow pace in patients who suffered stroke [3]. These patients' torsos swing abnormally, and their walking continuity and symmetry are lost. Hemiplegic gait, known as walking dysfunction, occurs at a very high prevalence in stroke survivors and it severely affects patient's quality of life. Hemiparetic gait is characterized by disturbances of symmetry, step length, decreased stance time in the paretic limb, and decreased range of motion in the hip and knee joints during the swing phase and balance disturbances [4]. It occurs in more than 80% of stroke survivors. Despite effective rehabilitation treatment, about a fourth of stroke patients have residual hemiplegic gait that requires full physical assistance, which significantly reduces patient's quality of life. Therefore, how to improve the hemiplegic gait is concern of neurologists.

After stroke, the treatment of abnormal gait is a persistent clinical problem. Current rehabilitation treatment methods mainly involve neurodevelopmental therapy, including Bobath technology [5], Brunnstrom technology [6], proprioceptive neuromuscular facilitation technology [7], and Rood technology. Meanwhile, TheraSling therapy (TST) has also been widely used. In this therapy, elastic and inelastic cloth bands, elastic bands, and bandages are used for performing specific winding methods on patients' limbs. The winding methods are aimed at correcting posture, promoting sensation, stabilizing core muscle group, and reconstructing neural network. TST plays a significant role in the treatment of balance disorder and gait abnormality. The purpose of this study is to use rope-band TST and neurodevelopmental therapy for the treatment of abnormal gait after stroke; and observe lower limb motor function, walking ability, balance load ability, and treatment and improvement of the patient's side walking length and limb muscle strength.

Material and Methods

Patients

Fifty-six patients with stroke were recruited into this study from January 2016 to October 2016. All the patients were diagnosed with abnormal gait after stroke and assigned randomly to either the control group (n=28) or the TST experimental group (n=28). The patient inclusion criteria were as follows: 1) stroke patient with first onset or previous onset but without limb dysfunction; 2) patient had clear consciousness and could cooperate with the rehabilitation training; 3) the vertical position was more than grade 2, the affected side could

bend at the hip and the knee, and the affected side could bear a heavy burden of three-fourths of the body weight; 4) patient signed informed consent of this treatment. Patient exclusion criteria were as follows: 1) patient had unclear consciousness, cognitive impairment, problem cooperating with rehabilitation training; 2) patient had stroke history with left limb dysfunction; 3) patient had lower extremity trauma, pre-existing fractures, bone and joint disease history with limb dysfunction; 4) patient had malignant carcinoma history.

Rehabilitation training

Lower limb motor function, balance ability, walking ability, stride length, and pace of the patients in the 2 groups were evaluated before training. Then, we performed gait analysis to determined key problems in the walking cycle, particularly those in the hips, ankle joints, pelvis, and torsos. The 2 groups were subjected to nerve development therapy for rehabilitation training, and the observation group was subjected to TST for 6 weeks. Both therapies were performed 45 minutes daily and 6 days a week. The project evaluation results were compared after 6 weeks of training.

Specific methods

1) Muscle strength training was focused on continuous resistance training [8]; intensive training of the quadriceps femoris, hamstring muscles, calf triceps, tibialis anterior muscle, gluteus medius, and other muscle groups; strengthening of the patients' lower limb cushioning, hip, knee, ankle flexion, and heels and improving their outreach ability. 2) Joint activity training was mainly conducted of open joint activity on the basis of muscle strength training. The inhibition of joint movement and promotion of separation movement were emphasized. 3) Core muscle training was performed for enhancement of trunk strength and improvement of pelvic control. The limb load and side support were strengthened for the improvement of the patient's position balance, center of gravity transfer ability, and walking ability [9,10]. 4) Position balance training included center of gravity transfer control, cross obstacle training, and capacity training. A balance bar was used for a single leg load, and the sitting-station transfer was performed for the increase of training intensity [11,12]. 5) Pelvic and trunk control ability training included trunk flexion rotation and movement training, bridge-type movement, right and left side of the pelvis control training, and tilt control training. The observation group was treated with TST, and winding was carried out in 2 parts. A 2.5 cm wide medical elastic band was used. The first part focused on flexor muscle synergy. The patient sat, hips and knees bent, with calf extorsion, foot tipping downward; the patient takes one elastic band divided into 2 bundles and tightens the cross knot on the plantar toe joint of the foot to the lateral margin of the foot, with 1 bundle of

Figure 1. TheraSling therapy for patients with stroke: (A) view from front; (B) view from back; (C) view from side.

Table 1. The general character of the 2 groups.

Character	Control group (n=28)	TST experiment group (n=28)
Age (year)	55.4±8.2	56.7±7.6
Gender		
Male	16 (57.1%)	17 (60.7%)
Female	12 (42.9%)	11 (39.3%)
FAC score	2.31±0.74	2.25±0.71
Improved Barthel index	57.72±5.57	58.34±4.94
FMA	15.18±6.85	15.37±7.12
BBS	18.92±6.30	19.43±5.78
10 meters walking (s)	25.54±9.38	25.18±9.24
Step length (cm)	21.92±6.30	22.33±5.78
Paretic limb (%)		
Right	15 (53.6)	16 (57.1)
Left	13 (46.4)	12 (42.9)

tension in the back of the calf and 1 bundle along the front of the calf, with 2 in the medial of the knee. The taut bundle was then rounded outside of the femur on the front of the knee, another bundle at the rear of the femur and the taut bundle cross the upper part into a strand, then the strand follows the waist of the gluteus maximus to the opposite side, and the surrounding band was fixed for a week. The second part was for foot sagging. The affected limb, knee bent at 90°, the foot tip of calf extorsion to the outside side, taking a non-stretch

Character	Control group (n=28)	TST experiment group (n=28)
Time from stroke (month)		
Mean	3.5	3.8
Range	2–6	2–6
Brunnström stage ()		
III	3 (10.7)	4 (14.3)
IV	12 (42.9)	11 (39.3)
V	11 (39.3)	9 (32.1)
VI	2 (7.1)	4 (14.3)
Gait speed (m/min)	25.8±2.2	26.1±1.9

TST – TheraSling therapy; FAC – functional ambulation category; FMA – Fugl-Meyer assessment; BBS – Berg balance scale.

band with the width of 2.5 cm to be divided into a long part and a short part, set in the affected limb plantar toe joint inside and outside side; the 2 bundles were fixed on the lateral knee of the affected foot, a knot was fixed around a circle, then divided into 2 bundles, and knotted in the tibia knot in front of the knee; the long bundle downward to the back of the foot to find the strap around, slightly taut the short band at the top to make a cross knot fixed at the tibial nodule, and going around the inside of the tape (Figure 1).

Table 2. FAC score and improved Barthel index of the 2 groups before and after treatment ($\bar{x} \pm s$).

Groups	FAC score		<i>t</i>	<i>P</i>	Improved Barthel index		<i>t</i>	<i>P</i>
	Pre-treatment	Post-treatment			Pre-treatment	Post-treatment		
TST experiment group (n=28)	2.25±0.71	3.50±0.54	7.42	<0.0001	58.34±4.94	85.46±9.04	13.93	<0.0001
Control group (n=28)	2.31±0.74	2.88±0.77	2.82	0.007	57.72±5.57	74.10±7.64	9.17	<0.0001
<i>t</i>	0.31	3.49			0.44	5.08		
<i>P</i>	0.758	0.001			0.661	<0.0001		

TST – TheraSling therapy; FAC – functional ambulation category.

Evaluation index

The clinical efficacy of all the included patients were evaluated by 2 neurologist independently before and after treatment. The evaluation index included: functional ambulation category scale (FAC) [13]; Fugl-Meyer assessment (FMA) [14]; Berg balance scale (BBS) [15]; 10 meters walking time and step length; and the improved Barthel index.

Statistical analysis

The data was analysis by SPSS 17.0 software (SPSS, Inc., Chicago, IL, USA). The measurement data was demonstrated by $\bar{x} \pm s$ and the comparison between groups was performed by Student's *t*-test. The enumeration data were expressed with a relative number, and the comparison between groups was made based on the χ^2 test. $P < 0.05$ was considered significant statistical different.

Results

General characteristic of the included patients

The main characteristics of the control and TST experiment groups are showed in Table 1. There were no statistical differences in the aspects of age, gender, FAC, improved Barthel index, FMA, BBS, or 10 meters walking time and step length ($P_{\text{all}} > 0.05$).

FAC score and improved Barthel index

The before and after treatment FAC score and improved Barthel index are showed in Table 2. The FAC score and improved Barthel index were significant elevated in both the TST experiment group and the control group after 6 weeks treatment with statistical difference ($P < 0.05$), Figure 2A, 2B. The FAC score in the TST experiment group after treatment were significantly higher than those of the control group ($P < 0.05$).

These results indicated that the combination therapy could significantly improve lower limb function, which can elevate patient's self-care ability.

FMA and BBS score

The FMA and BBS score were both significant improved in the control and the TST experiment group after treatment with statistically significant difference ($P < 0.05$). The aforementioned scores of the TST experiment group after treatment were significantly higher than those of the control group ($P < 0.05$), Table 3. These results demonstrated that a patient's ability to balance on the affected side was enhanced significantly, and the overall movement ability of the lower extremities was also improved, Figure 2C, 2D.

10 meters walking time and step length

The 10 meters walking time and step length were both significant improved in the control group and the TST experiment group after treatment with statistically significant difference ($P < 0.05$), Figure 2E, 2F. The 10 meters walking time and step length of the TST experiment group after treatment were significantly higher than those of the control group with a statistically significant difference ($P < 0.05$), Table 4.

Discussion

TST is a rehabilitation treatment method for hemiplegia patients [16]. It improves limb alignment and asymmetric posture and remodels the neural network, thereby improving motion control [17]. In TST, elastic bands are used in patients with nerve injury for the inhibition of flexor joint movement and for body sensory stimulation input. Under the action of the bands, the center of gravity of each patient was in the center of his or her body, and the stability of the pelvis and torso of the patient and control over the hips and ankles was significantly improved. The patients in the TST experiment group were

Figure 2. Bar plot of efficacy of the TheraSling therapy combined with neuromuscular facilitation technique on hemiplegic gait in patients with stroke. (A) FAC score; (B) improved Barthel index; (C) FMA; (D) BBS score; (E) 10 meters walking time; (F) step length. FAC – functional ambulation category; FMA – Fugl-Meyer assessment; BBS – Berg balance scale.

trained in near-normal walking mode, and the efficacy and efficiency of the rehabilitation training increased considerably. TST has 4 effects, namely, posture correction, sensory promotion, core stabilization, and network rebuilding. It provides the correct mode input for patients in static posture and dynamic movement, retrains the neural network for the correction of body posture and movements, and improves the motion control ability of the patients. Meanwhile, elastic bands stabilize the core muscle group, thus facilitating the patients' overall exercise training and balance training [18]. The patients who used the bands learned correct posture, posture adjustment

and orientation, and action form and movement control, and demonstrated improved balance and stability. In TST, pressure is applied to active muscles, stimulating contraction, promoting muscle contraction, and increasing the number of sports units. Additionally, TST increases sensory inputs for the stimulation of joints and surrounding receptors through extrusion, promotes muscle contraction, and maintains joint stability. It also stimulates skin and pressure receptors, providing information on the body position and movement for the central nervous system. Such information provides clues for the right direction of movement for the patient, thereby enabling

Table 3. FMA and BBS score of the 2 groups before and after treatment ($\bar{x} \pm s$).

Groups	FMA		t	P	BBS		t	P
	Pre-treatment	Post-treatment			Pre-treatment	Post-treatment		
TST experiment group (n=28)	15.37±7.12	26.68±6.09	6.39	<0.0001	19.43±5.78	67.55±9.19	23.45	<0.0001
Control group (n=28)	15.18±6.85	22.36±5.96	4.18	0.0001	18.92±6.30	42.32±9.21	11.10	<0.0001
t	0.10	2.68			0.32	10.26		
P	0.919	0.010			0.754	<0.0001		

FMA – Fugl-Meyer assessment; BBS – Berg balance scale; TST – TheraSling therapy.

Table 4. 10 Meters walking time and step length of the 2 groups before and after treatment ($\bar{x} \pm s$).

Groups	10 meters walking (s)		t	P	Step length (cm)		t	P
	Pre-treatment	Post-treatment			Pre-treatment	Post-treatment		
TST experiment group (n=28)	25.18±9.24	15.82±3.98	4.92	<0.0001	22.33±5.78	60.55±9.19	18.63	<0.0001
Control group (n=28)	25.54±9.38	20.59±4.31	2.54	0.014	21.92±6.30	42.32±9.21	9.67	<0.0001
t	0.14	4.30			0.25	7.41		
P	0.885	<0.0001			0.801	<0.0001		

patients to perceive movement and direction by resisting resistance and to improve their control over their movements (e.g., balanced coordination of exercise). Furthermore, the action of the bands strengthens the creep of muscle and connective tissue, increases the afferent rate of muscle spindle, and relieves muscle spasm for the inhibition of the flexor joint mode.

Liu et al. [19] evaluated effectiveness TST therapy for walking stability in patients with stroke during convalescence and found that TST improved the walking stability compared to regular rehabilitation therapy. In Liu et al's work, the FAC score, improved Barthel index, FMA score, and BBS score were not evaluated. In our study, our results indicated that the incorporation of TST in therapy can improve patients' body coordination and their pelvic, hip, and ankle joint control. Thus, it can be performed for the alleviation of foot sagging, knee extension, and other difficult problems encountered in the gait training process. It can also inhibit abnormal flexor cooperative mode, facilitate limb muscle strength training, stimulate the brain to train the neural network, and suppress abnormal posture and movement pattern through reflex. These functions promote the formation of correct movement patterns.

The curative effect of therapy with TST is obviously superior to that of a single traditional rehabilitation treatment.

Conclusions

In this study, patients who underwent TST improved significantly in lower limb motor function, walking function, balance function, pace, stride length, muscle strength improvement, and self-care. The patients gained confidence, and their hospitalization period and hospitalization expenses were decreased. TST can be carried out not only in large general hospitals but also in community rehabilitation hospitals. It is an exact and effective method for the rehabilitation of patients with stroke. However, our study also had limitations. The sample size was small with 28 patients in the TST experiment and control groups. And the statistical power was limited with the small sample size. All the participants included in the preset work were from only a single medical center, thus the potential for sample selection bias existed. Therefore, further multicenter well-designed prospective randomized controlled trials are needed to confirm our findings.

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