

Effects of Negative Pressure Soft Tissue Therapy to Ankle Plantar Flexor on Muscle Tone, Muscle Stiffness, and Balance Ability in Patients with Stroke

The purpose of the study was to investigate the immediate effects of negative pressure soft tissue therapy on muscle tone, muscle stiffness and balance in patients with stroke. In total, 20 patients with stroke and assigned to the negative pressure soft tissue therapy group (NPST, n=10) or, placebo-negative pressure soft tissue therapy group (Placebo-NPST, n=10). Both groups underwent NPST or placebo-NPST once a day during the experimental period. MyotonPRO was used to assess the parameters for muscle tone and stiffness. Biorescue was used to assess the parameters for balance. Each group showed improvements in muscle tone, muscle stiffness, and balance ability ($p < .05$). Especially, Muscle tone, muscle stiffness, and anterior length in the limit of stability were the significant improvement on NPST group ($p < .05$). The results of the study suggest that the NPST is effective in improving muscle tone, muscle stiffness, and balance ability in patients with stroke.

Key words: *Negative pressure soft tissue therapy, Muscle tone, Balance ability*

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INTRODUCTION

Motor disorder in patients with hemiplegia due to stroke involves muscle weakness, abnormal muscle tone such as spasticity, abnormal movement patterns and posture, balance ability defects, and reduced weight-shift ability. Thus, it results from the problem in motor control ability¹⁾. Abnormal muscle tone due to spasticity results in changes in the physical properties of muscles and other tissues and affects both stiffness and viscoelasticity^{2, 3)}.

Muscle tone is an indicator of the amount of blood flow to a muscle and is defined as the resistance to passive stretching. Muscle tone is an essential component of balance maintenance, postural stability, and energy-efficient muscle contraction⁴⁾ and muscular stiffness is defined as the change in force with respect to changes in muscle length⁵⁾. In particular, spasticity in the ankle joint causes the plantar flexor of the ankle joint to stiffness, thereby decreasing the mobility of the ankle joint and resulting in asymmet-

ric weight bearing and posture. Thus, it reduces the ability to move the center of gravity without losing balance and involves an unstable posture control⁶⁾.

Modified Ashworth scale, F wave, H reflex, H/M ratio, and pendulum test are all used to determine spasticity⁷⁾. In particular, the modified Ashworth scale, which is widely used in clinical practice, may become subjective and its reliability is unsatisfactory because the evaluation result varies according to the clinical experience and treatment technology⁸⁾. In contrast, MyotonPRO, which is used in this study, noninvasively measures the biomechanical and mechanical properties of soft tissues such as muscles and tendons⁹⁾ and is being studied in various groups, including those with stroke and Parkinson's and the elderly^{10, 11, 12)}.

Various physiotherapy intervention methods have been applied in recent years to treat spasticity. High-frequency transcutaneous electrical nerve stimulation has been reported as effective at improving spasticity and balance ability in patients with stroke^{13, 14)}, and

functional electric stimulation was also effective in decreased spasticity and motor ability in patients with stroke^{15, 16}. Interferential current therapy applied to the gastrocnemius muscle in stroke patients was also reportedly effective in improving their spasticity, balance ability, and gait function¹⁷.

Negative pressure soft tissue treatment applied in this study enables the functional recovery of the fascia by increasing the horizontal and vertical stretching fascia structures with negative pressure. The activation of increased metabolism in the fascia relaxes the impairment of surrounding tissues with reduced lymphokinesis, which results from muscle tone and edema. Other effects include the activation of the lymphatic system, muscle relaxation, pain relief, and the rapid removal of harmful particles from the body to promote metabolism^{18, 19, 20}. However, there have been few studies on stroke patients; therefore, this study aims to investigate the effect of negative pressure soft tissue treatment on muscle tone, muscle stiffness, and balance ability in stroke patients.

SUBJECTS AND METHODS

Subjects

This study was conducted in O rehabilitation hospital (Gumisi, south korea) and Y university medical center (Daegu, south korea). The study included 20 individuals on the basis of the inclusion and exclusion criteria as follows: participants were included in the study if they 1)diagnosed with stroke more than 1 years previously 2)had no orthopedic diseases 3)scored more than 24 points on the mini-mental state examination-Korean version (MMSE-K). Participants with orthopedic disorders, hemi-neglect, dementia and skin problems were excluded. All participants received written and verbal descriptions

of the study procedures and signed consent forms indicating agreement to participate in the study. To eliminate potential experimental bias, 20 in patients were randomly assigned to negative pressure soft tissue therapy(NPST) group and placebo-negative pressure soft tissue therapy(placebo-NPST) group. Demographic information and characteristics of the participants were reported through Table 1.

Experimental procedure

Measurements for all participants in both groups were obtained both immediately before and one hour after therapeutic intervention under a blinded condition. Prior to intervention, both groups participated for 30 minutes in a standard physical therapy. Negative pressure soft tissue therapy was applied to the muscle belly surfaces the gastrocnemius on the paretic side with the patient in a supine position. Physiotouch®(HLD Healthy life Devices Ltd, Helsinki, Finland) was used to provide negative pressure soft tissue therapy. The mouthpiece to the treatment head was applied the 80mm. The negative pressure was applied between 120 to 200mmHg depending on the feeling of the patient. For the placebo-NPST, mouth head was contacted, but no electrical stimulation was applied. Both two group were applied for 30 minutes.

Measurements Method

Muscle tone & stiffness measurement

Muscle tone and stiffness of plantar flexor were measured with the MyotonPRO(Myoton AS, Estonia). The MyotonPRO can diagnose the muscle tone simply and noninvasively. This measurement has high reliability. It provides results entitled to credit because the intra-rater correlation coefficient is as high as 0,94-.99^{10, 11}. The subjects were positioned in a prone on the table. The MyotonPRO probe was positioned

Table 1. Characteristics of subjects

Variables	Placebo-NPSTG(n=10)	NPSTG(n=10)	p
Gender(M/F)	7/3	4/6	
Age (years)	58,90 ± 5,63a	56,90 ± 16,65	.163
MMSE-K (point)	26,60 ± 2,63	26,20 ± 2,39	.554
Time since stroke (mon.)	5,90 ± 1,73	5,40 ± 1,84	.665

*Means ± SD

MMSE-K : mini mental state examination-Korea

NPSTG : negative pressure soft tissue therapy group

Placebo-NPSTG : placebo-negative pressure soft tissue therapy group

vertically on the most sensitive parts (along trigger points) of gastrocnemius. In this way, muscle tone (Tone: Hz) and muscle stiffness (Stiffness: N/m) were measured. To obtain a measurement, the skin was pressured with a force of 0.18 N, and this was followed by five impulses of 0.4N, at intervals of 15 ms¹²⁾. The value of the mechanical variable was checked by measuring vibration on the surface of the skin with the MytonPRO. The trigger points were measured on either side three times and the average value of the result was recorded.

Evaluation of balance ability

Balance ability of patients was measured using the BioRescue(AP1153 BioRescue, Analysis system by biofeedback, France). The BioRescue can evaluate balance ability by measuring the area and distance of the movement. Before measuring the balancing ability, the measurement methods were explained to the subjects in detail. The default measurement posture sets the subject so that the centerline of their foot is aligned with the 30 degree indicator line drawn on the plate while in a standing position. Balance ability (center of pressure [COP] path length and COP travel speed) was measured while subjects stood for 60s with their eyes open. The subjects were prevented from seeing the monitor to avoid visual feedback, and the position of the feet was maintained during

repeated measurements to eliminate errors resulting from changes in foot positions. The subjects were in a standing position with their two legs supporting their body on the force plates. The evaluation was conducted three times and the average value of the result was recorded.

Data analysis

Statistical analyses were performed using SPSS 20.0. The normality of each data distribution was confirmed using the Shapiro–Wilk test. In order to find the changes of muscle tone, muscle stiffness, and Balance ability, the paired t–test was used to compare the differences pre and post–values. Independent t–test was used to compare the differences between the group. The significance level of this study was set at $p < .05$.

RESULTS

Changes in muscle tone and stiffness

The change in muscle tone and stiffness are as follows. NPST group showed a significant differences muscle tone($p < .05$). NPST group showed a significant differences muscle stiffness($p < .05$). There was a significant differences between two groups at pre–post intervention in muscle stiffness($p < .05$).

Table 2. A comparison of muscle tone and stiffness of ankle plantar flexor in affected side between pre–value and post–value in each group

Variables	Group	Pre–value	Post–value	t	p
Muscle tone(unit : Hz)	Placebo–NPSTG	16.15 ± 1.61a	15.66 ± 1.37	.707	.344
	NPSTG	17.01 ± 1.35	15.17 ± 1.13	3.467	.007*
Muscle stiffness(unit :N/m)	Placebo–NPSTG	316.20 ± 37.13	303.40 ± 24.21	1.809	.702
	NPSTG	322.70 ± 28.43	293.40 ± 28.96	–2.880	.018*

^aMeans ± SD
 MMSE–K : mini mental state examination–Korea
 NPSTG : negative pressure soft tissue therapy group
 Placebo–NPSTG : placebo–negative pressure soft tissue therapy group

Table 3. A comparison of muscle tone and stiffness of ankle plantar flexor in affected side between groups at pre–post intervention

Variables	Placebo–NPSTG	NPSTG	t	p
Muscle tone(unit : hz)	0.49 ± 1.55a	0.84 ± 0.77	–.639	.531
Muscle stiffness(unit : N/m)	12.80 ± 22.37	–29.3 ± 32.18	3.397	.003*

^aMeans ± SD
 NPSTG : negative pressure soft tissue therapy group
 Placebo–NPSTG : placebo–negative pressure soft tissue therapy group
 *($p < .05$)

Table 4. A comparison of balance ability between pre-value and post-value in each group

Balance ability	Group	Pre-value	Post-value	t	p
Anterior length in limit of stability(unit : mm2)	Placebo-NPSTG	814.70 ± 152.69a	817.20 ± 153.32	-5.07	.624
	NPSTG	778.10 ± 107.94	1003.50 ± 118.01	-8.179	.000*
Posterior length in limit of stability(unit : mm2)	Placebo-NPSTG	623.60 ± 112.98	628.90 ± 115.62	-1.699	.123
	NPSTG	679.10 ± 262.55	702.80 ± 265.01	-1.865	.094

[†]Means ± SD

NPSTG : negative pressure soft tissue therapy group

Placebo-NPSTG : placebo-negative pressure soft tissue therapy group

*($p < .05$)

Table 5. A comparison of balance ability between groups at pre-post intervention

Balance ability	Placebo-NPSTG	NPSTG	t	p
Anterior length in limit of stability(unit : mm2)	2.50 ± 15.60 a	225.40 ± 87.15	7.962	.000*
Posterior length in limit of stability(unit : mm2)	5.30 ± 9.87	23.70 ± 40.18	1.406	.190

[†]Means ± SD

NPSTG : negative pressure soft tissue therapy group

Placebo-NPSTG : placebo-negative pressure soft tissue therapy group

*($p < .05$)

Changes in balance ability

The change in balance ability are as follows. NPST group showed a significant differences in anterior length in limit of stability of balance ability ($p < .05$). There was a significant differences between two groups at pre-post intervention in anterior length in limit of stability of balance ability($p < .05$).

DISCUSSION

This study confirmed the effect of negative pressure soft tissue treatment on muscle tone, muscle stiffness, and balance ability in stroke patients. Spasticity causes the disruption of motor function in stroke patients, and intervention in spasticity is an important issue for stroke patients' rehabilitation ²⁴. Spasticity limits voluntary mobility due to muscle stiffness, and in particular, it can cause a loss of balance ability and problems with normal walking patterns in stroke patients ²⁵. Properly maintaining the balance of the body requires generating sufficient force to ensure stability during the desired movement ²⁶. In particular, many studies on balance have reported that ankle

joints significantly contribute to the stabilizing standing posture ^{27, 28}. One limiting factor in the ankle strategy in stroke patients is the abnormal muscle tone of the plantar flexor. This abnormal muscle tone limits the ankle joint motion and reduces the stable weight support and mobility. Thus, intervention in the abnormal muscle tone of the plantar flexor in stroke patients is an essential component of balance maintenance, postural stability, and energy-efficient muscle contraction ²⁹.

First, the negative pressure soft tissue treatment group showed a statistically significant difference in muscle tone and stiffness change, and only stiffness showed a significant difference when comparing the changes in the two groups. Second, in terms of the change in the range of forward and back movement of the stability limit to evaluate balance ability, only the change in the range of the forward movement showed a significant difference in the negative pressure soft tissue treatment group. There was only a statistically significant difference in the change in the range of the forward movement when comparing changes in the two groups.

In this study, the experimental group showed a significant difference in muscle tone. This may be because the negative pressure stretches the vertical

and horizontal stretching fascia structures, thereby expanding the lower part of the tissue and the skin applied with negative pressure. This results in expanding both the endothelium of the lymphatic vessels and the space for the circulation of blood and lymph, thus enabling functional recovery. In addition, continuous negative pressure keeps the muscle stretched by continuously stimulating the kidneys and activating the Golgi tendon organ. Then, signals delivered to the Ib afferent fibers are increased, resulting in decreased muscle tone and stiffness due to the decreased excitability of the alpha motor neurons in the same muscle. Guissard and Duchateau³⁰⁾, who conducted a similar study to ours, reported a significant decrease in the amplitude of H in the evaluation of muscle tone after applying kidney stimulation to the plantar flexor of the ankle joint. Tasi et al.³¹⁾ reported a decrease in the H/M and F/M ratios in the evaluation of muscle tone after applying kidney stimulation to the plantar flexor of the ankle joint. Thus, similar results were obtained for muscle tone reduction, although the methods of evaluating muscle tone were different. VP Vuorinen et al.³²⁾ demonstrated that negative pressure soft tissue treatment significantly reduced stiffness in seven patients with lymphoma. Thus, a similar effect was shown despite using a different patient group.

In comparison to the forward and back movement distance of the stability limit to evaluate the dynamic balance ability, the range of forward movement showed a significant difference in the negative pressure soft tissue treatment group. In this study, ensuring the range of motion in the dorsiflexion due to decreased muscle tone and stiffness after negative pressure soft tissue treatment increased the ankle motion. The increased input of the proprioceptive sense in the foot may have helped the ankle joint strategy maintain the stability limit in standing posture. Vedula et al.³³⁾ highlighted the necessity of both the ankle joint strategy and hip strategy for patients with hemiplegia to stabilize the body while maintaining a standing posture. Muscolino and Cipriani³⁴⁾ reported that the strategic use of the ankle joint in the early stages was closely related to static and dynamic balance maintenance. Therefore, negative pressure soft tissue treatment is expected to prevent the secondary limitation of the range of motion in the plantar flexor due to the reduction of muscle tone and stiffness and to serve as a necessary precedent step for balance ability.

This study's first limitation is its small number of subjects. There were ten subjects in each group and 20 in total, which is insufficient to generalize this

study's results. Second, we could not conduct the study by relating to more functional variables that could be improved by negative pressure soft tissue treatment. In follow-up studies, it was necessary to measure various factors such as walking and coordination ability. Third, this study only provides the immediate effects of negative pressure soft tissue treatment, so long-term effects such as the sustained effect of negative pressure soft tissue treatment are unknown. Therefore, follow-up studies should elucidate its sustained effect on functional movements such as gait based on the immediate effects of this study.

CONCLUSION

This study was conducted to identify the effect of negative pressure soft tissue treatment on muscle tone, muscle stiffness, and balance ability of the plantar flexor in patients with hemiplegia due to stroke. In conclusion, we found that such treatment had a positive effect on muscle tone, stiffness, and balance ability in patients with hemiplegia due to stroke. The results of this study suggest that negative pressure soft tissue therapy before functional exercise treatment can be effective in the functional recovery of patients with hemiplegia due to stroke.

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