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Effects of Overlapping Action of Clinically Applied Rehabilitation Interventions Based on the Theory of Neuroplasticity

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Abstract: This study was invested to investigate the effects of a treatment method that can apply the theory of neurorehabilitation for rehabilitation treatment of stroke patients on spasticity, balance ability, and walking ability. In this study, 30 people diagnosed by a rehabilitation medicine specialist were divided into experimental group A and experimental group B through a random assignment method. Experimental group A received extracorporeal shock wave therapy on the paralyzed lower extremity after proprioceptive neuromuscular facilitation treatment, and experimental group B received non-gravity treadmill training after proprioceptive neuromuscular facilitation treatment. All treatments were performed 3 times a week for 6 weeks, and pre- and post-evaluation were conducted. Spasticity, gait speed, dynamic balance ability, and ankle angle were measured to evaluate the treatment effect. In the results of the study, the decrease in spasticity was statistically significantly higher in experimental group A than in experimental group B, and the improvement in walking speed and dynamic balance ability was statistically significantly higher in experimental group B than in experimental group A. In addition, the change in ankle angle was greater in experimental group A than in experimental group B. In conclusion, various treatment methods should be applied simultaneously to improve the quality of life and quickly return to society in stroke patients.

Keywords: spasticity, balance, walking ability, stroke.

基于神经可塑性理论的临床应用康复干预的重叠效应

摘要：本研究旨在探讨一种应用神经康复理论的治疗方法应用于脑卒中患者康复治疗对痉挛、平衡能力和行走能力的影响。本研究将 30 名经康复医学专家诊断的患者采用随机分配的方法分为实验 A 组和实验乙组。实验 A 组在本体感觉神经肌肉促进治疗后对瘫痪下肢进行体外冲击波治疗,实验乙组在本体感觉神经肌肉促进治疗后进行无重力跑步机训练。所有治疗每周进行 3 次，持续 6 周，并进行前后评估。测量痉挛状态、步态速度、动态平衡能力、踝关节角度评价治疗效果。在研究结果中，实验组 A 的痉挛状态下降在统计学上显着高于实验组乙，实验组乙的步行速度和动态平衡能力的改善在统计学上显着高于实验组 A。实验 A 组踝关节角度变化大于实验乙组。综上所述，应同时应用多种治疗方法，以提高脑卒中患者

的生活质量，尽快回归社会。

关键词： 痉挛、平衡、行走能力、中风．

1. Introduction

Stroke is a case of cerebrovascular disease due to blood circulation disorder and means that symptoms of global or local neurological deficit persist. Stroke is a leading cause of adult disability. Disorders such as muscle weakness, loss of range of motion, and imbalance result in motor control disorders that affect stroke survivors' ability to live independently and be economically self-sufficient [1]. Although many traditional therapeutic interventions have been used in rehabilitation to promote functional recovery, research findings are inconsistent, and recent evidence suggests that intensive, repeated treatments must modify the neural tissue and restore motor function [2].

Stroke patients have problems with motor control due to muscle weakness, abnormal muscle tension, and abnormal movement patterns, which limit their ability to perform functional activities such as walking, climbing stairs, and activities of daily living [3]. Also, most patients who received adequate rehabilitation remain disabled. The central nervous system damage after stroke can be naturally recovered to a certain level by the post-lesional recovery mechanism within 3 months, which is the acute phase; however, but the recovery in the chronic phase is insignificant. For this reason, it is necessary to apply rehabilitation treatment at an early stage [4]. The reason why rehabilitation treatment for stroke patients should be started as soon as possible is to prevent the deterioration of the disease progression over time, to increase the patient's independence, and to improve the quality of movement on the paralyzed side to the level before brain damage. In other words, the goal of the initial treatment is to coordinate the ability of both sides as much as possible [5].

Neuroplasticity refers to the ability of the human brain to change with experience, and this feature of the brain was discovered only in modern times. Our brains have evolved the ability to reintegrate themselves in response to experience, and the plasticity of our brain anatomy allows us to tailor our brain design to fit our individual activities [6]. The brain is made up of neurons and glial cells, and learning can occur through changes in the length of neuronal connections, the addition or removal of connections, and the formation of new neurons, and plasticity is associated with this learning. Currently, exercise therapy, electrical therapy, manual therapy, and drug therapy are being applied in clinical practice to increase this neuroplasticity [7].

Most stroke patients show a flaccid state immediately after the initial stroke, but become accompanied by stiffness over time. Spasticity is a result of hyperexcitation of the stretch reflex in upper motor neuron syndrome, and is a movement disorder characterized by an increase in tonic stretch reflex with the speed of joint movement along with excessive tendon reflexes [8]. Stiffness causes disturbances in the patient's passive joint range of motion, active joint range of motion, functional performance, and balance ability and causes changes in the physical properties of muscles and other tissues, affecting the flexibility and viscoelasticity of muscles, tendons, and joints. Secondary changes due to spasticity are a big problem to be solved in the rehabilitation treatment of stroke patients [9].

Motor neuron syndrome in stroke patients causes a series of complications that change the stiffness of muscles, ligaments, and joints, with symptoms including movement disorders, increased reflexes, and excessive muscle tension [10]. Excessive muscle tension during stroke can partially change the connective tissue responsible for the motor ability of the muscle, promote fibrosis, and cause hypersensitivity of the muscles involved in the spine. In the management of patients with chronic hemiplegia, increased muscle tension is an important problem and can interfere with walking, eating, stool disposal, car washing, and other activities of daily living [11].

Locomotion is the movement of a body from one place to another according to its basic needs. Walking itself makes it one of the most common activities people do daily, and walking is an important human activity that enables us to become productive and engaged members of our communities [12]. If the ability to walk decreases, the quality of life decreases and participation in outdoor activities decreases, resulting in social isolation. Typical gait disturbances in stroke patients include reductions in guaranteed length, gait speed, and number of steps on the affected and unaffected lower extremities. Compared to normal people, chronic stroke patients reduced walking speed by 1/3 and walking distance by about 40%. These results are due to the loss of leg muscle strength, balance disorder, and spasticity due to neurological damage after stroke [13].

Improving the walking ability for increasing independence and activities of daily living after stroke is one of the biggest challenges and important treatment goals in rehabilitation of patients. Therapeutic methods applied to improve gait ability in clinical practice include extracorporeal shock wave therapy, treadmill gait training, lower extremity muscle

strengthening, task-oriented exercise, and exercise image training [14]. Useful and diverse external stimuli stimulate healing responses through cellular biochemical signal transduction and finally promote tissue repair, and can serve as important adjuvants in the rehabilitation of chronic and complex injuries [15].

In clinical medicine, extracorporeal shock wave therapy has been used for several indications, and recent studies have shown positive effects on its use in complex soft tissue wounds and ischemic tissues. The exact mechanism of extracorporeal shock wave therapy in damaged cells is slowly beginning to be elucidated. The application of physical energy in the form of shock waves or mechanical stimulation affects the acceleration of the response of damaged cells and tissues and promotes recovery with beneficial biological effects related to regeneration [16, 17].

Additionally, the possibility that the mechanical stimulation of extracorporeal shock wave therapy directly affects the muscle fibers adjacent to the tendon cannot be ruled out, and intermittent tendon compression lasting for a long time can neurophysiologically or clinically reduce spinal excitation. The shock wave used in extracorporeal shock wave therapy is a single acoustic therapy method characterized by short duration, rapid pressure rising and high peak pressure. The results of studies showing a decrease in muscle tone in nervous system patients after shock wave therapy and a sustained clinical effect of shock wave therapy on EMG can be used as evidence for the use of extracorporeal shock wave therapy in patients experiencing muscle spasms [18], [19].

In this study, extracorporeal shock wave therapy, which can promote neuroplasticity, was applied to damaged paralyzed lower limbs to investigate the effect on reducing spasticity and improving walking ability, which are essential factors for improving independence and returning to daily life in stroke patients.

2. Materials and Methods

2.1. Subjects

In this study, 33 patients receiving rehabilitation treatment at a hospital after being diagnosed with a stroke at a rehabilitation hospital were selected as study subjects. In this study, patients who had been diagnosed with a hemiplegic stroke for more than 12 months as a result of a brain imaging-based specialist diagnosis were selected as study subjects based on the following selection criteria.

1. Patients with a grade of 1 or higher for knee and ankle stiffness based on the Ashworth scale.

2. Patients with a score of 24 or higher on the MMSE.

3. Patients who can walk independently for more than 10 m, without visual damage that can affect walking.

4. Patients who agreed to participate after explaining the research purpose and method of this study.

Patients with orthopedic diseases in the lower limbs and those who received injection-related treatment for spasticity were excluded from the study. Before the experiment, a detailed explanation of the purpose, method, procedure, and risks of the experiment was provided to the subjects in accordance with the Declaration of Helsinki, and consent was obtained to participate in the experiment.

This study was conducted by dividing into Experimental Group A and Experimental Group B using a random assignment method, and three subjects were dropped from the study due to personal reasons during the study. Experimental group A (n=15) received extracorporeal shock wave therapy on the affected lower extremity after proprioceptive sensory neuromuscular facilitation treatment, experimental group B (n=15) received proprioceptive sensory neuromuscular facilitation, a general physical therapy, and then performed weightless treadmill training for 30 minutes. Therapeutic intervention of each group was conducted 3 times a week for 6 weeks, 18 sessions.

2.2. Intervention Methods

To apply extracorporeal shock wave therapy to experimental group A, an extracorporeal shock wave therapy machine (Optimus, Salus Talent 3, Korea) that generates shock waves was used. To apply extracorporeal shock wave therapy to the patient, the patient was placed in a side-lying position with the hemiplegic lower extremity uplighted, and then shock wave stimulation was applied to the patient at 3 Hz and power was applied in one step. Extracorporeal shock wave therapy was applied 1,500 times each to the distal musculo-ligamental junction of the quadriceps muscle and calf muscle of the injured lower extremity, and to the posterior aspect of the lateral and medial epicondyle of the femur. During the treatment, if the patient complained of pain or swelling occurred, the treatment was stopped and reapplied after taking a break.

In this study, a non-gravity treadmill device (Alter-G®; AlterG, Inc., Fremont, CA, USA) was used to apply treadmill exercise to experimental group B. In the initial treatment of treadmill exercise, only minimal weight support was provided within the range where the patient did not feel uncomfortable, and the exercise was performed under the supervision of a therapist while increasing the weight bearing by 1-3% depending on the patient each week. In addition, the patient was instructed to receive visual feedback while watching the monitor on the treadmill equipment, and the treadmill speed was set to 0.5 km/h or less for the patient's safe exercise. If the patient complained of difficulty during exercise, the weight bearing was

reduced and applied after rest, and exercise was performed for 30 minutes at a time.

In this study, all groups received proprioceptive neuromuscular facilitation treatment before extracorporeal shock wave therapy and treadmill exercise. To apply the flexion/adduction/external rotation pattern to the affected lower extremity, the subject was asked to take the starting postures of the pattern, such as hip extension/abduction/internal rotation, knee extension, and ankle plantar flexion, in a supine position. The beginning of the movement proceeded in the order of ankle dorsiflexion, knee flexion, and hip flexion/adduction / external rotation, which are opposite to the starting posture, according to the instructions of the researcher.

To apply the flexion/abduction/internal rotation pattern to the affected lower extremity, the subject placed both lower extremities in the 5 o'clock direction in a supine position. The lower extremity on the injured side was made to take the starting posture of the pattern, such as hip extension/flexion/external rotation, knee extension, and ankle plantar flexion, and both arms were placed comfortably next to the torso. The movement was started in the order of ankle dorsiflexion, knee flexion, and hip joint flexion/abduction/internal rotation, which are opposite to the starting posture, according to the researcher's instructions.

2.3. Assessment Methods

In this study, the Modified Ashworth Scale was used to evaluate the lower extremity spasticity of patients. The MAS is a test that uses the resistance to passive movement of various joints, score ranges from 0 to 4, with a score of 1 meaning no resistance and a score of 4 meaning very high resistance. To evaluate MAS, the environment was created so that the patient was not affected by the surroundings as much as possible, and the therapist measured the passive movements of the lower extremities to be measured after properly aligning the body. The patient's spasticity evaluation was evaluated before the first treatment and after the last treatment. For statistical processing of MAS, grade 0 was 1 point, grade 1 was 2 points, grade 2 was 3 points, grade 3 was 4 points, and grade 4 was 5 points. The average value obtained through three evaluations was used as the measured value.

The Dartfish program (myDartfish Express PC version 10.0, DFKOREA, Korea) was used to evaluate the patient's ankle angle during walking. In this study, to measure and compare the change in the ankle angle during the initial contact phase and heel tremor phases during walking, the camera was fixed from the outside at a distance of 3 m, while the experiment participant walked 10 m on a flat surface. To measure the angle of the ankle joint, markers were attached to anatomical locations on the lateral epicondyle of the femur, the lateral malleolus, and the head of the fifth toe. When the experiment participant walked, the angle at which the extension lines connecting each marker met was collected to collect images, and the average value was used as the measured value after a total of three evaluations using the Dartfish Motion Analysis software.

In this study, a timed up and go test was conducted to evaluate the patient's walking function and dynamic balance ability. The TUG is a test method that can quickly measure the patient's functional activity, mobility, and balance. The time required to sit in a chair with armrests, get up from the chair with the experimenter's start signal, walk a distance of 3m, return, and sit in the chair was measured. In this study, three tests were conducted and the average value was used as the measured value. Generally, more than 20 seconds means there is functional motor impairment, and this test can predict the occurrence of falls by evaluating balance ability and functional movement. The average value obtained through three evaluations was used as the measured value.

2.4. Statistical Analysis

Data collected to evaluate spasticity, ankle angle, and gait ability were analyzed using SPSS 18.0 for Windows. Normality was verified using the Shapiro-Wilk test, and was described as mean ± standard deviation using descriptive statistics. A paired t-test was conducted to determine the difference between the pre-test and post-test within groups A and B, and an independent t -test was conducted to determine out the difference in the amount of change between groups. And the significance level was set at $\alpha < 0.05$.

3. Results

In the MAS conducted to determine the spasticity of the subjects, group A showed a statistically significant decrease in spasticity, from an average of 3.01 points before the experiment to 2.15 points after the experiment ($P < 0.05$). However, in group B, the average spasticity level decreased, but there was no statistically significant change ($P > 0.05$). In a comparison between groups to compare the effects of treatment, group A to which extracorporeal shock wave therapy was applied showed a statistically significant reduction in spasticity compared to group B to which non-gravity treadmill was applied ($P < 0.05$) (Table 1).

Table 1 Comparison of modified Ashworth scale between groups

	Pre-test	Post-test	t	P
Group A	3.01 ± 0.34	2.15 ± 0.57	-1.058	0.000*
Group B	2.95 ± 0.73	2.57 ± 0.16	-0.371	0.154
t	0.764			
P	0.027**			

Notes: Group A: Extracorporeal shock wave therapy after PNF; Group B: Non-gravity treadmill after PNF; * Paired t-test $P < 0.05$; ** Independent t-test $P < 0.05$; Unit: Score

In the evaluation conducted to determine the ankle angle during the initial contact phase during walking, group A's average ankle angle decreased from 122.18 before the experiment to 113.64 after the experiment, and group B's ankle angle decreased from 130.84 before the experiment to 125.37 after the experiment ($P < 0.05$). In the comparison between the groups to determine the difference in the effect of treatment, group A to which extracorporeal shock wave therapy was applied showed a statistically significant decrease in ankle angle compared to group B to which non-gravity treadmill was applied ($P < 0.05$) (Table 2).

Table 2 Comparison of ankle angle of initial contact between groups

	Pre-test	Post-test	t	P
Group A	122.18 ± 12.16	113.64 ± 11.87	8.467	0.000*
Group B	130.84 ± 14.75	125.37 ± 12.03	4.313	0.000*
t	3.485			
P	0.000**			

Notes: Group A: Extracorporeal shock wave therapy after PNF; Group B: Non-gravity treadmill after PNF; * Paired t-test $P < 0.05$; ** Independent t-test $P < 0.05$; Unit: Angle

In the evaluation conducted to determine the ankle angle during the heel off phase during walking, group A's average ankle angle decreased from 95.48 before the experiment to 87.82 after the experiment, and group B's ankle angle decreased from 103.71 before the experiment to 98.53 after the experiment ($P < 0.05$). In the comparison between the groups to determine the difference in the effect of treatment, group A to which extracorporeal shock wave therapy was applied showed a statistically significant decrease in ankle angle compared to group B to which non-gravity treadmill was applied ($P < 0.05$) (Table 3).

Table 3 Comparison of the ankle angle of heel off between groups

	Pre-test	Post-test	t	P
Group A	95.48 ± 11.08	87.82 ± 10.92	7.843	0.000*
Group B	103.71 ± 13.64	98.53 ± 12.66	4.332	0.000*
t	2.942			
P	0.000**			

Notes: Group A: Extracorporeal shock wave therapy after PNF; Group B: Non-gravity treadmill after PNF; * Paired t-test $P < 0.05$; ** Independent t-test $P < 0.05$; Unit: Angle

In the TUG conducted to examine the walking ability and dynamic balance of the subjects, group B's average score was 28.65 points before the experiment and 22.75 points after the experiment, showing a statistically significant improvement in gait and balance ability ($P < 0.05$). However, in group A, the average TUG score decreased from 29.87 before the experiment to 26.55 after the experiment, but there was no statistically significant change ($P > 0.05$). In the comparison between the groups to determine the difference in the effect of treatment, group B applied with non-gravity treadmill showed statistically significant improvement in gait and balance ability than group A applied with extracorporeal shock wave therapy ($P < 0.05$) (Table 4).

Table 4 Comparison of timed up and go test between groups

	Pre-test	Post-test	t	P
Group A	29.87 ± 5.48	26.55 ± 7.19	2.187	0.000*
Group B	28.65 ± 6.57	22.75 ± 6.35	6.273	0.000*
t	-3.641			
P	0.000**			

Notes: Group A: Extracorporeal shock wave therapy after PNF; Group B: Non-gravity treadmill after PNF; * Paired t-test $P < 0.05$; ** Independent t-test $P < 0.05$; Unit: Score

4. Discussion

In this study, extracorporeal shock wave therapy and non-gravity treadmill exercise were applied to reduce spasticity, which causes many disabilities in stroke patients, and investigated changes in spasticity, balance, and walking ability. Stroke is defined as a disease in which blood flow supplied to the brain is blocked due to cerebrovascular disease, heart disease, diabetes mellitus, or the like, or a disorder occurs due to hemorrhage in the brain tissue. One of four stroke patients die within 1 month after acute onset, 9% recover completely, and even if 73% recover, they may experience physical problems such as movement disorders, sensory disorders, language disorders, and cognitive disorders depending on the brain lesion [20].

The restoration of walking ability is the first thing to be considered to minimize the disability of stroke patients and return to independent daily life. Decreased balance and walking ability in stroke patients cause restrictions in activities of daily living, lowering individual independence, and consequently reducing social activities [21]. Gait disorder is caused by damage to the integrative function and kinesthetic pathway of the higher central nervous system related to the lesion in stroke patients, and is further aggravated by inactivity or nonuse that occurs secondarily after direct damage. Ultimately, this is because abnormal contraction of muscles affects the decrease in gait speed and endurance, and neurological damage after a stroke causes decreased muscle strength, balance disorder, stiffness, decreased joint stability, and impaired proprioception [22]. In the case of stroke patients, the paralyzed side has a lower ability to control the nervous system and activate muscles than the paralyzed side, resulting in excessive muscle tone and paralysis due to poor interaction between agonist and antagonist muscles. In other words, the rehabilitation treatment of stroke patients should focus on improving rational muscle activation and balance maintenance abilities necessary for independent activities in daily life [23].

Since stroke patients most need improvement in walking function by treatment, independent walking acts as an important factor in the patient's life.

Functional gait performance depends on the patient's fitness level, and it is difficult for stroke patients to maintain functional gait speed even over very short distances because they cannot increase their gait speed without expending an unusually high amount of energy [24]. For this reason, it is necessary to apply therapeutic interventions that increase walking speed and endurance in the rehabilitation treatment of stroke patients. Additionally, important factors for efficient and effective walking include rotation of the pelvis, the tilt of the pelvis, angle of the ankle and knee joints in the stance phase, and muscle activity of muscles around the ankle and knee joints. In particular, it is difficult for stroke patients to actively control the dorsiflexor muscles of the ankle joint due to increased stiffness, and the muscle tension of the calf muscles abnormally increases, resulting in foot drop during walking [25].

Based on the above, to increase the strength and endurance of stroke patients, spasticity, which is the cause of abnormal muscle activity, must firstly be reduced. In many studies, various therapeutic intervention methods are currently being applied to reduce spasticity in patients with central nervous system damage, and representative methods include extracorporeal shock wave therapy, functional electrical stimulation therapy, proprioceptive neuromuscular facilitation, and treadmill exercise [26]-[28]. Recently, as the stability of ESWT has been confirmed, the application fields have been broadened and subdivided, and it has been confirmed that the therapeutic effect differenced depending on the intensity of pressure, the size of the energy field, and the distribution of pressure density. Preliminary studies have confirmed that the exposure of bone tissue to the high-density pressure field of extracorporeal shock wave therapy promotes bone formation and recovery [29]. In another study, when exposing fat cells to an extracorporeal shock wave pressure field with a micro-energy field, it was shown that the disassembly and absorption of fat cells increased, which was effective in treating obesity [30].

Recently, as studies showing that ESWT has a therapeutic effect on reducing spasticity have been published, it is being considered a new treatment method for spasticity. In particular, it has been reported that ESWT can be a therapeutic tool for patients with stroke, pressure ulcers, and lymphedema in addition to musculoskeletal disorders because it does not require preparation such as anesthesia during treatment, has few side effects, and is inexpensive [31]-[32]. Therefore, this study applied extracorporeal shock wave therapy to the quadriceps femoris (distal musculoskeletal junction) and triceps lower leg (proximal and distal musculoskeletal junction), which restrict the motion of the knee and ankle joints, to reduce spasticity. In the study results, a statistically significant reduction in spasticity was observed in experimental group A, in which extracorporeal shock wave therapy was applied to the injured lower extremity. These results are thought to be because the stimulation of the shock wave applied to the damaged area promoted the reorganization of the cortical region of the brain, and the microenvironment was changed to increase the expression of neurotrophic factors. Additionally, it is considered that the physical stimulation of the shock wave increases the speed of information transmission of sensory nerves, activating the tension control mechanism of muscle spindles and Golgi tendon .

Gait is a very fast and complex process in which motor nerves, sensory nerves, and the musculoskeletal system are used as a whole. It is a continuous and repetitive activity in which one lower extremity maintains a stable state in the stance phase, while the other lower extremity moves the body. Gait occurs because of highly coordinated alternating motions that move the body step by step while maintaining the required speed in a constant direction [33]. In the case of hemiplegic patients due to a stroke, they can maintain a certain level of balance according to the regeneration of the nervous system over time, and when mobility is secured, walking is possible even though it is unstable. The most difficult challenge for these people with cranial nerve damage to perform ambulation is the lack of the ability to generate the right amount of voluntary muscle contraction with activity and the inability to match the controlled intensity and timing of muscle activity. Additionally, patients with central nervous system damage have difficulty walking due to increased stiffness during voluntary exercise desired by the patient and consequent secondary joint contracture [34].

To optimize the gait performance of stroke patients, a treatment method that primarily prevents soft tissue shortening due to spasticity and improves the muscle strength and coordination of the lower limb muscles is needed. Guidelines for gait training in stroke patients focus on increasing the flexibility of the knee and ankle joints through the reduction of spasticity and increasing the strength and endurance of the calf muscle and rectus femoris muscle. These abilities are always necessary for walking or going up and down stairs, and other factors involved in gait after stroke include command performance, balance in a standing position, voluntary control, joint positioning, spatial orientation, and cognitive abilities [35]. In this study, non-gravity treadmill training was applied to the experimental group B to improve walking ability, and, as a result of the study, group B with treadmill application showed a statistically significantly faster walking speed than group A without treadmill application. These results are thought to be because weightless treadmill training improved muscle strength, endurance, and balance required for walking, and repetitive movements of the lower limbs during training increased muscle

coordination and motor control, activating the motor learning center.

Since this study was conducted in the era of COVID-19, the number of subjects was small and the evaluation period was very short because the study was conducted while complying with quarantine rules, making it difficult to generalize the results. Additionally, in this study, since the subject was a human body, it was difficult to conduct cytological evaluation, and various quantitative evaluation methods using mechanical equipment could not be applied. The effect of extracorporeal shock wave therapy varies depending on the flow density, frequency, and area of application. In the next study, a study should be conducted to determine the effect of shockwave on more various diseases and parts using a quantitative evaluation method using a machine targeting more patients.

5. Conclusion

In conclusion, ambulation, which acts as an important factor in social return and quality of life improvement, which is the rehabilitation goal of stroke patients, is difficult to solve with a single therapeutic intervention. Therefore, when applying rehabilitation treatment, it is necessary to apply a rehabilitation treatment method that can reduce spasticity that causes a restriction of joint movement related to walking and a treatment that can improve muscular endurance, muscle strength, and balance ability that can increase walking ability. That is, rehabilitation treatment of stroke patients using overlapping effects occurring between treatments by applying various treatment methods according to the patient's disability characteristics, rather than fragmentary treatment methods, should be performed in clinical practice.

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References

[1] TATER P, & PANDEY S. Post-Stroke Movement Disorders: Clinical Spectrum, Pathogenesis, and Management. *Neurology India*, 2021, 69(2): 272–283. https://doi.org/10.4103/0028-3886.314574

[2] IADECOLA C, BUCKWALTER M S, & ANRATHER, J. Immune Responses to Stroke: Mechanisms, Modulation, and Therapeutic Potential. *The Journal of Clinical Investigation*, 2020, 130(6): 2777–2788. https://doi.org/10.1172/JCI135530

[3] PANG M Y C, YANG L, OUYANG H, et al. Dual-Task Exercise Reduces Cognitive-Motor Interference in Walking and Falls After Stroke. *Stroke*, 2018, 49(12): 2990–2998. https://doi.org/10.1161/STROKEAHA.118.022157

[4] CRAMER, S. C. Recovery After Stroke. Contin. *Continuum (Minneapolis, Minn.)*, 2020, 26(2): 415–434. https://doi.org/10.1212/CON.0000000000000838

[5] KRAJCZY, E, KRAJCZY, M, LUNIEWSKI, et al. Assessment of the Effects of Dysphagia Therapy in Patients in the Early Post-Stroke Period: A Randomized Controlled Trial. *Neurologia Neurochirurgia Polska*, 2019, 53(6): 428–434. https://doi.org/10.5603/PJNNS.a2019.0053

[6] XING Y, & BAI Y. A Review of Exercise-Induced Neuroplasticity in Ischemic Stroke: Pathology and Mechanisms. *Molecular Neurobiology*, 2020, 57(10): 4218–4231. https://doi.org/10.1007/s12035-020-02021-1

[7] PENNA L G, PINHEIRO J P, RAMALHO S H R, & RIBEIRO C F. Effects of Aerobic Physical Exercise on Neuroplasticity after Stroke: Systematic Review. *Arquivos De Neuro-Psiquiatria*, 2021, 79(9): 832–843. https://doi.org/10.1590/0004-282X-ANP-2020-0551

[8] SALAZAR A P, PINTO C, RUSCHEL MOSSI J. V, et al. Effectiveness of Static Stretching Positioning on Post-Stroke Upper-Limb Spasticity and Mobility: Systematic Review with Meta-Analysis. *Annals of Physical and Rehabilitation Medicine*, 2019, 62(4): 274–282. https://doi.org/10.1016/j.rehab.2018.11.004

[9] MAHMOOD A, VELUSWAMY S K, HOMBALI A, et al. Effect of Transcutaneous Electrical Nerve Stimulation on Spasticity in Adults with Stroke: A Systematic Review and Meta-Analysis. *Archives of Physical Medicine and Rehabilitation*, 2019, 100(4): 751–768. https://doi.org/10.1016/j.apmr.2018.10.016

[10] GLAESS-LEISTNER S, RI S J, AUDEBERT H J, & WISSEL J. Early Clinical Predictors of Post Stroke Spasticity. *Topics in Stroke Rehabilitation*, 2021, 28(7): 508–518. https://doi.org/10.1080/10749357.2020.1843845

[11] SHARIFIFAR S, SHUSTER J J, & BISHOP M D. Adding Electrical Stimulation during Standard Rehabilitation after Stroke to Improve Motor Function. A Systematic Review and Meta-Analysis. *Annals of Physical and Rehabilitation Medicine*, 2018, 61(5): 339–344. https://doi.org/10.1016/j.rehab.2018.06.005

[12] GEERARS M, MINNAAR-VAN DER FEEN N, & HUISSTEDE B M A. Treatment of Knee Hyperextension in Post-Stroke Gait. A Systematic Review. *Gait & Posture*, 2022, 91: 137–148. https://doi.org/10.1016/j.gaitpost.2021.08.016

[13] ZHANG B, LI D, LIU Y, et al. Virtual Reality for Limb Motor Function, Balance, Gait, Cognition and Daily Function of Stroke Patients: A Systematic Review and Meta-Analysis. *Journal of Advanced Nursing*, 2021, 77(8): 3255–3273. https://doi.org/10.1111/jan.14800

[14] GUNNING E, & USZYNSKI M K. Effectiveness of the Proprioceptive Neuromuscular Facilitation Method on Gait Parameters in Patients with Stroke: A Systematic Review. *Archives of Physical Medicine and Rehabilitation*, 2019, 100(5): 980–986. https://doi.org/10.1016/j.apmr.2018.11.020

[15] SCHRÖDER J, TRUIJEN S, VAN CRIEKINGE T, & SAEYS W. Feasibility and Effectiveness of Repetitive Gait Training Early after Stroke: A Systematic Review and Meta-Analysis. *Journal of Rehabilitation Medicine*, 2019, 51(2): 78–88. https://doi.org/10.2340/16501977-2505

[16] GUO J, QIAN S, WANG Y, & XU A. Clinical Study of Combined Mirror and Extracorporeal Shock Wave Therapy on Upper Limb Spasticity in Poststroke Patients. *International Journal of Rehabilitation Research*, 2019, 42(1): 31–35. https://doi.org/10.1097/MRR.0000000000000316

[17] YOLDAŞ ASLAN Ş, KUTLAY S, DÜSÜNCELI ATMAN E, et al. Does Extracorporeal Shock Wave Therapy

Decrease Spasticity of Ankle Plantar Flexor Muscles in Patients with Stroke: A Randomized Controlled Trial. *Clinical Rehabilitation*, 2021, 35(10): 1442–1453. https://doi.org/10.1177/02692155211011320

[18] CABANAS-VALDÉS R, SERRA-LLOBET P, RODRIGUEZ-RUBIO P R, et al. The Effectiveness of Extracorporeal Shock Wave Therapy for Improving Upper Limb Spasticity and Functionality in Stroke Patients: A Systematic Review and Meta-Analysis. *Clinical Rehabilitation*, 2020, 34(9): 1141–1156. https://doi.org/10.1177/0269215520932196

[19] FAN T, ZHOU X, HE P, et al. Effects of Radial Extracorporeal Shock Wave Therapy on Flexor Spasticity of the Upper Limb in Post-Stroke Patients: Study Protocol for a Randomized Controlled Trial. *Frontiers in Neurology*, 2021, 12, 712512. https://doi.org/10.3389/fneur.2021.712512

[20] SURI R, RODRIGUEZ-PORCEL F, DONOHUE K, et al. Post-Stroke Movement Disorders: The Clinical, Neuroanatomic, and Demographic Portrait of 284 Published Cases. *Journal of Stroke and Cerebrovascular Diseases: The Official Journal of National Stroke Association*, 2018, 27(9): 2388–2397. https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.04.028

[21] MEHRHOLZ J, POHL M, KUGLER J, & ELSNER B. The Improvement of Walking Ability Following Stroke. *Deutsches Arzteblatt International*, 2018, 115(39): 639–645. https://doi.org/10.3238/arztebl.2018.0639

[22] PRESTON E, ADA L, STANTON R, et al. Prediction of Independent Walking in People Who Are Nonambulatory Early After Stroke: A Systematic Review. *Stroke*, 2021, 52(10): 3217–3224. https://doi.org/10.1161/STROKEAHA.120.032345

[23] MEESTER D, AL-YAHYA E, DENNIS A, et al. A Randomized Controlled Trial of a Walking Training with Simultaneous Cognitive Demand (Dual-Task) in Chronic Stroke. *European Journal of Neurology*, 2019, 26(3): 435–441. https://doi.org/10.1111/ene.13833

[24] SHANKARANARAYANA A M, GURURAJ S, NATARAJAN M, et al. Gait Training Interventions for Patients with Stroke in India: A Systematic Review. *Gait & Posture*, 2021, 83: 132–140. https://doi.org/10.1016/j.gaitpost.2020.10.012

[25] KLASSEN T D, DUKELOW S P, BAYLE, M T, et al. Higher Doses Improve Walking Recovery During Stroke Inpatient Rehabilitation. *Stroke*, 2020, 51(9): 2639–2648. https://doi.org/10.1161/STROKEAHA.120.029245

[26] KHAN F, AMATYA B, BENSMAIL D, & YELNIK A. Non-Pharmacological Interventions for Spasticity in Adults: An Overview of Systematic Reviews. *Annals of Physical and Rehabilitation Medicine*, 2019, 62(4): 265–273. https://doi.org/10.1016/j.rehab.2017.10.001

[27] DE OLIVEIRA K C R, SANDE DE SOUZA L A P, EMILIO M M, et al. Overflow Using Proprioceptive Neuromuscular Facilitation in Post-Stroke Hemiplegics: A Preliminary Study. *Journal of Bodywork and Movement Therapies*, 2019, 23(2): 399–404. https://doi.org/10.1016/j.jbmt.2018.02.011

[28] CABANAS-VALDÉS R, CALVO-SANZ J, URRÙTIA G, et al. The Effectiveness of Extracorporeal Shock Wave Therapy to Reduce Lower Limb Spasticity in Stroke Patients: A Systematic Review and Meta-Analysis. *Topics in Stroke Rehabilitation*, 2020, 27(2): 137–157. https://doi.org/10.1080/10749357.2019.1654242

[29] REILLY J. M, BLUMAN E, & TENFORDE A S. Effect of Shockwave Treatment for Management of Upper and Lower Extremity Musculoskeletal Conditions: A Narrative Review. *PM & R: The Journal of Injury, Function, and Rehabilitation*, 2018, 10(12): 1385–1403. https://doi.org/10.1016/j.pmrj.2018.05.007

[30] LEE K J, PARK J I, & OH S. Y. The Effects of Extracorporeal Shock Wave Therapy vs Hand Massage on Serum Lipids in Overweight and Obese Women. *Annals of Medicine and Surgery*, 2021, 63: 102057. https://doi.org/10.1016/j.amsu.2021.01.005

[31] MIHAI E E, POPESCU M N, ILIESCU A N, & BERTEANU, M. A Systematic Review on Extracorporeal Shock Wave Therapy and Botulinum Toxin for Spasticity Treatment: A Comparison on Efficacy. *European Journal of Physical and Rehabilitation Medicine*, 2022, 58(4): 565–574. https://doi.org/10.23736/S1973-9087.22.07136-2

[32] MICCINILLI S, BRAVI M, MASELLI M, et al. The Effectiveness of Extracorporeal Shock Wave Therapy on Breast Cancer-Related Lymphedema: A Literature Review. *Lymphology*, 2020, 53(3): 118–135. https://pubmed.ncbi.nlm.nih.gov/33350286

[33] JARCHI D, POPE J, LEE T. K. M, et al. A Review on Accelerometry-Based Gait Analysis and Emerging Clinical Applications. *IEEE Reviews in Biomedical Engineering*, 2018, 11: 177–194. https://doi.org/10.1109/RBME.2018.2807182

[34] CHOHAN S A, VENKATESH P K, & HOW C H. Long-Term Complications of Stroke and Secondary Prevention: An Overview for Primary Care Physicians. *Singapore Medical Journal*, 2019, 60(12): 616–620. https://doi.org/10.11622/smedj.2019158

[35] SOUISSI H, ZORY R, BREDIN J, et al. Co-Contraction around the Knee and the Ankle Joints during Post-Stroke Gait. *European Journal of Physical and Rehabilitation Medicine*, 2018, 54(3): 380–387. https://doi.org/10.23736/S1973-9087.17.04722-0

参考文:

[1] TATER P, 和 PANDEY S. 卒中后运动障碍：临床谱、发病机制和管理。印度神经病学，2021，69(2)：272–283。https://doi.org/10.4103/0028-3886.314574

[2] IADECOLA C、BUCKWALTER M S 和 ANRATHER, J. 对中风的免疫反应：机制、调节和治疗潜力。临床研究杂志，2020，130(6)：2777–2788。https://doi.org/10.1172/JCI135530

[3] PANG M Y C, YANG L, OUYANG H, 等。双任务锻炼可减少中风后步行和跌倒中的认知运动干扰。中风，2018, 49(12): 2990–2998. https://doi.org/10.1161/STROKEAHA.118.022157

[4] CRAMER, S. C. 中风后恢复。继续。连续体（明尼苏达州明尼阿波利斯 2020，26(2)：415–434。https://doi.org/10.1212/CON.0000000000000838

[5] KRAJCZY、E、KRAJCZY、M、LUNIEWSKI 等。卒中后早期患者吞咽困难治疗效果的评估：一项随机对照试验。波兰神经内科神经外科波兰神经内科神经外科，2019, 53(6): 428–434.

https://doi.org/10.5603/PJNNS.a2019.0053
[6] XING Y, 和 BAI Y. 运动诱导的缺血性中风神经可塑性综述：病理学和机制。分子神经生物学, 2020, 57(10): 4218–4231. https://doi.org/10.1007/s12035-020-02021-1
[7] PENNA L G、PINHEIRO J P、RAMALHO S H R 和 RIBEIRO C F. 有氧运动对中风后神经可塑性的影响：系统评价。神经精神病学档案, 2021, 79(9): 832–843. https://doi.org/10.1590/0004-282X-ANP-2020-0551
[8] SALAZAR A P、PINTO C、RUSCHEL MOSSI J. V 等。静态拉伸定位对中风后上肢痉挛和活动能力的有效性：采用荟萃分析的系统评价。物理与康复医学年鉴，2019，62(4)：274-282。https://doi.org/10.1016/j.rehab.2018.11.004
[9] MAHMOOD A、VELUSWAMY S K、HOMBALI A 等。经皮神经电刺激对中风成人痉挛状态的影响：系统评价和荟萃分析。物理医学与康复档案, 2019, 100(4): 751–768. https://doi.org/10.1016/j.apmr.2018.10.016
[10] GLAESS-LEISTNER S、RI S J、AUDEBERT H J 和 WISSEL J. 卒中后痉挛的早期临床预测因素。中风康复专题，2021, 28(7): 508–518。https://doi.org/10.1080/10749357.2020.1843845
[11] SHARIFIFAR S、SHUSTER J J 和 BISHOP MD。在中风后标准康复期间增加电刺激以改善运动功能。系统评价和荟萃分析。物理与康复医学年鉴，2018，61(5)：339–344。https://doi.org/10.1016/j.rehab.2018.06.005
[12] GEERARS M、MINNAAR-VAN DER FEEN N 和 HUISTEDE B M A. 卒中后步态膝关节过伸的治疗。系统评价。步态与姿势，2022，91：137–148。https://doi.org/10.1016/j.gaitpost.2021.08.016
[13] ZHANG B, LI D, LIU Y, 等 . 中风患者肢体运动功能、平衡、步态、认知和日常功能的虚拟现实：系统回顾和荟萃分析。高级护理杂志, 2021, 77(8): 3255–3273。https://doi.org/10.1111/jan.14800
[14] GUNNING E, 和 USZYNSKI M K. 本体感受神经肌肉促进法对中风患者步态参数的有效性：系统评价。物理医学与康复档案，2019, 100(5): 980–986. https://doi.org/10.1016/j.apmr.2018.11.020
[15] SCHRÖDER J、TRUIJEN S、VAN CRIEKINGE T 和 SAEYS W. 中风后早期重复步态训练的可行性和有效性：系统回顾和荟萃分析。康复医学杂志, 2019, 51(2): 78–88. https://doi.org/10.2340/16501977-2505
[16] GUO J, QIAN S, WANG Y, 和 XU A. 镜联合体外冲击波治疗脑卒中后上肢痉挛的临床研究。国际康复研究杂志，2019，42(1)：31-35。https://doi.org/10.1097/MRR.0000000000000316
[17] YOLDAŞ ASLAN Ş、KUTLAY S、DÜSÜNCELI ATMAN E 等。体外冲击波疗法是否能减少中风患者踝关节跖屈肌的痉挛状态：一项随机对照试验。临床康复，2021，35(10)：1442–1453。https://doi.org/10.1177/02692155211011320
[18] CABANAS-VALDÉS R、SERRA-LLOBET P、RODRIGUEZ-RUBIO P R 等。体外冲击波疗法改善中风患者上肢痉挛和功能的有效性：系统评价和荟萃分析。临床康复，2020, 34(9): 1141–1156. https://doi.org/10.1177/0269215520932196
[19] FAN T, ZHOU X, HE P, 等。径向体外冲击波疗法对中风后患者上肢屈肌痉挛的影响：随机对照试验的研究方案。神经病学前沿，2021, 12, 712512. https://doi.org/10.3389/fneur.2021.712512
[20] SURI R、RODRIGUEZ-PORCEL F、DONOHUE K, 等。中风后运动障碍：284 例已发表病例的临床、神经解剖学和人口统计学特征。中风和脑血管疾病杂志：国家中风协会官方杂志，2018，27(9)：2388–2397。https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.04.028
[21] MEHRHOLZ J、POHL M、KUGLER J 和 ELSNER B. 中风后步行能力的改善。德国国际医学杂志, 2018, 115(39): 639–645。https://doi.org/10.3238/arztebl.2018.0639
[22] PRESTON E, ADA L, STANTON R, 等。预测中风后早期不能行走的人的独立行走：系统评价。中风，2021，52(10)：3217–3224。https://doi.org/10.1161/STROKEAHA.120.032345
[23] MEESTER D、AL-YAHYA E、DENNIS A 等。慢性中风同时认知需求（双重任务）步行训练的随机对照试验。欧洲神经病学杂志，2019，26(3)：435–441。https://doi.org/10.1111/ene.13833
[24] SHANKARANARAYANA M、GURURAJ S、NATARAJAN M 等。印度中风患者的步态训练干预：系统评价。步态与姿势，2021，83：132–140。https://doi.org/10.1016/j.gaitpost.2020.10.012
[25] KLASSEN T D、DUKELOW S P、BAYLE、MT, 等。较高剂量可改善中风住院康复期间的步行恢复。中风, 2020, 51(9): 2639–2648。https://doi.org/10.1161/STROKEAHA.120.029245
[26] KHAN F、AMATYA B、BENSMAIL D 和 YELNIK A. 成人痉挛的非药物干预：系统评价概述。物理与康复医学年鉴，2019，62(4)：265–273。https://doi.org/10.1016/j.rehab.2017.10.001
[27] DE OLIVEIRA K C R、SANDE DE SOUZA L A P、EMILIO M M, 等。在中风后偏瘫患者中使用本体感觉神经肌肉促进的溢出：一项初步研究。车身和运动疗法杂志，2019，23(2)：399–404。https://doi.org/10.1016/j.jbmt.2018.02.011
[28] CABANAS-VALDÉS R, CALVO-SANZ J, URRÙTIA G, 等。体外冲击波疗法减少中风患者下肢痉挛的有效性：系统评价和荟萃分析。中风康复专题，2020, 27(2): 137–157. https://doi.org/10.1080/10749357.2019.1654242
[29] REILLY J. M、BLUMAN E 和 TENFORDE A S. 冲击波治疗对上肢和下肢肌肉骨骼疾病管理的影响：叙述性回顾。管理

与维修：损伤、功能和康复杂志，2018，10(12)：1385–1403。https://doi.org/10.1016/j.pmrj.2018.05.007

[30] LEE K J、PARK J I 和 OH S Y. 体外冲击波疗法与手部按摩对超重和肥胖女性血脂的影响。医学和外科年鉴，2021，63：102057。https://doi.org/10.1016/j.amsu.2021.01.005

[31] MIHAI E E, POPESCU M N, ILIESCU A N, 和 BERTEANU, M. 体外冲击波疗法和肉毒毒素治疗痉挛的系统评价：疗效比较。欧洲物理与康复医学杂志，2022，58(4)：565–574。https://doi.org/10.23736/S1973-9087.22.07136-2

[32] MICCINILLI S、BRAVI M、MASELLI M 等。体外冲击波治疗乳腺癌相关淋巴水肿的有效性：文献综述。淋巴学, 2020, 53(3): 118–135. https://pubmed.ncbi.nlm.nih.gov/33350286

[33] JARCHI D、POPE J、LEE T. K. M, 等。基于加速度计的步态分析和新兴临床应用综述。IEEE 生物医学工程评论，2018，11：177–194。https://doi.org/10.1109/RBME.2018.2807182

[34] CHOHAN S A、VENKATESH P K 和 HOW C H. 中风的长期并发症和二级预防：初级保健医生概述。新加坡医学杂志, 2019, 60(12): 616–620。https://doi.org/10.11622/smedj.2019158

[35] SOUISSI H、ZORY R、BREDIN J 等。中风后步态期间膝关节和踝关节的共同收缩。欧洲物理与康复医学杂志，2018 年，54(3)：380–387。https://doi.org/10.23736/S1973-9087.17.04722-0