Advances in Bioscience and Biotechnology, 2025, 16(9), 343-353
https://www.scirp.org/journal/abb
ISSN Online: 2156-8502
ISSN Print: 2156-8456

The Impact of Central-Peripheral Coordination Training on Post-Stroke Dysarthria

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How to cite this paper: Zhou, J.L. and Cheng, X.L. (2025) The Impact of Central-Peripheral Coordination Training on Post-Stroke Dysarthria. *Advances in Bioscience and Biotechnology*, **16**, 343-353.
https://doi.org/10.4236/abb.2025.169022

Received: August 2, 2025
Accepted: August 31, 2025
Published: September 3, 2025

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Abstract

Objective: To explore the Intervention effect of central peripheral cooperative training on post-stroke dysarthria. **Methods:** A total of 30 patients with post-stroke dysarthria admitted to the Department of Rehabilitation Medicine at the First Affiliated Hospital of Yangtze University from September 2020 to December 2022 were selected as the coordination group. Another 30 patients with post-stroke dysarthria admitted from September 2018 to September 2020 were selected as the sequential group. There were no statistically significant differences between the two groups in terms of age, gender, or severity of the primary disease. The sequential group was given sequential treatment of speech training, vocal electromyographic stimulation and transcranial direct current stimulation in chronological order. The coordination group was given transcranial direct current stimulation in addition to speech training and vocal electromyographic stimulation. The Frenchay articulation disorder grades and intervention effects of the two groups were compared. **Results:** The Frenchay Dysarthria Assessment scores in both the sequential group and the coordination group were significantly higher after the intervention compared to before the intervention. The Frenchay Dysarthria Assessment scores in the coordination group after the intervention were significantly higher than those in the sequential group, with a statistically significant difference ($P < 0.05$)**. Conclusion:** Central-peripheral coordination training can effectively improve dysarthria symptoms in stroke patients, enhancing intervention outcomes and quality of life.

Keywords

Stroke, Dysarthria, Speech Training, Peripheral Electrical Stimulation, Transcranial Direct Current Stimulation

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1. Introduction

Stroke is one of the major diseases that cause death and disability in humans. According to statistics in Europe, approximately one seventh of women and one tenth of men, or fifty percent, die directly or indirectly from stroke each year [1]. In the United States, 800,000 people suffer from strokes every year. There are approximately 2 million new stroke cases in China each year, and there are over 10 million stroke survivors [2]. After the acute stage of stroke, the prevalence of dysarthria is about 41.5% to 53% [3]. According to the research by Geddes *et al.*, language disorders related to stroke are the third most common type of disability. Post-stroke dysarthria is a problem that has been overlooked in the past, even though it is a very serious disabling condition [4]. Dysarthria is a general term for a class of speech disorders caused by neuromuscular lesions related to pronunciation. It is often manifested as weakness of the dysarthria-related muscle groups, abnormal muscle tone and uncoordinated movements, etc. [5], which affect the patient's respiratory movements, pronunciation, resonance, rhythm and other aspects. Neurorehabilitation is the main measure for the recovery of articulation disorder after stroke, including speech training, physical therapy, acupuncture treatment, etc. With the development of rehabilitation technology, various methods such as precise positioning and non-invasive direct stimulation of brain injury or brain functional areas are gradually emerging. Such as transcranial direct current stimulation (tDCS), transcranial magnetic stimulation (rTMS), brain-computer interface, mirror therapy, etc. At present, sequential therapy is adopted in the rehabilitation treatment of dysarthria. Speech training, physical therapy, acupuncture treatment, transcranial magnetic stimulation or electrical stimulation are all effective at different times of the day [6]. However, the daily treatment time for patients is relatively long, and the effect of each treatment method is monotonous. Whether central therapy and peripheral therapy can be combined in terms of time to achieve better rehabilitation treatment results is rarely reported at present. Therefore, this study provides a single-center observational retrospective analysis. We evaluated the differences between sequential treatment of speech training, physical therapy and transcranial direct current stimulation and concurrent treatment of speech training, physical therapy and transcranial direct current stimulation, and explored the therapeutic effect of dysarthria after stroke.

2. Materials and Methods

2.1. Research Design

This study is a retrospective analysis. Thirty patients with post-stroke dysarthria admitted to the Department of Rehabilitation Medicine of the First Affiliated Hospital of Yangtze University from September 2020 to December 2022 were selected as the coordination group (CG), and 30 patients with post-stroke dysarthria admitted from September 2018 to September 2020 were selected as the sequential group (SG). There were no statistically significant differences between the two groups in terms of age, gender, and the severity of the primary disease. There were a total of

30 cases in the sequential group, including 22 males and 8 females. Among them, 12 cases were hemorrhagic patients and 18 cases were ischemic patients. The patients' ages ranged from 18 to 79 (57.00 ± 14.14) years old. There were a total of 30 cases in the coordination group, including 23 males and 7 females. Among them, 6 were hemorrhagic patients and 24 were ischemic patients. The patients' ages ranged from 55 to 81 (64.66 ± 8.55) years old. The general information (gender, age, disease duration, etc.) of the two groups of patients showed no statistically significant difference ($P > 0.05$), and they were comparable. The sequential group was given sequential treatment including speech training, electromyographic stimulation of pronunciation, and transcranial direct current stimulation. The collaborative group was given transcranial direct current stimulation simultaneously with speech training and electromyographic stimulation of pronunciation.

2.2. Inclusion Criteria and Exclusion Criteria

Inclusion criteria: 1) According to the guidelines for the diagnosis and treatment of cerebral hemorrhage and ischemic stroke compiled by the Cerebrovascular Disease Group of the Neurology Branch of the Chinese Medical Association [7] [8], and confirmed as stroke patients by imaging examinations such as CT or MRI, they have not undergone speech training, physical therapy, or transcranial direct current stimulation before; 2) Medical records include a complete medical history, neurological examination of aphasia, and imaging examination diagnosis for stroke. 3) All patients underwent the same assessment using the Frenchay Dysarthria Scale to determine the type and degree of their dysarthria. 4) The patient is in good mental condition, with a score of no less than 20 on the Mental Health Examination Scale (MMSE), and has no cognitive impairment. They can cooperate with the implementation of relevant examinations and treatments. 5) Informed consent of the patient and his/her family. Exclusion criteria: 1) Visual or auditory impairment; 2) Accompanied by various types of aphasia; 3) Accompanied by functional disorders of important organs, such as heart and lung insufficiency, liver and kidney failure, malignant tumors, etc. 4) Those whose conditions are still unstable and require guardianship; 5) Those who are emotionally unstable and unable to cooperate with relevant examinations and treatments; 6) There are metal foreign bodies within 30cm of the treatment site, such as cochlear implants, built-in pulse generators, aneurysm clips, stents, metal internal fixators, etc. 7) There is local skin infection or ulcer. Dropout criteria: 1) Those who experience serious adverse events that subsequently affect subsequent treatment; 2) Those whose condition deteriorates during the treatment process or who suffer from serious other systemic diseases and are unable to continue participating in the trial; 3) Those who changed or combined therapies other than those in this study on their own during the treatment process. Eliminate criteria: 1) Those who cannot adhere to continuous treatment during the trial process; 2) Those who should not be included in the group but have already been included; 3) Where the collection of various evaluation scales is incomplete, thus making it impossible to accurately assess the therapeutic effect.

2.3. Rehabilitation Therapy

The sequential group received sequential treatment of transcranial direct current stimulation, physical therapy and speech training, while the coordination group received synchronous and collaborative treatment of direct current stimulation, physical therapy and speech training.

2.3.1. Speech Training

Speech rehabilitation exercises should follow the principle of individualization. Based on the assessment results of the patient's modified Frenchay dysarthria assessment method for eight functions including the larynx, tongue, respiration, lower jaw, lips, and soft palate, the relevant damaged muscle groups of the patient should be evaluated, and thus an individualized treatment plan should be adopted: Speech training requires individualized treatment by a rehabilitation therapist on a one-on-one basis based on the specific condition of the patient. Specific treatment time: Treat the patient's corresponding functional disorder once a day, for 5 days a week, excluding weekends. 3 weeks constitute one course of treatment, and a total of 1 course of treatment is provided. The content includes: relaxation training, soft palate training, lip, tongue and jaw training, intonation and rhythm training, vocalization training, and breathing training.

2.3.2. Physical Therapy (Electromyographic Stimulation of Pronunciation)

The Vocastim-Master swallowing and speech diagnosis and treatment instrument from Fitzmann, Germany, was adopted. Electrodes were placed on the patient's neck, and current was output. According to the specific damage of the patient's articulation disorder, the recurrent laryngeal nerve, sublingual nerve, glossopharyngeal nerve and other nerves related to speech function were stimulated respectively. The output intensity is 0 to 25 mA, which can be adjusted as needed during treatment. First, capture the average value between each peak of the patient's active muscle contraction, and then adjust the target value upwards or downwards until the patient feels a grasping sensation in the neck. The pulse width is 100 to 300 microseconds, the frequency is 80pps, and the stimulation time is ≥30 minutes each time, with one stimulation per day. Note during operation: When stimulating the neck muscles, avoid the carotid sinus. During the treatment process, keep the electrodes isolated from each other to avoid adverse irritation and skin burns caused by electrode contact.

2.3.3. Transcranial Direct Current Stimulation (tDCS)

tDCS is carried out by a constant current stimulator (Sichuan Intelligent Electronic Industry Co., Ltd.) and two surface-immersed sponge electrodes (5 cm × 7 cm). Over a period of 21 days, apply a uniform anode current for 20 minutes each day, increasing and decreasing by 30 seconds at the beginning and end of the session. Based on the common 10 - 20 electrode arrangement system, the active electrode (anode) is arranged in the Broca zone. The reference electrode is set on the shoulder.

Complete brain stimulation in accordance with the approved tDCS [9] standards.

2.3.4. Assessment of Articulation Disorders

The treatment outcomes before and after the intervention were evaluated using the Frenchay dysarthria score. The scale is divided into 29 items, covering eight major categories: reflexes, breathing, lips, jaws, soft palate, throat, tongue, and speech. Each item is further divided into 2 to 6 sub-items. Each item is classified into five items, a, b, c, d, and e, from mild to severe according to the degree of articulation disorder. The specific contents include reflexes such as coughing, swallowing, and salivation. Breathing includes both at rest and during speech. The lips include observing the static state, spreading the corners of the lips, closing the lips and puffing out the cheeks, alternating sounds, and speech. The jaw includes both at rest and during speech. The soft palate includes when consuming liquid food, when the soft palate is elevated, and when speaking; The throat includes the time of pronunciation, pitch, volume and speech time. The tongue includes the state of rest, the extended tongue, up and down movement, bilateral movement, alternating pronunciation, and speech. Speech includes reading words, reading sentences, conversation and speed. Classify the overall degree based on the total number of items a to determine the degree of functional impairment: extremely severe impairment 0-6/29; Severe disorder 7-13/29 Moderate disability 14-17/29; Mild disability 18-26/29 Normal 27-29/29 [10].

2.3.5. Evaluation Criteria for Therapeutic Effect Intervention Effect

The overall effect change is that the speech function assessment reaches normal, which is considered basic recovery. An improvement of 2 to 3 grades in the assessment of speech function is considered significant. A one-level improvement in the assessment of speech function is considered valid. No change in the classification of speech function is considered invalid. The total effective rate is effective + marked effect + recovery. For each detailed item, if there is no improvement, it is considered invalid; if there is an improvement of 1 level, it is considered effective; if there is an improvement of 2 levels or more, it is considered significant. The total effective rate is effective plus significant.

2.4. Statistical Analysis

Analysis of variance was used to compare the differences between the two groups before and after treatment. A P value < 0.05 is considered statistically significant.

3. Results

3.1. Cases

All 60 patients completed the experiment, and there were no cases of leakage.

3.2. Changes in the Overall Effect of French Scores in the Two Study Groups before and after the Intervention

Before treatment, the total number of (a) items in the coordination group was 178, including 22 cases of extremely severe disorder, 2 cases of severe disorder, 2 cases of moderate disorder, and 2 cases of mild disorder. After treatment, the total number of (a) items was 398, including 9 cases of extremely severe disorder, 4 cases of severe disorder, 5 cases of moderate disorder, 9 cases of mild disorder, 3 cases of normal, 20 cases of effective, and 10 cases of ineffective. Before treatment, the total number of (a) items in the sequential group was 233, including 15 cases of extremely severe disorder, 12 cases of severe disorder, and 3 cases of moderate disorder. After treatment, the total number of (a) items was 320, including 11 cases of extremely severe disorder, 10 cases of severe disorder, 3 cases of moderate disorder, 4 cases of mild disorder, 2 cases of normal, 9 cases of effective, and 21 cases of ineffective. See Table 1.

Table 1. Pre- and post-intervention overall effect variation changes in Frenchay scores in the two study groups.

Groups	Valid	invalid	totals	P value
CG	20	10	30	0.001865465
SG	9	21	30	
totals	29	31	60	

Changes in each sub-item of frenchay scores of the two groups of research subjects before and after the intervention (See Table 2).

Table 2. Pre- and post-intervention overall effect variation changes in Frenchay scores in the two study groups.

Category		Groups	Valid	Invalid	P value
Reflex					
	Cough	CG	28	2	0.0014
		SG	12	18	
	Swallow	CG	28	2	3.68E−06
		SG	17	13	
	Salivation	CG	22	8	0.06
		SG	12	18	
Breathe					
	Stationary	CG	17	13	4.69E−15
		SG	2	28	
	Speaking	CG	23	7	3.38E−14
		SG	7	23	
Lip					
	Stationar	CG	21	9	2.19E−06
		SG	6	24	
	Aabducted lips	CG	28	2	0.027
		SG	6	24	

Continued

	Puff out cheeks	CG	23	7	0.0016
		SG	9	21	
	Alternate pronunciation	CG	23	7	0.0067
		SG	10	20	
	Speaking	CG	20	10	0.00025
		SG	8	22	
Jaw					
	Stationary	CG	10	20	3.07E−20
		SG	3	27	
	Speaking	CG	12	18	2.68245E−14
		SG	4	26	
Soft palate					
	Consume liquid	CG	8	22	7.46741E−09
		SG	8	22	
	Elevationsoft palate	CG	22	8	0.00832
		SG	10	20	
	Speaking	CG	21	9	1.07428E−07
		SG	5	25	
Throat					
	Pronunciation time	CG	24	6	0.01349
		SG	11	19	
	Pitch	CG	24	6	0.0002526
		SG	9	21	
	Volume	CG	19	11	9.5483E−14
		SG	2	28	
	Speaking	CG	20	10	1.864E−09
		SG	4	26	
Tongue					
	Stationary	CG	16	14	4.2529E−22
		SG	0	30	
	Stick	CG	21	9	7.068E−11
		SG	3	27	
	Up and down movement	CG	22	8	1.366E−10
		SG	3	27	
	Movement on both sides	CG	19	11	9.548E−14
		SG	2	28	

Continued

	Alternate pronunciation	CG	25	5	4.60E−10
		SG	3	27	
	Speaking	CG	20	10	3.1751E−11
		SG	3	27	
Speech					
	Read words	CG	20	10	0.001117
		SG	19	11	
	Read a sentence	CG	22	8	0.0014
		SG	18	12	
	Conversation	CG	18	12	1.9789E−07
		SG	27	3	
	Speed	CG	22	8	2.78E−06
		SG	6	24	

4. Discussion

Dysarthria is a common and persistent complication after stroke [11]. The incidence of dysarthria after stroke in the acute stage is 25% to 70%. Among them, 42% of patients still show persistent speech symptoms after the acute stage, and 15% of stroke patients have dysarthria for a long time [12]. The main pathogenesis is organic lesions in the nerves and muscles related to language, leading to paralysis, weakened contractility and uncoordinated movement of the relevant muscles, and subsequently abnormal vocalization, pronunciation and resonance [13]. It is characterized by slow and laborious speech, unclear pronunciation and heavy nasal sounds, which cause problems in the patient's language function, social participation and psychological emotions [14]. Neurorehabilitation is the main measure for the recovery of dysarthria after stroke. Timely and effective rehabilitation can improve the language function of patients and enhance their quality of life. At present, the rehabilitation treatments for dysarticulation mainly include speech training, electromyographic stimulation of speech, transcranial direct current stimulation and traditional Chinese medicine treatment. Each single treatment method has certain effects [6], but the daily treatment time for patients is relatively long. Therefore, this study provides a single-center observational retrospective analysis. To evaluate the differences between sequential treatment of speech training, physical therapy and transcranial direct current stimulation and concurrent treatment of speech training, physical therapy and transcranial direct current stimulation, and to verify the therapeutic effect of dysarthria after stroke.

In our study, the case selection was retrospective. There was no difference in gender among the patients. Due to the fact that there was one 18-year-old patient in the sequential group, the age range was relatively large, but there was no overall difference. In terms of the causes of the disease, there was no difference in cerebral hemorrhage and cerebral ischemia between the two groups. However, the proportion of ischemia was higher than that of hemorrhage overall. However, it is also consistent with the incidence rate in Chinese mainland [7] [8], so the baseline data of the two groups are comparable.

The main treatment for dysarthria after stroke is rehabilitation therapy, with speech training as the foundation. Peripheral neuromuscular electrical stimulation therapy and central stimulation therapy are both effective methods. In our trial, both the sequential group and the synergistic group showed varying degrees of improvement in dysarthria compared to before treatment. Because speech training is based on the theory of motor relearning, it reconstructs the function of articulatory muscles through speech motor training. Neuromuscular electrical stimulation is a low-frequency electrical stimulation therapy that promotes muscle activity and restores muscle control ability by stimulating intact peripheral motor nerves [15]. In this study, NMES electrode patches were placed on the muscles on both sides of the neck. By outputting low-frequency current, the nerves related to articulation, such as the sublingual, hypopharyngeal and recurrent laryngeal nerves under the electrodes, were stimulated to promote the movement of the articulation muscle groups, improve the blood circulation in the pharynx and enhance muscle contraction [16]. In our experiment, based on the universal 10-20 electrode arrangement system, the active electrodes (anodes) were arranged in Broca zones (The motor centers that control the muscles of the throat are located in Broca zones 44 and 45), and the reference electrodes were set at the shoulder. Direct current is conducted from the scalp to the anodic cortex and subcortical areas, leaving the brain at the cathode. Weak current alters the resting membrane potential, causing depolarization. Therefore, the alteration of the pulse discharge rate of cortical excitatory neurons induces neural plasticity [17], enhances local cerebral blood flow [18] [19], improves the neurological function of stroke patients, and alleviates the symptoms of dysarthria.

Although speech training, peripheral nerve electrical stimulation and transcranial direct current stimulation can all improve dysarthria after stroke to varying degrees, a more significant finding is that the simultaneous implementation of speech training, peripheral nerve electrical stimulation and transcranial direct current stimulation has a better rehabilitation effect than the sequential implementation. Whether it is for the overall classification and scoring of dysarthria or for each detailed item, The results all showed that the coordination group was significantly superior to the sequential group ($P < 0.05$). We speculate that through transcranial direct current stimulation, central nervous system depolarization can be induced first, resulting in changes in cortical excitability. At the same time, through peripheral motor training and neuromuscular stimulation, the activation of related functional brain regions can be better induced, increasing the activation of rector synapses, or inducing the generation of new synapses and re-establishing the connections between synapses, thereby reorganizing brain functions. At the same time, it promotes the reconstruction of correct movement patterns in the surrounding area, facilitates the repair and regeneration of damaged nerves, re-establishes nerve conduction pathways, and promotes the re-innervation of the nervous system. The discovery of this result will surely provide guidance for our future rehabilitation of articulation disorders, save patients' rehabilitation treatment time and improve the treatment effect. Of course, in our experiment, it was also found that when the pericerebral collaborative treatment further improved each function of articulation, there was no significant difference in the improvement of laryngeal articulation time, lip Angle abduction, and salivation compared with the sequential group. Among them, salivation might be caused by the fact that the improvement of lip Angle abduction did not extend significantly, which might be related to the shorter recovery period. This will be further observed in our subsequent treatment.

As this trial is a single-center retrospective design, this study has some limitations, such as a relatively small number of cases, grouping by time sequence, some sampling errors, a short treatment duration, and the difficulty in demonstrating long-term treatment effects. Therefore, a prospective investigation of a broader sample is needed to overcome these deficiencies.

5. Conclusion

In our experiment, it was initially found that the combined treatment of central direct current stimulation, peripheral neuromuscular electrical stimulation and speech training can better improve the articulation disorder symptoms of stroke patients, which is conducive to improving the intervention effect and quality of life of patients.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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