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Research article

The effect of the concept of modified unaffected-side active treatment on the gaits of patients with central nervous system damage

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ABSTRACT

This study was conducted to investigate the effects of unaffected-side active treatment on the gait of hemiplegic patients. The study subjects were 20 patients who showed hemiplegic symptoms after a stroke. Through a random classification method, the subjects were divided into an experimental group (n = 10) who underwent treadmill exercise based on the concept of unaffected-side active treatment to strengthen the paretic side lower extremity after proprioceptive neuromuscular facilitation (PNF) treatment and a control group (n = 10) who underwent general treadmill training without unaffected side-active treatment after PNF treatment. The therapeutic interventions were performed three times a week for 4 weeks. To analyze behavioural motor motions, the patient's gait speeds and ankle angles were measured using the timed up-and-go (TUG) and the Dartfish program before treatment and 14 and 28 days after beginning treatment. The study results showed that the TUG and ankle angles significantly differed between the experimental and control groups at 14 and 28 days after beginning treatment. These significant differences between the two groups were verified. In conclusion, a lower limb strengthening treadmill exercise based on unaffected-side active treatment can increase gait speed and ankle angle by improving motor control ability.

Keywords: Stroke, Hemiplegia, Unaffected side, Gait, Rehabilitation.

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INTRODUCTION

Cerebrovascular diseases are neurological diseases that occur when a problem affects the normal blood supply to the brain and occur quite frequently. Stroke, which is caused by cerebrovascular diseases, is known to cause common disorders, malignant tumours, and heart diseases in adults, as well as various symptoms, such as motor function disorders, cognitive impairments, perceptual dysfunction, and language disorders to patients as sequelae or complications [1]. In particular, a lack of motor ability in the lower extremities affects the walking ability and balance and increases the risk of falls. The decreased walking ability of hemiplegic patients due to lower extremity atonicity, spasticity, and sensory dysfunction in the affected side is known to be a major factor that makes independent daily life difficult [2]. Stroke clinically causes abnormalities in sensation, movement, muscle tone, cognition, perception, coordination, balance, postural control, and reflexes. Sensorimotor disorders appear on the ipsilateral side and on the opposite side of the damage, and sensory recovery was found to be closely related to the level of motor recovery [3]. In addition, sensory defects affect the quality of life of stroke patients, and up to 80% of them experience sensory defects after onset. Therefore, sensorimotor disorders affect muscle strength, balance, and gait and require long-term rehabilitation because they increase dependence on activities of daily living. The human brain has plasticity, and the functional reorganization of the brain achieves the recovery of damaged brain functions. As a mechanism to promote plasticity after brain injury, changes in the neural network are thought to occur along with changes at the cellular level, and the foregoing are induced through the reorganization of the cerebral hemispheres with the activation of nerve pathways that are not normally used and functional changes in the contralateral cerebral hemisphere [4].

Balance is defined as the ability to maintain the centre of gravity within the basal plane and the body's stability on the vertical axis. Balance is divided into static balance and dynamic balance. Static balance refers to the ability to maintain balance on fixed ground without bodily shaking, while dynamic balance refers to the ability to control the body without falling while moving. The body uses vision, vestibular sense, and proprioception to maintain dynamic and static balance [5]. Balance training in stroke patients is indispensable for functional recovery and independent living because the poorer balance in stroke patients interferes with walking and activities of daily living and increases the risk of falls. Physical changes due to stroke include muscle weakness, sensory loss, balance instability, joint contracture, hemineglect, and various gait disorders, and these problems cause comprehensive functional disorders that lead to falls. In addition, the inability to engage in voluntary muscle contraction and inappropriate muscle activity occurs. The damage becomes more severe over time, resulting in spasticity or changes in the muscles' original physiological and physical properties. Therefore, the recovery of muscle and postural control through appropriate treatment is an important goal of rehabilitation [6].

Post-stroke gaits are different from normal gaits. The normal gait cycle is divided into a stance phase in which both feet support the body while on the ground and a swing phase in which one foot moves forward away from the ground. The gait cycle of normal persons is 60% stance phase and 40% swing phase. However, since hemiplegic patients support more than 80% of their body weight on the non-paretic side while in a standing position, asymmetry becomes severe, and their walking speed, step count per minute, and stride length are generally reduced [7]. In addition, due to the reduced mobility of the affected side hip joint, knee joint, and ankle joint, hemiplegic patients show a decrease in the stride length, an increase in stance phase time, a decrease in swing phase time, and asymmetry in stride length. Therefore, the time they spend supporting their weight using the lower paretic-side limb is relatively shortened, and the stance phase time is lengthened, leading to the deterioration in balance and the quality of gaits. Consequently, the lower paretic-side extremity's ability to support weight is lowered, causing serious problems, such as falls or reduced walking speed [8].

In addition, the gait patterns of stroke patients include a slow walking speed, poor coordination, and sudden agitation during walking, as well as a tendency to generate movements through the joint contraction of the flexor and extensor muscles [9]. Only a few stroke patients can begin walking independently within a week after onset, and more than 80% of survivors can walk without assistance about 6 months after onset. However, even after beginning independent walking, there is a loss in overall functional activity and a problem with maintaining balance, which delays the recovery of activities of daily living and increases the risk of falling. Furthermore, the consequent sequalae lower the quality of life. Stroke disrupts motor and sensory nerve pathways and leads to abnormal sensory interpretation, interfering with postural and selective motor control, leading to movement, sensory, perception, cognitive, and language disorders[10].

Many studies using the concept of unaffected-side active treatment are being conducted, but there are many difficulties in directly applying it as a therapeutic intervention method in clinical practice. That is, it is considered reasonable to apply only the concept of this treatment rather than directly applying unaffected-side active treatment. Therefore, to solve the ethical problem of forced induction therapy, which can hardly be applied directly, this study applied lower extremity movements using only the concept of unaffected-side active treatment to post-stroke hemiplegic patients to examine the effects on changes in gait speed and ankle angles during walking.

MATERIALS AND METHODS

Subjects

In this study, 20 patients diagnosed with stroke were selected as study subjects according to the diagnosis of a rehabilitation medicine specialist based on evaluations using diagnostic imaging equipment. The criteria for selecting study subjects were patients within 12 months of stroke onset, patients with hemiplegic disorders on one side, patients with a mini-mental state examination (MMSE) score of 24 or higher, patients who could walk wearing a brace on the non-paretic side, patients who did not receive drug treatments to reduce spasticity, patients who were not receiving treatment due to fractures or falls, and patients who could participate in the experiment according to the researcher's instructions during the study period. Before the experiment, all study subjects were given a detailed and general explanation of the experiment, including all processes, purposes, methods, and limitations of the study, as well as their rights. They participated in the research only after signing the consent form in their own handwriting. In addition, all research processes were conducted per the Declaration of Helsinki and under the supervision of the Research Ethics Committee.

Using a randomized method, the study subjects were divided into an experimental group (n = 10) and a control group (n = 10). The experimental group underwent treadmill exercise using the concept of unaffected-side active treatment for 30 minutes after receiving PNF treatment, while the control group underwent regular treadmill exercise for 30 minutes after receiving PNF treatment. To apply the concept of unaffected-side active treatment to the experimental group, a knee orthosis was applied to the lower extremity of the non-paretic side and fixed so that the knee joint was fully extended to minimize the use of the lower extremity on the non-paretic side during walking. The therapeutic interventions in this study were applied 3 times a week for 4 weeks for a total of 12 times.

Intervention methods

Treadmill exercise was performed for 30 minutes in the same way for the experimental and control group patients, and FITEX 6080 was used as the treadmill equipment (Fitex, Korea). A therapist was positioned at the side or behind the patient to provide a sense of stability and to enable comfortable treadmill gait training. When any subject in both groups showed fatigue, dizziness, or muscle pain during training, the walking training was stopped, and the patient rested for a certain period. Before the experiment, the patients were taught to use safety handles in front of the treadmill or to use the handles on both sides when they lost their balance. A magnet-attached sensor ring designed to automatically stop the treadmill when it got too far from the treadmill instrument panel was connected to the patient's body to prevent falls that might occur during training. The treadmill speed applied to all groups was set differently for individual patients and gradually increased by 10% according to the progress of the experiment.

To apply the concept of forced unaffected-side active treatment in the experimental group, a knee brace was applied to the lower extremity on the non-paretic side. Before the experiment, the patients were put on a knee brace, were trained in flatland walking and were continuously provided with feedback from the therapist to suppress the compensatory action of the hip joint on the non-paretic side that could occur during walking. The knee brace applied to minimize the use of the lower extremity on the non-paretic side was an angle-adjustable knee brace, ensuring that patients walked while wearing the knee brace on the treadmill. The knee brace used in the study was G5 ROM (ORTEC Inc., KOREA), a rigid type consisting of uprights on both sides, angle-adjusting devices, thigh bands, calf bands, thigh cuffs, and calf cuffs. The concept of unaffected-side active treatment was devised to increase the muscle strength and ankle angle of the affected-side lower extremity during walking by increasing the use of the affected lower extremity and by reducing the mobility and activity of the unaffected-side lower extremity.

Assessment methods

In this study, the timed up-and-go (TUG) test was used to measure the patients' gait speeds. The TUG is an evaluation method for assessing walking speeds and dynamic balance ability during walking in clinical practice. It measures the time required for a patient sitting in a chair to walk a distance of 3 m and return to the chair and sit in it according to the evaluator's instructions. A TUG value of 20 seconds or higher means that there is functional motor impairment, and the smaller the measured value, the better the walking ability and balance. This study conducted TUG evaluations before treatment and 14 and 28 days after beginning treatment. Three trials were conducted for one evaluation, and the average value of the obtained data was used as the measured value.

The Dartfish program (Pro Suite, Korea) was used before treatment and 14 and 28 days after treatment to analyze the behavioral motor motions of patients with post-stroke hemiplegic disorders. To evaluate the patients' gaits, they were instructed to walk 10 m on a flat surface, and a camera was installed at a distance of 3 m to the side. Black indicators were attached to the lateral epicondyle of the knee, the lateral malleolus of the ankle, and the metatarsophalangeal joint of the fifth toe on the paretic side before a video was filmed. The video was filmed using a camera installed while the patient was walking, and thereafter, the medial angle of the ankle joint was measured during the toe-off period of the paretic side during the gait cycle using Dartfish software. This study used the average of the three ankle angles obtained through analysis as the measured value.

Data analysis

All experimental results are described as mean ± standard deviation (mean ± SD) through descriptive statistics. One-way analysis of variance (ANOVA) was performed, and least significant difference (LSD) tests were used as post hoc tests to compare and analyze periods by a group. Independent samples t-tests were conducted for comparison and analysis between groups by period. Statistical processing was performed using the PASW Win.18.0 package, and the statistical significance level (α) was set to 0.05.

RESULTS AND DISCUSSION

Results of study

In the TUG test to examine gait speed during walking, statistically, significant changes in gait speeds appeared in both the experimental and control groups. In the post hoc test results, significant differences were found in the experimental group 14 and 28 days after beginning treatment, respectively, compared to the pre-evaluation, and in the control group, significant differences were found 28 days after beginning treatment compared to the pre-evaluation (Table 1, Figure 1). In the analysis that examined the differences in treatment effects between the groups, there were statistically significant differences at 14 and 28 days after beginning treatment. The walking speed of the experimental group showed statistically significant increases from the 14th day compared to the control group.

Table 1: Comparison within groups of TUG tests for balancing ability and gait speed

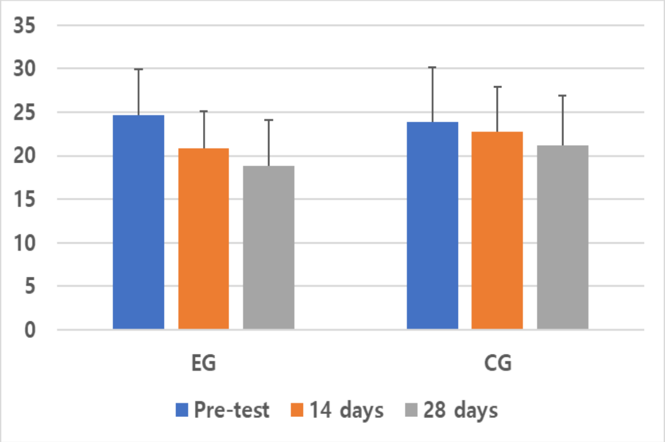
	EG	CG	t	p
Pre-test	24.65±5.31	23.84±6.33	0.785	0.692*
14 days	20.84±4.29	22.76±5.17	-2.154	0.026*
28 days	18.87±5.27	21.15±5.78	-4.734	0.000*
F	12.287	4.542		
p	0.000*	0.000*		

*EG: Experimental group, CG: Control group, mean±SD: mean±standard deviation, Unit: score, *p<0.05*

In the Dartfish analysis, which investigated the ankle angles of the paretic-side lower extremity during the toe-off period during walking, statistically significant changes in ankle angles were found in both the experimental and control groups. In the post hoc test results, significant differences were found in the experimental group at 14 and 28 days after beginning treatment compared to the pre-evaluation, respectively, and in the control group, significant differences were also found after 14 and 28 days compared to the pre-evaluation (Table 2,

Figure 2). Regarding ankle angle change amounts between the groups, there were statistically significant differences at 14 and 28 days after beginning treatment. That is, the amount of change in the ankle angles of the experimental group was statistically significant from day 14 compared to the control group.

Figure 1: Comparison between groups of TUG tests for balancing ability and gait speed



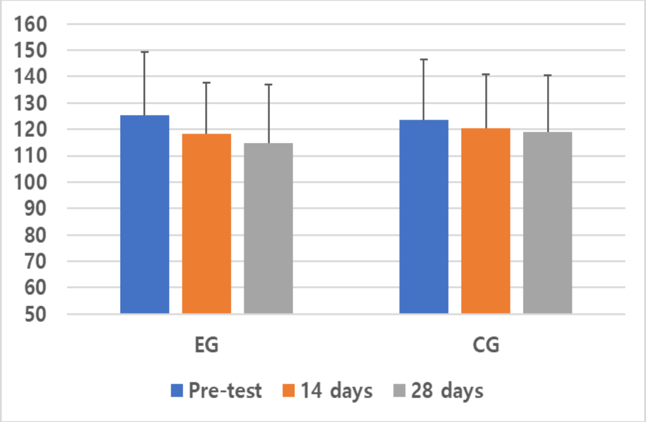
EG: Experimental group, CG: Control group, Mean±SD: mean±standard deviation, Unit: score

Table 2: Comparison within groups of ankles angle for gait performance

	EG	CG	t	p
Pre-test	125.48±23.74	123.73±22.67	-1.364	0.274
14 days	118.15±19.59	120.45±20.34	-3.218	0.000^{*}
28 days	114.78±22.28	118.92±21.46	-6.178	0.000^{*}
F	22.448	10.843		
p	0.000^{*}	0.000^{*}		

*EG: Experimental group, CG: Control group, mean±SD: mean±standard deviation, Unit: angle, *p<0.05*

Figure 2: Comparison between groups of ankles angle for gait performance



EG: Experimental group, CG: Control group, Mean±SD: mean±standard deviation, Unit: angle

DISCUSSION

Stroke is a general term for cerebrovascular diseases caused by the blockage or rupture of brain blood vessels. Only a small number of stroke patients recover completely from physical and mental damage after onset, and most suffer from problems such as movement disorders, language disorders, sensory disturbances, or cognitive disorders, and the rest die. Hemiplegia is a representative symptom of nerve damage occurring when motor and sensory functions on one side of the body are reduced due to neurological deficit symptoms caused by stroke [11]. Hemiplegia is a type of stroke symptom and is an acute neurological disorder that occurs in association with cerebral blood vessel blockage or rupture. It refers to paralysis symptoms appearing on one side (left or right) and not both. Neurological disorders usually occur in a local area, and since cerebral vascular circulatory disorders suddenly develop without notice, neurological symptoms last for 24 hours or more, leading to death in many cases. Muscle weakness and sensory changes due to hemiplegia cause motor function disorders, such as difficulty in trunk control, an unstable sense of balance, and decreased walking ability. In addition, in such a process, most hemiplegic patients show a hemiplegic gait pattern, which is an inefficient and biased gait pattern, with a slow gait speed due to muscle weakness and loss of balance [12].

The gait speeds of patients with brain damage are generally lower than those of normal individuals. In the case of hemiplegic patients, the swing phase is lengthened due to insufficient activity from the hip joint flexor and ankle joint plantar flexor muscles of the lower extremity on the paretic side the kinematic energy consumption of both lower limbs increases [13]. At the end of the swing phase and the beginning of the stance phase, the muscle activity of the triceps surae and tibialis anterior on the paretic side decreases, and during the first and second stance phases, the muscle activity in the non-paretic-side lower limb abnormally increases sometimes to compensate for the decrease in the muscle activity on the lower paretic-side limb. In addition, the activity of the rectus abdominis muscle and the latissimus dorsi muscle on the paretic side is reduced compared to that of the non-paretic side and normal persons. Abnormal gaits in which the speed at which the trunk is straightened, and bent is also slowed due to a delay in the time to start muscle contraction [14].

In the treatment of hemiplegic patients after a stroke, walking occupies a very important facet. The most important core elements in walking, which is considered the first goal of rehabilitation, include improving balance and increasing the strength of surrounding muscles [15]. Balance refers to the ability to maintain the center of gravity of the body and to continuously maintain body postures in response to changes in the environment during body movements. The ability to maintain balance is one of the most basic and essential elements for human beings in their daily lives and activities. Currently, balance is divided into static balance and dynamic balance when evaluated. Static balance is evaluated by the movement of the centre of mass on a pressure plate on the floor, while the dynamic balance is rarely evaluated [16]. In the movement of the human body, proactive postural control makes it possible to utilize the body's feedback system while reducing balance and increasing body agitation within a given space for the start of the movement. The central nervous system maintains the body's balance in space through posture control in the lower extremities and trunk when rapid movements of the human body, such as walking, are performed [17]. Previous studies that used electromyograms to assess post-stroke hemiplegic patients confirmed that there was a decrease in proactive postural control on the paretic side and higher muscle activity in the epidermal muscle than in the deep muscle. These studies found a correlation between deficits in proactive postural control and functions for movement and postural control in hemiplegic patients [18]. After stroke onset, damage occurs in the peripheral nervous system due to connections in the nervous system. When damaged, peripheral nerves usually take a long time to recover, and the degree of recovery is often incomplete. Peripheral nerve damage causes a partial or total reduction in the ability to control sensory nerves, motor nerves, and autonomic nerves in the denervation area and reduces functional activities due to sensory and motor ability impairment. Furthermore, the quality of life of patients eventually deteriorates [19].

In addition, the dominant part of the damaged nerve is accompanied by abnormal sensations, such as spontaneous pain, mechanical allodynia, hyper esophoria, and the rmohyperesthesia, and over time, damage occurs in the spinal ganglion and the nerve cells of the anterior spinal horn and dorsal cells. Disorders caused by damage to the nervous system negatively affect functional and independent daily life. Therefore, treatment using appropriate interventions is an important factor in promoting recovery [20]. Treatment methods for damage to the nervous system are primarily divided into invasive and non-invasive methods. Invasive methods include injection therapy and surgical restoration, while non-invasive methods include proprioceptive neuromuscular facilitation, electrical stimulation treatments, exercise treatment, aquatic therapy, and drug treatment. The most important purpose in treating nerve damage is to create an environment that can maximize neuroplasticity. Non-use of the affected side causes increased spasticity, decreased muscle strength, soft tissue shortening, and pain on the affected side. Among the therapeutically designed interventions to control learned non-use is unaffected-side active treatment [21,22].

This study investigated the effects of treadmill exercise using knee joint fixation on the unaffected side with the concept of unaffected-side active treatment on gait speed and ankle joint changes during walking in hemiplegic patients. Compared to the control group, the experimental group that underwent unaffected-side active treatment showed statistically significant increases in gait speed and ankle joint angle at 14 and 28 days after beginning treatment. Gait training, in which the lower extremity of the paretic side was forced to be used as a result of immobilization of the non-paretic side, improved the gait speed and the angle of the ankle joint over time. These results are thought to be attributable to the fact that when exercise using the concept of unaffected-side active treatment is applied to a patient with a damaged nervous system, the stimulation caused by the continuous use of the paretic side increases the activities of neurotrophic factors and activates cells in the damaged area to affect nerve regeneration, remodelling, and reinnervation. In addition, other studies have reported that unaffected-side active treatment was much more effective in improving the gait quality than traditional treatment in the past and that these effects were possible thanks to repetitive motions on the paretic side and motor learning through special task-oriented training. In addition, it was said that the acquisition of motor skills could be induced through active and repetitive motor learning, and the interdependence and interrelationship of the nervous system contributing to functional movement control could be increased. In conclusion, since the abnormal gait of post-stroke hemiplegic patients can be mitigated and controlled through forced movement of the paralyzed lower extremity, clinically controlled forced induction therapy should be applied to the paretic-side lower extremity to improve walking ability.

CONCLUSION

In this study, it was difficult to control variables, such as the weight of the brace, because a knee brace was applied to the paretic-side lower extremity to solve the ethical problem. In addition, the compensatory action that occurs during walking in hemiplegic patients could not be blocked entirely, and since the speed of the treadmill was applied according to the patient's ability, the treatment effect based on the speed of the treadmill could not be assessed. In the future, based on the results of this study, a forced-induction treatment method that can be more conveniently applied will hopefully be used to conduct studies that can identify changes in patients' gaits and quality of life through quantitative and continuous evaluations of many study subjects.

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Conflict of interest:

The authors declare no conflicts of interest for this study.

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