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Research Article

Electromyographic Biofeedback in the Treatment of the Hemiplegic Hand

A Placebo-Controlled Study

ABSTRACT

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Objective: To evaluate the efficacy of electromyographic (EMG) biofeedback treatment in the functional recovery of the hemiplegic hand.

Design: A total of 27 patients were randomly assigned to EMG biofeedback or placebo EMG biofeedback groups. Both treatments were applied five times a week for a period of 20 days. In addition, the patients in both groups received an exercise program according to the Brunnstrom's neurophysiologic approach. Goniometric measurements for wrist extension, scale for judging the performance of drinking from a glass, Brunnstrom's stages of recovery for hand, and surface EMG potentials were used for the clinical assessments. All patients were assessed before treatment and after 20 treatment sessions.

Results: The results showed that there were statistically significant improvements in all variables in both groups, but the improvements in active range of motion and surface EMG potentials were significantly greater in the EMG biofeedback group at the end of the treatment.

Conclusion: Our study demonstrates the potential benefits of EMG biofeedback in conjunction with neurophysiologic rehabilitation technique to maximize the hand function in hemiplegic patients.

Key Words: Electromyographic Biofeedback, Hemiplegia, Rehabilitation

Stroke is the most common neurologic disease that leads to death and disability in the elderly population.[1,2] Every year, a significant number of stroke patients survive and are left with significant disabilities.[3,4] Hemiparesis is the most common cause of disability after stroke, affecting 70–85% of all patients,[1] and it has been estimated that 60% of all surviving stroke patients may require rehabilitation treatment.[5] It is important to identify effective stroke rehabilitation strategies as the number of stroke survivors and medical costs increase.

Different treatment strategies for the rehabilitation of hemiplegic patients are available today, such as conventional exercise programs, proprioceptive neuromuscular facilitation techniques,[6,7] muscle strengthening and physical conditioning programs,[8] neurophysiologic approaches,[9] and functional electrical stimulation.[10] Electromyographic (EMG) biofeedback has been used in the treatment of hemiplegia since the 1960s,[11,12] and in several studies, the effectiveness of this technique has been investigated.[13–17] Most of these studies have reported that EMG biofeedback can help to achieve improvements even in the chronic state, in treating hemiparesis of upper or lower limbs.[18] In contrast to these successful results, in some studies, no superiority of this technique has been found when compared with placebo.[19]

Rehabilitation techniques have been more successful in restoring function in the lower limbs than in the upper limbs.[20] Nakayama et al.[21] reported that further recovery of upper limb function should not be expected if functional recovery has not occurred by the 11th week. Especially, conventional therapy has not always been completely successful in the restoration of upper limb function.[22] Because of these reasons, it is important to develop techniques or combination therapies for the treatment of the hemiplegic upper limb.[11] Because there is not enough evidence that EMG biofeedback can facilitate recovery after stroke, we aimed to evaluate the efficacy of EMG biofeedback treatment in the functional recovery of the hemiplegic hand.

PATIENTS AND METHODS

Patients

The study was carried out at Osmangazi University, Faculty of Medicine Hospital, Eskisehir, Turkey. A total of 27 patients with hemiparesis of vascular origin, 11 women and 16 men with a mean age of 57.44 ± 10.69 yr (range, 39–77 yr), were admitted to our rehabilitation unit. The length of time since onset of hemiparesis ranged from 3 to 6 mo, with an average of 4.59 ± 1.19 mo. All patients had a middle cerebral artery vascular lesion. The subtype of stroke experienced by patients included computed tomographically confirmed infarct in 18 patients (67%) and hemorrhage in nine patients (33%). All patients were hospitalized during the study period.

The inclusion criteria included: (1) ability to communicate, (2) full comprehension, (3) no visual or auditory defect, (4) having significant motivation, (5) stable health status, and (6) stage 2 or 3 hemiparesis according to the modified Brunnstrom's scale of motor recovery for the hand. Exclusion criteria were: (1) spasticity greater than stage 3 according to the modified Ashworth scale,[23] (2) previous hemiparesis, (3) flask hemiplegia (Brunnstrom's stage 1), (4) dementia, (5) deformities of the upper limb (previous fractures, contractures, or deformities caused by inflammatory arthropathies such as rheumatoid arthritis), and (6) previous physical therapy or EMG biofeedback training.

Passive range of motion was within normal limits in all patients, and none of the patients had sensorial deficit and pain. The patient's functional ability was assessed with the Barthel index.[24]

Study Design

We conducted a clinical, prospective, randomized, placebo-controlled study. The patients were assessed by an independent physician who was blind to the study protocol. The ethics committee of the Osmangazi University Medical School approved this study, and all patients gave their written consent.

Treatment

A total of 27 patients, who fulfilled the entry criteria, were admitted to this study, and they were randomized into two groups using numbered envelopes. Group 1 consisted of 14 subjects who received an exercise program according to Brunnstrom's approach and EMG biofeedback. Group 2 consisted of 13 subjects who received placebo EMG biofeedback therapy and the same exercise program. The rehabilitation program was given to all patients by the same physiotherapist as described by physicians. The treatment protocol that we used in this study has been used in previous studies.[25]

EMG Biofeedback Application. For the EMG biofeedback treatment, a two-channel device was used (Electro-Medical Supplies Medi-Link, Model 79 EMG Biofeedback Module, EMS, London, UK). Surface electrodes were placed over the musculus extensor carpi radialis and extensor digitorum communis of the paretic arm. In hemiplegic patients, the extension of wrist and fingers is usually deteriorated, and this leads to limitation of hand functions, especially hand grasp. That is why, specifically, we preferred these muscles for the EMG biofeedback training. With the wrist in the flexion position and the forearm pronated, the patient was instructed to extend his or her wrist until the myoelectric potentials were

TABLE 1
Demographic and clinical features of patients

	Group 1 (n = 14)	Group 2 (n = 13)
Age, yr	57.00 ± 10.53	57.92 ± 11.27
Sex, female/male	6/9	5/8
Duration after stroke, mo	4.43 ± 1.09	4.77 ± 1.30
Stroke type, Inf/Hem	9/5	9/4
Side of hemiparesis, R/L	7/7	6/7
Barthel index	69.29 ± 8.05	70.38 ± 8.38

Inf, infarction; Hem, hemorrhage; R, right; L, left.

converted into a visual or auditory signal.[26] The sensitivity of the EMG biofeedback ranged from 2 μV to 2 mV.

Placebo EMG Biofeedback Application. The EMG electrodes were applied to the musculus extensor carpi radialis and extensor digitorum communis of the paretic arm. The EMG biofeedback machine was switched on but turned away from the patient so that no visual or auditory feedback was given.[19]

Both EMG biofeedback and placebo EMG biofeedback were applied five times weekly, with a duration of 20 min for 20 treatment sessions. In addition, the patients in both groups received an exercise program according to the Brunnstrom's neurophysiologic approach,[27] with a duration of 45 min/day for a period of 20 treatments.

Evaluation

The clinical assessments were performed according to the following methods at baseline and at the end of the treatment. All clinical assessments were performed by a blinded evaluator.

Active Range of Motion. Active range of motion of the wrist extension measurements were made with the subject in a sitting position. The same investigator performed goniometric measurements for each subject.

Brunnstrom's Stages of Recovery for Hand. Levels of recovery of muscle function for hand were assessed in terms of Brunnstrom's six stages.

Scale for Judging the Performance of the Movement Complex of Drinking from a Glass. The following scale was used to judge the ability to drink from a glass:[18]

0. No modulation of spastic tonus
1. Ability to reduce or increase spastic tonus
2. One of the following movements is possible: finger extension or finger flexion, pronation, or supination
3. Patient able to gasp and lift the glass
4. Patient able to grasp and lift the glass to the mouth and to release the glass at the table at the end of the movement sequence
5. Ability to do the movement complex without a drink in the glass.
6. Ability to do the movement complex of drinking from a glass with a beverage in the glass

Surface EMG Potentials

The surface EMG potentials during isometric contraction of the wrist and finger extensors were also recorded before and after the treatment.

Statistical Analysis

Baseline homogeneity was evaluated by t test for parametric data (age, duration of symptoms) and by χ^2 (sex) or Fisher's exact (dominant arm) tests where appropriate for small samples for nonparametric data. For changes in various symptoms after the treatment within each group, the Wilcoxon's and paired t tests were used. The Mann-Whitney and t test were used to compare the therapeutic results between the groups. Differences were considered significant if the P values were $\leq$0.05, and all results are expressed with a 95% confidence interval.

RESULTS

A total of 31 patients were enrolled in the study, and all of them completed the study period. Table 1 shows the demographic and clinical features of the patients. There were no significant differences in age, stroke onset, sex, lesion laterality distribution, type of stroke, and functional status between the two groups.

Brunnstrom's Stages of Hand Recovery. A significant improvement was observed in the Brunnstrom's stages of motor recovery in both groups at the end of the treatment (group 1, $P < 0.001$; group 2, $P < 0.01$).

TABLE 2
Brunnstrom's stages of recovery assessments before and after treatment

	Treatment						
	Before			After			P
	2	3	4	2	3	4	Value
Group 1, n = 14	8	6	—	2	6	6	<0.001
Group 2, n = 13	7	6	—	3	7	3	<0.01
P value		>0.05			>0.05		

Although the patients in the biofeedback group showed greater improvement, the difference between the groups did not reach statistical significance (Table 2).

Scale for Judging the Performance of the Movement Complex of Drinking from a Glass. There was also a significant improvement for this variable in both groups (group 1, $P < 0.01$; group 2, $P < 0.01$). Statistically significant differences could not be demonstrated between the groups (Table 3).

Active Range of Motion. Both groups showed improvement in range of active wrist extension after treatment (group 1, $P < 0.001$; group 2, $P < 0.05$). Comparison between the groups showed significant improvement in active range of motion in the EMG biofeedback group over the placebo group ($P < 0.05$) (Table 4).

EMG Surface Potentials. The EMG biofeedback group exhibited a significantly greater increase in EMG surface potentials ($P < 0.001$) compared with the placebo EMG biofeedback group ($P < 0.01$), and the difference between the groups was in favor of the EMG biofeedback–treated groups ($P < 0.001$) (Table 5).

TABLE 3
Scale for judging the performance of the movement complex of drinking from a glass assessment before and after treatment

	Treatment										
	Before					After					*P*
	2	3	4	5	6	2	3	4	5	6	Value
Group 1, $n = 14$	12	2	—	—	—	3	8	2	—	1	<0.01
Group 2, $n = 13$	9	4	—	—	—	4	7	2	—	—	<0.01
P value			>0.05					>0.05			

DISCUSSION

Stroke leaves many of its survivors with mental and physical disabilities, which create a major economic and social burden.[28] Many survivors of stroke receive expensive, time-consuming, and intensive rehabilitation in an attempt to improve independence.[29,30] Rehabilitation after stroke to improve functional ability has been suggested to decrease long-term social and economic costs. Because of these reasons, there is a need for properly designed rehabilitation programs.[28]

EMG biofeedback has been used in the rehabilitation of hemiplegia since the 1960s.[11,12,31] Although many research studies have been performed to investigate the complex neurophysiologic mechanisms underlying its motor effect, these mechanisms are still unclear and might include the following: elimination of active inhibitory influences, unmasking of existing pathways to subserve new movement strategies, transfer of function to intact neural structures, use of alternative pathways, or sprouting of collateral axons to form new synapsis.[32,33]

In rehabilitation, EMG biofeedback has gained an important place in the treatment of upper motor neuron lesions, especially in education of muscles and inducing relaxation of spastic muscles. There are a few systematically controlled studies that demonstrate the benefits of EMG biofeedback in the rehabilitation of hemiplegia. In a pilot study, comparing the efficacy of an integrated behavioral–physical therapy treatment program including EMG biofeedback or a standard exercise program, Basmajian et al.[11] found that both groups showed clinically significant improvements that exceeded previously reported experience. In two other controlled studies, Wolf and Binder[15] and Inglis et al.[22] applied EMG biofeedback plus physical therapy against physical therapy alone. Both studies found that in chronic stroke patients, EMG biofeedback, when used as an adjunct to physical therapy, resulted in improvement in upper limb range of motion and muscle strength. Although positive, these authors were more restrained in their enthusiasm for biofeedback for the upper limb than were authors of earlier controlled clinical reports. Similar results were reported by Crow et al.,[34] who found that patients receiving EMG biofeedback for a hemiplegic arm made significant improvement when compared with placebo EMG biofeedback–treated patients.

TABLE 4
Baseline values and changes in the active range of motion of wrist extension

	Baseline	Change from Baseline[a]	*P* Value
Group 1, $n = 14$	3.93 ± 5.25	−4.29 (0 to −10)	<0.001
Group 2, $n = 13$	5.78 ± 6.07	−1.54 (0 to −5)	<0.05
P value	>0.05	<0.05	

[a] Values are the mean changes from baseline and 95% confidence intervals for the mean.

TABLE 5

Baseline values and changes in the surface electromyographic potentials during isometric contraction of wrist extensors (in millivolts)

	Before Treatment	Change from Baseline[a]	*P* Value
Group 1, $n = 14$	12.58 ± 4.52	−16 (−5 to −43.40)	<0.001
Group 2, $n = 13$	11.13 ± 2.79	−0.79 (0 to −2.20)	<0.01
P value	>0.05	<0.001	

[a] Values are the mean changes from baseline and 95% confidence intervals for the mean.

In the literature, we encountered no study that compared the effectiveness of EMG biofeedback with other techniques such as functional electrical stimulation in the treatment of the hemiplegic upper limb, but in a study by Cozean et al.,[35] the efficacy of functional electrical stimulation and EMG biofeedback was investigated in hemiplegic patients with gait dysfunction. These two therapeutic modalities were tested alone and in combination in this prospective, controlled, randomized trial. The results of the study showed that combined therapy with EMG biofeedback and functional electrical stimulation resulted in significant improvement. Also, there are some studies reporting successful results in which electromyographically triggered neuromuscular stimulation technique is used in the treatment of motor dysfunction after stroke.[36,37]

In this study, most patients achieved improvement. The main finding of this randomized study is that hemiplegic patients treated with EMG biofeedback exhibit significantly greater hand function recovery, and this finding was consistent with previous studies.[25,38] Initiating wrist extension is often difficult for many patients because of the flexor synergy in the upper limb. EMG biofeedback training facilitates wrist extensor activity and decreases the flexor spasticity.[18,25] By this way, EMG biofeedback training improves the functional ability of the hand. This method also offers considerable help in orientation and sensory control and uses potential activity competence that would otherwise remain dormant. Because patients learn to perform useful movements that are helpful in daily living, they are motivated to participate more intensely.[18]

Our study has some limitations, such as the small sample size and lack of long-term observation. Because outcomes were assessed only at discharge, it is not clear whether the observed improvements were maintained in the long-term.

Our study demonstrates the potential benefits of EMG biofeedback in conjunction with neurophysiologic rehabilitation to maximize the hand function in hemiplegic patients, and our results are comparable with most of previous studies. However, in most of these studies, there were important variations in the stroke duration of the patients and localization of the cerebral lesions, which would limit the generalizability of the results. This is also the first placebo-controlled study in which the efficacy of EMG biofeedback has been examined in the treatment of the hemiplegic hand. For these reasons, we believe that the results obtained in this study might suggest a new insight, and we suggest that there is a need for future studies investigating the long-term therapeutic effects of EMG biofeedback.

REFERENCES

1. Dobkin B: The rehabilitation of elderly stroke patients. *Clin Geriatr Med* 1991;7: 507–23
2. Wilson DB, Houle DM, Keith RA: Stroke rehabilitation: A model predicting return home. *West J Med* 1991;154: 587–90
3. Kunkel A, Kopp B, Müller G, et al: Constraint-induced movement therapy for motor recovery in chronic stroke patients. *Arch Phys Med Rehabil* 1999;80: 624–8
4. Adams HP: Treating ischemic stroke as an emergency. *Arch Neurol* 1998;55: 457–61
5. Mandel AR, Nymark JR, Balmer SJ, et al: Electromyographic versus rhythmic positional biofeedback in computerized gait retraining with stroke patients. *Arch Phys Med Rehabil* 1990;71:649–54
6. Dickstein R, Hocherman S, Pillar T, et al: Stroke rehabilitation: Three exercise therapy approaches. *Phys Ther* 1986;66: 1233–8
7. Knott M, Voss DE: *Proprioceptive Neuromuscular Facilitation: Patterns and Techniques*, ed 2. New York, Harper and Row, 1968
8. Teixeria-Salmela LF, Olney SJ, Nadeau S, et al: Muscle strengthening and physical conditioning to reduce impairment and disability in chronic stroke survivors. *Arch Phys Med Rehabil* 1999;80:624–8
9. Basmajian JV: Research or retrench: The rehabilitation profession challenged. *Phys Ther* 1975;55:1211–8
10. Stanic U, Acimovic R, Gros N, et al: Multichannel electrical stimulation for correction of hemiplegic gate. *Scand J Rehabil Med* 1978;10:75–92
11. Basmajian JV, Gowland C, Brandstater ME, et al: EMG feedback treatment of upper limb in hemiplegic stroke patients: A pilot study. *Arch Phys Med Rehabil* 1982;63:613–6
12. Chaudhuri G: Rehabilitation of the stroke patient. *Geriatrics* 1980;35:45–54
13. Balliet R, Levy B, Blood KMT: Upper extremity sensory feedback therapy in chronic cerebrovascular accident patients with impaired expressive aphasia and auditory comprehension. *Arch Phys Med Rehabil* 1986;67:304–10
14. Binder SA, Moll, Wolf SL: Evaluation of electromyographic biofeedback as an adjunct to therapeutic exercise in treating the lower extremities of hemiplegic patients. *Phys Ther* 1981;61:886–92

15. Wolf SL, Binder SA: Electromyographic biofeedback application to the hemiplegic patient: Changes in upper extremity neuromuscular and functional status. *Phys Ther* 1983;63:1393–1403

16. Colborne GR, Olney SJ, Griffin MP: Feedback of ankle joint angle and soleus electromyography in the rehabilitation of hemiplegic gait. *Arch Phys Med Rehabil* 1993;74:1100–6

17. Burnside IG, Tobias S, Bursill D: Electromyographic feedback in the remobilization of stroke patients: A controlled trial. *Arch Phys Med Rehabil* 1982;63:217–22

18. Wissel J, Ebersach G, Gutjarh L, et al: Treating chronic hemiparesis with modified biofeedback. *Arch Phys Med Rehabil* 1989;70:612–7

19. Bradley L, Hart BB, Mandana S, et al: Electromyographic biofeedback for gait training after stroke. *Clin Rehabil* 1998;12:11–22

20. Basmajian JV: The winter of our discontent: Breaking intolerable time locks for stroke survivors. *Arch Phys Med Rehabil* 1989;70:92–4

21. Nakayama H, Jorgenson HS, Raaschou HO, et al: Recovery of upper extremity function in stroke patients: The Copenhagen stroke study. *Arch Phys Med Rehabil* 1994;75:394–8

22. Inglis J, Donald MW, Monga TN, et al: Electromyographic biofeedback and physical therapy of hemiplegic upper limb. *Arch Phys Med Rehabil* 1984;65:755–9

23. Bohannon RW, Smith MB: Interrater reliability of modified Ashworth scale of muscle spasticity. *Phys Ther* 1987;2:206–7

24. Wade DT, Colin C: The Barthel ADL index: A standard measure of physical disability. *Int Disabil Studies* 1988;10:64–7

25. Rathkolb O, Baykoushev S, Baykousheva V: Myobiofeedback in motor reeducation of wrist and fingers after hemispherical stroke. *Electromyogr Clin Neurophysiol* 1990;30:89–92

26. Kelly JL, Baker MP, Wolf SL: Procedures for EMG biofeedback training in involved upper extremities of hemiplegic patients. *Phys Ther* 1979;12:1500–7

27. Brunnstrom S: *Movement Therapy in Hemiplegia: A Neurophysiological Approach*. New York, Harper Row, 1970, pp 34–56

28. Dombovy ML, Sandok BA, Basford JR: Rehabilitation for stroke: A review. *Stroke* 1986;17:363–9

29. Prescott RJ, Garraway WM, Akhtar AJ: Predicting functional outcome following acute stroke using a standard clinical examination. *Stroke* 1982;13:641–7

30. Smith ME, Garraway WM, Smith DL, et al: Therapy impact on functional outcome in a controlled trial of stroke rehabilitation. *Arch Phys Med Rehabil* 1982;63:21–4

31. Basmajian JV: Biofeedback in Rehabilitation Medicine, in De Lisa JA (ed): *Rehabilitation Medicine: Principles and Practice*, ed 2. Philadelphia, Lippincott Company, 1993, pp 425–39

32. Wolf SL: Electromyographic biofeedback applications to stroke patients: a critical review. *Phys Ther* 1983;63:1448–55

33. Bach-y-Rita P: Central nervous system lesions: Sprouting and unmasking in rehabilitation. *Arch Phys Med Rehabil* 1981;62:413–7

34. Crow JL, Lincoln NB, Nouri FM, et al: The effectiveness of EMG biofeedback in the treatment of arm function after stroke. *Int Disabil Studies* 1989;11:155–60

35. Cozean CD, Pease WS, Hubbel SL: Biofeedback and functional electric stimulation in stoke rehabilitation. *Arch Phys Med Rehabil* 1988;69:401–5

36. Cauraugh J, Light K, Kim S, et al: Chronic motor dysfunction after stroke: Recovering wrist and finger extension by electromyography-triggered neuromuscular stimulation. *Stroke* 2000;31:1360–4

37. Francisco G, Chae J, Chawla H, et al: Electromyogram-triggered neuromuscular stimulation for improving the arm function of acute stroke survivors: A randomized pilot study. *Arch Phys Med Rehabil* 1998;79:570–5

38. Prevo AJ, Viser SL, Vogelaar VW: Effect of EMG feedback on paretic muscles and abnormal co-contraction in the hemiplegic arm, compared with conventional physical therapy. *Scand J Rehabil Med* 1982;14:121–31