The Effect of Upper Extremity Electrical Stimulation in Addition to Conventional Rehabilitation in Individuals with Chronic Stroke: Randomized Controlled Study

Kronik İnmelilerde Konvansiyonel Rehabilitasyona Ek Olarak Uygulanan Üst Ekstremite Elektrik Stimülasyonunun Etkileri: Randomize Kontrollü Çalışma

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ABSTRACT Objective: To investigate the effect of electrical stimulation of wrist and finger extensor muscles applied in addition to the conventional rehabilitation program on wrist spasticity, hand motor function, and quality of life in individuals with chronic stroke. **Material and Methods:** Patients were randomized into two groups as control (n=20) and treatment groups (n=20). Patients in the treatment group received surface neuromuscular electrical stimulation to the wrist and finger extensors of the hemiplegic upper extremity for 30 minutes, 5 days a week for 3 weeks in addition to conventional rehabilitation. The control group received only the conventional rehabilitation program. All subjects were evaluated before and after treatment. The hemiplegic upper extremity hand motor functions and spasticity were evaluated using Brunnstrom's Motor Stage Recovery, Fugl Meyer Assessment Scale(FMAS), Modified Ashworth Scale (MAS) respectively. The Duruöz Hand Index, Functional Independence Measure (FIM), and Nottinhgam Health Profile (NHP) were also applied. **Results:** When the pre- and post- treatment variances of values were compared between the treatment and control groups, the variance of wrist extension angle (p<0.001), MAS value of wrist (p=0.012), NHP sleep (p=0.036), and NHP physical activity scores (p=0.043) were significantly higher in the treatment group than in the control group. The difference of variances between the groups was not significant in respect of the Brunnstrom stage of upper extremity or hand, Fugl-Meyer of upper extremity, MAS of elbow, NPH pain, NPH emotional, NPH social isolation, Duruöz Hand Scale, FIM motor, FIM cognitive and FIM total scores. **Conclusion:** Even though most of the outcome measures improved significantly in both groups, electrical stimulation applied to the forearm in addition to a conventional rehabilitation program was more effective in decreasing the spasticity and increasing range of motion of the wrist in hemiplegic upper extremity rehabilitation due to stroke when compared to a conventional program only. Furthermore, the combined program had more favorable effects on physical activity and sleep.

Keywords: Stroke; upper extremity; electrical stimulation; muscle spasticity; quality of life; rehabilitation

ÖZET Amaç: Kronik inmeli hastalarda konvansiyonel rehabilitasyona ek olarak; el bileği ve parmak ekstensörlerine uygulanan elektrik stimülasyonunun, el bileğinde spastisite, el motor fonksiyonu, yaşam kalitesi üzerine etkisini araştırmaktır. **Gereç ve Yöntemler:** Hastalar tedavi (n=20) ve kontrol (n=20) grubu olmak üzere iki gruba randomize edildi. Tedavi grubundaki hastalar hemiplejik üst ekstremiteye yönelik konvansiyonel rehabilitasyon programına ek olarak; üç hafta, haftada beş gün, günde 30 dk yüzeyel nöromusküler elektrik stimülasyonu tedavisi aldı. Kontrol grubu yalnız konvansiyonel rehabilitasyon programına alındı. Tüm hastalar tedavi öncesi ve sonrası değerlendirildi. Hemiplejik üst ekstremite motor fonksiyonları ve spastisitesi sırasıyla Brunnstrom Motor Evrelemesi, Fugl Meyer Değerlendirme Skalası (FMDS) ve Modiye Ashworth Skalası (MAS), ile değerlendirildi. Aynı zamanda Duruöz El indeksi, Fonksiyonel Bağımsızlık Ölçeği (FBÖ) ve Nottinhgam Sağlık Profili (NSP) uygulandı. **Bulgular:** Tedavi ve kontrol gruplarında tedavi öncesi ve sonrası değerlerin farkları karşılaştırıldığında; el bilek ekstansiyonu açısı (p<0,001), el bileği MAS değeri (p=0,012), NSP uyku (p=0,036) ve NSP fiziksel aktivite skor farkı (p=0,043) tedavi grubunda anlamlı derecede yüksek idi. Üst ekstremite Brunnstrom Motor Evrelemesi, FMDS, dirsek MAS, NSP ağrı, emosyonel reaksiyonlar, sosyal izolasyon skorları, Duruöz El indeksi, FBÖ motor, FBÖ kognitif, FBÖ total değerleri farkı bakımından gruplar arasında anlamlı fark yoktu. **Sonuç:** Her iki grupta da son durum ölçeklerinin büyük bir kısmı istatistiksel olarak anlamlı düzelme göstermiş olsa da inmeye bağlı hemiplejik üst ekstremite rehabilitasyonunda konvansiyonel rehabilitasyon programına ek olarak uygulanan ön kol elektrik stimülasyonu tedavisi, yalnız konvansiyonel rehabilitasyon programı ile karşılaştırıldığında, el bileğinde spastisiteyi azaltmakta, eklem hareket açıklığını artırmakta daha etkindi. Ayrıca, kombine program fiziksel aktivite ve uyku üzerine daha fazla olumlu etkiye sahip idi.

Anahtar Kelimeler: İnme; üst ekstremite; elektrik stimülasyonu; kas spastisitesi; yaşam kalitesi; rehabilitasyon

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Stroke is a major health burden, and with increasing incidence together with the rise in the elderly population, health care costs for management of this disease are also increasing.[1] The loss of muscle control, abnormal movement patterns, and spasticity are present in the upper extremity of individuals with stroke. These problems lead to disturbed shoulder biomechanics which is the most frequent upper extremity problem in stroke. Brachial plexus and peripheral nerve lesions, complex regional pain syndrome, heterotopic ossification, and thalamic pain are other complications that occur in the upper extremity of stroke patients.[2] The functional independence level after stroke is associated with the motor impairment, and the predictor of the functional prognosis of the upper limb is related with the severity of the initial motor involvement.[3]

Conventional methods, neurophysiological treatment methods, functional electrical stimulation (FES) biofeedback techniques, and orthoses are used in rehabilitation.[4,5] Conventional methods consist of exercises to provide normal range of motion (ROM) of joints, adequate muscle strength, balance and mobility and activities of daily living training. Pasive and active exercise programs are applied.[4]

Spasticity is a symptom which develops after lesions of the brain and/or spinal cord. After a stroke, spasticity affects activities of daily living, and may sometimes hinder the rehabilitation program. Shoulder pain is also more frequent in patients with spasticity.[6] Electrical stimulation decreases spasticity by increasing the nerve activity of Ib fibers, facilitating the recurrent inhibition of Renshaw cells, and inhibiting the antagonists reciprocally.[7] The localization of electrical stimulation applied are to agonists, antagonists or both.[6] Electrical stimulation applied in the early stage after acute stroke has been shown to prevent contracture, and decrease spasticity.[7-9] Electrical stimulation is reported to be effective in improving activities of daily living, increasing ROM, and improving motor function.[7] Electrical stimulation of the upper limb is used in stroke rehabilitation programs with the aim of facilitating and accelerating motor function, muscle training, prevention of shoulder subluxation, decreasing hand edema, and decreasing spasticity.[10]

The aim of this randomized controlled study was to investigate the effect of electrical stimulation of the wrist and finger extensor muscles in addition to the conventional rehabilitation program on hand motor function, wrist spasticity, hand related activity limitation and quality of life in individuals with chronic stroke which developed as a result of a cerebrovascular event.

MATERIAL AND METHODS

This prospective cohort study was performed with the approval of the Institutional Review Board of Ankara Physical Medicine and Rehabilitation Training and Research Hospital. Informed consent for participation in the study was obtained from all patients or a family member of the patient. The study was designed is in compliance with the Helsinki Decleration (2008).

PATIENTS

This study included 40 individuals with stroke, who were hospitalized in Ankara Physical Medicine and Rehabilitation Training and Research Hospital for hemiplegia rehabilitation. Patients with disease duration of 6 months to 2 years, stable general medical condition, spasticity of the elbow and wrist on the hemiplegic side [≥2 on the Modified Ashworth Scale (MAS)], and sufficient cognitive function to understand the implementation were included in the study. Patients with a pacemaker or metal implant, severe arrhytmia, decompensated heart disease, active infection, tumor, bilateral hemisphere involvement, traumatic brain damage, multiple sclerosis, Parkinson, convulsion, a history of previous upper limb botulinum toxin injection, previous disease affecting the upper limb (arthritis etc), skin lesion at the site of the application, joint contracture, and those who were not able to tolerate the application were excluded from the study.

For each patient, a record was made of age, gender, comorbidities, time elapsed since stroke, and hemiplegic side.

DESIGN OF THE STUDY

The patients were randomized with the sealed envelope method into two groups as a control (n=20) and a treatment group (n=20). Patients in the treatment group received surface neuromuscular electrical stimulation to the wrist and finger extensors of the hemiplegic upper extremity (m.extensor carpi radialis longus and brevis, m. extensor digitorum comminis, m. extensor indicis proprius, m. Extensor pollicis longus and brevis) for 30 minutes, 5 days a week for 3 weeks in addition to conventional rehabilitation. The conventional rehabilitation program included neurodevelopmental treatment (Bobath method), ROM exercises, progressive resistive exercise, heat application and stretching for the upper extremity.

Surface neuromuscular electrical stimulation was delivered using Optimed Ultra Electronic Pulse Massager Opti-110 equipment (double output and 4 electrodes). Current duration was 200-500 msn, frequency 20-50 Hz and on-off time 2 s - 2s.[11] The control group received conventional rehabilitation program only. All the cases in the control and treatment groups were evaluated before and after treatment.

CLINICAL OUTCOME MEASURES

Hemiplegic upper extremity and hand motor functions were evaluated using the Brunnstrom Motor Recovery Stages, and the Fugl Meyer Assessment Scale (FMAS).[12,13] Spasticity of wrist was evaluated with the MAS, and the functional level of activities of daily living was assessed with the Functional Independence, Measure (FIM).[14,15] The Duruöz Hand Scale (DHS) was used to assess the limitation of activities related with hand.[16] Quality of life was assesed using the Nottingham Health Profile (NHP).[17]

The presence of any limitation in ROM of the wrist, elbow and shoulder was assesed and recorded before and after treatment. Active extension range of the wrist was measured while the patient was sitting with the forearm pronated. The centre of the goniometer was placed on the styloid of the ulna.

The Fugl Meyer Assessment Scale is a valid and safe method assesing shoulder, elbow, forearm, wrist and hand coordination and velocity parameters, with a total maximum score of 66 for the upper extremity.[13]

The Functional Independence Measure is a valid and reliable tool which assesses the functional level of activities of daily living. The FIM consists of 18 items in two sections of motor-FIM [13 items; selfcare (6 skills), control of sphincter (2 items) mobility (3 skills), locomotion (2 items)] and cognitive-FIM [5 items; language (2 items) and psychosocial skills (3 items)]. Each item is assesed with a Likert scale, which indicates the care level (1= totally dependent, 7= totally independent).[15]

The NHP quality of life assessment measure consists of 38 items in 6 subgroups of energy level, pain, physical activity, sleep, emotional reactions and social isolation. Higher scores indicate that patients have more difficulties.[17]

The Duruöz Hand Scale was developed for the evalution of hand related activity limitations in patients with rheumatoid arthritis.[16] The DHS is an easily applicable questionnaire, the reliability and internal consistency of which have been studied with repeated tests in stroke patients.[18] The answers are evaluated using a likert scale with 6 grades (0-5) with a total score range of 0-90. The subjects are asked to state the level of difficulty during activities performed without any aids; higher scores indicate more limited activities.[16]

STATISTICAL ANALYSIS

The control and treatment groups were evaluated before and after treatment. SPSS for Windows 15.0 software was used for analysis of the data. The distribution of continuous variables was investigated using Shapiro Wilk Test. Descriptive statistics for continuous variables were indicated as mean±standard deviation (SD) and median (interquartile range or minimum-maximum), and descriptive statistics for categorical variables were indicated as number of cases (n) and percentage (%).

The Wilcoxon Sign Rank Test was used to compare changes before and after treatment within the group, for both groups. The significance of between-group variance in terms of median values was assessed using the Mann Whitney U Test. Categorical variables were evaluated with Pearson's Chi-square Test or Fisher's Exact Test. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

The study included 40 individuals with stroke. The treatment group of 10 males and 10 females received electrical stimulation in addition to conventional rehabilitation, while the control group of 8 males and 12 females received only conventional rehabilitation. The mean age was 64.50±10.53 years (range, 47-87) in the treatment group and 61.25±7.64 years (range 49-79) in the control group. No statistically significant difference was determined in respect of age between the groups. The duration of disease was 10.60±4.42 months (range, 6-24 months) in the treatment group, and 10.40±3.97 months (range, 6-22 months) in the control group with no statistically significant difference between the two groups (p=0.946).

When the groups were compared in terms of affected side (p=0.527), stroke type (p=0.705) and dominant hemisphere (p=0.507), no statistically significant difference was determined (Table 1).

The pre-treatment values of the treatment and control groups indicated no statistically significant differences (Table 2).

In the comparison of changes before and after treatment within the groups statistically significant increases were determined in the ROM of wrist ex-

TABLE 1: The comparison of general characteristics between the groups (n=40).

	Treatment group (n=20)	Control group (n=20)	P
Gender (Male/Female)	10/10	8/12	0.525
Type of Stroke (Ischaemic/Hemorrhagic)	15/5	16/4	0.705
Side of Hemiplegia (Right/Left)	9/11	11/9	0.527
Age (years) (Mean ± SD)	64.5±10.5	61.25±7.6	0.271
Time elapsed since CVA (months) (Mean ± SD)	10.60±4.42	10.40±3.97	0.946

TABLE 2: The comparison of pre-treatment variables in the treatment and control groups for (n=40).

	Treatment Group (n=20) (Median)	Control Group (n=20) (Median)	p value
BRSof upper extremity	2	2	0.678
BRS of hand	2	2	0.067
MAS value of wrist	2	3	0.348
MAS value of elbow	3	2	0.747
FMAS upper extremity score	7.5	5	0.358
Pain Item Score of NHP	50	56.25	0.623
Emotion Item Score of NHP	66.6	66.6	0.837
Sleep Item Score of NHP	80	60	0.095
Physical activity Item Score of NHP	87.5	87.5	0.940
Social isolation Item Score of NHP	30	60	0.366
Energy Item Score of NHP	99.9	66.6	0.319
Duruöz Hand Scale	90	90	0.409
Wristextension angle (degrees)	21.43	19.58	0.578
FIM motor score	22.5	24.5	0.860
FIM cognitive score	32.5	28	0.336
FIM total score	56	48	0.920

NHP: Nothingam Health Profile; BRS: Brunnstrom motor recovery stage; MAS: Modified Ashworth Scale; FIM: Functional Independence Measure.

tension, in the Brunnstrom Motor Stage of the upper extremity and hand, in the FMAS upper extremity values and in all the FIM scores. Statistically significant decreases were determined in the spasticity level of the elbow and wrist, Duruöz Hand Scale, and NHP (all of the 6 subgroups) in both groups (Table 3).

The variance of wrist extension angle (p=0.01), MAS value of the wrist (p=0.012), NHP sleep (p=0.036), and NHP physical activity scores (p=0.043) were significantly higher in the treatment group than in the control group. The difference of variances between the groups was not significant for the Brunnstrom stage of upper extremity or hand, FMAS upper extremity, Modified Ashworth Scale of elbow, FIM motor, FIM cognitive and FIM total scores, Duruöz hand scale score, NPH pain, NPH emotional, and NPH social isolation (Table 4).

DISCUSSION

This study showed that both conventional rehabilitation and electrical stimulation in addition to conventional rehabilitation programs improved ROM, motor function, spasticity, hand related activity limitation, activities of daily living, and quality of life related measures in individuals with stroke. Even though all the above measures improved significantly in both groups, electrical stimulation applied in addition to the conventional rehabilitation added more benefit, particularly in wrist spasticity, wrist extension angle, NHP sleep and physical activity sub-dimension. This study can be considered to add valuable knowledge to the

TABLE 3: The comparison of pre and post treatment values for each groups (n=40).

	Treatment Group (n=20)			Control Group (n=20)		
	Pretreatment (Median)	Posttreatment (Median)	p değeri	Pretreatment (Median)	Posttreatment (Median)	p value
BRS of upper extremity	2	4	0.002	2	3	0.008
BRSof hand	2	4.5	0.001	2	3	0.001
MAS value of wrist	2	0	0.000	3	1.5	0.002
MAS of elbow	3	2	0.002	2	2	0.001
FMAS upper extremity score	7.5	27.5	0.002	5	15.5	0.002
Pain Item Score of NHP	50	37.5	0.003	56.25	43.75	0.000
Emotion Item Score of NHP	66.6	27.7	0.000	66.6	44.4	0.001
Sleep Item Score of NHP	80	30	0.001	60	40	0.004
Physical activity Item Score of NHP	87.5	37.5	0.000	87.5	62.5	0.001
Social isolation Item Score of NHP	30	20	0.002	60	30	0.002
Energy Item Score of NHP	99.9	33.3	0.011	66.6	33.3	0.003
Duruöz Hand Scale	90	37,5	0.000	90	68	0.001
Wrist extantion angle (degrees)	0	50	0.000	0	17.5	0.000
(Mean ± SD)	15,5±21,5	46,7±21,9		11,0±18,8	21,0±17,0	
(75%quarter)	28.75	63.75		21.25	30	
Limitation of elbow n(%)						
Yes	8 (%40)	3 (%15)	0.059	10 (%50)	5 (%25)	0.025
No	12 (%60)	17 (%85)		10 (%50)	15 (%75)	
Limitation of shoulder n(%)						
Yes	9 (%45)	3 (%15)	0.034	10 (%50)	7 (%35)	0.83
No	11 (%55)	17 (%85)		10 (%50)	13 (%65)	
FIM motor	22.5	64	0.000	24.5	37	0.000
FIM cognitive	32.5	38	0.001	28	33	0.00
FIM total	56	98.5	0.000	48	65	0.00

NHP: Nothingam Health Profile; BRS: Brunnstrom motor recovery stage; MAS: Modified Ashworth Scale; FIM: Functional Independence Measure.

TABLE 4: The comparison of the treatment and the control groups for the pre and posttreatment changes (n=40).

	Treatment (n=20) median	Control (n=20) median	P
BRSof upper extremity	0.95	0.5	0.140
BRS of hand	1.15	0.8	0. 488
MAS value of wrist	1.6	0.9	0.012
MAS value of elbow	0.65	0.55	0.737
FMAS upper extremity score	7.4	3.8	0.547
Pain Item Score of NHP	15.8	16.5	0.955
Emotion Item Score of NHP	28.8	21.09	0.349
Sleep Item Score of NHP	27.0	13	0.036
Physical activity Item Score of NHP	27.5	16.3	0.043
Social isolation Item Score of NHP	22	18	0.863
Energy Item Score of NHP	23.31	23.31	0.703
Duruöz Hand Scale	26	12.2	0.121
Wrist extantion angle (degrees)	31.25	10.0	0.000
FIM motor	20.75	10.45	0.551
FIM cognitive	4.9	3.6	0.691
FIM total	25.5	15.5	0.472

NHP: Nothingam Health Profile; BRS: Brunnstrom motor recovery stage; MAS: Modified Ashworth Scale; FIM: Functional Independence Measure.

literature by presenting the outcomes of electrical stimulation in addition to conventional rehabilitation on quality of life and hand related activity limitation.

In the current study, the NHP physical activity score improved more in the treatment group. Even though most of the NHP physical activity items concern the lower extremity, items about reaching and dressing are related to the upper extremity.[17] Therefore, decreased spasticity in the wrist, and increased wrist extension in the treatment group with the addition of electrical stimulation to conventional rehabilitation could explain the better physical activity scores. The improvement in NHP sleep scores might be due to the decreased effect of the spasticity on sleep quality and uninterrupted sleep during the night.

Şahin et al. showed that electrical stimulation of wrist extensors applied in addition to heat and stretching was superior to a heat and stretching program in respect of improvement of FIM, MAS, wrist ROM and Brunnstrom Motor Stages in stroke survivors suffering from wrist spasticity (Ashworth 2-3) with disease duration >1 year.[7] Similarly, in the current study the improvement in wrist spasticity and ROM was superior in the treatment group. However there was no difference between the groups in the pre- and post- treatment variance of Brunnstrom motor stage and FIM total. This may have been due to the improvement of FIM scores and Brunnstrom motor stages with conventional rehabilitation. In addition, pretreatment values of FIM scores and Brunnstrom motor stages were lower, and the patients were older in the current study than in the previously mentioned study. The older average age of the current sample and the lower initial scores could be the reason for the insignificant difference in motor improvement and participation in activities of daily living.

One of the topics about electrical stimulation in stroke may be the timing, and there are reports in the literature of early, very early or chronic disease studies and case reports.[8,9,19] Malhotra et al. reported that electrical stimulation applied in addition to routine therapy consisting of exercises in the early period of acute stroke was useful in preventing contractures but not effective on wrist spasticity or stiffness.[8] In that study, spasticity of the wrist was not an inclusion criterion. In the early period after stroke, spasticity may not be prominent whereas it becomes more evident over the course of the disease. Thus, in that study the ineffectiveness of electrical stimulation on spasticity might be due to the course of the disease and neurodevelopmental stages.[4] The current study was different from that study as patients at the chronic stage with the spasticity of the wrist were included. Therefore in the current study electrical stimulation was more effective in decreasing spasticity.

Yan et al. also assessed the effect on walking and motor movements of functional electrical stimulation of agonist and antagonist lower extremity muscle groups with a timing mimicked gait in addition to a conventional rehabilitation program in the very early period of stroke. A significant decrease in lower extremity spasticity and an increase in the torque of ankle dorsoflexion were determined.[9] That study also showed decreased spasticity in the lower extremity with a program consisting of electrical stimulation plus rehabilitation but was different in respect of the time elapsed since the event.

The improvement in upper extremity motor function after 2 weeks of functional electrical stimulation application of the distal upper extremity in addition to conventional rehabilitation was also reported in a case report of an individual with acute stroke.[20] In that case, electrical stimulation was applied in an acute rehabilitation program. In both the acute and chronic periods, electrical stimulation has benefits on different problems.[7-9,20] The timing of electrical stimulation in stroke may be another topic to be clarified in rehabilitation, thereby enabling problem targeted management.

In a randomized controlled study by Hara et al., power assisted functional electrical stimulation was applied to the extensor carpi radialis longus and brevis, extensor digitorum communis, extensor digitorum proprius, and deltoid muscles, for 30-60 minutes/day, 6 days/week as a home program for a period of 5 months. The system which was used by Hara et al., picks up EMG signals from the muscles with contraction and sends stimulation to amplify target muscle contraction. Muscles with no contraction were not stimulated. Even though that study was somewhat different with the exercise component and active participation to muscle contraction, the localization of the electrical stimulation of forearm muscles, resultant increase in wrist extension and decrease in spasticity of the upper limb were similar to the current study.[19] Those results and the current study results support the effectiveness of stimulation on wrist extension and spasticity.

In addition to muscle stimulation studies there have also been nerve stimulation studies. Stefanvoska et al. investigated the effect of chronic peroneal nerve stimulation (for 6 months) on reflex hyperactivity and voluntary movements in hemiplegic patients. They showed a decrease in resistance to passive movement, and an increase in voluntary control after 12 months follow-up. It was concluded that the improvement in spasticity could not be distinguished from spontaneous improvement.[21] Although the aim and stimulation type of the current study were different, the site, application duration and improvement of spasticity after electrical stimulation were similar.

Lai et al. showed that peripheral median nerve stimulation for 40 minutes enhanced EMG-EEG coherence-(during steady thumb flexion) in both healthy subjects and individuals with stroke. Improved force steadiness was also determined and it was concluded that increased coherence might be related to electrical stimulation related changes in the neuromuscular system. The improvement in motor performance may be related to electrical stimulation induced strong sensory input and increased sensorymotor integration.[22] In a review by Weingarden et al. about functional electrical stimulation induced neural changes and recovery after stroke, the possible connection of the peripheral nerve system and brain plasticity was also emphasized.[23] Thus the mechanisim of the current study results may be related with those connections. There is a need for experimental investigation of muscle stimulation and brain responses to clarify the underlying mechanism of improvement and this could be another topic for future studies.

STUDY LIMITATIONS

This study has some limitations. All the patients in the control group also received treatment due to ethical restrictions. This conventional rehabilitation program was applied to the subjects according to the needs of the patients. Even though all the programs included ROM, neurodevelopmental treatment, progressive muscle strengthening, heat and stretching exercises, the therapists were not always the same. The number of patients was small. Although interrater agreement for MAS for the wrist flexor muscles has been reported as high, the intrarater measurements have not been good.[24] More reliable measurement scales are still needed.

In conclusion both conventional rehabilitation and electrical stimulation applied in addition to conventional rehabilitation improve the hemiplegic upper extremity. However, electrical stimulation in addition to a conventional rehabilitation program is more effective in decreasing the spasticity and, increasing the ROM of the hemiplegic wrist compared to conventional program only. Furthermore, greater improvements were observed in physical activity and sleep with the addition of electrical stimulationin to conventional rehabilitation compared to conventional rehabilitation only.

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