# Selective Effects of Neuromuscular Electrical Stimulation in Post-Polio Patients

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## ABSTRACT

*This study aimed at investigating the effects of different physical therapy modalities on muscle strength of the ipsilateral and contralateral limb muscles in post-polio patients. Forty volunteer unilateral post-polio syndrome patients, ranging in age from 12 to 14 years were selected and divided into two groups of equal number, each comprised 20 patients. A program of strengthening exercises for the quadriceps muscles of the sound limb treated the control group, while the study group received the same treatment regimen in addition to NMES for the same group of muscles. Treatment of both groups continued for 20 successive weeks, 5 sessions per week. Strength of the ipsilateral and contralateral quadriceps muscle was evaluated using the MIRAC device, in addition to thigh circumference measurement before and after the suggested period of treatment. Results at the end of this study revealed a significant increase in the peak torque values of the quadriceps muscle of both limbs, in addition to a significant increase in girth measurement of both thighs. The results of the study group, treated by the combined method of treatment were more significant ($p<0.01$) than the results of the control group, treated by the therapeutic exercises only ($p<0.05$). According to the results of this study, it can be concluded that NMES combined with remedial strengthening exercises may help in increasing muscle strength of both the treated and the untreated limbs among the post-polio syndrome patients.*

## INTRODUCTION

Recent literature has considered paralytic poliomyelitis, caused by a small ribonucleic acid virus invading the central nervous system, has ceased to be a common catastrophe in areas where vaccinations are administered routinely. However, the evidence of the crippling effects of such a disease is still widespread among its victims[24].

The last poliomyelitis epidemic occurred in the 1950s. Forty years later, polio individuals were at risk of sequelae to the disease. These sequelae include the onset of fatigue, muscle pain, joint pain, weakness, and atrophy. These mentioned sequellae have been defined as progressive post-poliomyelitis muscular atrophy or post-polio syndrome[10]. Dalakas et al (1984)[4] stated that the slowly progressive muscle weakness may occur in muscles that were previously affected by poliomyelitis and recover or in muscles that were clinically unaffected by the acute illness, whether in the sound or in the affected limb.

These new problems may lead to new deficits in activities of daily living (ADL), walking, climbing stairs, dressing and personal assistance[13]. Many etiologies have been postulated for these new problems, which include further loss of anterior horn cells, increased metabolic demand on the motor unit and instability of the neuromuscular connections[2]. Anatomical, clinical and electromyographic investigations have implicated overuse as the source of post-poliomyelitis symptoms[23]. Recently, the medical profession has become increasingly aware of these problems[15,25].

Historically, neuromuscular electrical stimulation (NMES) has been used for centuries for therapeutic and diagnostic purposes. It was extensively utilized by physical therapists during the rehabilitation setting as an adjunctive tool in tool in the restoration of function in innervated weak musculature and after denervation[3].

These have been studies to determine whether strength or endurance training benefit post-polio sequelae individuals[5,14]. Non-fatiguing strengthening exercises have been reported to result in improvement over a long period of time. Those exercises were used either alone or in combination with neuromuscular electrical stimulation for increasing strength of those muscles affected in post-poliq syndrome patients. Presently, the exercises that have been described for postpolio sequelae have been of the non-fatiguing type. If the conditioning program is excessive, it may lead to further loss of function instead of improvement[3,9].

## AIM OF THE WORK

The purpose of this study was to determine whether an endurance-training program lasting approximately 20 weeks would increase muscle strength of both ipsilateral and contralateral muscles.

## SUBJECTS, MATERIALS AND METHODS

### SUBJECTS

Forty patients with unilateral post-polio syndrome of both sexes, ranging in age from 12 to 14 years, represented the sample of this work. All of them had a history of old poliomyelitis, regardless the age of the onset of the disease. These selected subjects met the following criteria: After the initial onset, they lived in a state of stable functional abilities for at least 8 years, after which a progressive functional deterioration was observed. In addition to muscle weakness of the affected limb, they were also complaining from muscle weakness of the sound limb, as confirmed by muscle testing. No knee ROM abnormalities were recorded.

The patients were divided randomly into two groups of equal number, group A (control group) and group B (study group), each comprised twenty patients. They were 22 males and 18 females, 17 of them were right- while 23 were left side affected. Then, each group was exposed to a definite program of treatment for 20 successive weeks, 5 sessions per week.

### MATERIALS

- Neuro-muscular electrical stimulator:
- Isokinetic device (MIRAC system).
- Tape measure.

### METHODS

- **For evaluation**

1. Torque evaluation: The MERAC isokinetic dynamometer was utilized to measure the peak torque value of the quadriceps muscles of both sides at angular velocity of 90 /sec. This

tolerance. The MIRAC unit was calibrated at the beginning of each test to insure valid results. The patient was seated, with both knees flexed to 90 and inclined backward with stabilization by trunk straps to bring all parts of the quadriceps femoris muscle into action. The steps of the test were explained for each subject to allow him/her to be familiar with the test protocol. Then, the patient was allowed to perform three trials and the average was calculated. The test was carried out for both sides and the peak torque value for each side was recorded separately.

2. Girth Measurement: Using tape measure, the thigh circumference was evaluated. It was measured 10 cm above the upper end of patella.

This test protocol was conducted before and after the physical therapy program.

- **For treatment**

* Group A (Control group): Patients belonging to this group received a traditional physiotherapeutic program for strengthening the quadriceps muscle of the sound limb. Such a program comprised isotonic and isometric resisted exercises. Each session lasted 30 minutes and consisted of 5 minutes of general warm-up followed by low-resistance, high-repetition exercise for the quadriceps. A 5-minute cool-down period followed at the end of each session [8].

* Group B (Study group): Patients in the study group received the same program of treatment in addition to neuromuscular electrical stimulation for the quadriceps muscle of the sound limb for 30 minutes. The contraction-relaxation ratio was 1:1 (10 seconds for contraction, followed by 10 seconds for relaxation).

## RESULTS

The collected data were statistically treated to show the mean values and standard deviations before and after the treatment program as well as the mean difference throughout the whole period. Comparisons were conducted between the mean difference using t-test to show the statistical difference.

There was no significant difference between both groups in either quadriceps torque or thigh circumference before the start of the physical therapy program. As shown in table (1), before treatment the mean value of the quadriceps torque of the sound limb in the study group was 31.16 ± 1.795 Nm, which increased after 20 weeks of treatment to be 31.39 ± 0.810 Nm, with a mean difference of 0.23 Nm. Concerning the control group, the mean value of the quadriceps muscle torque of the sound limb was 31.28 ± 1.658 Nm before treatment, which increased to be 31.40 ± 1.658 Nm after the suggested period of treatment, with a mean difference of 0.12 Nm. The mean difference values of both the study and the control groups at the end of treatment were statistically significant ($p < 0.01$ and 0.02, respectively).

***Table (1): Mean values of quadriceps torque (in Nm) of the exercised (sound) limb in both groups before and after 20 weeks of treatment.***

| Evaluation time | Study | | Control | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Pre | 31.16 | ± 1.795 | 31.28 | ± 1.733 |
| Post | 31.39 | ± 0.810 | 31.40 | ± 1.658 |
| MD | 0.23 | | 0.12 | |
| t | 2.9950 | | 2.5641 | |
| p | < 0.01 Sig. | | < 0.02 Sig. | |

Concerning the quadriceps muscle of the affected limb of the study group, the mean torque value increased from 20.27 ± 1.073 Nm before treatment to 20.44 ± 1.151 Nm after 20 weeks of the combined method of treatment, forming a mean difference of 0.17 Nm. Before treating the control group, the mean value of the quadriceps muscle torque was 20.78 ± 1.066 Nm, which increased after treatment with the traditional method of treatment to be 20.87 ± 1.100 Nm, with a mean difference of 0.09 Nm, with a mean difference of 0.09 Nm. The mean difference values of both the study and the control groups at the end of treatment were statistically significant ($p < 0.01$ and 0.02, respectively) (Table 2).

***Table (2): Mean values of quadriceps torque (in Nm) of the non-exercised (affected) limb in both groups before and after 20 weeks of treatment.***

| Evaluation time | Study | | Control | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Pre | 20.27 | ± 1.073 | 20.78 | ± 1.066 |
| Post | 20.44 | ± 1.151 | 20.87 | ± 1.100 |
| MD | 0.17 | | 0.09 | |
| t | 3.3797 | | 2.8400 | |
| p | < 0.01 Sig. | | < 0.02 Sig. | |

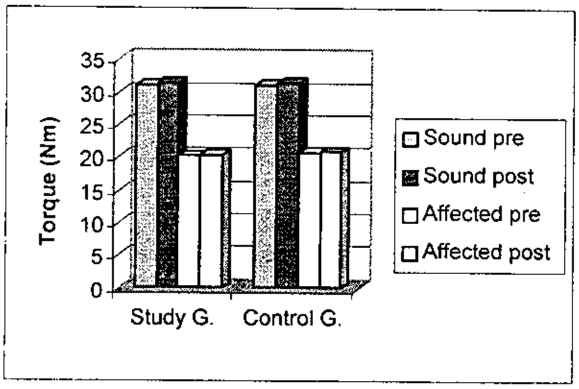


***Fig. (1): Shows mean values of quadriceps torque before and after treatment of both limbs, in the study and control groups.***

As revealed in table (3), the mean value of thigh circumference of the sound limb in the study group before treatment was 35.7 ± 1.809 cm. After 20 weeks of treatment, the mean value increased to be 36.1 ± 1.373 cm, which represented a mean difference of 0.4 cm. Before treatment of the control group, the mean thigh circumference of the sound limb was 36.3 ± 1.720 cm, which increased after 20 weeks of treatment with therapeutic exercises to be 36.7 ± 1.302 cm, having a mean difference of 0.4 cm. The mean difference in the thigh circumference of both the study and the control groups at the end of treatment were statistically significant ($p < 0.01$ and 0.02, respectively).

***Table (3): Mean values of girth measurements (in cm) of the exercised (sound) limb in both groups before and after 20 weeks of treatment.***

| Evaluation time | Study | | Control | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Pre | 35.7 | ± 1.809 | 36.3 | ± 1.720 |
| Post | 36.1 | ± 1.373 | 36.7 | ± 1.302 |
| MD | 0.4 | | 0.4 | |
| t | 2.9895 | | 2.6281 | |
| p | < 0.01 Sig. | | < 0.02 Sig. | |

As revealed in table (4), the mean thigh circumference of the affected limb in the study group increased from 29.8 ± 2.505 cm before treatment to be 30.2 ± 2.567 cm after the suggested period of treatment, forming a mean difference of 0.4 cm. Similarly, the mean value of the thigh circumference of the affected limb of the control group increased from 29.9 ± 2.260 cm before treatment, to be 30.2 ± 2.561 cm after treatment, with a mean difference of 0.3 cm. The mean difference in thigh circumference of both the control and the study groups at the end of treatment were statistically significant ($p < 0.05$ and 0.01, respectively).

***Table (4): Mean values of girth measurements (in cm) of the non-exercised (affected) limb in both groups before and after 20 weeks of treatment.***

| Evaluation time | Study | | Control | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Pre | 29.8 | ± 2.505 | 29.9 | ± 2.360 |
| Post | 30.2 | ± 2.567 | 30.2 | ± 2.561 |
| MD | 0.4 | | 0.3 | |
| t | 2.6281 | | 2.3473 | |
| p | < 0.02 Sig. | | < 0.05 Sig. | |

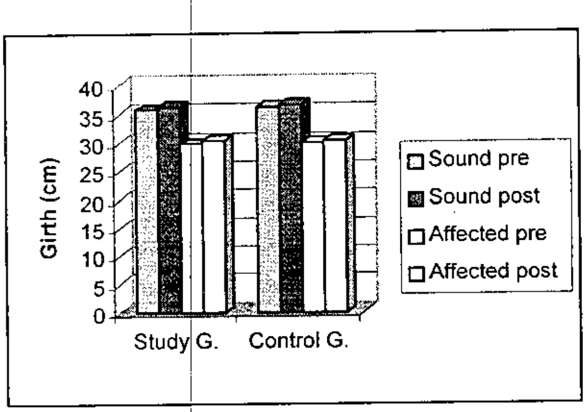


***Fig. (2): Shows mean values of thigh circumference before and after treatment of both limbs, in the study and control groups.***

## DISCUSSION

In the rehabilitation setting, neuromuscular electrical stimulation has been used by physical therapists to reeducate muscle action, retard muscle atrophy and enhance muscle performance (22). In the treatment of weak atrophied muscle, it is frequently used as an adjunct to voluntary resisted exercises to improve muscle function[7].

In the present study, the neuromuscular electrical stimulation was utilized to improve muscle efficiency of both the ipsilateral and contra-lateral limb muscles. The results revealed a significant increase in muscle torque of the quadriceps muscle of both treated and untreated limbs of both groups. The study group, treated by NMES in addition to therapeutic exercises, showed more significant results ($P < 0.01$) than the control group, treated by the therapeutic exercises alone ($P < 0.05$).

The results came in agreement with those of Laughman et al (1983)[17], who observed a significant increase in the strength of the untreated quadriceps muscle. Their patients were treated by a program of isometric exercises plus NMES for 5 weeks, 5 sessions per week.

The results of this piece of work were also coincident with those of Lai et al (1988)[16], who found significant strength improvements in the isometric strength of the untreated limb of the study group, treated by high- or low-intensity electrical stimulation. Furthermore, they added that the control group (received no NMES), had no significant changes in the muscle strength of the untreated limb.

The results also go with those of Mills and Quintana (1985)[19], who used high-resistance weight training for certain group of muscles for increasing the strength of the contra-lateral non-exercised weak group. Their findings indicated an increase in the strength of the ipsi-lateral and contra-lateral muscles, which is indicated through an increase in the number of motor unit potentials in these muscles.

In 1982, Gonyea and Sale[12] attributed the increase in motor unit potentials, due to exercise program, to be caused through collateral sprouting from the survived motor units. Such an increase in motor unit potentials will lead to a simultaneous improvement in muscle tension. They stated also that increasing recruitment and firing rates of the motor units might have an effect on muscle tension. Moritani et al (1985)[21] added that greater degree in motor unit synchronization increases the rate of tension generation per cross sectional area for a given muscle. Furthermore, they preferred using isotonic exercises than isometric ones in achieving such task.

Gollinck and Saltin (1982)[11] announced that high weight training might result in increasing the stored adenosine triphosphate and creatin phosphate. They added that the applied load determines the rate of chemical reactions, associated with contraction of muscles. Moreover, an increase in the activity of the mitochondrial enzymes of the exercised muscles.

In a histologic evaluation done by Ernstoff and associates (1996)[8], a large variation in fiber typing from individual to individual with postpolio sequelae has been noticed. Further increase in size in some subjects demonstrated that these muscles might still possess the ability to adapt to a training program. The program was mainly of endurance-type activities, but included exercises that require relatively high-performance forces. They found some variations in the training effects on different muscle groups, which may be due to different factors such as different training intensity and variations in pre-training muscle function and, thus, trainability as discussed above.

Dubowitz (1985)[5] and Einarsson and Grimby (1990)[6] also studied the mean fiber areas for all fiber types. The observed increase in muscle size has been hypothesized that the increase in mean fiber area resulted from the greater stress placed on the remaining fibers causing the corresponding hypertrophy.

A cardiovascular training effect was seen in most subjects as the heart rate at a sub-maximal workload decreased after training. It has been suggested that a 3- to 6-month program must be completed to be beneficial[1].

These results also support those of Perry et al (1995)[23], who stated that post-poliomyelitis syndrome results from long-term substitutions for muscular weakness that place increased demands on joints, ligaments, and muscles. They confirmed that treatment, based on the early identification of overuse of muscles and ligamentous strain, should aim at modification of lifestyle and include use of a brace.

The results provide additional support for the cross-transfer or cross-educational effect of muscle strengthening. It has been suggested that the mechanism of cross-education consist of neural factors (motor control) that increase the maximum level of muscle activation at various levels of the nervous system[21]. Lloyd et al (1986)[18] added that cross-education phenomenon was also observed in the subjects, treated by electrical stimulation, even though they exerted no voluntary effort. Thus, the cross-education effect of muscle strengthening through NMES may be attributed to a mechanism similar to that of muscle strengthening through voluntary exercises. This is achieved by neural factors acting via increased facilitation or disinhibition at various levels of the nervous system[20]. The individual variations in the training response in these subjects, who have light or moderate walking difficulties and can participate, in a group-training program. This further substantiates the difficulty in choosing the proper exercise level for an individual to gain maximal improvement and to avoid overwork. Careful individual monitoring by clinical observations with assessment of symptoms in relation to function and repeated muscle function measurements is, therefore, necessary in physical training of post-polio subjects[8].

## CONCLUSION

From this study that post-polio subjects may benefit from endurance training programs and that there appears to be no harmful shortterm effects in the muscle. According to the results of this work, it can be also concluded that NMES in addition to therapeutic exercises may result in increasing muscle strength, not only of the exercised limb, but also of the untreated one (cross-education effect).

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## ملخص البحث

## تأثيرات منتقاه للتنبيه الكهربائي العصبي العضلي في مرض شلل الأطفال

تهـدف هـذه الدراسـة إلى معـرفة تأثير وسائل العلاج الطبيعي المختلفة على عزم عضلة الفخذ ذات الأربعة رؤوس ، سواء التي طبق عليها برنامج العلاج أو مثيلتها التي على الجانب الأخر في حالات مرضى شلل الأطفال المزمن .

شـملت الدراسـة أربعيـن مريضا من المصابين بمرض شلل الأطفال المزمن ممن تتراوح أعمارهم من ١٢ إلى ١٤ عاما ، تم تقسيمهم إلى مجموعتين متسـاويين ( المجموعـة الضـابطة والمجموعـة محل البحث ) ضمت كل مجموعة ٢٠ مريضا ، تم تطبيق التمرينات العلاجية التقليدية في المجموعة الضـابطة لتقوية عضلة الفخذ ذات الأربعة رؤوس في الجانب السليم ، أما المجموعة محل البحث فتم علاجهم بواسطة نفس البرنامج بالإضافة إلى التنبيه الكهـربي العصبي العضلي للعضلة ذاتها ، استمر علاج المجموعتين لمدة عشرين أسبوعا متصلة ، كما تم قياس عزم العضلة ذات الأربعة رؤوس في الجانبين (السليم والمصاب) باستخدام جهاز " ميراك " بالإضافة إلى قياس محيط الفخذ في الجانبين قبل وبعد فترة العلاج .

أثبـتت نتائج الدراسة وجود زيادة ذات دلالة إحصائية في عزم العضلة ذات الأربعة رؤوس وأيضا في محيط الفخذ في الجانبين (السليم والمصاب)، كما أثبتت وجود زيادة مماثلة ذات دلالة إحصائية بالنسبة للمجموعة محل البحث عن المجموعة الضابطة، وعليه فينصح بإضافة التنبيه الكهربائي للتمرينات العلاجية المتبعة في علاج مثل هذه الحالات .