

# Nerve Regeneration by Shock Wave Detected through Analysis of Stroke Patients' Walking

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## Abstract

The purpose of this study was to investigate the effects of extracorporeal shock wave therapy to reduce spasticity during walking through nerve regeneration. The subjects of this study were 20 patients who were treated for stroke in a rehabilitation hospital. They were then randomly divided into an experimental group and a control group. The control group (n = 10) underwent a normal type of proprioceptive neuromuscular facilitation therapy, while the experimental group (n = 10) underwent a normal type of proprioceptive neuromuscular facilitation therapy and then extracorporeal shock wave therapy. The timed up and go test was used to evaluate the gait functions and dynamic balancing of the subjects. The modified Ashworth scale was used in this study to measure the spasticity of the subjects. Dartfish software was used to measure the angles of the ankle joints. Extracorporeal shock wave therapy was applied 700 times to the middle of the calf muscles of the affected side and 700 times to the musculotendinous junction of the calf muscles. The stimuli were applied to the sites to be treated for a total of 1,400 times at 3 Hz and 0.129 mJ/mm<sup>2</sup>. There was a statistically significant difference between pre-test and post-test of timed up and go in all groups. There was a statistically significant difference between pre-test and post-test of ankle joints angle in all groups. Also, the results of AJA assessment was a statistically significant difference between EX and Con groups. In conclusion, the extracorporeal shock wave therapy can reduce spasticity during walking through nerve regeneration.

**Keywords:** Nerve Regeneration, Shock wave, Stroke, Analysis, Spasticity

## 1. Introduction

Medical and economic developments have led to improvements in the standard of living and increases in life expectancy. However, along with these positive developments, the number of stroke patients has been increasing due to other rapid changes in modern society, such as irregular lifestyles, dietary changes, environmental pollution, and excessive stress[1]. Stroke is a cerebrovascular disease caused by a blood circulation disorder, in which symptoms of local or general neurological deficits last for at least 24 hours. When such symptoms last for less than 24 hours, it is called a transient ischemic attack. The symptoms of a neurological deficit include vessels blocked by blood clots or embolic materials, vessel rupture, lesions in a vessel wall, changes in blood permeability, and an increase in blood viscosity[2]. The pathological changes in a stroke not only cover gross findings, such as thrombosis, embolism, exfoliation, and vessel rupture, but also more fundamental and primary changes, such as atherosclerosis, hypertensive atherosclerosis, arteritis, aneurysmal dilatation, and developmental deformities[3].

A stroke is induced when the blood supply to the brain is blocked or the brain tissue bleeds because of cerebrovascular disease, heart disease, or diabetes[4]. One out of four stroke patients dies, and 9% fully recover within one month of an acute onset. However, even after recovery, 73% of patients can show physical and mental problems (i.e., movement, sensory, speech, and cognitive disorders), according to the location of the brain lesions[5].

Many patients who survive a stroke return to their homes and communities with significant physical and social disabilities, including impaired motor control, and a decrease in sensory, cognitive, perception, and psychological functional aspects. Even after medical intervention and physical therapy while hospitalized, most patients face several difficulties in their daily lives due to inconvenient functional activities and restricted movement. Stroke patients have problems regulating their motility due to muscular weakness, abnormal muscle tension, and abnormal motor patterns, which limit their ability to perform functional activities such as walking, stair climbing, and other daily living activities[6]. Even patients who have undergone appropriate rehabilitation tend to have disabilities. Many stroke-induced hemiplegic patients exhibit a delayed onset of ground reaction force in their paralyzed lower limbs when they lift the non-paralyzed lower limbs, indicating that their active horizontal force, which is required to move the body center laterally, is reduced[7].

Stroke-induced damage in the central nervous system can be naturally restored to a certain degree by the recovery mechanism within three months after the onset of the acute phase, while it tends to be only slightly restored during the chronic phase[8]. This is why stroke patients' rehabilitation should be initiated as soon as possible. The goal of the rehabilitation is to enhance the patient's independence and, ultimately, to help the patient use and develop the latent abilities of the affected side, under the assumption that the intensification of dependence is associated with a deterioration in disease progression[4]. In other words, the purpose of the rehabilitation treatment for stroke patients is to improve the qualitative movements of the injured side in such a way that both sides of the body can be cooperatively

moved as much as possible within the range of the brain damage. Recovering walking ability after stroke should be considered most important for stroke patients because it is most directly related to their independence, and to a degree, restoration of their functions before the injury.

Stroke-induced hemiplegic patients have problems such as asymmetrical postures, balance reaction disorders, decreased walking ability, and loss of mobility performing delicate functions[13]. Their walking patterns show slow cycles, slow speeds, differences between the affected step length and the unaffected step length, and short stance phases with a relatively long swing phases on the affected side. Patients with lesions in the central nervous system reveal several functional deficits as a result of spasticity, including hyper responsiveness to and impaired selective control of extension, pattern changes in muscle recruitment in initial shifts, and changes in the proprioceptor[9]. Stiffness restricts the qualitative flexibility of eccentric muscle motions during the stance phase. A rapid extension triggers intermittent spasms, while a slow extension induces muscle hypersensitivity. Stiffness of the soleus muscle and the gastrocnemius muscle causes continuous plantarflexion of the ankle joints, while stiffness of the hamstring, such as continuous flexion of the knee joints, induces limitations in the terminal swing phase and can restrict the advance of the femoral region in the stance phase[10].

When hemiplegic patients walk, a significant problem is the limited dorsiflexion of the ankle joints. Many stroke patients have foot drop because it is hard for them to actively control the dorsiflexor muscles partially and the muscular tension of their gastrocnemius muscles increases abnormally. In normal walking, the ankle should be actively dorsiflexed in order for the toes to detach from the ground during the swing phase. However, hemiplegic patients with foot drop are unable to control the dorsiflexor muscles in the swing phase[11]. They compensate for this by bending the hip and the knee joints to detach the foot from the ground, performing circumduction of the lower limb or pelvic lift. These walking patterns consume energy, lower speed, induce feelings of insecurity, increase stiffness, and are quickly wearing[12].

Among electrical stimulation therapy, extracorporeal shock wave therapy (ESWT) is known to be effective in recovery of the damaged area by controlling the microenvironment through destruction of damaged tissues and cells as well as promoting neovascularization and increasing the growth factor by precisely exposing the affected area to a shock wave. Research on the effects of ESWT, not only on orthopedic diseases, but also for diseases from nerve injury, is under progress[13].

Extracorporeal shock wave therapy is a treatment in which high-amplitude pressure from outside the body focuses energy on the lesions involved in the disorder. It has been reported that direct stimulation by ESWT induces healing responses at the cellular level, accelerating the formation of new blood vessels by promoting growth factors in the tissues. Meanwhile, stimulation by shock waves has been reported to suppress the nociceptors to increase the pain threshold or to induce several biological effects such as inflammation reduction and wound healing[14].

Extracorporeal shock waves are divided into a focus type and a radial type, according to energy transmission. In the radial type, the air condensed in a pneumatic device inside the shock wave machine is emitted in a second to collide with numerous linearly arranged pendulums, generating a pressure wave that makes the energy expand radially. In the focus type, a number of piezoelectric elements are arranged sporadically on a conical collecting plate within the shock wave machine causing a piezoelectric effect, and the generated individual shock waves are focused on one point[15].

The differences in the delivery of the two types of extracorporeal shock waves are significant for treating patients' lesions. While the radial type is effective on large areas, such as large muscles, because it diffuses the energy radially, the focus type is effective on narrow, small areas because it focuses high-pressure energy on one point. The radial type is useful for treating the epidermis and muscles[16], rather than ligaments or tendons, because the intensity of the shock wave decreases based on distance. However, the focus type, which penetrates into the body with concentrated, high pressure, shows significant curative effects on joints, ligaments, and tendons that are relatively hard and deep in the body[17].

Recently, ESWT was reported effective for treating stiffness and is considered a new type of stiffness treatment. According to several studies, ESWT can serve as a therapeutic tool for stroke patients with dystonia, decubitus, or lymphedema, as well as patients with musculoskeletal disorders, for the therapy does not require anesthesia when applied, shows less adverse effects, and is economical when the effects are considered[18].

Thus, in this study, ESWT was applied to hemiplegic patients with spastic foot drop to investigate the effectiveness of the therapy to reduce spasticity during walking through nerve regeneration.

## 2. Experimental subjects and methods

### 2.1. Subjects

The subjects of this study were 20 patients who were treated for stroke in a rehabilitation hospital. The subjects were assessed as at least grade 1+ for ankle stiffness based on the Ashworth scale[10], had no musculoskeletal abnormalities in the knee joints, had a stroke at least 12 months earlier, recorded at least 24 points in the MMSE to be able to understand and follow the investigators' instructions, had no joint contractures or severe lesion inflammation requiring treatment, had not undergone treatment for spasticity with injections, and had hemorrhagic or infarctive stroke determined by computed tomography or magnetic resonance imaging.

All subjects who consented to participate were provided with a detailed explanation of the purpose, procedures, and risks of the experiment. They were then randomly divided into an experimental group and a control group. The control group (n = 10) underwent a normal type of proprioceptive neuromuscular facilitation (PNF), while the experimental group (n = 10) underwent a normal type of PNF and then ESWT. The therapy was applied to the subjects once a day, five times a week for 20 times over four weeks (Fig. 1). All the subjects comprehend the purpose of this study and provided written informed consent before participation according to the ethical standards of the Declaration of Helsinki.

### 2.2. Experimental procedure

ESWT and PNF were performed by the same therapists who had more than 10 years of clinical experience.

### 2.2.1 Extracorporeal Shock Wave Therapy

To apply the shock wave to the experimental group, an extracorporeal shock wave machine generating a magnetic shock wave (Optimus, Salus Talent 3, Korea) was used. The stimuli were applied to the sites to be treated for a total of 1,400 times at 3 Hz and 0.129 mJ/mm<sup>2</sup>. ESWT was applied 700 times to the middle of the calf muscles of the affected side and 700 times to the musculotendinous junction of the calf muscles.

Changes in stiffness caused by the surrounding environment, stress, or temperature were minimized, while the dosages of drugs that could affect stiffness were not changed during the therapy period.

### 2.2.2 Modified Ashworth Scale

The PNF patterns used in this experiment were as follows. In the supine position, the patients underwent a pattern of hip joint extension – adduction – lateral rotation, knee joint extension, ankle joint plantarflexion – inversion, a pattern of hip joint flexion – adduction – medial rotation, knee joint flexion, ankle joint dorsiflexion – eversion during toe flexion and then toe extension, and then returned to their initial posture.

Next, they underwent the patterns the other way—a pattern of hip joint extension – adduction – medial rotation, knee joint extension, ankle joint plantarflexion – eversion, a pattern of hip joint flexion – adduction – lateral rotation, knee joint flexion, ankle joint dorsiflexion – inversion during toe flexion and then toe extension, and then returned to their initial posture. Each pattern was applied for five minutes with a three-minute rest between patterns. The total PNF patterns took 30 minutes per day.

## 2.3 Result measurement method

For all the evaluations, a pre-test was performed before the first intervention, and a post-test was carried out after the last intervention at the end of four weeks.

### 2.3.1 Timed Up and Go Test

The Timed Up and Go test (TUG) was used to evaluate the gait functions and dynamic balancing of the subjects, a test that is useful to quickly measure patients' functional motility, mobility, and balance. We measured the time that it took for a subject to rise from an arm-chair at the starting signal of the investigator, walk three meters, turn around, walk back to the chair, and sit down. The average from the three measurements was regarded as the measurement value in this study. More than 20 seconds generally indicates functional motor impairment. The test can be used to predict falls by evaluating balance ability and functional motility, and has recently been used to evaluate functional motility and mobility of patients with stroke or Parkinson's.

### 2.3.2 Modified Ashworth Scale

The Modified Ashworth Scale (MAS) was used in this study to measure the spasticity of the subjects. Spasticity was evaluated at the same time as the subjects' gait functions and dynamic balancing. For the statistical analysis of the MAS, five grades from 0 to 4 were scored (grade 0 = 1 point, grade 2 = 2 points, grade 3 = 4 points, and grade 4 = 5 points).

### 2.3.3 Dartfish software

Dartfish software (Pro Suite, Dfkorea, Korea) was used to measure the angles of the ankle joints. Using a camcorder, all subjects' ankle angles were filmed sideways from a distance of three meters while they walked barefoot. The subjects were asked to walk comfortably and naturally on a 10-meter walkway. Each subject was filmed at the halfway point, and only videos that showed perfect walking from the initial stance phase to the phase of toe lift were evaluated. In order to measure the ankle angles in mid stance during walking, the internal angle between the line connecting the fifth metatarsal head and the lateral malleolus and the line connecting the lateral malleolus and the lateral epicondyle of the femur were measured by using photos that showed the moment that the non-affected lower limb was completely detached from the floor. Subjects were asked to walk on the walkway three times, and the average from the three measurements was regarded as the measurement value.

## 2.4. Data analysis

A Shapiro-Wilk test was used to test normality. Mean  $\pm$  standard deviation was described by using descriptive statistics. A paired t-test was used to examine the homogeneity of the patients and significant differences within groups on TUG, MAS, and ankle angles, while an independent t-test was used to investigate differences in variations between groups. The PASW Win. 18.0 package was used for statistical processing. Statistical significance was set at  $\alpha < .05$ .

## 3. Results

### 3.1. General Characteristics of Subjects

The general characteristics of the study subjects are as follows (Table 1). Homogeneity tests of pre-test are as follows (Table 2).

### 3.2. Results of Timed Up and Go Test

There was a statistically significant difference between pre-test and post-test of TUG in all groups ( $p < .05$ ) (Table 3). But, the results of TUG assessment was no statistically significant difference between EX and Con groups ( $p > .05$ ) (Table 4).

**Table 1.** General characteristics of subjects

	Ex (n=10)	Con (n=10)
Age (years)	62.15±11.53	61.31±13.16
Height (cm)	164.92±8.45	166.32±10.43
Weight (kg)	58.13±5.78	57.32±6.48
Gender (Male/Female)	3/2	3/2
Affected side (Right/left)	3/2	4/1
Stroke type (Hemorrhage/Infarction)	2/3	3/2

Mean±SD: Mean±standard deviation

Ex: experimental group

Con: Control group

**Table 2.** Homogeneity test of pre-test

	Ex (n=10)	Con (n=10)	t	p
TUG	28.54±9.34	30.78±10.47	-1.854	0.165
MAS	2.17±0.69	2.35±0.74	-0.163	0.872
AJA	123.87±20.97	119.35±22.43	3.745	0.098

\*p<0.5, Mean±SD: Mean±standard deviation

Ex: experimental group

Con: Control group

TUG: Timed up and go

MAS: Modified ashworth scale

AJA: Ankle joint angle

**Table 3.** Variation of TUG within treatment period on each group

TUG	Pre-test	Post-test	t	p
Ex (n=10)	28.54±9.34	25.69±10.65	3.154	0.012*
Con (n=10)	30.78±10.47	27.98±10.78	2.468	0.038*

\*p<0.5, Mean±SD: Mean±standard deviation

Unit: Second

Ex: Experimental group

Con: Control group

TUG: Timed up and go

### 3.3. Results of Modified Ashworth Scale

There was no statistically significant difference between pre-test and post-test of MAS in all groups ( $p>.05$ )(Table 5). Also, the results of MAS assessment was no statistically significant difference between EX and Con groups ( $p>.05$ )(Table 6).

**Table 4.** Variation of TUG between groups

	Ex (n=10)	Con (n=10)	t	p
TUG (Pre-post)	3.458±0.44	2.96±0.65	0.598	0.315

\*p<0.5, Mean±SD: Mean±standard deviation

Unit: Second

Ex: experimental group

Con: Control group

TUG: Timed up and go

**Table 5.** Variation of MAS within treatment period on each group

MAS	Pre-test	Post-test	t	p
Ex (n=10)	2.17±0.69	2.01±0.62	0.119	0.618
Con (n=10)	2.35±0.74	2.28±0.52	0.073	0.796

\*p<0.5, Mean±SD: Mean±standard deviation

Unit: Score

Ex: experimental group

Con: Control group

MAS: Modified ashworth scale

**Table 6.** Variation of MAS between groups

	Ex (n=10)	Con (n=10)	t	p
MAS (Pre-post)	0.12±0.07	0.08±0.06	0.034	0.876

\*p<0.5, Mean±SD: Mean±standard deviation

Unit: Score

Ex: experimental group

Con: Control group

MAS: Modified ashworth scale

### 3.4. Results of Ankle Joint Angle

There was a statistically significant difference between pre-test and post-test of AJA in all groups ( $p < .05$ ) (Table 7). Also, the results of AJA assessment was a statistically significant difference between EX and Con groups ( $p < .05$ ) (Table 8).

**Table 7.** Variation of AJA within treatment period on each group

AJA	Pre-test	Post-test	t	p
Ex (n=10)	123.87±20.97	112.41±18.37	10.329	0.000*
Con (n=10)	119.35±22.43	113.59±19.77	5.184	0.000*

\* $p < 0.5$ , Mean±SD: Mean±standard deviation

Unit: Angle

Ex: experimental group

Con: Control group

AJA: Ankle joint angle

**Table 8.** Variation of AJA between groups

AJA (Pre-post)	Ex (n=10)	Con (n=10)	t	p
	11.84±3.94	7.16±3.66	4.039	0.000*

\* $p < 0.5$ , Mean±SD: Mean±standard deviation

Unit: Angle

Ex: experimental group

Con: Control group

AJA: Ankle joint angle

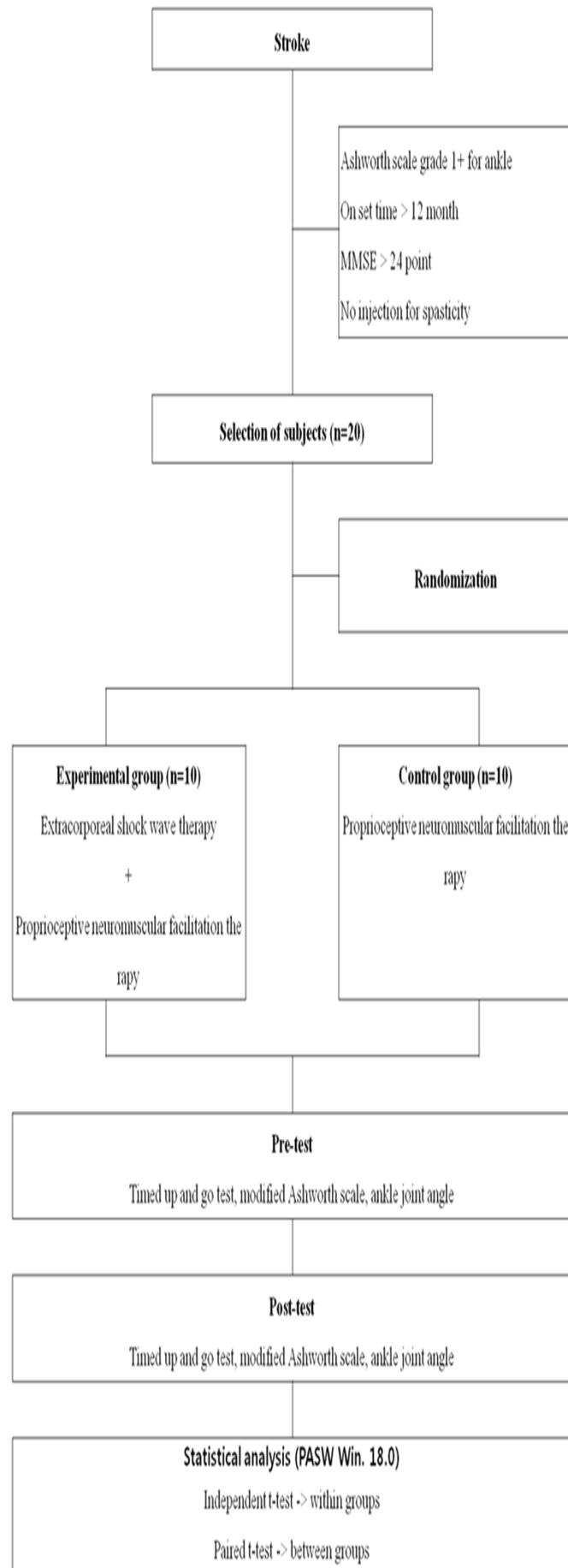
## 4. Discussion

Rehabilitation after nerve injury is a process that is undertaken to perform necessary actions for human survival, and it is constantly modified and reorganized. Functional recovery ranges from short-term functional changes immediately after injury to long-term structural changes, such as remapping of the sensorimotor cortex[19]. Functional recovery of stroke patients is related to cortical reorganization. Cortical restoration based on nerve lesions can occur by connecting to the previously nonfunctional synapses in an adjacent area or by replacing a part of the map with the neighboring sensory area[20].

Improving patients' walking is of the utmost importance in the treatment of stroke. Stroke patients' independent walking is considered a vital factor in their lives, and functional walking depends on the patient's stamina[21]. Because stroke patients, in particular, have difficulty with functional walking and are unable to maintain an effective walking speed even with very short distances, they tend to choose a speed with which they will consume minimal energy. However, they can only increase their walking speed when they consume more energy than they can control. Thus, stroke patients need exercises that improve their walking speed and endurance as their activities are limited to their home. In order to optimize walking performance, they need to increase flexibility to prevent shortening of the soft tissue by spasticity and to improve strength and coordination of the lower limb muscles[22].

Stroke patients should increase flexibility in the ankle joints through spastic reduction and improve active and passive extension of the gastrocnemius muscles or the rectus femoris muscles, which are necessary for walking and stair climbing. Other factors related to walking after a stroke include the ability to follow directions, balancing in a standing position, voluntary control and joint position sense of the affected lower limbs, spatial orientation, and cognitive ability[23].

The Bobath approach of neuro-development treatment and PNF have been applied as therapies to improve stroke patients' gait ability and balancing. Although these methods focus on improving abnormal tension and asymmetric movements among the several factors that cause abnormal walking in stroke patients, they are insufficient for reducing spasticity to improve walking[14]. Stroke patients show reduced movement in the hip and the knee joints and in dorsiflexion of the ankles even after recovering their walking ability. Thus, such patients find stair climbing or obstacle crossing challenging, which are more difficult than walking, requiring appropriate flexion of the lower limb and detachment of the foot from the ground[24].

**Fig. 1:** Flow chart of study

Spasticity is a state of accelerated deep tendon reflex, which is common with stroke and other neurological problems. It indicates an increase in muscle tone and resistance against passive movements, thus causing decreased agility, decreased voluntary mobility, lowered coordination ability, bone transformations, and contracture[3]. Spasticity is common in patients with central nervous system injuries, serving as an important factor influencing successful rehabilitation. Although medical drugs, surgical procedures, and physical therapy have been applied in the treatment of spasticity, no method has directly treated the symptoms of spasticity. The purpose of treating spasticity is to reduce its intensity and to help patients perform daily activities by preventing or correcting hypofunctioning or abnormalities caused by spasticity. In this context, the treatment of stroke patients should focus on minimizing spasticity through controlled exercise[25].

Related to the muscle spindle, spasticity occurs when synaptic excitability increases due to an abnormal increase in the activity of alpha motor neurons caused by injury to the central nervous system or by an increase in sensitivity of the motor neurons due to extension[16]. It also occurs when excitability of the motor nerves controlling the intrafusal muscle fiber increases excitability of the afferent sensory fibers in the muscle spindle responding to extension, or when the excitatory interneurons are excited by afferent inputs too easily.

Spasticity is useful for maintaining stiffness in the lower limbs during standing or walking, thereby providing stability to stroke patients and helping to prevent several complications such as atrophy, osteoporosis, and deep thrombosis, which contributes to maintaining cardiopulmonary function. However, it also induces clonic muscular spasm, dyspraxia, and voluntary motor disturbances in minute movements. It also tends to lead to skin damage and joint contracture, and obstructs treatment or nursing[26].

High-energy shock waves have long been a subject of attention. In the 1950s, Russian scientists found that they could crush urinary stones. German researchers in the 1960s detected tremors similar to an electric shock when the target of a shock wave was touched at the exact time it was active[27]. How to use the wave to crush urinary stones began to be studied in 1974. In addition, the effects of shock waves were also proven safe in animal experiments. A shock wave generated in water was confirmed to be safely delivered into the body without any apparent loss of energy because the acoustic levels of water and the human body are similar[28].

Currently, ESWT has developed into a non-surgical therapy replacing surgery in the treatment of several musculoskeletal disorders that are difficult to deal with using existing conservative techniques. It focuses energy to lesions to be treated by generating high-amplitude pressure from outside the body[14]. It has been reported that direct stimulation by extracorporeal shock waves induces healing responses at the cellular level, promoting the formation of new blood vessels by accelerating growth factors in the tissues. According to some research, stimulation by shock waves suppresses the nociceptors to increase the pain threshold or induce several biological effects such as inflammation reduction and wound healing. These physical and biological effects of ESWT enable its use in the treatment of various disorders, such as stroke, cerebral palsy, calcific tendonitis, lateral epicondylitis, and Plantar fasciitis[17].

Although ESWT was recently reported effective for treating stiffness and is considered a new type of stiffness treatment, the existing research only used clinical indicators to judge its therapeutic effects on spasticity, and few studies have performed an evaluation through gait analysis[29]. In this study, a decrease in spasticity was observed in the assessment via MAS after ESWT was applied.

Even those studies on lower limb spasticity mostly focused on the effects immediately after the therapy, and few of them determined whether the effects continued. Thus, in this study, ESWT was applied to patients with lower limb stiffness after stroke, and both clinical and gait analysis were performed in an attempt to determine its therapeutic effects and their continuity[30].

In this study, ESWT was applied to the muscular area and the musculotendinous junction where the Golgi tendon organ is located. It has been reported that extracorporeal shock waves suppressed the excitability of the alpha motor neurons in stroke patients because the amplitude of the reflex decreased and returned to its original state when pressure was applied to the Achilles tendon[31]. Other studies have reported that the shock wave applied to the Golgi tendon organ in the musculotendinous junction increased inhibitory signals to reduce spasticity because the shock wave induced passive relaxation in the spastic joints, stretching the Golgi tendon organ to suppress the alpha and the gamma motor neurons[32].

Similarly in this study, when the extracorporeal shock wave was applied to the affected lower limbs, the reduction in spasticity decreased the internal angle of the ankle joint in mid stance with statistical significance. The results of this study suggest that shock waves can reduce spasticity and these results may have a great effect on the activities of daily living of stroke patients.

The mechanism by which ESWT relieves stiffness, however, is still unclear. Some researchers suggest that the relieving effects could be induced by spinal excitability, mechanical vibration stimulation, and influence on the Golgi tendon organ[33].

The results of this study may be insufficient for generalization because the number of subjects was small, and the evaluation period was rather short. In addition, we performed neither a cytological evaluation (because the subjects of this study were human) nor a multilateral quantitative method. Since ESWT is highly affected by flux velocity, frequency, and the site of application, further studies are needed to apply multilateral quantitative methods to a large number of patients in order to investigate disorders, sites, and effects related to extracorporeal shock waves.

## 5. Conclusion

In this study investigated the effect of extracorporeal shock wave therapy on timed up and go test, modified Ashworth scale, and ankle joint angle through neurological recovery after nerve injury. The subjects of this study were 20 patients who were treated for stroke in a rehabilitation hospital. The control group (n = 10) underwent a normal type of proprioceptive neuromuscular facilitation (PNF), while the experimental group (n = 10) underwent a normal type of PNF and then ESWT. The results of this study showed that there was a statistically significant difference in TUG test and AJA between the pre-test and the post-test. However, MAS was not statistically significant in comparison within groups and between groups. In other words, the extracorporeal shock wave therapy was effective in reducing spasticity in a dynamic state rather than a static state. In the future, I hope that research will be conducted on why extracorporeal shock wave therapy are effective in reducing spasticity in a dynamic state. Also, I hope that research on the continuously effect for a long time and duration of ESWT applied to the lower extremity.

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