# 09 - MEDIUM AND LOW FREQUENCY ELECTROTHERAPY IN THE MUSCLE STRENGTH

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**Introduction**

Several functional and therapeutic application have being developed since the XVIII century using electrical stimulation. Its application in athletes training started in the early 70's to improve physical conditioning along with the training program. (Briel, Lopes and Pinheiro, 2003)

By definition, surface neuromuscular electrical stimulation (NMES) is the use of an external controlled electrical current applied to the skin surface trough proper electrodes with the objective to stimulate a specific muscle or muscle group and/or its nervous terminals producing a muscle contraction. (Nunes, 2004)

This study aimed to evaluate and compare the acquired muscle strength in the triceps brachii of no active women after a low or medium frequency current NMES protocol, demonstrating the evolution of the muscle in a quantitative form.

**Material and Methods**

The present study was carried out in the Physiotherapy clinic of Guarulhos University, in São Paulo State. We selected 15 healthy women, aging from 18 to 27 years old, with no co-morbidities, with body mass index (BMI) from 18.5 to 24.9 kg/m2, which is considered normal according to the Ministry of health.

Participants were selected by convenience trough a verbal invitation. Then they participated in a meeting where all the details of the study were clarified, including risks and benefits. Right after that they received an informed free consent form to be to which they should agree and sign. All experimental procedures of this study were approved by the UNG ethical committee by the protocol number 73918817.0.0000.5506.

Participants were excludedif they had history of previous regular physical activity or resistance training with the goal of muscular training in the last 6 months as well as during the period of the study, also if they were obese or present any associated disease, such as diabetes, high blood pressure and co-related diseases. They were also excluded if they presented any trauma or orthopedic problems in the upper limbs that would interfere with the test performance (contusions, sprains, tendinitis, bursitis, etc) and if they refused to take part in the study.

The application of low frequency FES was carried out using the TENSOR device, manufactured by DGM electronics equipment LTDA®, that produces a biphasic low frequency alternating current with a sinusoidal pulse and for the Russian current we used a VMDNS: 16-255 model of Endophasys-R®, manufactured by KLD Biosystems electronic equipment LTDA®, which produces a biphasic medium frequency alternating current with a sinusoidal pulse.We cleaned the spot in the triceps brachii where the 5x9 cm self-adhesive electrodes pads (Carci LTDA®) were put with a piece of cotton with ethylic alcohol.

Initially the participants filled a personal data questionnaire with information on their age, and dominance of the upper limbs, right after that, they were weighted in a Filizola® scale (Personal line model) and their height was measured using a TBW® stadiometer. From these measures we calculated BMI (weight divided by height, in centimeters, squared).

Then, participants were evaluated regarding the elbow extensors muscles force from the dominant and non-dominant upper limb using a digital dynamometer (Lafayette manual muscle tester), this evaluation was carried out by somebody from the research team that was not related to this study.

The methodology used to evaluate muscle force was described by Freitas et al., the participants laid in a stretcher in supine position, with their upper member positioned with the shoulder abducted to 30o, the elbow flexed to 90o and the forearm supine. During the test, the device was put in the back of the distal portion of the forearm. The researcher applied a force in the opposite direction of the elbow extension movement of the participants, after the verbal command of the researcher they exerted a gradual force until they reach their maximal contraction of the elbow extension that should last 5 seconds. The test was repeated 3 times with 2 minutes of interval between them. The maximum peak value was used as reference in each test and an average of them was made. This procedure was done before and after the NMES protocol. Two days after the force evaluation the NMES protocol started.

The parameters used in this study were, Russian current of 2,500 Hz, modulated frequency of 50Hz, cycle phase of 50%. FES stimulation was with a frequency of 50Hz, pulse duration of 200 microseconds. Both currents had the contraction time (ON) set to 20 seconds and rest (OFF) set to 20 seconds, ramp-up and ramp-down of 2 seconds and intensity enough to produce a muscle contraction up to the participant tolerance level, without causing any pain. The participants were instructed not to voluntarily contract the muscle along with the current stimulus, so we could evaluate the sole effect of the treatment in the muscle force gain. The whole procedure lasted 20 minutes.

The participants had the triceps muscle belly cleaned with a piece of cotton soaked in ethylic alcohol to assure the fixation of the electrode pads. They were seated with their knees flexed and the 5x9 self-adhesive electrodes were placed close to the origin and insertion of the stimulated muscle.

The muscle that had more strength (measured previously) was not stimulated and served as a control.

Current intensity was increased 3 times in intervals of 5 minutes, respecting the participant tolerance, so it could reach the strongest and visible muscle contraction during the entire protocol time, and avoiding that the current would accommodate.

Data was tabulated to the SPSS program and presented as a table. The pre and post data were analyzed using the paired T test, between groups data were analyzed using Student T test with significance set to $p<0.05$.

**Results**

Data from demographic data such as age and anthropometric variables are expressed in table 1.

Table 1. Distribution of participants regarding age, weight, height and BMI.

| | Russian Current<br>Average ± Standard deviation | FES Current<br>Average ± Standard deviation |
|---|---|---|
| **Age (years)** | 20.0±1.6 | 20.5±1.2 |
| **Bodymass(Kg)** | 51.5±4.6 | 54.5±5.0 |
| **Height (m)** | 1.60±0.04 | 1.61±0.03 |
| **BMI (kg/m²)** | 19.8±2.0 | 21.0±1.5 |

Results showed significant increase in the muscle strength in both arms, with an average gain of the stimulated muscles of the FES group of 7.2 pounds and of the Russian current group of 14.5 pounds (Table 2).

Table 2. Average, standard deviation and P value of muscle force changes (pounds) of the participants submitted to NMES measured with the portable dynamometer. Comparison of intragroup pre and post test of the control and stimulated arm.

| | Pre Avg±SD | Post Avg±SD | Variation-Δ Avg±SD | P value |
|---|---|---|---|---|
| **Russian Current** | | | | |
| Stimulated arm | 23.9±6.5 | 38.4±9.2 | 14.5±3.5 | P<0.001* |
| Control arm | 27.8±7.5 | 32.9±4.8 | 5.1±4.3 | 0.017* |
| **FESCurrent** | | | | |
| Stimulated arm | 32.7±4.6 | 39.9±4.6 | 7.2±1.2 | P<0.001* |
| Control arm | 36.2±6.0 | 38.2±5.2 | 2.0±1.2 | 0.005* |

In Table 3 we can observe that the FES current group presented more strength in the pre test in both arms when compared to the Russian current group. After the application of the protocols there was no significant difference between the currents, with a significant variation within the groups. However, when we evaluate the variation (Δ= post – pre) between the currents, the Russian current showed gains significantly higher when compared to FES in the stimulated arm with no difference in the control arm.

Table 3. Average, standard deviation and variation of muscle strength (pounds) of the participants submitted to NMES measured with the portable dynamometer. P value, Pre and post test values from the control and stimulated arms.

| | Russian Current N=8 Avg±SD | FES Current N=7 Avg±SD | P value |
|---|---|---|---|
| Stimulated arm Pre | 23.9±6.5 | 32.7±4.6 | 0.01* |
| ControlarmPre | 27.8±7.5 | 36.2±6.0 | 0.03* |
| Stimulated arm Post | 38.4±9.2 | 39.9±4.6 | 0.70 |
| Controlarm Post | 32.9±4.8 | 38.2±5.2 | 0.06 |
| Variation (Δ) stimulatedarm | 14.5±3.5 | 7.2±1.2 | P<0.001* |
| Variation (Δ) controlarm | 5.1±4.3 | 2.0±1.2 | 0.19 |

The intensity of the current applied changed from the first to the fifth week, with values increasing in both studied groups.

Discussion

Electrostimulation has been used for decades to improve muscle strength and performance or even provide some degree of function to people with skeletal muscle disease. The first literature report on the effects of electricity in muscle activation was written in 1971 by Galvani. (Michael and Humbert, 2008; Silva et al., 2007)

From then, several researchers studied deeply the effects of electric stimulation in the muscle strength gains. To discuss the data of our study only the articles that would verify the efficacy of NMES of medium and low frequency in the muscle strength improvement with no exercise associated were selected.

One study published by Guirro, Nunes and Davini (2000) compared two different currents regarding the strength acquired after a NMES protocol. The authors evaluated the effects of quadriceps femoris stimulation in the non-dominant limb of 18 female volunteers. They were randomly dividedin 3 equal groups (2 NMES and 1 control). Strength analysis was obtained through a load cell of a dynamometer. Sessions happened 5 consecutive days, from Monday through Friday for 3 weeks, 30 minutes long in the quadriceps muscle belly. The parameters used for the Russian current were: current of 2,500 Hz modulated in 50Hz, pulse duration of 100 microseconds. Low frequency (FES) used a 50Hz frequency with a pulse duration of 300 microseconds. In both groups, the T on and T off was of 5 seconds and ramp up and ramp down of 0.5 second each. Both protocols were effective for muscle strength gains, given that the Russian current group had an average of strength gain of 46% and FES of 40%, so the group stimulated with the Russian current showed a superior average gain than FES.

Soares et al., (2002) evaluated the hand grip strength increment in healthy and not trained individuals comparing NMES of low and medium frequency. The protocol had 2 seconds of ramp up and down interval, 5 seconds of sustaining and 10 seconds of rest, with the low frequency of 65Hz and the medium frequency, current of 2,000 Hz modulated in 50Hz and a third group that served as control. The protocol had 10 sessions of 20 minutes each,3 times a week in non-consecutive days and the strength

evaluation was made with a dynamometer. In the end of the study both groups showed significant gain with the average for the low frequency group of 8.7% and the average for the medium frequency was 22.75%, with the last one being superior.

Domingues et al., (2009) evaluated hand grip strength after NMES. There were 29 participants divided in 5 groups: G1 NMES with Russian current in the extrinsec muscle of fist and fingers; G2 similar to G1, with further voluntary contraction associated; G3 NMES of low frequency; G4 NMES of low frequency and voluntary contraction associated and G5 as a control group.

Hand grip strength was evaluated with a dynamometer before the use of NMES and after 12 and 24 sessions. The electrostimulation protocol happened 3 times a week, for 8 weeks with a total of 10 contractions in the initial 12 days and reaching 20 contractions in the remaining 12 days. Results showed significative gains of all groups compared to the control group with no difference among the intervention groups.

Another study published by Macedo, Buck and Cavalli (2008) compared 2 currents in the quadriceps strength gain in sedentary men and women. The authors analyzed 36 individuals of both genders, with a random division in groups A (Russian), B (low frequency) and C (Control) and within the groups, men and women were observed separately. Russian current protocol was 2,500 Hz of frequency modulated at 50Hz, 50% of phase, the low frequency current was 50Hz, 10 microseconds of pulse duration, T on and T off of 15 seconds and 15 minutes of session for both. Strength analysis was made with an isokinetic dynamometer where the peak torque for the Russian current was 2.41% and for the low frequency was 4.53% in the end of the protocol. The authors concluded that the low frequency groups showed superior strength gains, although it was not statistically different compared to the Russian current group.

Vaz and Frasson (2018) reviewed the recent literature over a comparison between the NMES of low and medium frequency. They analyzed 15 studies that were included according the study inclusion criteria. The authors concluded, based on the available evidence that NMES of medium frequency generates equal or less strength, equal or more fatigue and equal or more discomfort when compared to low frequency NMES.

A previous literature review with the same objective used just studies with NMES on the quadriceps muscle, with 7 studies included according to the inclusion criteria. The latest evidence suggest that the low and medium frequency have the same effects on evocated torque and discomfort level from the quadriceps in healthy individuals. (Silva et al., 2015)

Conflicting data regarding the best choice to gain muscle strength using NMES were shown in this discussion. Our findings pointed to a bigger strength gain to the group stimulated with the medium frequency current as observed in the other studies cited above (Soares et al., 2002; Guirro, Nunes and Davini, 2000). However, there is an important data reported on the Guirro, Nunes and Davini (2000) study. These authors state that the participants previous strength interferes in the NMES results. This phenomenonwas also observed in our study. Soares et al., (2002), although it was not reported in their results, also presentedin the Russian currentstimulated group a previous smaller strength when compared to the FES group.

In our study, the groups were randomized and then we evaluated the participants strength, that presented a previous significant difference of 23.9 pounds for the Russian current group and 32.9 in the FES group before the NMES, and this might be a determinant element in the final result of this study.

Some studies reported that current modulated to 50Hz frequency produces better results to increase strength. In our study we also used the current modulated to 50Hz frequency and it was efficient to increase strength in the elbow extension muscles after the experimental period; Doucet, Lam and Griffin (2012) reinforce this notion stating that the use of electric current either to improve function or to improve strength should be with currents of 20 to 50Hz.

About the current intensity, the participants were stimulated, during the experimental protocol period, to use elevated although tolerable levels of intensity, since there is a linear relationship between the strength increase and the intensity of the applied current. (Bohórquez, Souza and Pino, 2013).

One observation caught our attention during the protocol execution, during the days of the protocol, the ability to endure a higher intensity by the participants showed successive increases, in the end of the protocol, all participants had higher intensity levels that the ones of the beginning. Similar data were presented in the studies cited. (Guirro, Nunes and Davini, 2012; Marquez, Santos and Freitas, 2010; Avila, Brasileiro and Salvini, 2008)

The muscle strength gain followed by hypertrophy is that the electrical stimulation activates a great number of motor units than the ones somebody would activate without it. NMES is a therapeutic technique that is able to promote neural adaptation and in the myofibrillar structure that would culminate in strength gain. (Gondin et al., 2011; Hortobagyi, Maffíuletti, 2011). Chronically training with NMES modify gene expression leading to muscle fiber phenotype changes (Durigan et al., 2014; Gondin et al., 2011) and induces the increase in satellite cells (Guo et al., 2012) furthermore the time and intensity of the training protocol are important factors that determine the therapy efficacy. (Narvaez M, 2017; Briel, Pinheiro and Lopes, 2003)

However, there are still some controversy in the literature regarding the proper patterns to be used with this type of stimulation. The electrically induced muscle fatigue is another negative element in the NMES protocols that has to be observed and evaluated during the current application, in order to minimize the damage that might occur.

Our research showed significant increase of muscle strength with the use of the currents used in the study alone. Yet this fact still needs other scientific confirmation due to the variety of situations observed during the NMES application. One of these situations is the controversy about the parameter that should be used, as stated by Oliveira et al., 2007.

So we would like to point out the need of new research that would compare NMES of medium and low frequency in the muscle strength gain in healthy individuals and that the initial strength of the participants is measured before the randomization so the groups can be homogenous about this aspect.

**Conclusion**

Our results demonstrated that both Russian and FES currents are effective when applied isolated to increase muscle force in sedentary women, improving muscle performance, with the best results being promoted by the use of medium frequency current.

Although the groups differ in strength at the moment of pre-stimulation and it can not affirm the superiority of the medium frequency in the muscle strength gain question, it can qualify, according to the results presented and the research literature, that both fulfill their function of promoting gains of muscle strength after a given period of electrostimulation.

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**Abstract**

Introduction: Neuromuscular electrical stimulation (NMES) has been used as one of the pillars of the therapeutic modalities for the gain of muscle strength. Objective: To compare the strength gain in the elbow flexor muscles in women after the use of Neuromuscular Electrical Stimulation (NMES) of low and medium frequency. Materials and Methods: 15 women were selected, with normal body mass index (BMI), previously healthy, sedentary and aging from 18 to 27 years old. They were randomically separated in 2 groups, Russian current (n=8) and low frequency (FES) group (n=7), with the stimulation only in the weakest arm of the participants. FES frequency was 50Hz, pulse duration of 200 microseconds and Russian current, medium frequency alternating current of 2,500 Hz, was modulated to 50Hz, duty cycle of 50%, for both methods the ramp-up and ramp-down was 2 seconds, 20 seconds of ON and OFF time, for 20 minutes in the triceps brachii, for 5 weeks, with intensity enough to promote a muscle contraction visible and tolerable. Strength measurements were made with a portable dynamometer before the start of the NMES protocol and after the end of it. Results: we used the paired T test and the T Student test with the significance level set to $p<0.05$. There was an increase of muscular strength in both arms for the same group, with the average gain in the FES stimulation of 7.2 pounds and in the Russian current stimulation of 14.5 pounds, with intragroup and inter group statistic significance. Conclusion: The Russian current stimulation was more efficient in promoting strength muscular gains when compared to FES, although both low and medium frequency currents were able to promote significant improvements but the groups were different as to the force at the time pre-stimulation.

**Key words**: Electric stimulation therapy, muscular strength, physiotherapy modalities.

**Résumé**

Introduction: La stimulation électrique neuromusculaire (EENM) vient étant utilisée comme un des piliers des modalités thérapeutiques pour le profit de la force musculaire. Objectif: Évaluer le profit de force musculaire des extenseurs du coude dans des femmes après EENM. Matériels et Méthodes: 15 femmes ont participé de l'étude avec un indice de masse corporelle (IMC) normal, auparavant en bonne santé, dans lesquels ils ne pratiquent pas d'activité physique, 18 à 27 ans, divisées de manière randomizasé dans deux groupes (8 femmes: Courant Russe et 7 femmes: low fréquence (FES). A été utilisée la FES avec les paramètres 50 Hz de fréquence, durée d'impulsion de 200 microsecondes et la Courant Russe avec les paramètres de chaîne porteuse de 2.500Hz, fréquence modulée de 50 Hz, phase (cycle) de 50%, les deux avec des paramètres de montée et descente

de 2 secondes, temps ON et OFF de 20 secondes pour un temps total de 20 minutes dans le tríceps brachial avec une intensité suffisante pour fournir de la contraction musculaire visible et tolérable, pour une période de 5 semaines. La mensuration de force a été faite au moyen d'un Dynamomètre portable avant le début et à la fin du protocole EENM. Résultats: Pour l´analyse statistique est utilisé l'essai t apparié et T Student et considéré le niveau d'importance de p=0,05. Il a y eu une augmentation de la force musculaire dans les deux les bras, étant la moyenne de profit au groupe FES 7.2 livres et dans le groupe Courant Russe 14.5 livres – statistiquement significatif. Conclusion: Les deux chaînes ont été efficaces dans le profit de la force musculaire, mais le groupe de courant russe a présenté un résultat supérieur.

**Mots-Clés:** Thérapie par stimulation électrique, force musculaire, modalités de physiothérapie

**Resumen**

Introduccion: La estimulacon elétrica neuromuscular (EENM) se há convertido en un pilar de las modalidades terapéuticas para el incremento de fuerza muscular. Objetivo: Evaluar si existe diferencia en el incremento de fuerza muscular de los extensores del codo en mujeres después de utilización de la estimulación eléctrica neuromuscular (EENM) de baja y media frequência. Materiales y métodos: Fueron seleccionados 15 mujeres, con índice de Massa Corpórea (IMC) normal, anteriormente saludables, no practicantes de actividad física, conedad de 18 a 27 años que fueron divididas de maneraaleatoriaen dos grupos con 8 para el grupo de corriente Russa y 7 para el grupo de frequência baja (FES). Fue utilizado laFEscon frequência de 50Hz, conduración de pulso de 200 microsegundos y la Corriente Russa concorriente portadora de 2.500 Hz, de frequência modulada de 50 Hz, fase (ciclo) de 50%, ambos com subidas y bajadas de 2 segundos, tiempo ON y OFF de 20 segundos, por 20 minutos en el tríceps braquial, durante 5 semanas, con una intensidad suficiente para proporcionar contracción muscular visible y tolerable. La medida de fuerza fueecha por medio de um Diámetro portátil anteriormente al inicio del protocolo EENM y al final. Resultado: Para la análise estatística fue utilizado eltest y pareado y T Student y considerado el nivel de significância p=0,05. Huboun aumento de fuerza muscular en ambos los brazos, en que la media de incremento en el grupo FES fue de 7,2 libras y en el de corriente Russa de 14,5 libras, que es estatisticamente significante. Conclusión: Las corrientes medias y la frequência fueron eficientes en el incremento de fuerza muscular, apesar de eso, el grupo de corriente Russa apresento el maior resultado.

**Palabras clave:** terapia por estimulación eléctrica, fuerza muscular, modalidades de fisioterapia.

**Resumo**

Introdução: A estimulação elétrica neuromuscular (EENM) vem sendo utilizada como um dos pilares das modalidades terapêuticas para ganho de força muscular. Objetivo: Avaliar se há diferença no ganho de força muscular dos extensores do cotovelo em mulheres após a utilização da Estimulação Elétrica Neuromuscular (EENM) de baixa e média frequência. Métodos. Foram selecionadas 15 mulheres, com índice de Massa Corpórea (IMC) normal, previamente saudáveis, não praticantes de atividade física, com idade de 18 a 27 anos que foram divididas de maneira randomizada em dois grupos com 8 para o grupo de corrente Russa e 7 para o grupo de baixa frequência (FES). Foi utilizado a FES com frequência de 50Hz, duração de pulso 200 microssegundos e a Corrente Russa com corrente portadora de 2.500 Hz, frequência modulada de 50 Hz, fase (ciclo) de 50%, ambos com subida e descida 2 segundos, tempo ON e OFF de 20 segundos, por 20 minutos no tríceps braquial, durante 5 semanas, com uma intensidade suficiente para proporcionar contração muscular visível e tolerável. A mensuração de força foi feita por meio de um Dinamômetro portátil anteriormente ao início do protocolo de EENM e ao final do mesmo. Resultados: Para análise estatística foi utilizado o teste t pareado e T Student e considerado o nível de significância de p=0,05. Houve aumento da força muscular em ambos os braços, sendo a média de ganho no grupo FES de 7,2 libras e no Corrente Russa de 14,5 libras, sendo estes, estatisticamente significante. Conclusão: As correntes de média e baixa frequência foram eficientes no ganho de força muscular, porém, o grupo de corrente Russaapresentou resultado superior.

**Palavras-chave:** Terapia por estimulação elétrica, força muscular, modalidades de fisioterapia.