Bioengineering Research

The Effect of EMS on Strength of Biceps Brachii Muscle

Mohammad Najafi [1*], Siamak Khorramymehr [1], Koorosh Nakhaei [2]

[1] Faculty of Science and Medical Technologies, Islamic Azad University, Science and Research Branch of Tehran, Tehran, Iran.
[2] Faculty of Engineering, Department of Biomedical Engineering, Islamic Azad University, Islamshahr Branch, Islamshahr, Tehran, Iran.

Correspondence to: Najafi M. (E-mail: info@mohammadnajafi.ir)

Abstract

The method of electrical muscle stimulation (EMS) method, which is defined as the contraction of muscles by the creation of internal electrical stimuli, is used to increase the strength and volume of athletes' muscles in order to increase their performance. EMS has gained a lot of attention in recent years and can be used as a strength training tool for healthy people. EMS can be used as a test tool to assess neuro or muscular functions in vivo. In this paper, the effect of using the EMS method to strengthen muscle fibers is investigated by training the biceps brachii muscle. For this purpose, after studying many volunteers, 12 of them were selected and the strength of their biceps brachii muscles evaluated by a dynamometer before and after the EMS. The obtained results show that the biceps brachii muscle strength significantly increases in the volunteers after training by EMS for a duration of two weeks.

Keyword: Electrical muscle stimulation, elbow flexion, biceps brachii, dynamometer
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1. Introduction

Electrical Muscle Stimulation (EMS), also known as Neuromuscular Electrical Stimulation (NMES), is the induction of muscle contraction using electrical shocks [1]. EMS has gained a lot of attention in recent years and can be used as a strength training tool for healthy people [2-3] and athletes [4-5]. It can also be used as a rehabilitation and prevention tool for patients who are almost or completely immobile [6-10]. Also, many wearable and low-cost devices has developed for EMS in order to easily use by individuals [11-13].

EMS can be used as a test tool to assess neuro or muscular functions in vivo, which can be used as a recovery tool after exercise for athletes [2]. Electric currents are generated by a device and conducted through electrodes on the skin close to the stimulated muscle [4]. Electrodes are usually pads that are attached to the skin. These currents mimic the action potential that comes from the central nervous system and causes muscle contraction. The use of EMS has been cited by sports scientists as a complementary technique to exercise. EMS may help the strengthening of weak muscles [4]. There are several theories on how EMS can strengthen muscle. At best, only 30% of all muscle fibers in the body are in a state of contraction, and the remaining 70% is idle and unused. EMS can be used to electrically stimulate these relaxed muscle fibers to increase their strength [14].

In a study in [15], the effect of random modulation of EMS on muscle fatigue was investigated. Given those muscle contractions induced by electrical stimulation lead to muscle fatigue and limit activities such as standing and walking, they hypothesized that they could reduce the change in modulation parameters

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during electrical stimulation with muscle fatigue. They studied 7 people with paraplegia of the quadriceps and anterior tibialis using surface electrodes. Their study showed that 10 minutes of rest between muscle stimulations is not enough to fully improve muscle strength (tired muscle) [15].

Another study in [16], the independent effects of current intensity-pulse duration and current frequency on muscle fatigue during neuromuscular electrical stimulation was examined, and their second goal was to determine whether the torque ratio stimulated by activated areas can explain muscle fatigue or not. Studies on 7 healthy participants in whom neuromuscular electrical stimulation was performed on the extensor muscles of the knee showed that changes in current intensity and pulse duration did not affect fatigue, but reducing stimulation frequency resulted in less fatigue. It may be because of the reduction of stimulated torque in the areas of activated muscles [16]. In another study in [17], they compared the effects of various interventions, including massage, passive rest-EMS, on lactate depletion and muscle recovery after strenuous exercise. To do this, 12 healthy male students participated in the tests over 5 days. After doing strenuous exercise, lactate and heart rate and muscle strength and total quality recovery were measured. The results showed that EMS and massage were not more effective than passive rest-EMS in the recovery process from strenuous exercise [17].

Reducing hand tremors is possible by using superficial electrical stimulation of the muscle. Hand tremor is one of the most common movement disorders in humans, which is an involuntary and almost sinusoidal movement. Tremor affects various joints in the body, including the elbow joint [18]. One of the methods used to electrically stimulate the opposite muscles to reduce vibration is reciprocal phase stimulation. In this method, due to the fact that the system has a time delay, perturbation, nonlinear, and time-varying relationships, it is necessary to use a powerful and powerful controller [19]. In a study, MPC controllers were used according to their characteristics. The simulation results showed that the MPC has a satisfactory performance compared to the PID and Fuzzy controllers - which have already been used - and illustrated that the tremors can theoretically be reduced using electrical stimulation [20].

To determine the effect of neuromuscular electrical stimulation (NMES) exercise twice a week compared to 3 times a week on quadriceps muscle strength, 7 healthy adult men with an average age of 21 to 25 voluntarily is selected in [21]. They were chosen in three groups. The first group did not receive any electrical stimulation, the second group received electrical neuromuscular stimulation twice a week and the third group received electrical stimulation on quadriceps muscle three times a week. In each session, both groups were stimulated for 10 minutes and the whole process was completed in four weeks. The quadriceps muscle strength produced during the NMES was measured during each minute of treatment. The force of maximal voluntary isometric contraction (MVIC) femoris quadriceps was assessed before the first week and at the beginning of weeks 2, 3, and 4 with a final measurement after the fourth week for all subjects. Only the mean changes for quadriceps MVIC before and after 4 weeks of NMES training were significantly different between the observing group and group 3. Based on the electrical stimulation parameters of healthy individuals used in this study, NMES significantly increased quadriceps muscle strength during exercise in 3 training sessions per week. Using a different electrical stimulation pattern or a different patient population may increase strength by 1 or 2 sessions per week [21].

Also, the effect of neuromuscular electrical stimulation (NMES) on quadriceps and the extent of increased strength, physical activity, and physical function in the elderly with osteoarthritis (OA) of the knee was examined in a study in [22]. In this procedure, 34 adults under the age of 60 with OA-like symptoms on knee radiographs were selected and treated with the home method of electrical neuromuscular stimulation (NMES). The initial result observed from this method showed that most of the quadriceps torque occurred in the isometric state. Secondary results include increased daily strides, increased overall activity efficiency, the ability to fast walk 100 steps continuously, mountaineering, and sitting-standing activities without interruption in a chair. They were able to increase the intensity of isometric muscle contraction to 30-40% of the maximum muscle strength with a portable electrical muscle stimulator device in 12 weeks and three days a week [22, 23]. Moreover, EMS were investigated by image processing to enhance the emotional responses to media [24, 25].

In this paper, the effect of using the EMS method to strengthen muscle fibers on the biceps brachii muscle (Figure 1) is studied. After the studies are conducted among the volunteers, 12 individuals are selected and with the help of a dynamometer, the strength of their biceps brachii is evaluated before and after the EMS exercise. The results of this study show that the strength of volunteers' biceps brachii significantly increased after training for two weeks by the EMS method.

2. Material and Method

In order to evaluate the effect of using the EMS method on biceps brachii muscle (Figure 2) among the volunteers, their muscle strength was evaluated with the help of a dynamometer in Figure 2 before and after the EMS method.

Figure 1: The biceps brachii muscle is seen in the green area.

Figure 2: Dynamometer device for using in the study.

This device is used to measure the strength of the arm muscle, which as shown in Figure 2, consists of 3 force gauges, a plate for standing, a chain for transmitting force, and a display. In order to obtain the desired result and repeatability of the tests, standard conditions were defined so that the volunteers can be tested again after performing the exercises according to the initial conditions. The dynamometer in this research was made by medical-biomechanical engineering students at the Science and Research Branch of Tehran that its load cells are calibrated and used in projects related to measuring muscle strength.

2.1. Statistical Society

This study is a field study and was performed in the clinic unit of Erfan Niayesh Hospital. The tests were selected by simple sampling. Conditions for entering the tests are the age range of 24-40 years, no pain, no treatment, and rehabilitation for the joints (shoulders, elbows, and wrists) and no professional exercise in a particular field. Finally, after examining 34 volunteers for the test, 12 of them were selected. After knowing the test conditions and how to do it, each person signed a consent form and was entered the research. Each person was briefly explained the purpose and operation of the EMS and dynamometer. Among the 12 selected individuals, 9 of them were male and 3 persons were female. Also, 10 of them were right-handed and 2 persons were left-handed. The age range of the volunteers was between 21-37 years. Height was between 176-185 centimeters for men and 162-171 centimeters for women, and weight

Table 1: **Specification and personal information of volunteers**

Num.	gender	age	Weight (Kg)	Height (cm)	Number of sessions	Training time with EMS (Min)
1	man	26	85	178	8	157
2	man	27	89	182	8	160
3	man	34	75	181	7	151
4	man	24	79	176	8	157
5	man	37	88	185	7	155
6	man	31	92	178	7	155
7	man	24	83	182	8	162
8	man	21	102	185	8	158
9	man	26	81	178	7	153
10	woman	29	68	162	8	159
11	woman	25	61	168	8	157
12	woman	25	62	171	7	155
Ave.		27.4	80.25	177.16	7.58	156.58

Figure 3: The correct way to exercise with dumbbells

for men was 75-102 kilograms and for women was 63-69 kilograms. In terms of sports activities, 66% of the people (8 people) studied in this study did not have sports activities and 34% stated that they owned sports activities and referred to items such as swimming and football as amateurs. The characteristics of these people have been shown in Table 1.

2.2. Investigation method

In the first stage, data collection was performed so that volunteers are asked to stand straight and while their elbow angle is 64 degrees rather than to the horizon, isometrically contract the front muscles of the arm, which cause flexion of the elbow, and pull the dynamometer handle (the chain of the dynamometer was adjustable according to the height of the people). Meanwhile, the amount of force produced by the muscles while the person is holding the contracted muscles and trying to pull the handle is recorded and used as primary data for comparison with after the muscles are tired with dumbbells.

To record information in the first phase of the test, which assessed the amount of force after muscle fatigue without training with the EMS method, candidates were asked to close and open the elbow joint with dumbbells in three sets of 12 as shown in Figure 3. It should be noted that the weight of the dumbbell is 14 kg for men and 5 kg for women, and after each set, there was a rest time of 74 seconds. After performing this exercise, people were asked to pull the handle of the device as in the previous step to get the amount of force from the elbow flexion again. To record the information of the second phase of this test, each of these individuals practiced with the EMS method and dynamometer device for two weeks, one day in between, while the electrode pads of the device were mounted on their skin in the upper and lower part of the biceps brachii muscle. Also, the volunteers exercised with the electric pulse in two 14-minute periods which muscle rested for 3 minutes between the periods. After performing this two-week exercise, the force of maximum isometric voluntary contraction in the volunteers was determined with a dynamometer before exhausting the biceps brachii muscle, and after recording it, their muscles get tired again similar to phase one of the test. As a consequence, by re-recording the amount of force applied to the dynamometer, the effect of using an electrical stimulation device on the biceps brachii muscle was determined. To confirm the correctness of this test, each person repeats this task three times and if there is no more than a 14 % difference, the average of three tests was calculated for comparison.

SPSS software was used to analyze the obtained data from both test phases. Mean and standard deviation indices were used for descriptive statistics. In the inferential statistics section, the Kolmogorov-Smirnov test was used to determine the normality of the data distribution and to compare the mean of the results before and after EMS. A paired t-test was also used at a significant level ($P < 0.05$).

3. Result

The force produced by the arm muscles in the elbow flexion movement is considered as an evaluated parameter in this study so that reducing this amount as muscle fatigue and increasing it indicates the strengthening of muscle strength after training with EMS device. The results shown in this section are the maximum isometric voluntary contraction force of the anterior arm muscles (biceps brachii, anterior arm, superior zygomatic arm, and circular rotator cuff) created by elbow flexion. The results obtained from the maximum isometric voluntary contraction force of the forearm muscles before the training of the biceps brachii with the electrical muscle stimulation device are shown in Table 2 and Figure 4.

The results obtained from the maximum isometric voluntary contraction force of the forearm muscles after the training of the biceps brachii with the electrical muscle stimulation device are shown in Table 3 and Figure 5.

4. Discussion

Exhaustion of the forearm muscles by dumbbells in three sets of 12 in a two-week training period shows the amount of force produced for 14 seconds of maximum isometric contraction of the elbow flexion movement at an angle of 64 degrees with the EMS

Table 2: Force obtained from elbow flexion, before and after fatigue without EMS

Num.	Before Fatigue	After Fatigue	Difference (%)
1	505	421	16.63
2	468	402	14.1
3	523	447	14.53
4	482	390	19.08
5	453	374	17.44
6	471	411	12.74
7	445	356	20
8	497	388	21.93
9	439	341	22.32
10	392	314	19.9
11	378	325	14.02
12	416	363	12.74
Ave.	455.75	377.66	17.13
S.d	42.63	38.21	----

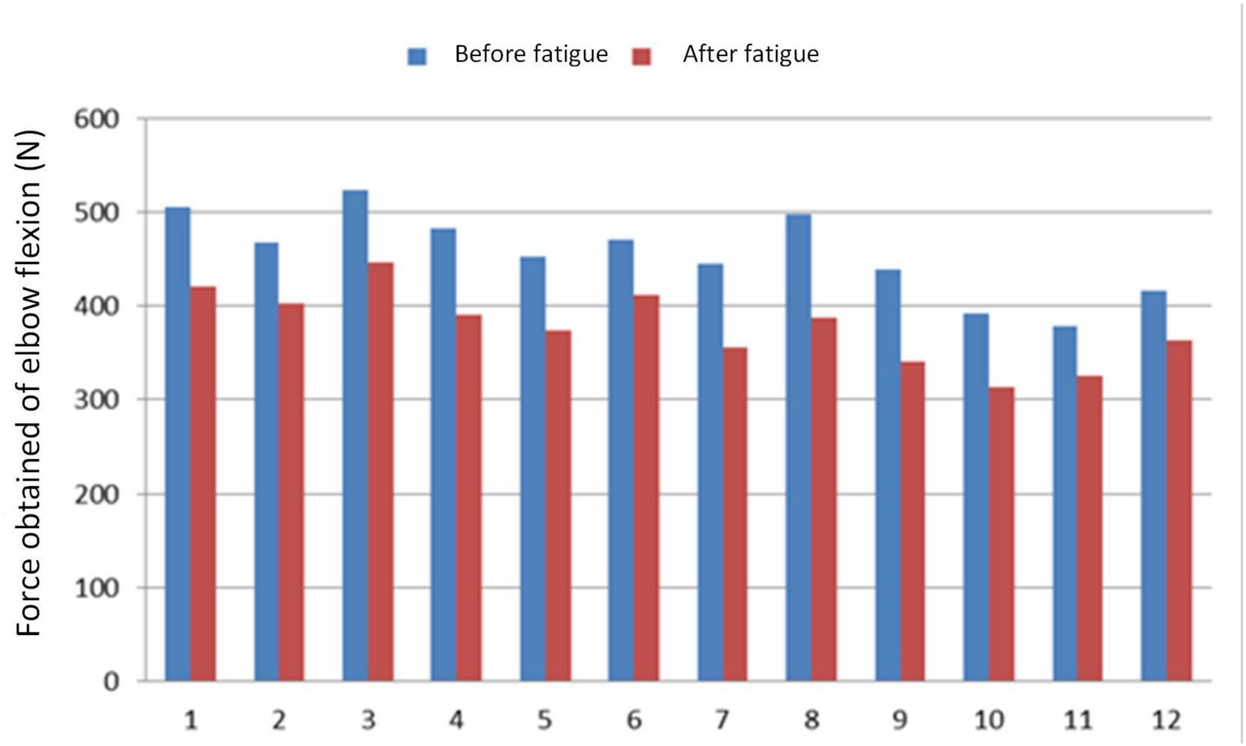

Figure 4: Comparison of the force obtained from elbow flexion, before and after fatigue without EMS

Table 3: Force obtained from elbow flexion, before and after fatigue with EMS

Num.	Before Fatigue (N)	After Fatigue (N)	Difference (%)
1	559	481	13.95
2	515	469	8.93
3	571	492	13.84
4	556	476	11.2
5	509	452	14.89
6	564	480	12.64
7	530	463	16.21
8	586	491	17.54
9	496	409	16.84
10	475	395	14.94
11	462	393	13.95
12	473	406	14.16
Ave.	524.66	450.58	14.12
S.d	40.69	36.97	----

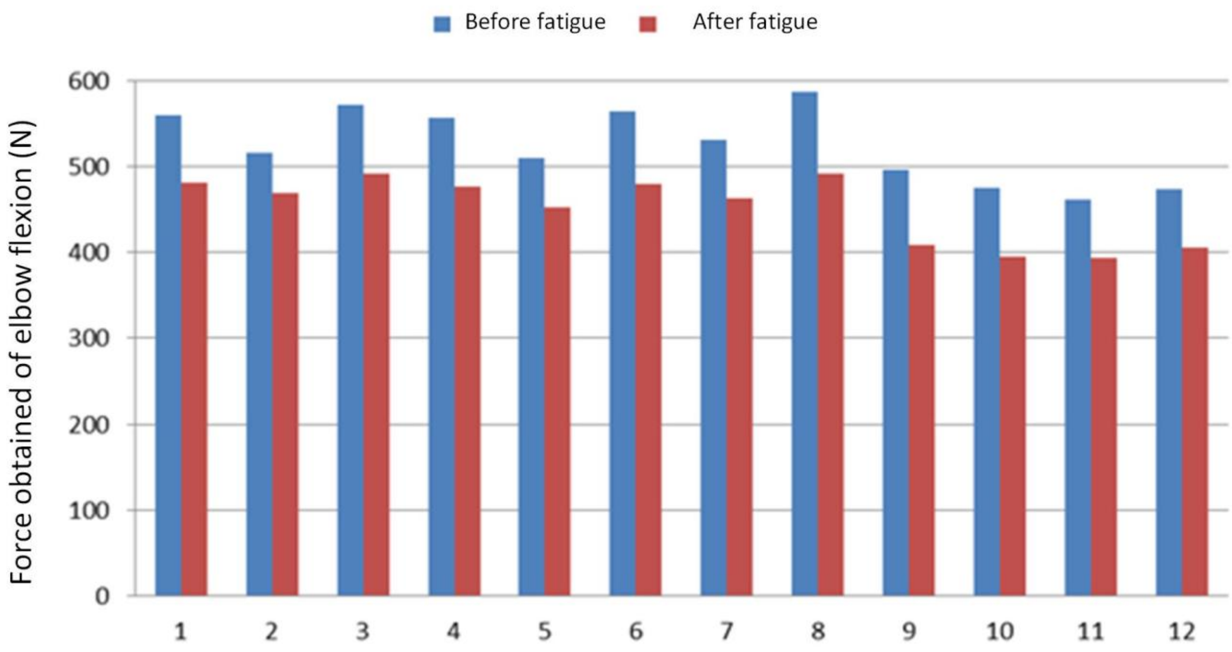

Figure 5: Comparison of the force obtained from elbow flexion, before and after fatigue with EMS

Table 4: Comparison of mean (standard deviation) of elbow flexion force in biceps brachii muscles, before and after fatigue with and without using EMS.

Type of test	Before Fatigue	After Fatigue		
	Elbow flexion force (N)	Elbow flexion force (N)	Percentage reduction	Significance level
Without EMS	455.72 (42.63)	377.66 (38.21)	17.13	0.03
With EMS	524.66 (40.69)	450.58 (36.97)	14.12	0.02

Table 5: Comparison of mean (standard deviation) of elbow flexion force in biceps brachii muscles, before and after fatigue with and without using EMS associated with parried t-test.

Type of test	Without EMS	With EMS		Paired t-test	
	Elbow flexion force (N)	Elbow flexion force (N)	Percentage Increase (%)	T statistics	Significance level
Before Fatigue	455.75 (42.63)	524.66 (40.69)	15.12	-4.62	0.01
After Fatigue	377.66 (38.21)	450.58 (36.97)	19.31	-6.05	0.01

device has been created a significant increase in power and muscle strength. As the result section and Table 4 illustrate, muscle strength and power decreased after performing the arm movement with the dumbbell. But the important point is a reduce in the loss of strength of the biceps brachii muscles after training with the EMS method so that after doing this exercise, the obtained results in Tables 2 and 3 showed that except for one case, all participants in this study observed a lower percentage of loss of muscle strength.

For the two phases of the tests, the mean percentage of reduction in muscle strength after muscle fatigue was 17.13% and 14.12% for before and after using with EMS, respectively. Also, according to Table 5, it was found that exercising with the device and the EMS method has increased muscle strength.

The mean percentage of increase in muscle strength after this exercise was 15.12% and 19.31% for before and after fatigue, respectively. The results show better muscle function and a reduction in fatigue compared to the results before benefiting electrical muscle stimulation, which is proof of the effect of this device. The results of this study also showed that the use of an electrical muscle stimulation device (EMS) reduces the amount of muscle fatigue in dynamic activity because of the increasing adaptation of muscle cells, blood vessels, and nerves. It also increases the efficiency of muscle contraction involved in activity by slowing down the slope of reducing muscle strength and the speed of conduction of muscle fibers. This causes more stability of the joints and reduces the incidence of joint injuries.

Therefore, it can be stated that the process of contraction of muscle fibers depends on the amount of dynamic activity and causes changes in the physiological contraction and movement control. Therefore, it is suggested that the effect of using this device is investigated by kinematic methods and motion analysis.

5. Conclusions

In this paper, the effect of using the EMS method to strengthen muscle fibers on the biceps brachii was studied. After the examinations of 37 volunteers, 12 individuals were selected based on the required inputs and with the help of a dynamometer, the strength of the biceps brachii muscle was evaluated before and after the EMS exercise. The results of this study showed that the strength of the biceps brachii muscle in the volunteers significantly increased after two weeks of training by EMS. Therefore, EMS has a high effect on the strength of the biceps brachii muscle.

Conflict of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

Acknowledgments

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