BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Advances in Medicine Science
https://ojs.bilpublishing.com/index.php/jams

Observation of the Effect of Gait-induced Functional Electrical Stimulation on Stroke Patients with Foot Drop

Anqi Zhang Mengjiao Wu Luxi Mao Qianhuan Zhang Bingqian Zhou Jingxin Wang*

Zhengzhou Central Hospital Affiliated to Zhengzhou University, Zhengzhou, Henan, 450000, China

ARTICLE INFO

Article history
Received: 9 September 2021
Revised: 16 September 2021
Accepted: 24 January 2022
Published Online: 31 January 2022

Keywords:
Foot drop
Functional electrical stimulation
Lower limb function
Balance function

ABSTRACT

Objective: To explore the effects of functional electrical stimulation and functional mid frequency electrical stimulation on lower limb function and balance function in stroke patients. **Methods:** 20 cases of stroke patients with foot drop after admission were randomly divided into the observation group and the control group, 10 cases in each group. On the basis of the two groups of patients, the observation group used the gait induced functional electrical stimulation to stimulate the peroneal nerve and the pretibial muscle in the observation group. The control group used the computer medium frequency functional electrical stimulation to stimulate the peroneal nerve and the anterior tibial muscle for 2 weeks. Before and after treatment, the lower extremity simple Fugl-Meyer scale (FMA), the Berg balance scale (BBS) and the improved Ashworth scale were evaluated respectively, and the comparative analysis was carried out in the group and between the groups. **Results:** After 2 weeks of treatment, the scores of FMA and BBS in the two groups were significantly higher than those before the treatment ($P < 0.05$), and the scores of FMA and BBS in the observation group were higher than those in the control group ($P < 0.05$), and the flexor muscle tension of the ankle plantar flexor muscle of the observed group was lower than that of the control group ($P < 0.05$). **Conclusions:** Exercise therapy combined with gait induced functional electrical stimulation or computer intermediate frequency functional electrical stimulation can significantly improve lower limb function and balance function in patients with ptosis, and the therapeutic effect of functional electrical stimulation combined with gait is better.

**Corresponding Author:*
Jingxin Wang,
Zhengzhou Central Hospital Affiliated to Zhengzhou University, Zhengzhou, Henan, 450000, China;
Email: 1160542181@qq.com

  DOI: https://doi.org/10.30564/jams.v5i1.3688

1. Introduction

Stroke is more common in middle-aged and elderly people, because the patient's central nervous system is damaged, which can lead to abnormalities in the patient's limb function, leading to symptoms of hemiplegia. Although the walking pattern of more than 80% of stroke patients will be greatly improved, about 20% of stroke patients will have foot drop and varus problems [1,2], which directly leads to the formation of circle gait This inefficient and abnormal walking pattern leads to shortened step length, slower pace, excessive physical exertion, and decreased walking stability, which increase the risk of falling [3]. Therefore, how to improve the foot drop of stroke patients, correct the ankle varus deformity, and establish a safe and stable normal gait pattern is something that rehabilitation therapists and patients must consider. At present, most of the clinical use of functional electrical stimulation in the computer intermediate frequency therapeutic apparatus is used to treat the foot drop and varus problems in stroke patients. However, the patient is required to not move the treatment limb during the treatment, which has relatively large restrictions on the patient's movement. The foot drop walking aid is a convenient gait-inducing functional electrical stimulation device, which can timely send out electric signals to stimulate the common peroneal nerve during different walking cycles of the patient, so that the tibialis anterior muscle and the peroneus brevis muscle can be stimulated in a timely manner. This promotes the dorsiflexion movement of the ankle joint during the walking cycle, creating a more three-dimensional walking experience for the patient, and can give timely electrical stimulation to the tibialis anterior muscle and the peroneus brevis muscle during walking training. Xiao Feina [4] et al. found through research that exercise training combined with foot drop walker training can reduce muscle tension of the lower limbs. Exercise therapy plus gait-induced functional electrical stimulation or computer mid-frequency functional electrical stimulation and its effect on balance function have not been reported in the literature. Therefore, this experiment is mainly to explore the therapeutic effects of gait-induced functional electrical stimulation and computer intermediate frequency functional electrical stimulation on the lower limb function and balance function of stroke patients with foot drop, and to explore a comprehensive physical therapy method that is more suitable for stroke patients with foot drop.

2. Materials and Methods

2.1 Clinical Data

From January to December 2020, 60 cases of stroke and foot drop patients in Zhengzhou Central Hospital Affiliated to Zhengzhou University were selected. Inclusion criteria: 1) Good cognitive function, able to cooperate with therapist's treatment and guidance, MMSE score greater than or equal to 23 points; 2) Primary disease is stroke; 3) Lower limb Brunnstrom staging ≥ stage II; 4) Lower limb muscle tone modified Ashworth Grade 2 and below; 5) Have foot drop symptoms and can walk with assistance; 6) The patient understands and accepts the treatment plan of this study. Exclusion criteria: 1) Accompanied by other organ dysfunction; 2) Mental disorders and cognitive impairment, MMSE score less than 23 points; 3) Severe stroke complications that affect rehabilitation; 4) Patients with pacemakers in their bodies. The cases were randomly divided into experimental group and control group. The specific conditions of the patients are shown in Table 1.

Statistical comparison of the data in the table shows that there is no significant difference between the groups ($P>0.05$), which is comparable.

2.2 Method

The experimental group was treated with exercise therapy and foot drop walker for 20 minutes, once a day, for 5 days a week, for 2 consecutive weeks. The conventional comprehensive treatment is the same as the control group. Foot drop walking aid treatment method: Use the XFT-2001D foot drop walking aid, let the patient take a sitting position, slightly bend both knees, wipe the skin of the electrode pad area with alcohol cotton balls, and take the corresponding lower limbs. Run

Table 1. Clinical data of the two groups ($\bar{x}\pm$**s**)

Group	Number of cases	gender		age	Course of disease (months)	Paralyzed side (example)	
		male	Female			Left	Right
test group	30	15	15	59.3±8.2	4.7±1.2	14	16
Control group	30	15	15	59.8±11.6	4.0±1.7	15	15

the instrument, use warm water to moisten the quick positioning electrode pads, tie the host to the affected calf, let the quick positioning electrode contact the superficial peroneal nerve of the calf, turn on the power switch of the host and remote control, select the training mode and then adjust The intensity of electrical stimulation and the movement of the electrodes according to the patient's specific conditions to find a significant valgus and dorsiflexion movements. Then switch to walking mode, use the programmer to analyze the patient's gait, adjust the electrical stimulation parameters according to the patient's sensitivity and the results of the gait analysis (the stimulation parameters are voltage 3.7 V, pulse width 100-200-300 μS, current 0-100 mA, Frequency 16.7-33 Hz). Set the starting angle, landing angle and standing angle of the programmer, and the programmer will determine the most suitable stimulation method for the patient in the gait analysis system.

The control group was treated with exercise therapy and computerized intermediate frequency functional electrical stimulation of the tibial anterior muscle for 20 minutes, once a day, for 5 days a week, and both were treated continuously for 2 weeks. The prescription number for the computerized intermediate frequency functional electrical stimulation of the tibialis anterior muscle is intermediate frequency I. The two electrode pads are used to stimulate the tibialis anterior muscle and the common peroneal nerve. The treatment time is 20 minutes.

Exercise therapy includes: pulling the Achilles tendon, pressing and stimulating the tibialis anterior and peroneus brevis muscles, increasing the mobility of the ankle joint, guiding the ankle dorsiflexion movement, strengthening the ankle dorsiflexor muscle strength, walking function training, and balance function training

2.3 Observation Items

Before treatment and after two weeks of treatment, the two groups of patients were evaluated on the affected lower extremity short-form Fugl-Meyer scale score (FMA), Berg balance scale score (BBS), and modified Ashworth grading score.

The Fugl-Meyer scale is divided into 17 sub-items, each item has a minimum score of 0 and a maximum of 2 points. The score range is 0-32 points. The higher the score, the better the function. The Fugl-Meyer scale can make accurate and quantitative assessments of the limb function of stroke patients. The Fugl-Meyer scale is used for evaluation with detailed content, is closely related to the patient's daily activities, and can change the patient's abnormal movement patterns. Intuitive reflection [5].

The Berg Balance Scale is divided into 14 sub-items. Each item has a minimum score of 0 and a maximum of 4 points. The minimum total score is 0 points, and the full score is 56 points. The higher the score of the scale, the better the patient's balance and can be accurate. Assess the patient's balance ability, which is suitable for clinical and scientific research applications [3,6].

Modified Ashworth Scale (MAS) is a widely recognized clinical evaluation index. It is divided into 0-4 grades. The higher the grade, the higher the muscle tension. The grading standard is assessed by manual testing and subjective feeling. Spasms [7].

2.4 Statistical Methods

The SPSS19.0 software package was used for statistical analysis. The following statistical methods are mainly used: 1) Describe the evaluation results of the FMA score and BBS score of the affected lower extremity before and after treatment with the mean and standard deviation of each group of samples. 2) The paired sample t test was used to compare the differences between the experimental group and the control group before and after treatment on the simplified FMA scale score and the BBS balance scale score of the affected side. 3) The independent sample t test was used to compare the difference between the experimental group and the control group before and after the treatment of the affected side of the lower extremity FMA scale score and the BBS balance scale score difference. 4) The paired sample t test was used to compare the difference between the FMA scale score and the BBS balance scale score of the affected side of the lower extremity before treatment in the experimental group and the control group. 5) The independent sample t test was used to compare the difference of the modified Ashworth scale score difference between the experimental group and the control group before and after treatment.

3. Results

The FMA, BBS scores and modified Ashworth grading data before and after treatment in the experimental group and the control group are as follows. See Table 2, 3, 4.

There was no significant difference in FMA, BBS scores and modified Ashwoth scores between the two groups of patients before treatment ($P>0.05$); after 2 weeks of treatment, the FMA and BBS scores of the two groups of patients were significantly higher than before treatment ($P<0.05$). The difference in FMA and BBS scores of the experimental group was higher than that of the control group ($P<0.05$), and the reduction of muscle tension in the experimental group was higher than that of the control group ($P<0.05$), indicating that exercise therapy combined

  DOI: https://doi.org/10.30564/jams.v5i1.3688

Table 2. FMA score results of experimental group and control group ($\overline{x}$ **±s**)

Group	Number of cases	before therapy	After treatment	Before and after difference	P value
Observation group	30	17.0±5.5	24.8±5.7	7.8±3.3	0.010
Control group	30	21±3.5	24.0±3.8	3.3±0.9	0.010
P value		0.085		0.010	

Note: P<0.05 is statistically significant.

Table 3. BBS score results of experimental group and control group ($\overline{x}$ **±s**)

Group	Number of cases	before therapy	After treatment	Before and after difference	P value
Observation group	30	12.5±15.0	20.5±14.5	8.0±2.9	0.010
Control group	30	15.5±3.5	19.5±18.1	3.7±0.8	0.010
P value		0.108		0.010	

Note: P<0.05 is statistically significant.

Table 4. BBS score results of experimental group and control group ($\overline{x}$ **±s**)

Group	Number of cases	before therapy	After treatment	Before and after difference	P value
Observation group	30	1.9±0.2	1.4±0.3	-0.6±0.32	0.010
Control group	30	1.9±0.2	1.7±0.3	-0.2±0.26	0.037
P value		1.00		0.011	

Note: P<0.05 is statistically significant.

with gait inducing function electrical stimulation or computer mid-frequency functional electrical stimulation can significantly reduce the ankle plantar flexor muscle tension in patients with stroke and foot drop, improve the motor function and balance function of the lower limbs, and combine with gait-induced functional electrical stimulation to have a better therapeutic effect.

4. Discussion

4.1 Current Status of Foot Drop in Stroke Patients

In recent years, the incidence of stroke is getting higher and higher, and the age of onset is getting younger and younger, but the treatment of stroke is not as optimistic as expected. Although the walking pattern of more than 80% of stroke patients will be greatly improved, about 20% of stroke patients will have foot drop and varus problems, which are likely to cause circle gait. The circular gait is due to insufficient hip flexion and knee flexion during the swing phase, and hip flexion and knee flexion are accompanied by abduction and external rotation of the hip joint, while weakness of the tibialis anterior and peroneus brevis muscles and foot drop cause the foot to drag the floor. The long-term use of this inefficient and abnormal walking pattern can easily lead to slower walking speed, shorter step length, excessive physical exertion, and decreased walking stability and safety. Due to the lack of adequate ankle dorsiflexion, the feet cannot fully touch the ground when walking, which can easily lead to inefficient gait and increase the risk of falls. Many patients want to walk down the ground due to premature walking training, but its function has not reached this level, which will also make the symptoms of foot drop and inversion more obvious. Therefore, improving foot drop, correcting ankle varus deformity, thereby enhancing gait rhythm and stability, helping to establish a normal walking pattern, is of great significance for the rehabilitation of stroke patients.

4.2 Reasons Why the Two Types of Functional Electrical Stimulation Have Therapeutic Effects for Patients with Foot Drop after Stroke

Rehabilitation treatment methods currently used in clinical practice include: conventional sports training, functional electrical stimulation treatment, ankle-foot orthosis treatment, intramuscular sticking treatment, surgical treatment, etc. Previous studies have shown that long-term use of functional electrical stimulation can have a good therapeutic effect because functional electrical stimulation can strengthen the residual corticospinal tract connections in stroke patients. In short, long-term sensory stimulation and walking training can activate the remaining corticospinal tract connections, thereby increasing the strength of the tibialis anterior and peroneal brevis muscles and the self-control ability of the ankle joint [8]. Wang Guili [9] and other studies have shown that gait-induced functional electrical stimulation can further promote the recovery of lower limb motor function and balance function in patients with stroke, foot drop and varus. In this experiment, the control group used computer mid-frequency functional electrical stimulation, and the experimental group used XFT-2001D foot drop walker to treat the symptoms of foot drop in stroke patients. The FMA and BBS scores of the patients in both groups were obtained before and after treatment. The significant improvement P <(0.05) also confirmed that the foot drop walker treatment has a good effect on improving the ankle dorsiflexion disorder of patients with foot drop after stroke.

4.3 The Mechanism of Action of the Foot Drop Walker on Improving the Ankle Dorsiflexion Function of Stroke Patients

Clinically, when using computer mid-frequency functional electrical stimulation to induce ankle dorsiflexion activities, patients often adopt the lying or sitting position, which is more passive stimulation, and it is difficult for patients to participate in active ankle dorsiflexion exercises. The foot drop walking aid can be carried out at the same time as walking training. The patient actively contracts the tibialis anterior muscle to produce ankle dorsiflexion during the walking swing period and avoids dragging the lower limbs. At this time, the foot drop walker can perform on the tibialis anterior muscle. Functional electrical stimulation causes more pronounced ankle dorsiflexion. The foot drop walking aid has the effect of instantly correcting foot drop. It can improve the walking pattern by stimulating the common peroneal nerve through functional electrical stimulation to induce ankle dorsiflexion. On the other hand, long-term functional electrical stimulation can produce physiological effects on the ankle joint. The changes can increase the strength of the ankle dorsi flexor muscle, the control of the ankle joint, and the degree of motion of the ankle joint. Even if the device is closed, some therapeutic effects can be produced when the device is closed. Long-term sensory stimulation and walking training can activate the remaining corticospinal tract connections, thereby increasing the muscle strength of the tibialis anterior and peroneus brevis and the self-control ability of the ankle joint. Therefore, people can walk faster and safer without using the foot drop walking aid.

Li Wei [10] and others have shown through research that the foot drop walker has a significant therapeutic effect on reducing the abnormal muscle tension of the three heads of the calf in children with spastic cerebral palsy, thereby improving the ankle dorsiflexion function of the children. In this experiment, the reduction of calf triceps muscle tension in the experimental group was significantly higher than that in the control group ($P<0.05$), indicating the therapeutic effect of the foot drop walking aid in reducing calf triceps muscle tension and improving ankle dorsiflexion function It is better than computer mid-frequency functional electrical stimulation.

4.4 The Influence of Foot Drop Walking Aids and Computer Intermediate Frequency Treatment Devices on the Balance of Stroke Patients with Foot Drop

When walking, a stable contact surface and support surface cannot be formed, resulting in unstable weight bearing on the affected side in the early stage of support, increasing the risk of falling, and reducing the patient's balance function. Both foot drop walking aids and computer mid-frequency functional electrical stimulation can improve the patient's balance during walking by improving the patient's ankle motion control. As early as 1961, Liberson [11] and others used functional electrical stimulation to successfully treat the foot drop gait of patients with hemiplegia. A clinical randomized study [12] pointed out that functional electrical stimulation combined with walking training can improve the safety and stability of walking in stroke patients with foot drop.

However, when a patient with foot drop after a stroke uses computer intermediate frequency functional electrical stimulation to stimulate the tibial anterior muscle to induce ankle dorsiflexion, the electrode sheet is easy to fall and the equipment is limited, so it is impossible to walk on the patient. While training, stimulate the ankle dorsiflexion and valgus movements, and give timely stimulation during the appropriate walking cycle. The foot drop walking aid, as a convenient and portable functional electrical stimulation device, can timely send out electric signals to stimulate the common peroneal nerve during different walking cycles of the patient, and stimulate the tibialis anterior muscle and the peroneus brevis muscle in a more timely and appropriate manner. To create a more three-dimensional walking experience for the patient, and the patient's dynamic balance function is also significantly improved. In this study, patients reported that their walking stability has been improved after wearing a foot drop walker. Through the treatment of foot drop walker, patients with stroke and foot drop can complete a safer, more natural and stable walk.

  DOI: https://doi.org/10.30564/jams.v5i1.3688

Domestic Yan Tiebin [13] and others have also done clinical research on the application of FES, but the postures adopted by patients during treatment are sitting and lying positions, which do not fully meet the definition of functional electrical stimulation. Liu Cuihua [14] and others reported that gait-induced functional electrical stimulation can significantly increase the patient's walking speed and reduce physical energy consumption. Huang Guozhi [15] and others have shown through research that the foot drop walker can improve the safety, independence and stability of walking in stroke patients. In this experiment, comparing the control group who used the foot drop walking aid for treatment and the observation group who used computer mid-frequency functional electric puncture, the BBS scores before and after treatment were poor, and it was found that the effect of the experimental group was better than that of the control group ($P<0.05$), indicating that the foot drop walking aid is better than the computer intermediate frequency treatment device in improving the balance function of stroke foot drop.

4.5 Advantages of Foot Drop Walking Aids in Community Rehabilitation of Stroke Patients

The XFT-2001 foot drop walking aid is small in size, does not affect the appearance, and is mild in stimulation. It can be continuously stimulated for a long time. It is more convenient to carry than the computer's mid-frequency functional electrical stimulation. In this experiment, the patient had no resistance to the foot drop walking aid. In addition, the price of the XFT-2001 foot drop walking aid is only half of the computer intermediate frequency therapy device, which can reduce the family burden of patients who want to go back to their homes for community rehabilitation.

On the one hand, the foot drop walking aid includes improving the movement function of the patient's ankle joint and correcting the abnormal walking pattern. On the other hand, the patient can use the foot drop walking aid to walk safely and independently in the family and community, prompting the patient to walk. Return to family and society as soon as possible.

In our clinic, the frequency of use of computer intermediate frequency therapeutic devices is more extensive than that of foot drop walking aids. The main reason is that the use of foot drop walking aids has not been promoted in China, and many people do not know the effect of its use. Therefore, we need to increase our publicity so that patients can get better and more effective treatment.

5. Conclusions

Both gait-induced functional electrical stimulation and computer intermediate-frequency functional electrical stimulation can significantly improve the function and balance of the lower limbs of patients with stroke and foot drop. The therapeutic effect of gait-induced functional electrical stimulation is better than that of computer intermediate frequency functional electrical stimulation. In addition, it has a compact size, does not affect the aesthetics, is mildly stimulated, and can be continuously stimulated for a long time. It is more convenient to carry than neuromuscular electrical stimulation, and can be used at the same time during walking, so it is worthy of promotion.

References

[1] O'Dell, M.W., Dunning, K., Kluding, P., et al., 2014. Response and prediction of improvement in gait speed from functional electrical stimulation in persons with poststroke drop foot. PM&R. 6(7), 587-601.

[2] Bethoux, F., Rogers, H.L., Nolan, K.J., et al., 2014. The effects of peroneal nervefunctional electrical stimulation versus ankle- foot orthosis in patients with chronic stroke: a randomized controlled trial. Neurorehabil Neural Repair. 28(7), 688-697.

[3] Begg, R.K., Tirosh, O., Said, C.M., et al., 2014. Gait training with real-time augmented toe-ground clearance information decreasea tripping risk in older adults and a person with chronie stroke. Front Hum Neurosci. 8(3), 471-475.

[4] Xiao, F.N., Lin, Ch.Sh., 2016. The effect of foot drop stimulator on lower limb motor function of patients with stroke and foot drop. Practical Integrated Traditional Chinese and Western Medicine. (06), 43-45.

[5] Shen, F., 2011. Application of Fugl-Meyer Scale in the Evaluation of Rehabilitation Efficacy of Stroke Rehabilitation in Community. Proceedings of the Fifth Academic Conference of China Disabled Rehabilitation Association. 405-407.

[6] Weng, Ch.Sh., Wang, J., Wang, G., et al., 2007. Conceptual validity of the Berg balance scale in stroke patients. Chinese Journal of Rehabilitation Medicine. 11, 974-977.

[7] Deng, S.Y., Lu, Q., Xi, Sh.Y., et al., 2016. Research on the correlation between isokinetic test indexes and modified Ashworth scale for ankle spasticity assessment. Chinese Rehabilitation Theory and Practice. 02, 178-183.

[8] Neurorehabilitation and Neural Repair27(7) 579-

591© The Author(s) 2013 Reprints and permissions:sagepub.com/journalsPermissions.nav. DOI: https://doi.org/10.1177/1545968313481278.

[9] Wang, G.L., Jia, J., 2016. Observation on the efficacy of functional electrical stimulation in the treatment of stroke with foot drop and varus. Chinese Rehabilitation. 06, 434-437.

[10] Li, W., Zhang, R., Luo, Y.L., et al., 2013. Observation on the effect of gait-induced functional electrical stimulation on improving lower limb motor function in children with spastic diplegic cerebral palsy. Chinese Journal of Rehabilitation Medicine. 28(12), 1126-1130.

[11] Liberson, W.T., Holmquest, H.J., Scot, D., et al., 1961. Functional elec-trotherapy: stimulation of the peroneal nerve synchronized with the swing phase of the gait of hemiplegic patients. Archives of Physical Medicine and Rehabilitation. 42, 101-105.

[12] Embrey, D.G., Hohz, S.L., Alon, G., et al., 2010. Functional electrical stimulation to dorsiflexors and plantar flexors during gait to improve walking in adults with chronic hemiplegia. Arch Phys Med Rehabil. 91(5), 687-696.

[13] Yan, T., Hui-chan, C.W., Li, L.S., 2005. Functional electricial stimulation improves motor recovery of the lower extremity and walking ability of subjects with first acute stroke:a randomized placebo-controlled trial. 36(1), 80-85.

[14] Liu, C.H., Zhang, P.D., Rong, X.Ch., et al., 2011. Observation on the effect of gait-induced functional electrical stimulation on stroke patients with foot drop. Chinese Journal of Rehabilitation Medicine. 26(12), 1136-1139.

[15] Shan, Sh.R., Huang, G.Zh., Zeng, Q., et al., 2013. The effect of gait-induced functional electrical stimulation on gait spatiotemporal parameters in patients with foot drop after stroke. Chinese Journal of Rehabilitation Medicine. 28(6), 558-563.

  DOI: https://doi.org/10.30564/jams.v5i1.3688