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Original Article

Effects of computer assisted cognitive rehabilitation on brain wave, memory and attention of stroke patients: a randomized control trial

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Abstract. [Purpose] This study investigated brain wave, memory and attention changes in adult stroke patients using computer assisted cognitive rehabilitation (CACR). [Subjects] Twenty-five stroke patients were randomly allocated to either the CACR group (n=12) or the control group (n=13). [Methods] Two expert therapists provided the CACR group and the control group with traditional rehabilitation therapy in 30-minute sessions, semi-weekly, for 6 weeks. CACR was provided only to the CACR group. The control group received traditional rehabilitation therapy only. Before and after the 6 weeks of intervention, electroencephalography (EEG) and a computerized neurocognitive function test (CNT) were performed, and the results were analyzed. [Results] After the intervention, the CACR group showed significant differences in the frontal lobe (Fp1, Fp2, and F4) and in the parietal lobe (P3 and P4), and also showed significant differences in CNT memory (DST and VST forward/backward test) and attention (VCPT correct responses), but no notable changes were observed in the control group. [Conclusion] These results suggest that CACR is feasible and suitable for individuals with stroke. Detailed and diverse investigations should be performed considering the numbers and characteristics of subjects, and the limitations affecting the CACR training period.
Key words: Computer assisted cognitive rehabilitation (CACR), Brain wave, Computerized neurocognitive function test (CNT)

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INTRODUCTION

Stroke patients suffer neurotransmission problems, decreases in cognitive and visual perceptions, damage to the sensitivity of sight, decrease in peripheral sensory sensitivity, and disorders in the vestibular system. Stroke also causes trouble with spatial recognition, and adjustment of movement[1)]. Stroke can result in various problems when performing activities of daily life, such as eating, clothing, bathing and moving, eventually leading to partial or complete dependency[2, 3)]. Stroke limits body function, and its effects vary depending on the location of the affected area and the level of injury sustained, and it often induces other disorders involving cognition, visual perception, sensation, and linguistic abilities[4)].

Cognitive impairment often accompanies various neurological disorders such as stroke. Mobility is also affected when stroke patients experience cognitive disorders over a long period. As cognitive impairment increases the difficulty of rehabilitation, a therapeutic approach involving cognitive impairment is vital for rehabilitation training, and cognitive rehabilitation using an integrated treatment method is essential.

There are many methods of treatment for increase of cognitive functions, such as music therapy, reminiscence therapy, methods for compensating cognitive functions such as memory assistants, methods for improving memory capability using picture cards or family photos, methods for inducing improvement in learning ability through virtual reality for people with memory damage, and computer assisted cognitive rehabilitation (CACR)[2)].

CACR has recently been highlighted as a cognitive rehabilitation method. CACR was initially used for improving the memory of patients with brain damage[5)]. It provides objective evaluation and instant feedback on the patients' task performance, and also gives cognitive training based on the neuropsychological patterns of patients to stimulate the damaged location[2, 6)]. Clinical use of CACR has increased in the treatment of neurological patients, since its level of difficulty can be adjusted to suit an individual's cognitive level, which reduces treatment time and costs[7, 8)]. In order to eliminate problems arising from cultural and linguistic

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differences, CACR has been translated into the Korean language and is being used in clinics, and investigations on the effectiveness of CACR for brain-damaged patients are continuing[9, 10].

Recent developments in medical engineering have led to increased clinical use of CACR in the cognitive rehabilitation field. However, only a limited number of studies have investigated the effectiveness of brain wave changes and cognitive improvements using this training method to treat stroke patients. This study aimed to determine the most effective treatment method for clinicians in the cognitive rehabilitation field by investigating the changes in stroke patients' brain waves, memory and attention elicited by CACR, and the manner in which these changes affect daily life.

SUBJECTS AND METHODS

The study participants were chosen from among thirty stroke patients who were hospitalized and receiving occupational therapy and physical therapy at a General Hospital in Kyeongki province between December 2013 and January 2014. The general characteristics of the participants are shown in the Table 1. Participant selection criteria were: hemiparetic stroke patients with stroke onset within 3 months to 1 year, who were able to follow verbal instructions, and communicate to a certain level. In addition, participants were chosen from among patients who were able to perform all tests and had experienced light cognitive function failures that scored between 18 and 23 on the mini mental state examination (MMSE). Subjects were excluded if they had diplegia, had never attended a school, were biased, or had received CACR within the past year. All the patients who participated in this study signed a written consent form after receiving a full explanation of the expected result and side effects of the study. CACR training was conducted over a period of 6 weeks, in consideration of the hospitalization period. As the participants were recruited successively, the training was conducted over 8 weeks. The evaluation included measurements of brain waves and cognitive function. The control group received occupational therapy and physical therapy, for half an hour 5 times a week for 6 weeks. The CACR group received the same rehabilitation as the control group with extra CACR training for half an hour 5 times a week for 6 weeks. Exercise was prescribed and supervised by two experienced physical therapists. All of the protocols used in this study were approved by Gachon University. Before beginning the study, the procedures, risks and benefits were explained to all of the participants, who gave their informed consent. The CACR program used in the present study, RehaCom (Hospi, Seoul, Korea), was developed in 1989, and has been used for clinical purposes and in previous research[11]. It provides cognitive rehabilitation treatment for patients with cognitive disorders or deficiency with the help of a computer. Feedback on the result during and after the treatment is provided, which is helpful for completing the training and developing the right learning strategies for the patient. A joystick and touch screen can be used as the input device in RehaCom, and the patients could complete the training using a reaction board while seated and watching the screen. The attention and concentration programs were chosen from the various CACR programs of RehaCom and performed for 30 minutes each time according to each patient's functional ability; the awakening, reactivity, attention and concentration, simultaneous attention, and selective attention programs were used.

Table 1. General characteristics

	CACR	CON
Gender (male/female)	7/5	9/4
Age (years)	60.0±4.7	63.7±6.3
Lesion side (right/left)	9/3	8/5
Duration (month)	5.3±2.3	6.0±2.2
MMSE (score)	18.8±4.1	20.5±3.2
Education (years)	11.0±1.6	10.7±1.8

All variables are the mean±standard deviation (SD). CACR: computer assisted cognitive rehabilitation training group; CON: control group; MMSE: mini mental state examination

QEEG-8 (Laxtha Inc., Daejeon, Korea) was used to collect brain wave data. The participants were seated in a comfortable chair, and the method of the trial was explained before brain wave measurements were performed. The poles were checked after being attached to the participant's scalp to determine if they were functioning properly. After a 3-minute break, brain waves were measured for 3 minutes while the participants stared at a designated spot to the front in a fixed posture. The brain wave poles were attached to 8 regions of the scalp, and brain waves were measured using the monopolar derivation method. The attachment location of the poles followed the international 10/20 Electrode System. Eight poles were attached in the following order: left frontopolar lobe (Fp1), right frontopolar lobe (Fp2), left frontal lobe (F3), right frontal lobe (F4), left temporal lobe (T3), right temporal lobe (T4), left parietal lobe (P3), and right parietal lobe (P4). The reference electrode was attached behind the right earlobe, and the ground electrode was attached to the left earlobe.

A computerized neurocognitive function test (CNT) was used to assess memory and attention. It is comprised of 5 main categories and 17 sub-test for brain disorders. Among these sub-tests, the digit span test (DST) and visual span test (VST), which test memory, and the visual continuous performance test (VCPT) and auditory controlled continuous performance test (ACCPT), which test attention, were used. These four tests, DST, VST, VCPT, and ACCPT were performed in order from the easiest to the hardest, and they were performed by everyone in the same order. When the patients used the touch screen, we let the patients use their non-paralyzed arms[12].

SPSS ver. 12.0 was used to calculate the averages and standard deviations. The significance of brain wave, memory and attention differences within a group, before and after the treatment, was tested using the paired t-test, and the significance of differences between the groups was tested using the independent t-test. For all data, statistical significance was accepted at values of $p<0.05$.

Table 2. Comparison of relative beta waves

EEG	Channel	CACR		CON	
		Pre	Post	Pre	Post
Relative beta wave (Hz)	Fp1*	0.09±0.05	0.15±0.08*	0.09±0.06	0.10±0.06
	Fp2*	0.08±0.04	0.13±0.08	0.08±0.06	0.09±0.06
	F3	0.10±0.04	0.15±0.07	0.09±0.02	0.09±0.03
	F4*	0.10±0.03	0.16±0.08*	0.10±0.05	0.10±0.05
	T3	0.16±0.07	0.18±0.08	0.14±0.05	0.16±0.05
	T4	0.14±0.05	0.18±0.07	0.14±0.05	0.14±0.05
	P3*	0.10±0.02	0.14±0.07	0.09±0.0147	0.09±0.01
	P4*	0.09±0.02	0.13±0.07	0.09±0.01	0.09±0.02

All variables are the mean±standard deviation (SD); *p<0.05; **p<0.01; CACR: computer assisted cognitive rehabilitation training group; CON: control group; Fp1: left frontopolar; Fp2: right frontopolar; F3: left Frontal; F4: right frontal; T3: left temporal; T4: right temporal; P3: left parietal; P4: right parietal

Table 3. Comparison of memory and attention

CNT		Subtest	CACR		CON	
			Pre	Post	Pre	Post
Memory (digit)	DST	Forward test**	3.43±0.53	4.59±0.77*	4.09±1.20	4.10±1.22
		Backward test*	2.27±0.68	3.28±1.04	2.55±1.18	2.79±1.44
	VST	Forward test**	3.98±0.92	5.17±1.44**	3.96±0.75	4.07±0.96
		Backward test*	2.93±1.09	3.72±1.60*	3.21±1.15	3.30±1.13
Attention (digit)	VCPT	correct response*	119.83±4.26	123.00±1.70*	121.07±1.49	122.00±3.48
		reaction time (sec)	0.78±0.07	0.61±0.15**	0.68±0.13	0.59±0.09
	ACCPT	correct response	57.41±1.88	56.91±1.16	57.84±1.57	57.76±2.31
		reaction time (sec)	0.65±0.14	0.62±0.14	0.62±0.17	0.61±0.18

All variables are the mean±standard deviation (SD); *p<0.05; **p<0.01; CNT: computerized neurocognitive function test; CACR: computer assisted cognitive rehabilitation training group; CON: control group; DST: digit span test; VST: visual span test; VCPT: visual continuous performance test; ACCPT: auditory controlled continuous performance test

RESULTS

Change of brain waves at the eight channels and CNT with respect to CACR training are shown in Tables 2 and 3. The CACR group showed before and after test changes ($p<0.05$) in the frontal lobe (Fp1, Fp2 and F4) and the parietal lobe (P3 and P4), but no notable changes were observed in control group. The CACR group showed a statistically significant difference in CNT memory (DST & VST forward/backward test) ($p<0.01$) and attention (VCPT correct response) ($p<0.05$), but no notable changes were observed in the control group.

DISCUSSION

This study investigated the beta wave, memory and attention changes in stroke subjects after CACR training.

The activities that affect brain activation in each part of the brain include attention and judgement related which are processed in assignments for the frontal lobe and assignments that require perception for spatial and temporal information and which are processed in language for the parietal lobe[13, 14]. The main role of the prefrontal cortex includes cognitive activities such as dealing with new situations, whereas the frontoparietal cortex is concerned with space and controlling intended motions[15, 16]. The relative beta waves of each channel following training showed that the frontal lobe (Fp1, Fp2, F4) and the parietal lobe (P3, P4) had higher brain activity in the CACR group. Moreover, the relative beta wave exhibited increased activation in the frontal lobe (F3) and the parietal lobe (P4) in the CACR group compared to the control group.

In a study by Kim et al.[17], brain injury patients and healthy individuals performed 10 attention assignments of ComCog CACR training. Functional MRI showed that the frontal and temporoparietal lobes were more activated than the temporooccipital lobe, supplementary motor area, and anterior cingulate gyrus before the intervention than in healthy controls. However, after the cognitive training the frontal lobe activation had decreased and the anterior cingulate gyrus and right parietal lobe were more activated. This result reflects the improvement in the patients' cognition elicited by CACR, and continuing the CACR may have spread the activation to other parts of the brain. Moreover, a difference in the level of brain activation could be predicted based on the extent of injury that had been sustained by the patient, indicating the necessity of more subdivided and specialized research into the differences in brain activation depending on which area of the brain is injured. CACR can be performed by patients with a wide range of cognitive function. However, for a more effective treatment, it will be necessary to select different treatments for different diagnoses, inhibitory vs. reward brain waves as appropriate for the diagnosis. To obtain better evidence of the effects of CACR training, standardized and accurate EEG measurement and analysis of more than 8 channels will be necessary.

CNT concentration assessments can check the attention deficit of brain damaged patients, and it can also be used as an indicator of the degree of brain damage or recovery of a patient[12]. Shim et al.[9] conducted ComCog CACR, with traditional rehabilitation therapy for stroke hemiplegic patients, and the results of cognitive function assessments with CNT showed that the CACR group showed significant improvements in memory and attention compared to the group that only received traditional rehabilitation therapy. In our study, the CACR group showed a significant difference in CNT memory (DST and VST forward/back ward test) ($p<0.05$) attention (VCPT correct response) ($p<0.05$), but no notable changes were observed in the control group.

CACR practice based on cognitive rehabilitation therapy usually focuses on memory and attention, and Kim et al.[10] reported significant improvements in long-term and short-term memory after CACR memory training, and Gilsky[18] showed that even though brain-damaged patients are slower than normal people, they can still acquire a great deal of knowledge and skills related to everyday life.

The results cited above indicate that CACR is more helpful at improving the cognitive function of stroke patients than the use of traditional rehabilitation alone. Besides these effects, CACR, which use computer games, is a helpful therapeutic mediation method, considering the convenience and appeal of games. The recovery depends on the injured area and the injury period; however, intensive rehabilitation, duration, and the patients' will to recover also play important roles[19]. A rehabilitation method, which is performed over a long period, should be easy and interesting to maintain the active participation of the patient. The average age of the participants in this study was 60.0 years, and thus, most patients were unfamiliar with computers and electronic devices. However, the patients were familiar with program selection and the assignment after the second run, and most of the participants actively participated in the CACR.

Standardized and more accurate brain wave measurement and analysis are required to provide sufficient evidence of the benefits of CACR training. In addition, if cognitive function recovery can be expedited by conducting CACR for stroke patients with cognitive injury, the patients would be expected to have a quicker rehabilitation. Thus, CACR program development and activation are required, and more specialized research based on the location of the brain lesion in patients with cognitive injury would be beneficial.

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