Effect of Neuromuscular Electric Stimulation on Muscle Strength and Mass of Sarcopenic Patients in ICU

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ABSTRACT:

Background*:* Neuromuscular electrical stimulation (NMES) is regarded as an important tool for preventing muscle mass as well as strength loss in intensive care unit patients (ICU). **(1).** *Purpose of the study*: to determine the impact of neuromuscular electric stimulation on muscle strength as well as mass of sarcopenic patients. **Subjects***:* Forty Participants aging from 50 to 65 years from both sexes admitted to intensive care units of AL-Sheikh Zayd AL-Nahyan Hospital, Cairo, Egypt, two groups were selected at random: study group (A) received session for 60 minutes daily until discharge (30 minutes upper limb & 30 minutes lower limb) electrical stimulation using biphasic, symmetrical impulses at 30-50 Hz, 400 µsec pulse duration, 12 seconds on as well as 6 seconds off, at intensities allowed to cause visible contractions. They also received ROM strengthening exercise 10-20 repetitions. And a control group (B) received ROM strength exercise 10 – 20 repetitions according to 1RM for the muscles of both upper as well as lower limbs. Measurements were conducted before starting the treatment on admission and before discharge. **Method of Evaluation***:* Lafayette dynamometer and creatinine. **Results***:* Creatinine levels and muscle strength both increased significantly after treatment, but the effects were more pronounced in the treatment group. *Conclusion:* In sarcopenic patients, neuromuscular electrical stimulation increases both muscle strength and muscle mass.

Key words: sarcopenia**,** Electric stimulation, Dynamometer**.**

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INTRODUCTION:

Sarcopenia is characterised by a loss of skeletal muscle mass as well as strength. It is possible to further categorize sarcopenia into primary, age-related sarcopenia as well as secondary sarcopenia which is linked to multiple risk factors, including malnutrition, immobilization, disease, as well as inflammation (**2).** Sarcopenia is a complex disorder with a wide range of symptoms and manifestations that can affect people of any age **(3).**

Muscle is the largest organ in the body and makes up 40% of body mass. Between the ages of 25 and 80, there is a clear and gradual decrease in the size and number of muscle fibers (up to 30%). **(4).** It is well-established that a lack of muscle strength negatively affects functional performance as well as autonomy, making it difficult to engage in the fundamental as well as instrumental activities of daily living (ADL) **(5).**

Graduation of muscle strength is an important tool for proper physical training prescription, assistance on the diagnosis of muscle dysfunctions as well as disabilities in sick people, and guidance on preventive programmes for injuries caused by imbalances among antagonistic muscle chains. **(6).**

Positive effects on muscle strength and architecture, as well as functional ability, can be seen after patients undergo neuromuscular electrical stimulation, which involves applying a series of intermittent and superficial stimuli to skeletal muscle tissue to produce visible contraction via activation of nerve branches **(7).** Skeletal muscle contractions are triggered by NMES, leading to enhanced protein synthesis in muscle as well as neural adaptation **(8).** It is widely recognized as an effective method for preventing the loss of muscle mass as well as strength in ICU patients **(1).**

Patients in critical care units often receive NMES treatment for skeletal muscle disorders. In critically ill patients, NMES shortens the time they need to be on mechanical ventilation, improves their muscle strength early on, also, it reduces the occurrence of ICU-AW **(6).**

Muscle strength can be measured with precision using the Hand-Held Dynamometer (HHD), a portable device that allows for the assessment of maximum isometric contraction. Because of its portability and light weight, it can be used repeatedly with consistent results. These features make it suitable for use with a wide range of settings and audiences **(9).** HHD provides a convenient, inexpensive, and adaptable method of measuring muscular strength. HHD are small enough to fit in the palm of your hand, allowing the user to apply direct resistance to an extremity's movement while simultaneously measuring the force exerted by the participant's muscles **(10).** HHD is a reliable as well as valid method for measuring the strength as well as power of isometric lower limb muscles **(11).**

Plasma (serum) creatinine is a product of the breakdown of muscle-specific creatine as well as phosphocreatine. Despite its long history as a GFR marker, creatinine does not accurately reflect renal function, particularly in the elderly, because it is impacted by body weight, muscle mass, nutritional status, gender, ethnicity, and physical activity, as well as in the early stages of renal impairment **(12).** Muscle mass influences serum creatinine levels; patients suffering from sarcopenia have lower serum creatinine levels. However, the concentration of cystatin C in the blood does not correlate with muscle mass (**13).**

MATERIAL AND METHODS

Forty Participants aging from 50 to 65 years from both sexes admitted to intensive care units of AL-Sheikh Zayd AL-Nahyan Hospital, Cairo, Egypt, from June 2021 through December 2022, the research was conducted. Two equal groups were selected at random: study group (A) received electrical stimulation using biphasic, symmetrical impulses at 30-50 Hz, 400 μsec pulse duration, 12 seconds on as well as 6 seconds off, at intensities allowed to cause visible contractions. Electric stimulation was done daily for 60 minutes daily until discharge (30 -minute session for lower limb and 30-minute sessions for upper limb) bilaterally on 2 muscle groups (Quadriceps & Tibialis Anterior, in the first session and Wrist Extensors & Elbow Flexors in second session). And a control group (B) received ROM strengthening exercise for both Upper and lower Limbs (active or resisted according to 1RM (10-20 repetitions) for 30 minutes daily until discharge (Hip flexion/extension, Hip abduction/adduction, Knee flexion/ extension as well as Ankle dorsiflexion/plantar flexion).

Inclusive Criteria Included:

All participants were admitted to ICU at El Sheikh Zayed Al-Nahyan Hospital, Cairo, Egypt, with cardiopulmonary or chest diseases. They were conscious and oriented from both sexes. all participants aging 50- 65 years.

Exclusive Criteria Included:

Participant were excluded if they met those criteria: pre-existing neuromuscular diseases, participant medical conditions that precluded the us e of EMS as bone fractures or either skin lesions (e.g., infection & burn), participant with cardiac pacemakers and participants who took some drugs that interfere with creatinine as blood test as (chemotherapy drugs).

Ethics:

The Faculty of Physical Therapy at Cairo University's Ethical Committee Board Giza, Egypt approved this study's protocol; [No: P.T.REC/012/002362]. Before beginning the study, each participant gave their informed consent. The treatment and assessment methods were fully explained to all participants, as were any potential side effects. All adverse events experienced by participants throughout the course of the treatment protocol were to be reported as: skin redness ….

Measurements:

Lafayette Dynamometer: One of the most reliable clinometric tools, dynamometry provides a more objective alternative for measuring muscular strength. (**14).**

Creatinine Level: Skeletal muscle non-enzymatically converts creatine phosphate to creatinine, and the rate at which creatinine is produced endogenously under normal renal function is proportional to the amount of skeletal muscle in the body (**15).**

Treatment procedures:

Group A [Study Group] The procedures of the treatment were divided into:

a) Neuromuscular Electric stimulation for 60 minutes daily from first day of admission until discharge. NMES for 30 minutes was applied at the same time on the Quadriceps as well as Tibialis Anterior muscles for the both lower limbs. For Quadriceps electrodes placements were one on medial side of thigh & second one on bulk of muscle. For tibialis anterior electrodes placement were one in front of head of fibula and other on the front of the lower leg, above the ankle joint

The other 30 minutes of NMES was implemented on Wrist Extensors and elbow flexors of both upper extremities. Electrodes placement for wrist extensors (one on bulk of extensors muscles & other proximal to wrist joint) and for elbow flexors on bulk of biceps brachii with 5 cm apart from each other. The current was rectangular adhesive electrodes (90 × 50 mm) were positioned on placed proximally with respect to each muscle belly of the target muscles. The stimulator (Chattanooga primer) emitted biphasic, symmetric impulses of 30-50 Hz, 400 μsec pulse duration, 12 seconds on and 6 seconds off, with sufficient intensities to induce visible contractions. In cases of uncertainty, contraction was confirmed by palpating the involved muscles.

B) ROM strengthening exercise:

The patients were received ROM exercise active or resisted 10 – 20 repetitions according to 1RM for the following muscles of both upper and lower limbs:(Shoulder flexion/abduction, Elbow flexion/extension, Wrist flexion/extension, Hip flexion/extension, Hip abduction/adduction, Knee flexion/ extension and Ankle dorsiflexion/plantar flexion)

For control group: ROM strengthening exercises were done for upper and lower limbs (10-20 repetitions) muscles for 30 minutes daily from first day admission until discharge (Shoulder flexion/abduction, Elbow flexion/extension, Wrist flexion/extension, Hip flexion/extension, Hip abduction/adduction, Knee flexion/ extension and Ankle dorsiflexion/plantar flexion.

Statistical analysis

Ages were compared between groups using an unpaired t-test. The Shapiro-Wilk test was utilised to ensure data were normally distributed. To examine whether or not there was homogeneity in the variances among groups, Levene's test was carried out. Mixed MANOVA was performed to examine the impact of treatment on muscle strength as well as creatinine. For further multiple comparison, post-hoc tests with the Bonferroni correction were performed. All statistical tests were conducted with a p value of less than 0.05 considered significant. All statistical analysis was carried out via the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Results

- *Subject characteristics*:

Table (1) presented the characteristics of subject for both groups A & B. There was no substantial difference among groups in age as well as sex distribution ($p > 0.05$).

Table 1. Comparison of the characteristics of subject for both groups A & B.

	Group A	Group B	p-value
	Mean ±SD	Mean ±SD	
Age (years)	61.60 ± 4.53	59 ± 5.47	0.11
Sex, N (%)			
Females	15 (75%)	15 (75%)	1
Males	5 (25%)	5 (25%)	

SD, Standard deviation; MD, Mean difference, p value, Probability value

<u>Effect of treatment on muscle strength and creatinine:</u>

Mixed MANOVA showed a substantial interaction effect of treatment as well as time ($F = 14.58$, $p = 0.001$). There was a substantial main effect time ($F = 54.41$, $p = 0.001$). There was a substantial main effect of treatment ($F = 2.82$, $p = 0.01$).

- **Within group comparison**

There was a substantial improvement elbow, wrist, knee as well as ankle muscles strength after treatment for both groups contrasted with that before treatment ($p < 0.01$).

The % of change in elbow flexors as well as extensors, wrist flexors as well as extensors, knee flexors as well as extensors, dorsiflexors as well as planter flexors of group A was 44.44, 4933, 41.19, 53.58, 42.04, 42.44, 41.61 and 42.98% respectively whereas, in group B was 22.50, 18.87, 24.71, 21.01, 11.98, 12.42, 18.36, 17.4 and 6.78% respectively **(Tables 2-3).**

There was a substantial improvement in creatinine level after treatment for group A contrasted with that before treatment ($p < 0.001$), whereas there was no substantial change for group B ($p > 0.05$). (Table 2-3).

- **Between group comparison**

There was no substantial difference among groups before treatment ($p > 0.05$). Comparison among groups after treatment showed a substantial improvement in elbow, wrist, knee as well as ankle muscles strength in addition creatinine level of group A contrasted with that for group B ($p < 0.001$). **(Tables 2-3).**

Table 2. Mean elbow and wrist muscles strength pre and post treatment of group A and B:

	Pre treatment	Post treatment			
	Mean ±SD	Mean ±SD	MD	% of change	p value
Elbow flexors strength (kg)					
Group A	3.69 ± 0.99	5.33 ± 1.29	-1.64	44.44	0.001
Group B	3.60 ± 0.95	4.41 ± 1.07	-0.81	22.50	0.001
MD	0.09	0.92			
	p = 0.77	***p = 0.01***			
Elbow extensors strength (kg)					
Group A	3.73 ± 0.87	5.57 ± 0.89	-1.84	49.33	0.001
Group B	3.71 ± 0.89	4.41 ± 0.87	-0.7	18.87	0.001
MD	0.02	1.16			
	p = 0.92	***p = 0.001***			
Wrist flexors strength (kg)					
Group A	3.86 ± 1.28	5.45 ± 1.13	-1.59	41.19	0.001
Group B	3.48 ± 0.92	4.34 ± 0.86	-0.86	24.71	0.001
MD	0.38	1.11			
	p = 0.28	***p = 0.001***			
Wrist extensors strength (kg)					
Group A	4.05 ± 1.36	6.22 ± 1.39	-2.17	53.58	0.001
Group B	3.76 ± 0.92	4.55 ± 0.98	-0.79	21.01	0.001
MD	0.29	1.67			
	p = 0.44	***p = 0.001***			

SD, Standard deviation; MD, Mean difference; p value, Probability value

Table 3. Mean knee and ankle muscles strength and creatinine pre and post treatment of group A and B:

	Pre treatment	Post treatment			
	Mean ±SD	Mean ±SD	MD	% of change	p value
Knee flexors strength (kg)					
Group A	4.71 ± 0.93	6.69 ± 1.17	-1.98	42.04	0.001
Group B	4.34 ± 0.90	4.86 ± 0.95	-0.52	11.98	0.007
MD	0.37	1.83			
	p = 0.21	***p = 0.001***			
Knee extensors strength (kg)					
Group A	4.83 ± 0.94	6.88 ± 1.02	-2.05	42.44	0.001
Group B	4.59 ± 1.09	5.16 ± 1.16	-0.57	12.42	0.001
MD	0.24	1.72			
	p = 0.45	***p = 0.001***			
Dorsiflexors strength (kg)					
Group A	4.47 ± 1.02	6.33 ± 1.24	-1.86	41.61	0.001
Group B	4.03 ± 0.98	4.77 ± 1.21	-0.74	18.36	0.001
MD	0.44	1.56			
	p = 0.17	***p = 0.001***			
Planter flexors strength (kg)					
Group A	4.49 ± 1.14	6.42 ± 1.34	-1.93	42.98	0.001
Group B	4.08 ± 1.17	4.79 ± 1.16	-0.71	17.40	0.001
MD	0.41	1.63			
	p = 0.27	***p = 0.001***			
Creatinine (mg/dl)					
Group A	1.55 ± 0.69	3.07 ± 1.27	-1.52	98.06	0.001
Group B	1.77 ± 0.87	1.89 ± 0.83	-0.12	6.78	0.68
MD	-0.22	1.18			
	p = 0.39	***p = 0.001***			

SD, Standard deviation; MD, Mean difference; p value, Probability value

DISCUSSION

Study group (A) had greater improvement in muscle strength from admission day one to discharge day than the control group did (B).

Following the initiation of the NMES intervention, study group (A) showed percentage of change in strength of elbow flexors, extensor, wrist flexor, extensors, knee flexors, extensors, dorsiflexors and plantar flexors of group (A) was 44.44%, 49.33%, 41.19%, 53.58%, 42.04%, 42.44%, 41.61%, and 42.98% respectively. These results suggest that the NMES intervention aids in a more rapid recovery of muscle strength during the ICU stay.

These results agree with those reported by **Liu et al., 2020, Baron et al., 2019, Chen et al., 2019 and Fischer et al., 2016,**

ICU patients who begin the NMES intervention as soon as possible have been shown by **Liu et al., 2020** to benefit from increased muscle strength, decreased MV, decreased length of ICU stay, decreased length of hospital stay overall, accelerated recovery, enhanced quality of life after discharge, and to some extent help in the prevention of ICU-AW.

Baron et al., 2019 discussed how various NMES parameters have been used with promising outcomes for maintaining strength as well as muscle mass across multiple studies. Benefits were also observed in the following areas: local and systemic microcirculation, with the possi bility to ESC (endothelial stem cell); in the amplitude of joint movement; in terms of preventing atrophy; in the decline of the MV's length; in the length of stay in the ICU**.**

Chen et al., 2019 In their RCT with a blinded outcome assessment, electrical muscle stimulation improved muscle strength among subjects receiving PMV (prolonged MV), However, it did not work to enhance physical function as well as hospitalization outcomes.

Fischer et al., 2016 noted that NMES had no impact on muscle layer thickness however, was linked to a higher rate (4.5) of restoring muscle strength during the ICU stay.

On the other hand, there are same studies don't support the hypothesis of this study: **Dent et al., 2021, Grunow et al., 2019, Zinglersen et al., 2018, Patsaki et al., 2017**

Dent et al., 2021 resulted in the recommendation that resistance training be prescribed as a primary treatment option for older adults having sarcopenia.

Grunow et al., 2019 found no difference in strength between those who received NMES and those who received a sham treatment, which suggests that there are multiple factors involved in the pathophysiology of ICU-AW.

Zinglersen et al., 2018 result in no further impacts on functional performance when implementing simultaneous NMES throughout hospital stay, However, many of the geriatric patients had seen increases in their functional measures after participating in the chair-based training programe. **Patsaki et al., 2017** reported that ICU survivors who received NMES and individualized physiotherapy did not show greater gains in muscle strength as well as functional status at hospital discharge.

The outcomes of this research revealed an improvement in creatinine which indicate muscle mass with a percentage (98.06%) regarding the study group contrasted with the control group was (6.78 %).

These results agree with those reported by **Pring et al., 2021, Segers et al., 2021, Katsogianni et al., 2019, Hanada et al., 2019.**

Pring et al., 2021 drawing the conclusion that NMES may enable patients to engage in more physical activity than they would be able to do if they were not disabled. This aids in muscle preservation by facilitating earlier mobilization as well as a speedier return to "normal" exercise and function, which in turn reinforces muscle preservation. Long-term outcomes like disease-free survival improve with both greater muscle mass as well as quality.

Segers et al., 2021 found that NMES-treated muscle retained more of its mass compared to control muscle, simultaneous with an increase in the size of type 1 and type 2 myofibers compared to those in the non-stimulated muscle. When comparing stimulated and control muscles, there was no discernible difference in strength.

Katsogianni et al., 2019 conclude that a medium and a high-frequency NMES protocols applied in ICU patients resulted in similar effect on muscle layer thickness of the quadriceps muscle.

Hanada et al., 2019 found that patients who underwent liver transplantation showed less loss of quadriceps muscle mass 30 days after surgery when subjected to NMES of the muscle. Furthermore, quadriceps muscle thickness was substantially associated with both quadriceps muscle strength as well as exercise tolerance.

CONCLUSION:

It was concluded that neuromuscular electric stimulation improves muscle strength and mass of sarcopenic patients in ICU.

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