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Effects of Mental Activity Training Linked With Electromyogram-triggered Electrical Stimulation on Paretic Upper Extremity Motor Function in Chronic Stroke Patients: A Pilot Trial

Kronik Felçli Hastalarda Paretik Üst Ekstremite Motor Fonksiyonları Üzerinde Elektromiyografi ile Tetiklenen Elektrik Stimülasyonu Eşliğinde Mental Aktivite Eğitiminin Etkileri: Pilot Çalışma

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Summary

Objective: To study whether mental activity training linked with electromyogram-triggered electrical stimulation (MAT-EMG) improves motor function of a paretic upper extremity in chronic stroke patients.

Materials and Methods: Eighteen patients with chronic stroke for more than 12 months were included in the study. Nine patients were randomly allocated to MAT-EMG and 9 to generalized functional electrical stimulation (FES) on the forearm extensor muscles of the paretic extremity 20 times over 4 weeks, for 40 minutes/session. Outcome measures were: active range of motion (ROM) of the wrist joint, strength of the forearm extensor muscles, the modified Ashworth scale (MAS), Fugl-Meyer motor assessment for the upper extremity (FMM-UE), motor activity log (MAL) and the modified Barthel index (MBI) scores.

Results: The group receiving MAT-EMG improved by 6.13 points in FMM-UE scores ($p<0.05$), and the group receiving FES improved by 1.13 points, after intervention. There was a significant difference in FMM-UE scores between the two groups. This was caused by the noticeable increase in the FMM-UE wrist and shoulder scales in the MAT-EMG group. However, nosignificant difference was observed in other measures between the groups.

Conclusion: We found that MAT-EMG had a greater effect than FES on recovery of motor function in the paretic extremities of chronic stroke patients. *Turk J Phys Med Rehab 2013;59:133-9.*

Key Words: Mental activity, electromyogram-triggered electrical stimulation, functional electrical stimulation, stroke

Özet

Amaç: Elektromyografi ile yapılan elektrik stimülasyonu eşliğinde mental aktivite eğitiminin (MAT-EMG) kronik felçli hastalarda paretik üst ekstremite motor fonksiyonunun iyileştirilmesindeki yararının incelenmesi.

Gereç ve Yöntem: On sekiz felçli hasta (12 ay ve daha fazla süredir) çalışmaya dahil edildi. Paretik ekstremite önkol ekstansör kaslarına 4 haftada 20 kez 40 dakikalık seanslar halinde MAT-EMG rastgele seçilen 9 hastaya, genel fonksiyonel elektrik stimülasyonu (FES) ise diğer dokuz hastaya uygulandı. Sonuçlar, uygulama öncesi ve sonrası yapılan Modifiye Ashworth Skalası (MAS), Fugl-Meyer Motor Testi (FMM-UE), Motor Aktivite Logu (MAL), Modifiye Barthel İndeksi (MBI) ile birlikte, el bileği eklemi aktif hareket açıklığı (ROM) ve ön kol ekstansör kaslarının dayanıklılık ölçümü ile değerlendirildi.

Bulgular: Gruplar arasında FMM-UE skorları bakımından anlamlı fark görüldü. MAT-EMG uygulanan grup uygulama sonrasında 6,13 puan ilerleme kaydetti ($p<0,05$). FES grubu 1,13 puan ilerleme gösterdiyse de, grup içi fark istatistiksel olarak anlamlı değildi. MAS skorları MAT-EMG grubunda, ROM ise her iki grupta önemli ölçüde gelişme gösterdi. Ancak MAS ve ROM skorları açısından gruplar arasında önemli bir fark görülmedi.

Sonuç: Kronik felçli hastalarda paretik ektremite motor fonksiyonlarının iyileşmesinde MAT-EMG nin FES den daha fazla etkisi olduğu görüldü. *Türk Fiz Tıp Rehab Derg 2013;59:133-9.*

Anahtar Kelimeler: Mental aktivite, elektromiyografi ile elektrik stimülasyonu, fonksiyonel elektrik stimülasyonu, felç

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Introduction

Paresis of the upper extremities after stroke may limit the overall function in patients and has a negative effect on body image, resulting in psychological problems. In patients with little or no volitional action at paretic sites after 6 months or longer, contracture of the joints, loss of motor skills, and whole-body dysfunction may worsen. Conventional therapy, such as neurodevelopmental treatment does not effectively address these problems (1). Recently, constraint-induced movement therapy was introduced to manage stroke patients with paretic upper extremities (2,3). However, in patients with little or no motor function in the paretic hand or arm, the therapy is difficult to apply. Alternatively, neuromuscular electrical stimulation is a current approach for improving wrist and finger extension (4,5). Generalized functional electrical stimulation (FES) consists of cycles of contraction and rest due to preset, repetitive electrical stimulation requiring no volitional action of the patient (6,7). Another type of electrical stimulation, electromyogram (EMG)-triggered electrical stimulation, is an approach that elicits muscle contraction through EMG signals generated by voluntary muscle activity in the affected muscle (8,9). In previous studies, EMG-triggered stimulation was reported to have a greater effect on motor activity and functional ability than simple and preset electrical stimulation (4). However, these studies did not show a significant difference between EMG-triggered stimulation and FES (8-10).

Recently, mental practice (MP) has been introduced as another rehabilitation technique to improve motor function in stroke patients. MP was known to activate the same neuromuscular structures as physical practice of the same skills. But most studies on MP were conducted including physical practice (11,12). Some researchers asserted that they did not find any benefit of mental activity training in stroke patients (13). Therefore, further studies about the effect of MP are needed.

Mental activity training linked with EMG-triggered electrical stimulation (MAT-EMG) introduced in this trial is an approach that improves motor function of a paretic extremity by repetitive training using mental imaging (such as thinking of elevating or waving the hand or arm) combined with an instrument built in EMG. In this intervention, mental activity training was the main concern, and EMG-triggered stimulation is used as a tool to improve ability to execute the mental activity.

In this trial, mental activity training was an ideomotor training that the subject practiced mentally without executing the real movement. The patient imagined a specific movement (for example, waving the hand, or extending the wrist) earnestly and the observable muscle contraction was controlled strictly.

The practical process of this intervention was fulfilled through an instrument equipped with EMG. During executing a mental activity, electrical potentials were generated in the muscle cells, and were picked by the instrument. When the potentials reached a preset threshold, the instrument induced electrical stimulation automatically to elicit muscle contraction (Figure 1).

On the screen of the instrument, there was a display showing the amplitude of EMG potentials attained through mental activity, and it was used for visual feedback. In addition, electrical stimulation linked with mental activity acted as a somatosensory cue to support the execution of the training.

The purpose of this trial was to determine if the MAT-EMG had a significant effect on improving motor activity of paretic upper extremities and to compare MAT-EMG and FES.

Materials and Methods

Subjects

The participants were recruited from the rehabilitation center of a university hospital. We interviewed 31 patients with paretic upper extremity for more than 12 months after stroke. Eighteen subjects were enrolled and the remainders were excluded because of very severe spasticity [modified Ashworth scale (MAS) grade 3 or 4] or complete flaccidity of the upper extremity [Medical Research Council scale (MRC) grade 0], impaired cognitive function, or long distance between hospital and home.

Inclusion criteria were: (1) ≥12 months after stroke, (2) willing to receive intervention, (3) mini-mental state examination score ≥24, (4) active extension of the wrist ≤20°, and (4) ability to perform electrical stimulation through MAT-EMG without assistance. Exclusion criteria were: (1) cardiac pacemaker, (2) severe pain in the paretic upper extremity, or (3) skin lesion, hypersensitivity, or peripheral nerve injury at the electrode site.

Written informed consent was obtained from each subject prior to the trial. The trial protocol was approved by the hospital IRB (institutional review board).

The subjects were divided into two groups by block randomization method using randomization envelopes containing a code specifying the group. Nine patients received MAT-EMG and 9 received FES.

Intervention

Mentamove (Mentamove Deutschland GmbH, Munich, Germany) was used for MAT-EMG and Microstim (Medel GmbH, Germany) for FES. In Mentamove the surface electrodes were applied for the measurement of EMG signals till 2 μV (self-adhesive special electrodes, oval shape, 40x60 mm, Axelgaard Manufacturing), and in FES, self-adhesive NMES electrodes (square shape, 48x48 mm, Bio-Protech). The electrodes of the two instruments were respectively attached on the forearm extensor muscles of the paretic extremity. Both interventions were carried out 20 times, via two 20-minute sessions over about 4 weeks. The patients were not limited with regard to other rehabilitation treatments.

The picture for the display of the instrument is shown in Figure 2. The menu of training stages was composed of mental activity (maximum 12 sec), stimulation (6 sec), and relaxation

(12 sec). The stimulation threshold was set to the sum of the resting intensity (electric signal gained during relaxation without mental effort) and the offset value. The offset value was the value of the signal intensity attained through mental activity for stimulation and was administered by the operator before the beginning of the intervention. The display of the EMG potentials captured during mental activity was indicated by the lower one of the two crossbars on the monitor, and when subjects executed mental activity properly, the crossbar grew to the right.

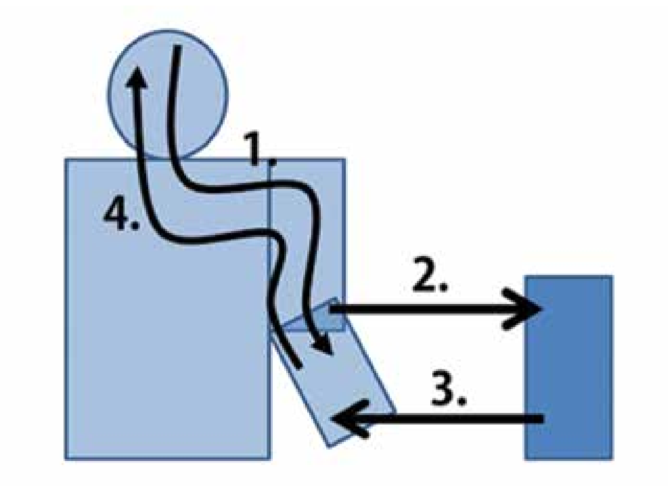

Figure 1. Processes of mental activity training linked with EMG-triggered electrical stimulation. 1. During mental activity, Action potentials from the brain reach axon terminal on forearm, and a change of EPP, non-propagating reversals of the end-plate potential, occurs. 2. The instrument picks up these EPPs on the forearm. 3. When the potentials reach a preset threshold, automatic electrical stimulation was triggered. 4. The cortical activation occurs by somatosensory and visual feedback.

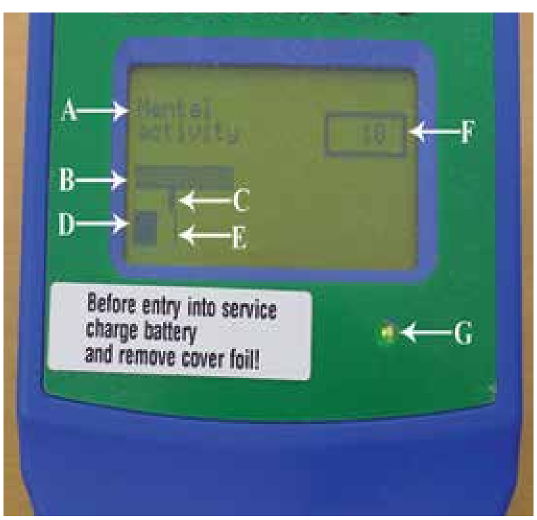

Figure 2. Displays of the instrument screen. A: the menu of training stage, B: the current offset value, C: stimulation threshold, D: the EMG potentials picked up from muscles activated by mental practice, E: the maximum amplitude of the EMG potentials gained during mental activity, F: the numerical value of the EMG potentials, and G: light-emitting diode.

Adjustments to this modality included the following: (1) Stimulation intensity was increased stepwise until movement of the finger and wrist occurred; (2) offset value was 5 μV (when current voltage for mental activity exceeded this offset value, the stimulator performed electrical stimulation); (3) stimulation time was 6 sec; (4) break time (relaxation time) was 12 sec; (5) maximum time for mental activity was 12 sec; and (6) correction factor was 10% (whenever 3 trials were performed successively or not, offset value increase or decrease automatically by the adjusted value of correction factor).

The process of MAT-EMG was conducted as follows: (1) The patients were rehearsed enough to use a meaningful mental activity (thinking of waving the whole arm earnestly in this trial) (2). Working menu in LCD monitor displayed 'Please relax'. The subjects were completely relaxed in a comfortable position to avoid movement as much as possible, and showed the EMG potential at resting level displayed in the monitor for control of the relaxation (3). After 12 seconds, working menu was changed into 'Mental activity', and then, the light-emitting diode below the display flashed green. The subjects started the mental activity and executed a meaningful movement mentally. They were instructed to imagine waving their own hand as much as possible. Then they were asked not to use any observable muscle contraction and guided to use metal activity only by therapists throughout the treatment. (The patients were given 12 seconds for mental activity. When they generated the potential to reach threshold in time, immediately the instrument induced electrical stimulation, and when they executed successfully, 12 seconds were given again. In case that they failed more than 3 times, the threshold was declined automatically) (4). When the EMG potential due to mental activity reached threshold, working menu was changed into 'Stimulation active', and the diode showed the red color. At the same time, the instrument induced electrical stimulation to contract muscles (4). After stimulation for 6 seconds, the red color of the diode went out and the menu 'Please relax' reappeared.

To evaluate whether the contraction of the target muscle occurred or not during executing the mental activity training of this trial, a diagnostic electromyograph (Medelec Synergy EMG and EP system, software version 11, Oxford Instruments; lower filter-10 Hz, high filter-10 KHz, sensitivity-50 μV) was used. Parameters of the EMG were low frequency filter of 10 Hz, high frequency filter of 10 KHz, and a sensitivity of 50μV. The needle electrode (disposable concentric needle electrode, length 25 mm, diameter 0.30 mm, recording area 0.019 mm^2, Nihon Kohden) was inserted into the extensor digitorum muscle alongside electrodes of the instrument. Consequently, during mental activity, the crossbar of the display (showing the amplitude of signals detected by the instrument) increased, but no motor unit action potentials (MUAPs) were found in the electromyography using needle electrode. That meant that no muscle contraction occurred during the mental activity training.

Additionally, to analyze the signals picked by the instrument, surface electrodes (disposable adhesive 4-disk electrodes, 20 mm diameter disk, Hurev), instead of the needle electrode, were used in the same mode of the electromyograph. They were attached to the extensor digitorum muscle alongside electrodes of the instrument. During executing mental activity, some small waveforms with amplitudes under 50 μV were detected on the EMG screen. Immediately before the potential of signals (picked up by the instrument) reached the threshold to trigger electrical stimulation, they increased in number and amplitude. Thus, it was reasoned that the signals picked up by the instrument during mental activity were caused by the end-plate potential (EPP, the summation of multiple miniature end-plate potential) that did not exceed the muscle membrane threshold level to produce a muscle fiber action potential resulting in an observable muscle contraction (14).

Table 1. Baseline Characteristics.

	FES (n=8)	MAT-EMG (n=8)
Gender		
Male	4 (50.0%)	6 (75.00%)
Female	4 (50.0%)	2 (25.00%)
Age, years		
Mean (SD)	51.25 (11.02)	54.25 (12.44)
Stroke type		
Ischemic	5 (62.50%)	5 (62.50%)
Hemorrhagic	3 (37.50%)	3 (37.50%)
Paretic side		
Right	6 (75.00%)	4 (50.0%)
Left	2 (25.00%)	4 (50.0%)
Time from stroke (months)		
Mean (SD)	40.75 (14.98)	36.00 (15.32)
MMSE		
Mean (SD)	27.88 (1.64)	28.63 (1.85)

FES: Functional electrical stimulation
MAT-EMG: Mental activity training linked with EMG-triggered electrical stimulation
MMSE: Mini-mental state examination
SD: Standard deviation

The FES was automatic, without voluntary activity or mental effort required to move the arm. Biphasic pulses with a frequency of 35 Hz and a pulse width of 200 μS were applied for 12 sec. The amplitude was adjusted to obtain an optimal response with no discomfort, pain, skin irritation, or muscle spasm (average 15-25 mA).

Outcome Measures

The ROM of the wrist joint was measured with a goniometer (SG75, ±2° error within a range of 90°, 10 Hz frequency) linked to a Biometrics DataLINK (Biometrics Ltd, UK). Sensors were attached to the medial border of the radius and the dorsal surface of the third metacarpal bone. The relaxed position with the hand pronated was defined as 0°. The ROM values were obtained depending on the degree of wrist joint extension.

The isometric muscular strength during wrist joint extension was measured using Biometrics DataLINK. EMG sensors were integral electrodes with a fixed electrode distance of 20 mm, fixed to the extensor digitorum and extensor carpi radialis muscles surface using die-cut, medical-grade, double-sided adhesive tape. The root mean square of the EMG signals due to maximal contraction for 5 seconds was defined as muscular strength.

Spasticity was measured using the MAS, and the functional performance of a paretic extremity was evaluated by the Fugl-Meyer Motor Assessment of Upper Extremity (FMM-UE), Amount of Use (AOU) scale, Quality of Movement (QOM) scale, and the Motor Activity Log (MAL). The performance and independence in

Table 2. Outcome Measures of Each Group.

	FES			MAT-EMG			p
	Before	After	Difference	Before	After	Difference	
ROM (deg)	16.00 (21.97)	20.90 (26.57)	4.95* (5.17)	23.80 (15.19)	34.49 (21.75)	10.69 * (9.19)	0.23
RMS (mV)	0.13 (0.08)	0.27 (0.11)	0.15 (0.23)	0.30 (0.17)	0.40 (0.23)	2.32 (5.59)	0.19
MAS	1.88 (1.25)	1.75 (1.16)	0.25 (0.46)	2.50 (0.76)	1.88 (0.99)	0.75* (0.46)	0.11
FMM	20.88 (11.74)	22.00 (12.77)	1.13 (1.64)	25.63 (10.03)	31.88 (12.91)	6.13* (3.40)	0.03*
AOU	7.75 (8.15)	9.25 (9.29)	1.50 (2.14)	11.88 (6.92)	16.13 (9.42)	4.25 (7.30)	0.72
QOM	8.25 (7.38)	9.13 (8.46)	0.88 (1.36)	16.75 (9.57)	20.88 (15.41)	4.13 (8.11)	0.96
MBI	72.50 (16.73)	73.75 (18.01)	1.25 (1.91)	86.00 (11.54)	87.75 (12.09)	1.75 (2.19)	0.72

FES: Functional electrical stimulation, MAT-EMG: Mental activity training linked with EMG-triggered electrical stimulation, ROM: Range of Motion of wrist joint, RMS: Root Mean Square of extensor muscles of forearm, MAS: Modified Ashworth Scale, FMM: Fugl-Meyer Motor Assessment of upper extremity, AOU: Amount of Use of Motor Activity Log, QOM: Quality of Movement of Motor Activity Log, MBI: Modified Barthel Index

NOTE. P values are results compared between groups. All values except P are mean and standard deviation of measures. Standard deviation was shown in parentheses.

*P<0.05

Table 3. Domains of Fugl-Meyer Motor Assessment of Upper Extremity.

	FES			MAT-EMG			
	Before	After	Difference	Before	After	Difference	p
Shoulder	18.50 (9.34)	18.63 (9.52)	0.13 (0.35)	21.25 (7.30)	24.13 (8.56)	2.88* (2.75)	0.03*
Wrist	1.00 (1.07)	1.75 (1.76)	0.75 (1.04)	0.75 (1.75)	3.63 (2.20)	2.75* (1.83)	0.02*
Hand	0.63 (0.74)	0.75 (0.89)	0.13 (0.35)	1.75 (2.31)	2.13 (2.64)	0.38 (0.74)	0.65
Coordination	0.75 (1.16)	0.88 (1.36)	0.13 (0.35)	1.88 (0.83)	2.00 (.93)	0.13 (0.35)	1.00

FES: Functional electrical stimulation, MAT-EMG: Mental activity training linked with EMG-triggered electrical stimulation, ROM: Range of Motion of wrist joint, RMS: Root Mean Square of extensor muscles of forearm, MAS: Modified Ashworth Scale, FMM: Fugl-Meyer Motor Assessment of upper extremity, AOU: Amount of Use of Motor Activity Log, QOM: Quality of Movement of Motor Activity Log, MBI: Modified Barthel Index

*P<0.05

*There was a significant difference between the wrist and shoulder of Fugl-Meyer Motor Assessment of upper extremity before and after intervention in MAT-EMG group (P value was 0.05).

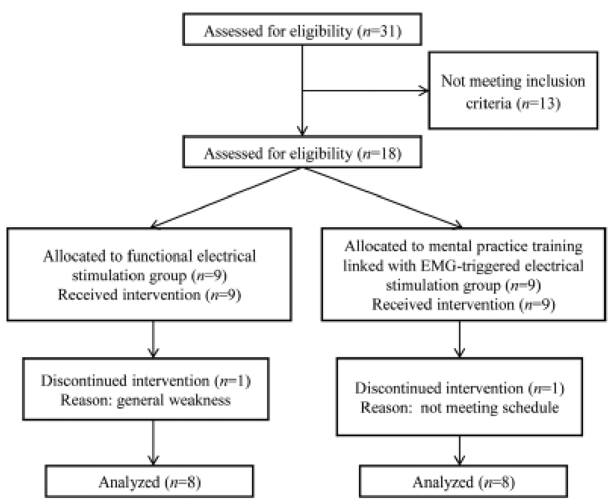

Figure 3. Flow diagram of the trial.

activities of daily living was measured using the modified Barthel index (MBI). All measurements were performed before and after intervention by two occupational therapists. They were blind for which group patients belonged to.

Analysis

To assess independence between the two groups before intervention, the independent t-tests were performed on age and time from stroke, and the Mann-Whitney U test was used on measures before the intervention. The Wilcoxon signed-ranks test was conducted to compare measures before and after intervention in each group. The Mann-Whitney U test was used to compare the change in outcome measures between the two groups. All data analyses were conducted using SPSS version 12.0 for Windows. The significance level was set at 0.05.

Results

The flow diagram is shown in Figure 3. Eighteen subjects were enrolled and 16 completed intervention. One in the MAT-EMG group was excluded from the analysis as he did not participate in the intervention several times. The other one in the FES group discontinued due to a severe upper respiratory tract infection.

Baseline characteristics are summarized in Table 1. In the comparison of the two groups before intervention, the MAT-EMG group had higher scores in the root mean square, QOM, MAL and the MBI. However, there were no significant differences between the two groups in the FMM-UE and the MAS related to motor function of the upper extremity.

Outcome Measures Before and After Intervention

Table 2 shows all outcome measures for both groups.

The ROM of the wrist joint increased significantly in both groups after intervention, but the difference in effect between the two groups was not significant.

The root mean square of forearm extensor muscles showed no difference before and after intervention in either group. No, significant difference was found in the change scores of the measure between groups.

The MAS score decreased significantly after the intervention in the MAT-EMG group. It also declined in the FES group but not significantly. The difference in the change scores between the two groups was not significant.

The FMM-UE scores increased significantly in the MAT-EMG group after intervention. However, the difference between the scores before and after the intervention in the FES group was not significant. A significant difference in the change scores of the measures between the two groups was shown, and the point changes in the MAT-EMG group were higher than the other group. Thus, MAT-EMG had a meaningful effect on improving the motor function of the paretic extremity, but FES did not.

There was no significant difference in AOU, QOM and MBI scores within and between the two groups.

Post hoc power analyses were done using G*Power 3.0.10 for comparing the changes in each outcome measure between the two groups. The power of FMM-UE scores was 0.97, and the others were less than 0.8.

Domains of the Fugl-Meyer Motor Assessment of Upper Extremity

The FMM-UE domain scores for both groups are shown in Table 3. A significant difference was observed before and after intervention in the wrist and shoulder scale for the MAT-EMG group but not for hand or coordination scales or for any scales in the FES group. Also, a significant difference was found in the change scores of each wrist and shoulder domain between groups.

Post hoc power analyses for the test comparing changes of each domain between the two groups were done using G*Power 3.0.10. The power of the shoulder and wrist score was 0.85 and 0.82 respectively, and the other two were less than 0.8.

Discussion

This trial examined the effects of MAT-EMG on motor function of a paretic upper extremity in chronic stroke patients. Our results showed that MAT-EMG had a greater effect than FES on recovery of motor function in the paretic extremities of chronic stroke patients.

The characteristic of MAT-EMG used in this trial is the reinforcement of the mental activity through EMG-triggered electrical stimulation. For that, an instrument (built in EMG) was employed as a tool to induce the execution of mental activity through visual feedback (by a display to show EMG potentials) and somatosensory input by electrical stimulation in time with mental activity. MAT-EMG is presumed to improve motor function according to the following mechanisms: (1) an activation of motor cortex by mental activity itself, (2) reorganization of the motor and somatosensory cortices (15).

How the instrument in this trial picked up EMG signals related to mental activity executed without the observable muscle contraction was our concerns. At rest, there is spontaneous random release of acetylcholine (ACh) in synaptic vesicles of the axon terminal. Some ACh bind to its receptor, and result in a small amount of postsynaptic membrane depolarization [it is referred to as a miniature end-plate potential (MEPP), about 1 mV]. When signals from the brain in the form of action potential reach the axon terminal, multiple vesicles in the axon terminal release ACh. The summated effect of multiple MEPPs produces the end-plate potential (EPP). The EPP is localized non-propagating reversals of the end-plate potential. If the EPP reaches threshold, the EPP is quickly outdone by the generation of an action potential. This action potential depolarizes the muscle membrane and the all-or-none propagation of an impulse is initiated in the muscle fiber. While the subject executes the mental activity after resting and in relaxed state, the amount of ACh released in vesicle of the axon terminal increases, resulting in the changes in the EPP (16). The instrument of our trial is thought to pick up the EMG signals of the EPP below threshold that generates MUAPs to make observable muscle contraction.

The instrument introduced for MAT-EMG is similar to generalized EMG-triggered electrical stimulation. However, the former employed EMG signals caused by a mental activity as a trigger, while the latter used signals generated by the voluntary muscle contraction (mainly MUAP). In addition, MAT-EMG is possible to be used in stroke patients with almost no observable muscle contraction (MRC grade 1), while generalized EMG-triggered electrical stimulation or constraint-induced movement therapy are universally applicable in patients with muscle strength MRC grade 2 (poor) or greater (17,18). Thus, this intervention may be recommended as a tool that improves the motor function of the paretic extremity for early or chronic stroke patients with little muscle strength. Practically, one subject enrolled for this trial had little muscle strength (MRC grade 1) in forearm, but he could carry out MAT-EMG successfully by the help of the therapist. Our intervention could be applied also in patients with MRC grade 2 or more muscle strength. However, there has been no trial comparing MAT-EMG with generalized EMG-triggered stimulation for patients with the observable muscle contraction. Further studies are needed on whether any intervention is more effective than the other in improving motor function and if there is a difference between the two interventions in brain image study.

Meanwhile, FES showed a tendency to increase FMM-UE score of the paretic upper extremity after intervention, but results were not significant. In a previous trial, Wu et al. (5) reported that electric somatosensory stimulation of the paretic extremity might improve performance on the Jebsen-Taylor Hand Function test in chronic stroke patients. Additionally, de Kroon et al. (19) suggested that therapeutic electrical stimulation had a positive effect on improving motor control of the upper extremity in stroke patients. Possible explanations for our conflicting results include: (1) most subjects had poor function without the ability to grasp or release objects; (2) the subjects were monitored by a therapist to limit the observable muscle contraction; and (3) the effect of electrical stimulation was too weak to improve function.

We found that the motor function of the site receiving stimulation improved significantly. That is, the wrist scores of the FMM-UE in the MAT-EMG group increased significantly after intervention. Although not significant, a similar tendency was seen in the FES group. This means that the therapeutic effect appeared in the directly stimulated area. Or the result may be attributed to mental activity itself, a thinking of waving earnestly the hand, used in this trial. Therefore, we can assume that activation of the specific area of the motor cortex working to move the wrist happens by mental activity, electrical stimulation or all. Further studies are needed to observe which one has more influence on the wrist function between electrical stimulation and mental activity.

We used a mental image waving the hand to improve motor function of an upper extremity. However, it was difficult to find patients with paresis of upper extremity more than 1 year and to execute a mental activity suitable for this intervention. A mental activity to simply extend the wrist was not able to induce electrical stimulation by the instrument. Through a mental image to wave the whole arm hard and earnestly by the help of therapists, the intervention could be carried out. As a result, a significant increase in the shoulder and wrist scales of the FMM-UE (associated with motion to wave the whole arm) was shown.

Limitations

This pilot trial was conducted to verify whether MAT-EMG improved the motor function of paretic extremity in chronic stroke patients. Limitations of this trial were the small number of participants and the short duration of the intervention. We propose further trial to supplement these parameters.

Conclusions

The MAT-EMG is more effective than FES in improving motor function of a paretic extremity in chronic stroke patients. We recommend MAT-EMG as another intervention for the rehabilitation of stroke patients with a paretic extremity.

Conflict of Interest

Authors reported no conflicts of interest.

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