Effects of an Exercise Protocol for Improving Handgrip Strength and Walking Speed on Cognitive Function in Patients with Chronic Stroke

Authors' Contribution:
Study Design **A**
Data Collection **B**
Statistical Analysis **C**
Data Interpretation **D**
Manuscript Preparation **E**
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Source of support: This study was supported by Sahmyook University

Background: Handgrip strength and walking speed predict and influence cognitive function. We aimed to investigate an exercise protocol for improving handgrip strength and walking speed, applied to patients with chronic stroke who had cognitive function disorder.

Material/Methods: Twenty-nine patients with cognitive function disorder participated in this study, and were randomly divided into one of two groups: exercise group (n=14) and control group (n=15). Both groups underwent conventional physical therapy for 60 minutes per day. Additionally, the exercise group followed an exercise protocol for handgrip using the hand exerciser, power web exerciser, Digi-Flex (15 minutes); and treadmill-based weight loading training on their less-affected leg (15 minutes) using a sandbag for 30 minutes, three times per day, for six weeks. Outcomes, including cognitive function and gait ability, were measured before and after the training.

Results: The Korean version of Montreal Cognitive Assessment (K-MoCA), Stroop test (both simple and interference), Trail Making-B, Timed Up and Go, and 10-Meter Walk tests ($p<0.05$) yielded improved results for the exercise group compared with the control group. Importantly, the K-MoCA, Timed Up and Go, and 10-Meter Walk test results were significantly different between the two groups ($p<0.05$).

Conclusions: The exercise protocol for improving handgrip strength and walking speed had positive effects on cognitive function in patients with chronic stroke.

MeSH Keywords: **Cognition • Hand Strength • Stroke • Walking**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/904723

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Background

Stroke is a condition caused by sudden interruption of blood supply to a part of the brain, and leads to physical, cognitive, and emotional deficits [1]. Previously, a study on the prevalence of cognitive disorders in patients with stroke found that 74% of patients with cortical stroke, 46% of patients with subcortical stroke, and 43% of patients with subtentorial stroke presented with a cognitive functional disorder. Managerial function was found to be the most commonly affected function among the different types of cognitive functions [2]. Approximately 91.5% of patients with subacute stroke were reported to have at least one cognitive disorder [3]. In these patients, a therapeutic approach is necessary for rehabilitation. Therapeutic approaches currently used for recovery of affected cognitive functions and for improved brain plasticity include either repetitive transcranial magnetic stimulation and transcranial direct current stimulation [4] or a computerized cognitive training-based approach that provides feedback [5]. In addition, neurofeedback training that targets specific brainwaves is considered feasible [1].

Most of the conventional therapies, such as repetitive transcranial magnetic stimulation, transcranial direct current stimulation, computerized cognitive training, and neurofeedback training involve treating cognitive damage by using direct stimulation [6]. Furthermore, aerobic exercise programs [7] have emerged as therapeutic cognitive approaches in recent studies. These studies have shown that physical exercises or physical therapy are now being applied more frequently as treatments for cognitive disorders.

According to a previous study in Japanese elderly persons, handgrip strength represents the health status of an individual [8]. Another study reported that decreased handgrip strength in women was related to reduced bone density [9]. Handgrip strength has been found to be useful in predicting early death, initial disorder development, postoperational complications, postfracture hospitalization period, and cognitive reduction in the elderly [10]. A study on the relationship between handgrip strength and cognition evaluated cognitive functions in 76 elderly persons by using the clinical dementia rating, Mini-Mental State Examination Korean version (MMSE-K), Lawton scale, and evaluation of activities of daily living. This study analyzed test–retest reliability by using handgrip strength. Because handgrip strength showed suitable reliability, an evaluation based on handgrip strength was reported to be applicable in patients with baseline dementia, as well as in those with minimal and severe dementia [11]. A study involving older Mexican Americans found that persons with weaker handgrip strength tended to score lower on the MMSE over time [12].

Another study reported that increased walking speed is a predictor of considerable reduction in mortality, as it can be measured easily, is clinically significant, and can potentially be used as a vital sign in the elderly [13]. Persons with lower walking speed have been reported to have greater elements of death probability than those with a higher walking speed [14]. An analysis of nine cohort studies found walking speed to be correlated with survival in the elderly [15]. Another study reported that cognitive impairment was related to decreased gait speed [16]: the lower the gait speed, the higher were the clinical dementia rating scores. In addition to a comprehensive exercise evaluation, cognitive evaluation was reported to be necessary for local residents [17]. The group with lower walking speed was found to experience considerable reduction in visual perception, executive function, and thinking ability than the group with higher walking speed [18].

A previous study found that complex exercise and aerobic exercise help improve cognitive function. However, insufficient data are available on enhancement of cognitive function by using handgrip strength as well as a combination of handgrip strength and increased walking speed. Most of the previous research was cross-sectional studies on correlations. Handgrip strength or walking speed exercise for improving cognitive function has not been sufficiently investigated. Additionally, there are insufficient data on the association of a conventional cognitive therapeutic approach with physical therapy elements.

The present study aimed to investigate the effects of an exercise protocol for improving handgrip strength and walking speed on cognitive function.

Material and Methods

Patients

This study investigated 30 patients diagnosed as having hemiplegia due to stroke. The patients were randomly assigned to either the exercise group or the control group. One of the patients in the exercise group was dropped due to being discharged from the hospital during the study period. To minimize the possibility of natural recovery, the study patients were selected on the basis of the following criteria: stroke effect of at least three months' duration, cognitive ability allows following research instructions, MMSE-K score ≥10 points, ability to walk at least 10 meters independently, and adequate vision for study tests. The exclusion criteria included bilateral stroke or previous stroke affecting the other side, insufficient gait ability for using the treadmill, risk of epilepsy, and use of anti-epileptics. The selected patients for this study demonstrated an understanding of the investigation and provided consent for study participation, accompanied by their guardians, after a disclosure of the study effects and side effects. This study was implemented under the approval of the Institutional Review Board of Sahmyook University.

Outcome measures

Cognitive function test

To assess the patients' cognitive function, the Korean version of Montreal Cognitive Assessment (K-MoCA), Trail Making test, and Stroop test were used. The K-MoCA is mainly used to assess mild cognitive disorders and has a reliability of 0.736 Cronbach's alpha in patients with stroke with cognitive impairment [19]. The maximum score is 30 points, and the cutoff score is 23. A score of 23 or higher is considered normal and a score of 22 or lower indicates cognitive impairment. Both Trail Making-A and -B tests were used. The test requires general abilities including visual perception, visual searching, motor ability, and agility. Part B of the test especially requires alternately connecting a digital string to a character string. Thus, the test requires maintaining two types of parallel thinking abilities: alteration of cognitive function such as set shifting ability and backward inhibition. The shorter, non-English Korean version was used, which was developed for the elderly. The reliability was 0.92. The cutoff result of Trail Making-A test was 29 seconds and that of Trail Making-B test was 75 seconds. In the event of a physical challenge, the threshold of Trail Making-A test was 78 seconds and that of Trail Making-B test was 273 seconds. The Stroop test is a tool used to evaluate the frontal lobe functions of inhibition and selective attention. The Stroop test consists of a simple test and an interference test that involves speaking printed letters, ignoring written letters, and speaking letter colors as fast as possible. In this study, the Korean version of the Stroop test was used for assessment; the reliability was 0.78–0.83 Cronbach's alpha.

Handgrip strength test

Handgrip strength was measured by using a Jamar hydraulic hand dynamometer (Model 5030J1; Sammons Preston Inc., Bolingbrook, IL, USA). The measurement was performed with the participants in a sitting position, with the adducted shoulder in a neutral position and no rotation. The elbow joints were positioned in 90° flexion, with the forearm and wrist in neutral positions. The measurements were performed three times, and the values were averaged.

Walking ability test

To measure walking speed, the 10-Meter Walk test was employed. In the test, participants are instructed to walk 14 meters in total, including initial and last 2 meters of acceleration and deceleration, plus 10 meters of actual walking. The time was recorded by using a stopwatch. The test was performed for three rounds, and measured values were averaged. The test-retest reliability was found to be 0.87 in patients with stroke. To check the participants' stability, the Timed Up and Go test
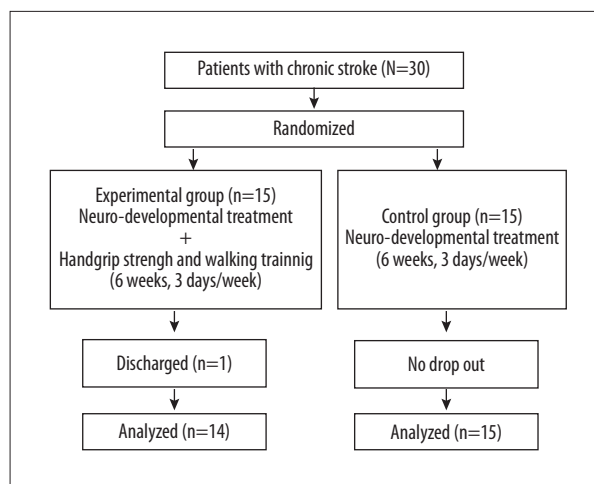

Figure 1. Flow diagram of the experimental procedure.

was conducted. The test quickly measures basic mobility and balance. Participants sit on an armed chair, walk 3 meters, return, and sit on the chair. The whole process is timed. Most normal adults require no longer than 10 seconds. Vulnerable elderly persons or those with physical challenges take 11–20 seconds. A time of 20 seconds or longer indicates impaired functional mobility. Participants performed three rounds of the test, and the recorded values were averaged. The intrarater test reliability was as high as r=0.99, and the interrater test reliability was r=0.98.

Procedures

The exercise protocol was implemented for six weeks. For three days, both before and after the training, only evaluations were conducted; thus, the experiment lasted for seven weeks in total. The evaluation items included cognitive function, handgrip strength, and walking speed. The 30 participants in this study were divided into exercise and control groups, according to the treatment method. Both groups underwent conventional physical therapy for 60 minutes per day. Additionally, the exercise group followed the exercise protocol for handgrip strength and walking speed for 30 minutes, three times per day, for six weeks. After the training, 14 exercise group participants, excluding one dropout case, and 15 control group participants, underwent postintervention evaluation for measurement of cognitive function, handgrip strength, and walking speed (Figure 1).

Interventions

The exercise protocol for handgrip strength improvement consisted of grasping training with a hand exerciser, grasping training with a power web exerciser, and the Digi-Flex repetition training. The grasping training was implemented by reorganizing the combined wrist and hand exercise method proposed by

Table 1. General characteristics of study participants.

	Experimental group (n=14)	Control group (n=15)	p
Age (year)	50.71±14.81	51.87±17.42	0.849
Height (cm)	164.36±7.13	166.07±6.82	0.516
Weight(kg)	66.29±7.65	63.33±10.65	0.397
MMSE-K (score)	26.35±5.31	25.53±3.27	0.623
Prevalence (months)	12.79±7.34	11.73±8.02	0.715
Gender			0.893
Male	9	10	
Female	5	5	

Values are presented as mean ± standard deviation' MMSE-K – Mini Mental State Examination Korean version.

Hutzler et al. (2013) with 2-second holding and 1-second release for each time. The training was applied to the unaffected side first, and then to the affected side, 15 times in three sets, for 15 minutes. This was performed for three weeks, to improve the exercise effect, the program frequency and intensity increased according to the participant's level. The hand exerciser, power web exerciser, and Digi-Flex have predefined levels for resistance. According to the participant's condition and handgrip strength, the levels were adjusted. Additionally, to help the participants better understand the task, a demonstration was provided along with feedback while the participants were following the movements for practice. To minimize any compensatory movements, the participants were not allowed to lean back in the chair and were asked to position their legs evenly with both feet on the ground.

The exercise protocol for increasing walking speed in this study involved the use of a motor-powered treadmill. During the treadmill walking training, the therapist stayed close to ensure participant safety. The treadmill speed was adjusted by the participants according to their comfort level, and the speed was recorded. In each round of training, the speed was increased by 0.1 km/hour. Concerning weight loading, 5% of body weight was applied to the unaffected side to increase the walking speed. The total training time was 20 minutes, which included 15 minutes of actual training and preintervention/postintervention warm-up and cool-down movements to ensure efficient training. The participants were allowed to take a break as needed.

The training involved the application of central nervous system developmental therapy in patients with stroke. Specifically, it included joint movements, mat exercises, and walking exercise for 10 minutes per round. The participants underwent physical therapy for 60 minutes per session, two sessions per day, five times per week, for six weeks in line with the hospital prescription and schedule. The main purpose was functional recovery by facilitating proprioception in supine, sitting, and standing positions according to the participants' functional levels. The program also included walking training in the therapy room.

Statistical analysis

All statistical analyses in this study were performed by using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). After the normality test, the preintervention/postintervention change in cognitive function, handgrip strength, and walking speed of the exercise and control groups were analyzed by using matching paired t-tests in line with the normal distribution hypothesis. Additionally, to compare the effects between the two groups, an independent t-test was used. The statistical significance level was set at $p<0.05$.

Results

No significant difference was found in the general and medical characteristics of the study participants (Table 1).

Change in cognitive function

K-MoCA test

The K-MoCA score of the exercise group increased by 2.64 points and that of the control group increased by 0.86 points. In the statistical analysis, significant increase was found only in the exercise group ($p<0.05$), with no significant difference found in the control group. In the comparison between the two groups, there was a significant increase in the exercise group compared with the control group ($p<0.05$) (Table 2).

Trail Making-A and -B tests

The Trail Making-A test result decreased to 14.0 seconds in the control group and to 11.58 seconds in the exercise group.

Table 2. Changes in cognitive function.

		Experimental group (n=14)	Control group (n=15)	P
K-MOCA (score)	Pre	20.78±7.11	21.4±4.82	0.047*
	Post	23.42±6.85	22.26±4.97	
	Difference	2.64±1.78	.86±2.69	
	P	0.000*	0.243	
TMT-A (sec)	Pre	80.38±93.09	46.96±47.97	0.864
	Post	66.38±80.33	35.37±30.05	
	Difference	−14±47.18	−14.59±23.01	
	P	0.278	0.072	
TMT-B (sec)	Pre	112.62±114.46	99.47±94.5	0.487
	Post	97.23±104.86	71.50±69.9	
	Difference	−15.39±24.18	−27.97±63.9	
	P	0.033*	0.112	
STS (sec)	Pre	29.22±11.49	37.56±31.93	0.367
	Post	24.00±31.91	29.81±29.41	
	Difference	−5.22±7.12	−7.75±7.79	
	P	0.017*	0.002*	
STI (sec)	Pre	52.64±31.91	50.24±33.05	0.145
	Post	42.79±27.63	46.41±34.52	
	Difference	−9.85±12.34	−3.79±8.66	
	P	0.011*	0.109	

Values are presented as mean ± standard deviation; K-MOCA – Montreal Cognitive Assessment Korean version; TMT-A, B – Trail Making Test-A, B; STS – Stroop Test Simple; STI – Stroop Test Interference. * $p<0.05$.

However, the difference between the two groups was not significant. The Trail Making-B test result decreased to 15.39 seconds in the exercise group and to 27.96 seconds in the control group. A statistically significant decrease was observed in the exercise group only ($p<0.05$) (Table 2).

Stroop test

The Stroop test result decreased to 5.21 seconds in the control group and to 7.75 seconds in the exercise group. Both the exercise group and the control group showed a statistically significant decrease ($p<0.05$). The Stroop test interference decreased to 9.84 seconds in the exercise group and to 73.82 seconds in the control group. Only the exercise group showed a statistically significant decrease ($p<0.05$) (Table 2).

Change in handgrip strength

This study found no significant post interference increase in handgrip strength in both groups in the unaffected side. However, in the affected side, only the exercise group showed an increase ($p<0.05$); the control group showed no such significant increase (Table 3).

Change in walking ability

10-Meter Walk test

The result of the 10-Meter Walk test of the participants in the exercise group was 37.9 seconds before the experiment, and it decreased to 30.57 seconds after the experiment. In the control group, the speed decreased from 46.42 seconds to 51.59 seconds after the experiment. The change in walking speed based on the effect of the training was analyzed. The exercise

Table 3. Changes in grip strength and walking speed.

		Experimental group (n=14)	Control group (n=15)	P
Grip strength in unaffected side (kg)	Pre	23.36±10.75	29.57±12.73	0.928
	Post	24.58±9.63	30.10±12.68	
	Difference	1.22±2.9	.53±4.03	
	P	0.140	0.621	
Grip strength in affected side (kg)	Pre	4.85±8.28	2.77±3.36	0.592
	Post	5.97±8.46	3.47±3.27	
	Difference	1.12±1.84	.7±2.31	
	P	0.041*	0.265	
10MWT (sec)	Pre	37.9±28.99	46.42±46.65	0.042*
	Post	30.57±26.5	51.59±54.81	
	Difference	−7.33±7.37	5.17±20.73	
	P	0.003*	0.350	

Values are presented as mean ± standard deviation; 10MWT – 10m walk test. * p<0.05.

Table 4. Changes in timed up and go test.

		Experimental group (n=14)	Control group (n=15)	P
TUG (sec)	Pre	42.41±30.07	46.01±37.36	0.011*
	Post	33.26±26.91	51.62±51.87	
	Difference	−9.15±8.49	5.61±18.38	
	P	0.001*	0.257	

Values are presented as mean ± standard deviation; TUG – timed up and go test. * p<0.05.

group showed a significant decrease (*p*<0.05), whereas no significant change was seen in the control group. The exercise group showed a significant post interference decrease in walking speed (*p*<0.05), whereas no significant change was seen in the control group (Table 3).

Timed Up and Go test

The result of the Timed Up and Go test in the exercise group was 42.41 seconds before the experiment and decreased to 33.26 seconds after the experiment. In the control group, the result was 46.01 seconds before the experiment and 51.62 seconds after the experiment. The effect of training on the Timed Up and Go test results was analyzed. Only the exercise group showed a significant decrease (*p*<0.05); no significant change was seen in the control group. Only the exercise group showed a significant decrease in the Timed Up and Go test results (*p*<0.05); the control group showed no significant decrease (Table 4).

Discussion

In patients with stroke, cognitive damage could affect daily activities and functional performance. Therefore, it is important to establish an initial evaluation and an effective treatment plan [20]. Approximately 91.5% of patients with subacute stroke are reported to have one or more cognitive disorders [3]. For this reason, a therapeutic approach to cognitive functional damage is essential in post-stroke rehabilitation [21].

In this study, patients with chronic stroke in the exercise group underwent an intervention to improve cognitive function. Changes in cognition were then assessed by using the K-MoCA, Stroop test simple, Stroop test interference, Trail Making-A test, and Trail Making-B test. Only the exercise group showed an increase in the K-MoCA. In the intragroup pre-intervention/post-intervention comparison, the Stroop simple, Stroop interference, and Trail Making-B test results demonstrated a decrease. In the control group, only the Stroop simple test results

showed a decrease. Similar to the findings of Camargo et al. (2012), this study also found that handgrip strength and walking speed had an effect on cognitive function.

According to a recent study on handgrip strength and cognitive function, apolipoprotein E ε4 is associated with dementia; apolipoprotein E ε2 is an allomorphic factor capable of protecting against dementia; and apolipoprotein E ε3 is a neutral factor. Apolipoprotein E ε2 is a gene capable of changing cognitive function. Persons with apolipoprotein E ε4 showed a significant correlation among memory implementation, processing speed, and vocabulary recognition, compared with those with apolipoprotein E ε2 and ε3. A delay in right handgrip strength decrease was reported to have a significant correlation in persons with ε2 compared with those with ε3 [22]. This is because ε2 is more strongly related to cognitive impairment and aging, as well as to potential dementia in the left cerebral hemisphere than in the right hemisphere [23]. In this study, although the researchers did not measure the expression of the apolipoprotein E ε2 factor, on the basis of the previous study, it is predicted that increase in handgrip strength leads to apolipoprotein E ε2 factor expression, which eventually affects cognitive function.

The potential correlation between walking speed and cognition is based on the fact that active movement affects neurotrophic factors including the brain-derived neurotrophic factor (BDNF) while increasing neurogenesis and post-brain damage resistance. It is also known to affect whole-body activity, learning, and neurotization [24]. For six weeks, the treadmill exercise increased the expression of insulin-like growth factor 1 and BDNF in diabetic white mice while increasing nerve cell generation to ease memory impairment [25]. Therefore, although the expression of BDNF was not measured in the present study, it can be inferred that the treadmill exercise program, during which speed was increased gradually, helped increase the expression of BDNF and walking speed, which affected cognitive function. In contrast, a previous study found that the apolipoprotein E ε4 factor aforementioned is related to walking speed. A group of patients with severe cognitive damage and with apolipoprotein E ε4 showed reduced walking speed, compared with a group without these factors [26]. Therefore, it is considered that the apolipoprotein E ε4 factor is related to cognitive impairment, handgrip strength, and walking speed.

In this study, the K-MoCA score increased from 20.78 to 23.42, which is higher than the cutoff score for those with normal cognition, indicating significant recovery under the proposed program. As the K-MoCA has a high reliability in evaluating cognitive impairment in patients with stroke [27], the intervention for the exercise group is deemed highly significant in helping patients recover their cognitive function. In the event of frontal lobe damage, it was reported that the Trail Making-B test performance decreased [28]. Thus, a positive effect could be observed in patients with impaired cognitive function due to frontal lobe damage or real brain damage, as shown in the present study.

The Stroop test has been used in previous studies for assessing frontal lobe functions like inhibition and selective attention [29]. In our study, a significant result was found in the Stroop interference test in the exercise group. On the basis of the preceding study, our study participants were deemed to have received a positive effect as they had impaired cognitive function due to frontal lobe real brain damage. It has also been previously reported that most exercise programs for improving cognitive function include aerobic exercise. Aerobic exercise has been found to induce improved cardiovascular function, increase blood flow to the brain, and prevent decline in cognitive function [30]. In our study, however, the proposed program was deemed significant, as it improved cognitive function even without aerobic exercise.

One of the most important goals for patients with stroke is improvement in ambulation. In these patients, walking speed is an essential factor representing the post-stroke quality of life and gait ability while greatly influencing daily activity performance [31]. The present study employed the 10-Meter Walk test and Timed Up and Go test to measure the walking ability of patients with stroke. The 10-Meter Walk test is broadly used for measurement of temporal changes such as that in walking speed. To increase walking speed, a cross-sectional study in which a weight load was applied on the unaffected side to induce symmetry was conducted; and the study reported a significant increase [32]. The Timed Up and Go test assesses functional mobility. The test requires recording the time required to walk 3 meters by rising from an armed chair, returning, and sitting back on the chair. The test is known to be applicable to a variety of patients including the elderly and patients with stroke [33].

In this study, the gait speed increased significantly. As in the previous study, this result might be explained as follows: the weight load on the unaffected side with treadmill training increased the weight bearing on the affected side; this, in turn, decreased the spasticity of plantar flexors in the lower part of the affected side. Stability increased significantly because, like in a previous study by Ivey et al. [33], treadmill walking training affected the lower-limb muscle strength, increased lower-limb asymmetry, and increased lower-limb stability to possibly affect balancing ability in patients with stroke [34].

Conclusions

The present study is significant in that it provides additional information on recent reports regarding the effect of handgrip

strength and walking speed on cognitive function. In addition, our study employed a simple exercise intervention and rather than a combined program or aerobic exercise. The proposed protocol in this study is expected to be useful for improving cognitive function or useful in situations in which cognitive treatment is difficult. Future studies will need to investigate additional exercise patterns for cognitive improvement in patients with chronic stroke with impaired cognition, in terms of intensity, enjoyableness, exercise style, and ease of application.

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