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The Efficiency of Functional Electrical Stimulation and Balance-Weighted Rehabilitation Therapy in Stroke Patients with Foot-Drop: A Pilot Study

Düşük Ayaklı İnmeli Hastalarda Fonksiyonel Elektrik Stimülasyonu ve Denge Ağırlıklı Rehabilitasyon Tedavisinin Etkinliği: Pilot Çalışma

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ABSTRACT Objective: This study aimed to evaluate the effects of FES and balance-weighted rehabilitation therapy in addition to conventional rehabilitation in stroke patients with foot-drop on motor function, ambulation, posture, balance, physical disability, gait quality and activities of daily living. **Material and Methods:** This study included 35 stroke patients with foot-drop. The patients were evaluated in respect of motor function, activities of daily living posture, balance and risk of falling. Brunnstrom stages of motor recovery was administered to assess motor function. The functional disability was assessed by Functional Independence Measure. Functional Ambulation Category was used to assess the patients' gait performance. Berg Balance Scale was used in functional balance and risk of falling. Posture was assessed using the Trunk Control Test. Video-assisted visual gait analysis (VGA) over a distance of 10 m was also applied to patients. The two gait phases of swing and stance were analysed. Walking speed (m/sn) and walking rhythm (step/min) were determined. All patients received conventional rehabilitation, FES and balance-weighted rehabilitation therapy 5 days a week for 4 weeks. The evaluation parameters were repeated in weeks 2 and 4, and these parameters were compared. **Results:** From the baseline values to the end of week 4, a significant improvement was determined in respect of functional disability, balance, upper and lower extremity functions, walking speed and rhythm. **Conclusion:** FES and balance-weighted rehabilitation therapy in addition to conventional rehabilitation is an effective treatment method for hemiplegic foot rehabilitation as it improves functional ambulation and increases the level of independence in daily living activities.

Keywords: Stroke; foot-drop; functional electrical stimulation; rehabilitation; balance

ÖZET Amaç: Düşük ayağı olan inmeli hastalarda, konvansiyonel rehabilitasyon tedavisine ek olarak fonksiyonel elektrik stimülasyonu (FES) ve denge ağırlıklı rehabilitasyon uygulanmasının; motor fonksiyon, ambulasyon, postür, denge, fiziksel yetersizlik, yürüme kalitesi ve günlük yaşam aktiviteleri üzerine etkilerinin değerlendirilmesi amaçlandı. **Gereç ve Yöntemler:** Çalışmaya düşük ayağı olan 35 inmeli hasta alındı. Hastaların motor fonksiyonları, fonksiyonel dizabiliteleri, ambulasyon seviyeleri, günlük yaşam aktiviteleri, postürleri, denge ve düşme riskleri değerlendirildi. Hastaların motor fonksiyonları, Brunnstrom motor evrelemeleri ile değerlendirildi. Ayrıca fonksiyonel dizabilite Fonksiyonel Bağımsızlık Ölçeği, yürüyüş performansı Fonksiyonel Ambulasyon Sınıflandırılması, fonksiyonel denge ve düşme riski Berg Denge Ölçeği ve Postür Gövde Kontrol Testi ile değerlendirildi. Hastalara 10 m için video destekli görsel yürüme analizi yapıldı. Salınım ve basma olarak 2 ayrı fazda inceleme yapıldı. Yürüme hızı (m/sn) ve yürüme ritmi (adım/dk) belirlendi. Tüm hastalara ortalama 4 hafta süre ile haftada 5 gün olmak üzere konvansiyonel rehabilitasyon, FES ve denge ağırlıklı rehabilitasyon programı uygulandı. Tedavinin 2 ve 4. haftasında tekrar değerlendirilme yapıldı ve bu parametreler karşılaştırıldı. **Bulgular:** Tekrarlayan ölçümler arasında; tedavi öncesi ve 4. hafta arasında fonksiyonel dizabilite ile değiştirilmesini, denge, üst ve alt ekstremite motor fonksiyonları, yürüme hızı ve ritminde anlamlı olarak iyileşme saptandı. **Sonuç:** Düşük ayağı olan inmeli hastalarda konvansiyonel rehabilitasyon programına ek olarak FES ve denge ağırlıklı rehabilitasyon, fonksiyonel ambulasyonu geliştirerek günlük yaşam aktivitelerindeki bağımsızlık düzeyini artırdığı için hemiplejik ayak rehabilitasyonunda etkili bir tedavi yöntemidir.

Anahtar Kelimeler: İnme; düşük ayak; fonksiyonel elektrik stimülasyonu; rehabilitasyon; denge

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Stroke is the second leading cause of death in all age groups in Turkey and in those aged >60 years throughout the world. Recent improvements in acute medical treatment, and more successful treatment of complications and comorbidities have reduced the mortality rate. The physical, psychological and socially significant deficits seen post-stroke have a negative impact on the quality of life.[1]

The gait of hemiplegic patients has been generally observed to be slow, spastic, poorly coordinated and asymmetrical. The swing phase is increased and the stance phase is decreased on the hemiplegic side and there is no heel strike in the walking pattern.[2] The spasticity of calf muscles or paralysis of the dorsiflexor muscles of the foot will result in foot-drop in hemiplegic patients. The initial contact is usually with the anterior or lateral edge of the foot. Ankle dorsiflexion and eversion are inadequate during the swing phase.

Functional electrical stimulation (FES) is one of the therapeutic strategies that are applied to improve impaired extremity function. It has been claimed that FES has a positive effect on spasticity, range of motion, and muscle strength. FES is a lower frequency electrical stimulation modality that is applied for functional purposes to correct activity.[3] The efficacy of FES has been demonstrated in the strengthening of atrophic muscles, hemiplegic shoulder subluxation, and hemiplegic hand and foot rehabilitation.[4]

The aim of this study is to investigate the effect of FES application on functionality, posture, balance and the quality of walking in stroke patients with drop foot.

MATERIAL AND METHODS

The prospective study included 35 stroke patients with foot-drop, aged 18-80 years of age, who were rehabilitated with stroke between September 2014 and May 2016 in our inpatient clinic.

The study inclusion criteria were defined as patients who had first stroke and medical stability, cognitive capability, intact contralateral lower extremity and ability to sit bedside independently for at least 30 seconds. Patients who had cerebellar involvement, uncontrolled seizure history, edema and history of trauma on the affected side, hip/knee/ankle joint contracture on that side, psychiatric disease or known progressive neurological disease, peripheral nervous system disease such as polyneuropathy, evidence of deep vein thrombosis or thromboembolism, painful hypersensitivity to FES and electronic system such as a cardiac pacemaker or metal implant were excluded from the study.

Also; patients with malignancy, edema on the side to be treated with FES, skin infection, phlebitis or severe varicose deficiency, fracture or dislocation, decompensation heart failure or ejection fraction <40%, bleeding tendency, and those who were pregnant or lactating were excluded.

The protocol was explained to all participants and their caregivers and informed consent was obtained at the beginning of the study. The study protocol was approved by the Dışkapı Yıldırım Beyazıt Training and Research Hospital Clinical Research Ethics Committee (Approval date and number: 26.01.2015 and 19/12) and all procedures were performed in compliance with the Helsinki Declaration.

For each patient, a record was made of demographic and disease characteristics including age, gender, education, job and marital status, body mass index, alcohol and smoking status, dominant hand, comorbidities, stroke duration, etiology, type and lesion location.

The Brunnstrom stages of motor recovery were applied to assess motor function. Brunnstrom is a six-stage evaluation tool with three different parts concerning hand, the lower and upper extremity (Stages 1-6, 1: no activity of the limb; 2: spasticity appears, and weak basic flexor and extensor synergies are present; 3: spasticity is prominent; muscle activation is all within the synergy patterns; 4: patient begins to activate muscles selectively outside the flexor and extensor synergies; 5: spasticity decreases; most muscle activation is selective and independent from the limb synergies; 6: isolated movements in smooth, well-coordinated manner).

National Institutes of Health Stroke Scale (NIHSS) was applied to assess neurological severity. The total score in the NIHSS is between 0-42. It is examined in 5 main sections as consciousness level, visual evaluation, motor and sense functions, neglect, and cerebellar functions.[5]

Functional disability was assessed with the Functional Independence Measure (FIM). FIM analyses the motor and cognitive function of disabilitiy. There are 18 items in the FIM, related to self-care, sphincter control, transfer, locomotion, communication and social cognition. Each item is scored between 1 and 7 points.[6]

The Functional Ambulation Category (FAC) was used to assess gait performance. The FAC evaluates ambulation in 6 categories ranging from 0 to 5, where 0 refers to the inability of walking or requirement of at least 2 assistants for walking and 5 represents independent walking anywhere.[7]

The Berg Balance Scale (BBS) was used to evaluate functional balance and the risk of falling. BBS is a measure consisting of 14 items, scored between 0 and 4, with a total score of 56. Scores of 0 to 20 represent balance impairment, 21 to 40 represent acceptable balance, and 41 to 56 represent good balance.[8]

Postural balance was assessed using the Trunk Control Test (TCT). The TCT examines four movements: rolling from supine position to the weak side and to the strong side, sitting up from a lying-down position and sitting balance. The highest score on the test is 100.[9]

Peak oxygen uptake (VO_{2peak}) was calculated by the equation (VO_{2peak}: 0.03×distance in meters+3.98) based on the 6-minute walk test.[10] The metabolic equivalent (MET) ($mL/O_2/kg/min$) calculation was made according to VO_{2peak} value.

Video assisted visual gait analysis (VGA) over a distance of 10 m was applied to the patients. The 2 gait phases of swing and stance were analysed. Walking speed (m/sn) and walking rhythm (step/min) were determined. The asymmetry index was examined as temporal and spatial.

In the swing phase, the body was evaluated in respect of forward/backward tilt, affected/normal side tilt and forward/backward rotation. Affected side elevation and circumduction were examined in the pelvis. Limited/excessive flexion, inadequate extension/external rotation and abduction were examined in the hip. Limited knee flexion was assessed. Varus, valgus and equinovarus deformity were examined in the foot.

In the stance phase, limited/excessive flexion and insufficient extension/external rotation/abduction were assessed in the hips at initial contact. The knee was assessed for genu recurvatum and limited extension. Heel-strike, flat-foot and heel-off were evaluated at the ankle. Initial contact of the foot was determined on the lateral and anterior lateral edges and flat.

TREATMENT PROTOCOL

All patients participated in a conventional stroke rehabilitation program, 5 days a week, for 4 weeks.

All patients were treated with balance training (THERA-Trainer balo, Manufacturer: Medica Medizintechnik GmbH Country: Germany) program, 15-minute session of a once a day, 5 times a week. The THERA-Trainer balo is a therapy device for dynamic exercise of balance (postural control). The standing and balancing table is suitable for patients with risk of falling. It is equipped with knee and pelvic supports for patients unable to stand. Thera-Trainer software includes biofeedback illustrations and movement exercises that specifically support relearning motor skills.

The specific FES device used in this study was the Bioness L300 Foot Drop System (Bioness Inc, Valencia, CA, USA), which comprises a stimulation cuff with electrodes affixed on the anterolateral aspect positioned below the knee, a control unit, and an in-shoe pressure sensor under the foot (Figure 1).

The stimulation unit initially is configured by a clinician, who uses a handheld, wireless computer interface. The Clinician's Programmer should only contain the Windows Mobile for Pocket PC operating system and Bioness Inc proprietary software.

FES walking and training mode was applied according to the ambulation status. Non-ambulatory patients were administered FES training mode in a 30-min session once a day, 3 times a week. When patients started to stand, the mode was changed from training mode to walking mode. Ambulatory patients

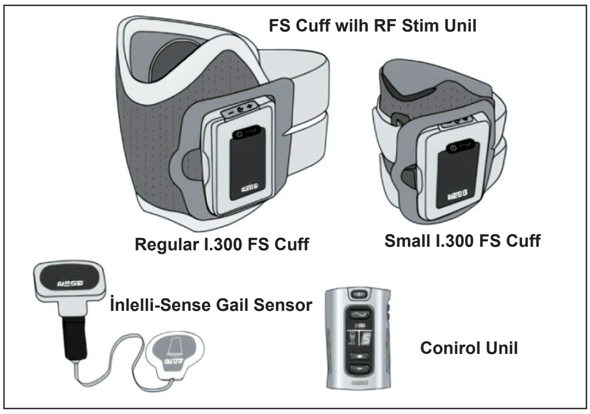

FIGURE 1: NESS L300 FES system components.

FIGURE 2: Gait training with functional electrical stimulation walking mode.

were applied FES walking mode in a 5-30 min session, once a day, 3 days a week (Figure 2).

The nerve electrode was positioned over the common peroneal nerve, distal and slightly posterior to the fibular head and the muscle electrode approximately 5 cm distal and anterior to the nerve electrode, over the belly of the tibialis anterior muscle. Pressure gait sensor was placed in the initial contact area of the patients who will be applied gait mode.

Gait and stimulation parameters (amplitude 0-100 mA, duration 200 microseconds, frequency 30 Hertz, and gait parameters, including ramp up/down 0.1 seconds) are individualized to achieve a functional and timely muscle contraction. FES and balance training practices of the patients were made by separate specialist.

In the 2nd and 4th weeks of treatment, FIM, FAC, BBS, TCT, number of therapeutic steps and duration were evaluated again by a non-blinded experienced physiatrist. In the 4-week re-evaluation, Brunnstrom and video assisted VGA for 10 meters were also applied. These parameters were compared.

STATISTICAL ANALYSIS

Analysis of the data was performed using SPSS 20.0 software (SPSS Inc., USA). Conformity of continuous variable to normal distribution was assessed with the Shapiro-Wilks test. The descriptive statistics were shown in the form of mean±standard deviation or median (minimum-maximum) values for continuous variables, and as number of observations (n) and percentage (%) for nominal variables. The Wilcoxon Signed-Rank test was applied to assess any statistically significant difference between recurrent measurements. Bonferroni correction was applied to control possible Type I errors in the comparisons. The results were considered statistically significant at a value of $p<0.017$.

RESULTS

The 35 patients comprised 30 (85.7%) males and 5 (14.3%) females with a mean age of 56.86±11.85 years. Ischemic stroke was determined in all patients, with the average time since the stroke, 39.00 days. The demographic and disease characteristics are presented in Table 1.

The medians of Brunnstrom stage for the hand, upper and lower extremities were 1.0, 2.0, and 3.0, respectively. The median value of the scales applied was 5.0 for NIHSS, 83.0 for FIM, 2.0 for FAC, 28.0 for BBS and 64.0 for TCT. The median duration of therapeutic walking was 14.0 minutes and the mean number of therapeutic steps was 472/14 minutes, therefore the therapeutic walking rhythm was determined to be 34 steps/minute. The median MET was 2 mL/O_2/kg/min, and the median normal walking rhythm was 45 steps/minute (Table 2, Table 3).

In the swing phase of the video-assisted VGA for 10 meters, anterior flexion of the trunk (n=10, 28.6%), pelvic circumduction (n=15, 42.9%), limited hip flexion (n=18, 51.4%) and valgus (n=16, 45.7%) were observed.

TABLE 1: Demographic and disease characteristics.

Parameter	n=35 n (%), Mean±SD
Gender	
Female	5 (14.3)
Male	30 (85.7)
Age (years)	56.86±11.85
Dominant hand	
Right	33 (94.3)
Left	2 (5.7)
Education	
Illiterate	4 (11.5)
Under 5-years	0
5-years	13 (37.1)
8-years	10 (28.6)
11-years	6 (17.1)
More than 11 years	2 (5.7)
Job	
Housewife	3 (8.6)
Officer	8 (22.9)
Retired	6 (17.1)
Workman	15 (42.8)
Farmer	1 (2.9)
Non-work	2 (5.7)
BMI (kg/m^2)	27.00±2.50
Marital status	
Married	25 (71.4)
Single	3 (8.6)
Widow	7 (20)
Comorbidity	
HT	15 (42.8)
DM	13 (37.1)
HPL	6 (17.1)
CAD	7 (20)
AF	3 (8.6)
Hypothyroidism	1 (2.9)
COPD	2 (5.7)
Heart valve disease	4 (11.4)
Alcohol status current	
Drink	4 (11.4)
Non-drink	30 (85.7)
Ex-drink	1 (2.9)
Smoking status	
Current smoke	13 (37.1)
Non-smoke	20 (57.2)
Ex-smoke	2 (5.7)
TIA	
Presence	2 (5.7)
Absence	33 (94.3)

continue →

TABLE 1: Demographic and disease characteristics *(continued)*.

Parameter	n=35 n (%), Mean±SD
Etiology (TOAST)	
Large-artery atherosclerosis	16 (45.7)
Cardioembolism	4 (11.4)
Small-vessel occlusion	6 (17.1)
Stroke of other determined etiology	5 (14.3)
Stroke of undetermined etiology	4 (1.4)
Stroke duration (days)	140.82±237.97
Stroke type	
Ischemic	35 (100)
Hemorrhagic	0
Hemiplegic side	
Right	17 (48.6)
Left	16 (45.7)
Lesion location	
MCA	17 (48.6)
ACA	6 (17.1)
PCA	7 (17.1)
PICA	5 (14.3)

SD: Standart deviation; BMI: Body mass index; HT: Hypertension; DM: Diabetes mellitus; HPL: Hyperlipidemia; CAD: Coronary artery disease; AF: Atrial fibrillation; COPD: Chronic obstructive pulmonary disease; TIA: Transient ischemic attack; TOAST: Trial of Org 10172 in Acute Stroke Treatment; MCA: Middle cerebral artery; ACA: Anterior cerebral artery; PCA: Posterior cerebral artery; PICA: Posterior inferior cerebellar arter.

In the evaluation of the stance phase, inadequate extension in the hip (n=18 51.4%) and genu recurvatum in the knee (n=20, 57.1%) were observed most often. Of the total patient group, 27 (77.1%) had no first rotation in the ankle, 15 (42.6%) did not have second rotation and 9 (25.7%) did not have third rotation. The initial contact of the foot was anterior lateral side (n=15, 42.9%).

When the asymmetry index was evaluated, temporal asymmetry was observed in 23 (65.7%) patients and spatial asymmetry in 13 (37.1%) patients.

Between baseline and week 4, a significant improvement was observed in FIM (p=0.004), FAC (p=0.001), BBS (p=0.008), therapeutic walking time (p=0.022), Brunnstrom hand/upper and lower extremity stages (p=0.002, 0.001 and 0.001, respectively), ankle rotation (p=0.005) and initial contact of the foot (p=0.013) in VGA, level of MET (p=0.001),

TABLE 2: Results of the parameters evaluated at baseline, 2nd and 4th weeks.

Parameters	Baseline (n), mean (SD)	2nd weeks (n), mean (SD)	4th weeks (n), mean (SD)
FIM	78.74 (23.69)	85.78 (19.67)	94.80 (12.69)
FAC	1.82 (1.31)	2.21 (1.00)	2.76 (1.04)
BBS	27.48 (20.72)	33.50 (18.25)	41.20 (13.60)
TCT	63.88 (19.13)	68.37 (16.03)	80.63 (13.75)
Therapeutic walking time (minute)	1.17 (0.75)	19.09 (10.55)	58.33 (12.97)
Therapeutic step number	472.03 (486.95)	854.37 (591.99)	1187.33 (538.49)

SD: Standart deviation; FIM: Functional Independence Measure; FAC: Functional Ambulation Categories; BBS: Berg Balance Scale; TCT: Trunk Control Test.

TABLE 3: Results of the parameters evaluated at baseline, 2nd and 4th weeks.

Parameters	Baseline (n), mean (SD)	4th weeks (n), mean (SD)	p value
Brunnstrom			
Upper exremity	1.77 (1.37)	2.77 (1.43)	0.001
Hand	2.38 (1.62)	3.38 (1.27)	0.002
Lower extremity	2.94 (0.63)	3.70 (0.93)	0.001
Walking speed	0.19 (0.13)	0.66 (0.24)	0.001
Walking rhytym	44.58 (26.29)	58.30 (16.95)	0.006
MET	2.42 (3.07)	10.37 (3.81)	0.001

A value of p<0.05 was considered statistically significant; MET: Metabolic equivalents; SD: Standart deviation.

temporal asymmetry, walking speed (p=0.001) and rhythm (p=0.006). After the 2nd week of treatment, there were significant differences in TCT (p=0.001) and the number of therapeutic steps (p=0.017) and the differences remained significant after 4 weeks of treatment (p=0.014 and p=0.001, respectively) (Table 3, Table 4, Table 5).

DISCUSSION

This study investigated the effects of FES and balance-weighted rehabilitation in addition to conventional rehabilitation therapy in stroke patients with foot-drop. Our study revealed that FES and balance-weighted rehabilitation had a positive effect on motor function, functional disability, ambulation level, posture, balance and gait quality. Hence, these findings suggest that FES and intensive balance training improves functional ambulation and increases the level of independence in daily living activities, and is an effective treatment method for hemiplegic foot rehabilitation.

For walking function, it is necessary to have a certain muscle strength and coordination in the lower extremities. Therefore, in studies investigating the effectiveness of FES in addition to conventional treatment in the literature; lower extremity Brunnstrom motor level was evaluated and a statistically significant improvement was reported in the Brunnstrom lower extremity motor stages.[11,12] Similar to both these studies, the current study results showed a significant improvement in the Brunnstrom lower extremity motor stages in the FES group.

However, walking is not just about the lower extremities. For the normalization of balance and gait, the upper extremity should also be involved reciprocally. For this reason, upper extremity and hand Brunnstrom motor stages were measured in our study. In the current study, a significant increase in BBS (p=0.008), Brunnstrom upper extremity (p=0.001) and hand (p=0.002) stage scores was observed between baseline and the 4th week. In addition, there was a significant improvement in TCT levels between the baseline and 2nd week (p=0.001) and 4th week (p=0.014) measurements.

Gait is a highly complex function that requires integration of mechanisms of locomotion with those of motor control, musculoskeletal function, balance and posture. Therefore, balance is also evaluated along with gait in studies. In FES studies where balance evaluation has been applied with comparisons

TABLE 4: Results and comparison of video assisted VGA.

Parameters	Baseline n (%), mean (SD)	4th weeks n (%), mean (SD)	p value
Swing phase			
Body:			
Forward tilt	10 (28.6)	8 (22.9)	
Backward tilt	2 (5.7)	3 (8.6)	
Patient side tilt	1 (2.9)	2 (5.7)	0.563
Normal side tilt	0	0	
Forward rotation	1	0	
Backward rotation	0	0	
Pelvis:			
Elevation	12 (34.3)	10 (28.6)	0.231
Circumduction	15 (42.9)	14 (40)	
Hip:			
Limited flexion	18 (51.4)	11 (31.4)	0.165
Excessive flexion	5 (14.3)	5 (14.3)	
Inadequate extension	0	0	
External rotation	0	0	
Abduction	0	0	
Knee:			
Limited extension	7 (20)	5 (14.3)	0.712
Foot:			
Varus	1 (2.9)	0	0.098
Valgus	16 (45.7)	14 (40)	
Equinovarus	10 (28.6)	8 (22.9)	
Stance phase:			
Hip:			
Limited flexion	3 (8.6)	0	
Excessive flexion	3 (8.6)	4 (11.4)	0.348
Inadequate extension	18 (51.4)	12 (34.3)	
Abduction	0	2 (8.6)	
Knee:			
Limited extension	7 (20)	4 (11.4)	0.127
Genu recurvatum	20 (57.1)	17 (48.6)	
Ankle:			
Heel strike	27 (77.1)	8 (22.9)	**0.005**
Foot flat	15 (42.6)	8 (22.9)	
Heel-off	9 (25.7)	4 (11.4)	
Initial contact:			
Anterior	11 (31.4)	7 (20)	**0.013**
Anterior lateral	15 (42.9)	5 (14.3)	
Lateral edge	0	2 (5.7)	
Flat	1 (2.9)	2 (5.7)	

A value of $p<0.05$ was considered statistically significant; VGA: Visual gait analysis; SD: Standart deviation.

TABLE 5: Results and comparison of asymmetry index.

Parameters	Baseline n (%), mean (SD)	4th weeks n (%), mean (SD)	p value
Hemiplegic side			
Stance period:			
Decreased	23 (65.7)	11 (31.4)	**0.002**
Equal	4 (11.4)	19 (54.3)	
Increased	0	0	
Swing period:			
Decreased	0	0	
Equal	4 (11.4)	19 (54.3)	**0.002**
Increased	23 (65.7)	11 (31.4)	
Normal side			
Stance period:			
Decreased	0	0	**0.002**
Equal	4 (11.4)	19 (54.3)	
Increased	23 (65.7)	11 (31.4)	
Swing period:			
Decreased	23 (65.7)	11 (31.4)	**0.002**
Equal	4 (11.4)	19 (54.3)	
Increased	0	0	
Hemiplegic side			
Step lenght			
Decreased	13 (37.1)	10 (28.6)	0.276
Equal	8 (22.9)	15 (42.9)	
Increased	6 (17.1)	5 (14.3)	
Normal side			
Step lenght			
Decreased	7 (20)	5 (14.3)	0.059
Equal	7 (20)	16 (45.7)	
Increased	13 (37.1)	9 (25.7)	

A value of p<0.05 was considered statistically significant; SD: Standart deviation.

of a conventional treatment group and a FES group, significant improvements have been reported in both groups.[13-19]

However, these studies often included patients in the chronic phase. Chronic patients develop balance with an incorrect postural pattern by providing appropriate balance modification to the disability pretreatment. These results suggest that FES has no effect on balance in chronic patients. In a multicentre clinical trial by O'Dell et al., 99 subacute-chronic stroke patients underwent FES and conventional therapy.[17] Significant increases in BBS scores were observed in 50% of the patients at week 12, and clinically significant results were obtained in more than 50% of the patients at week 42.

To the best of our knowledge, there is no other study in the literature that has evaluated TCT in peroneal nerve FES-treated stroke patients. The current study results suggest that FES applications performed in the subacute period may have an effect on the patient's balance.

In a comprehensive systematic review with meta-analysis that assessed FES applied to the peroneal nerve has revealed evidence for positive effects of FES on gait performance, balance and functional mobility when combined with physiotherapy.[20]

In the visual VGA evaluation of the current study, there was a significant improvement in the number of therapeutic steps (p=0.017) between baseline and the

2nd week. Between baseline and the 4th week, there was a statistically significant change in FAC (p=0.001), number of therapeutic steps (p=0.001), walking rhythm (p=0.001), walking speed (p=0.001) and therapeutic walking duration (p=0.022).

It has been reported that FES applications which are evaluated in addition to conventional rehabilitation or in 2 separate groups have an effect on the number of steps, walking time and walking speed. The increase when FES is used is greater than with the use of conventional therapy, although some studies have reported no difference.[12,14,16,21-24] In the comparisons before and after treatment, a significant improvement in walking speed was observed as in the current study. In other FES efficacy studies, it has been reported that the effect on walking speed was significant and this effect continued for up to 1 year on average. This increase in walking speed can be considered to be related to regular walking activity and exercises.[17-24]

In the current study, VGA showed significant improvements in ankle rotations and initial contact of the foot between the baseline and 4-week measurements. In parallel with this, a significant synchronisation with the normal side of the stance was observed. There have been few studies in literature evaluating VGA and FES, but there have been reported to have been significant improvements in these studies.[25-28] Although no significant difference in step lengths was reported in those studies, when the distribution of step length was examined in the current study, it was observed that the number of patients with equal step length was increased. This result may have been due to low patient numbers.

Another result of the current study was that a significant increase was observed in the levels of MET and FIM between baseline and the 4-week measurements. In the literature, there is no study of MET evaluation in patients with peroneal FES.

Walking is an action that consists of stance and swing phases, which is a combination of coordinated movements of two limbs. For this to be of high quality, it is necessary to expend minimum energy with reciprocal involvement of the upper extremity and the body remaining aligned on the midline.

The implementation of FES in a rehabilitation program can be effective, when it is considered that the functional disability of the patient is decreased and energy capacity is increased.

In addition, each patient has prognostic factors such as comorbidity, aerobic capacity, premorbid and current personality traits and family support that affect the response to rehabilitation. Almost all of the studies in literature may have been conducted with patient groups that differ in these respects. Therefore, there is a need for large-scale studies to examine prognostic factors.

LIMITATIONS

The most important limitations of this pilot study were the small number of patients and that there was no control group. These results will be better understood with future, large-scale studies including a control group.

CONCLUSION

The results of this study demonstrated that FES and balance-weighted rehabilitation in addition to the conventional rehabilitation program had a positive effect on motor function, functional disability, ambulation level, posture, balance and quality of walking in stroke patients with foot-drop. FES and intensive balance training improves functional ambulation and increases the level of independence in daily living activities, and is an effective treatment method for hemiplegic foot rehabilitation.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

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