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FUNCTIONAL ELECTRICAL STIMULATION AS A POSSIBLE NEW THERAPY IN CHRONIC HEART FAILURE

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Abstract

Purpose: The aim of this study was to evaluate the effect of low frequency electrical stimulation of quadriceps and calf muscles on muscles strength and blood flow in patients with chronic heart failure (CHF).

Methods: Fifty patients with chronic heart failure (CHF) were randomly selected from Cairo university hospital, their ages ranged from 40 to 60 years. They were divided into two groups, thirty patients for study group, and twenty patients for control group. Each patient in the study group received both low frequency electrical stimulation with frequency 5 sessions per week for three successive weeks, in addition to medical treatment. Each patient of the control group received the same medical treatment, Pre and post study muscles strength and blood flow assessment was done for each patient of both groups

Results: The result of this study revealed statistically significant difference in muscles strength and blood flow that showed a statistically significant improvement in patients for the study group in comparison to control group there.

Conclusion: Low frequency electrical stimulation of quadriceps and calf muscles improve muscles strength and blood flow in patients with chronic heart failure, Thus we recommend to use electrical stimulation of quadriceps and calf muscles in order to improve muscles strength and blood flow in patients with chronic heart failure

Key words: Electrical stimulation, skeletal muscles, chronic heart failure.

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Introduction:-

Heart failure (HF) is defined as a complex clinical syndrome that can result from any structural or functional cardiac disorder that impairs the ability of the ventricle to fill with or eject blood. The major causes of HF are coronary artery disease, hypertension, cardiomyopathy, and valvular heart disease (36).

Congestive heart failure (CHF) is a condition in which the heart is unable to pump the necessary amount of blood throughout the body. This causes blood to back up in the veins. Fluid pools in the liver and lungs. Swelling occurs first in the feet, ankles, and legs, and then throughout the body as the kidneys begins to retain fluid (15).

The main symptom of HF is the progressive decrease in functional capacity associated with dyspnea with prognostic implications independent of LVEF. The pathophysiological process of HF will eventually lead to skeletal muscle weakness and atrophy, and when the symptoms will affect daily activities, to a sedentary lifestyle and social isolation with an impact on the prognosis of the patient. CHF-related skeletal muscle dysfunction is the result of an ongoing imbalance in the activation of anabolic and catabolic pathways and has been shown to have significant prognostic importance (30)**.**

Congestive heart failure is a clinical syndrome with a complex pathophysiology initiated by left ventricular dysfunction leading to systemic and pulmonary congestion and elevated peripheral vascular resistance. Fluid retention along with peripheral vasoconstriction and reduced skeletal muscle perfusion provides the pathophysiological basis for the symptoms. Coupled with inactivity the stage is set for deconditioning. Skeletal muscle atrophy, changes of fiber-composition (i.e. an increase of type II fibers which are mostly anaerobic, at the expense of aerobic type I fibers), reduced capillary density and reduced cytochrome oxidase activity characterize the condition (1).

The syndrome of chronic heart failure (CHF) is typically characterized by decreased exercise capacity with reduced peak oxygen consumption. The exercise abnormalities are closely related to impaired skeletal muscle behavior. The skeletal muscle oxidative metabolism is depressed, intracellular PH level decrease, phosphocreatine depletion during exercise and phosphocreatine resynthesis decreases the increased sympathetic tone, stimulation of the rennin-angiotensin-aldosterone system influences the redistribution of regional blood flow and creates endothelial dysfunction of all vessels. This leads to an impaired peripheral vascular dilatation in response to vasodilator stimuli reduction of blood flow and O_2 supply in skeletal muscles (29).

Chronic heart failure is often accompanied by complete hypoperfusion, which affects a great part of the skeletal muscle mass. The intensity of catabolism increases, the reactive oxygen species and a large amount of circulating cytokines stimulate the development of apoptosis (apoptosis which is an energy dependent programmed cell death for removal of unwanted individual cells). Chronic hypoxia strongly damages the structural and metabolic integrity of muscle fibers. The resulting general atrophy decreases the power and fatigue resistance of muscles.

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Sometimes, this situation progresses to cardiac cachexia (17).

Patients with chronic heart failure develop significant skeletal muscle atrophy and abnormalities in skeletal muscle metabolic function. These skeletal muscle alterations may contribute to exertional fatigue which is a major limiting symptom in patients with CHF. The cause of the atrophy is related to disuse, repetitive ischemia linked to reduced blood flow on exercise (37).

The beneficial influence of exercise on the aero-metabolic capacity and fatigue tolerance in patients with chronic heart failure has been repeatedly reported. The commonly used methods of training, however, are based on systemic exercise and are not always tolerated by all CHF patients, especially by those with severe heart failure or with life-threatening arrhythmia. Anew approach to cardiac rehabilitation is represented by the method of low-frequency electrical stimulation (LFES) of skeletal muscles. In vitro conditions, a LFES of 10 Hz changes the phenotype of stimulated mammalian skeletal muscle fibers. LFES transforms the myosin chains of ”fast” type to ”slow” type ones, which is characterized by a higher resistance to fatigue LFES and also increases capillary density and enhances perfusion in strength muscles. The most important is the fact that all these experimental results are also applicable to human condition (17).

The leg musculature seems to be affected the most, also displaying a higher percentage of type II fibers, lower activities of mitochondrial enzymes, and a decreased capillary density. Isometric strength of the knee extensor muscles in patients with CHF is markedly lower due to a smaller muscle cross -sectional area: neuromuscular electrical stimulation (NMES) is in widespread use to delay atrophy of skeletal muscles associated with disuse in both disused and healthy muscles with the same efficacy as voluntary contraction. NMES allows training of skeletal muscles without active exertion. Thus patients with CHF using NMES could achieve positive training effects without facing the fear of over exertion or dyspnea probably appearing in voluntary exercise (37).

Many patients with severe CHF are unable to undertake more intensive physical activity. Peripheral muscles are weaker with a decreased mass, reduced aerobic capacity and increased susceptibility to fatigue. Low frequency electrical stimulation, such as used in our study, has previously been shown to produce an increase in oxidative capacity and improve muscle strength (37).

Neuromuscular electrical stimulation (NMES) applied to leg muscles offers an alternative training mode and represents an attractive option for CHF patients who are unable, non-adherent or unwilling to exercise. NMES consists of repeated, rhythmic stimulation of skeletal muscles in a static state, using skin electrodes positioned on the thighs and calf muscles, at an intensity that will lead to visible muscle contractions. The stimulator delivers a biphasic current of low frequency (10–25Hz), with gradually increasing stimulation amplitude of 40–80 mA maximized to the pain threshold of the subject. NMES has been consistently shown to elicit positive effects on functional capacity and skeletal muscle adaptations in patients with HF and unable to participate in traditional aerobic and/or resistance training programs (10)

In addition, there is a difference between conventional training and LFES training. In conventional exercise, more muscle groups are utilized and there are significant changes in central homodynamic variables. Electrical stimulation affects only a low number of muscle groups and makes the training safe even in patients with severe forms of CHF ; LFES can be considered a safe and well tolerated method that has no life-threatening side effects (14).

Purpose of the study:

Low frequency electrical stimulation (LFES) of the lower limbs may improve the skeletal muscle structural and functional patterns in chronic heart failure, including muscle strength and blood perfusion.

Subjects, Material and Methods

A group of 50 patients (30males and 20females) diagnosed with CHF, classified as New York Heart Association (NYHA) classes' III to IV, were included in the study. They were selected from Kaser El Aini hospital.

Their age was ranged 40-60 years. The mean age of the study group was (47.4 + 5.6 years) and control was (47.5 + 5.7years).

Their mean ejection fraction (EF) were less than 30 %.

$$E_f = \frac{SV}{EDV} = \frac{EDV - ESV}{EDV}$$

All patients on optimal pharmacological treatment (angiotensin converting enzyme inhibitor (ACEI,) beta blockers diuretics).

They were divided into two groups; study group 30 patients and control group 20 patients.

Evaluation equipment

Muscle strength measurement to determine the maximal muscle strength the Lafayette muscle test system (USER MANUAL) (MMT) Model 01163, White Plains, New York (10602) of quadriceps and calf muscles were performed .

Fig (1) Lafayette Muscle Test System (Mmt)

Blood flow velocimetry measurement

To evaluate changes in peripheral perfusion. The standard pulsed-wave Doppler velocimetry of the right femoral artery was performed using sonos 2000 echograph (Philips Envisor)

Fig (2) Doppler ultrasound (Philips Envisor)

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Fig (3)
Low frequency electrical stimulation

Therapeutic equipment

An Elpha 2000 dual-channel stimulator (Diameter, Odense, Denmark) was used.
The stimulated muscles included quadriceps and calf muscles on both lower extremities. Special rectangular electrodes, 80 × 100mm (St.Cloud International , Chantonnay , France), were used. (Jancik et al ,2003).

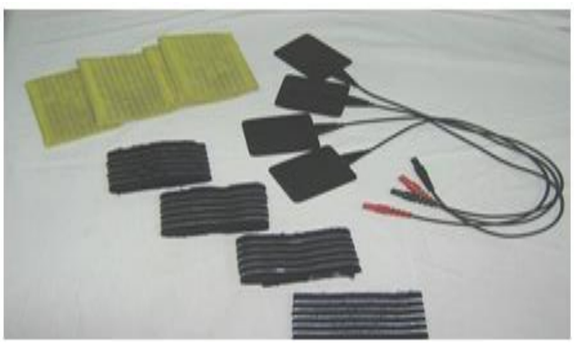

Fig (4) Electrodes and pads of electrical stimulation

Procedure of evaluation of muscle strength:

Manual Muscle Test System (MMT) of the quadriceps and calf muscles was performed before and after the end of the three weeks period of electrical stimulation .

All measurements were performed while the subject sitting ؛ the back well supported, the pelvis and knees flexed at an angle of 90 degrees.

The patients then were carried out 3 consecutive maximal voluntary extensions (contraction time 3sec-resting time 7sec) the highest value was considered as the maximal strength

Fig (5) Muscle test (quadriceps)

Fig (5) Muscle test (quadriceps)

Fig (6) Muscle test (Calf)

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Procedure of evaluation of blood flow velocimetry:

The standard pulsed-wave Doppler velocimetry of the right femoral artery was performed before and after the end of the three weeks period of electrical stimulation (Jancik et al, 2003).

Fig (7) Doppler ultrasound (procedure)

Procedure of the study:

Preparation of the patient:

- Explain the procedure to the patient and the purpose of the study .
- Assessment of muscle strength (for quadriceps and calf muscle) and blood flow (by Doppler Ultrasound) were taken before starting the procedure .
- Attach the electrodes to the site of treatment (quadriceps or calf muscle).

Low frequency electrical stimulation:

Electrical stimulation was performed for one hour/day for five days a week for three consecutive weeks.

- The stimulator delivers a biphasic current of 10 Hz frequency.
- The pulse duration was 200 msec with an (on-off).
- Stimulus mode (20sec stimulation, 20 sec pause).
- The maximal stimulation amplitude was 60 mA.

The muscles to be stimulated were the quadriceps and calf muscles of both legs.

- ❖ For the quadriceps muscles surface electrodes 80×100 mm were positioned on the thighs approximately 5cm below the inguinal fold and 3 cm above the upper patella border.
- ❖ For the calf muscles the electrodes were positioned approximately 2cm under the knee joint and just over the proximal end of the Achilles tendon.

Fig (8) Electrical stimulation (quadriceps

Fig (9) Electric stimulation (calf)

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Data analysis

The mean, standard deviation and the range will be calculated for all subjects. Paired "T" test will be used to determine the mean value of blood flow velocity and muscles strength for each subject before and after treatment program and to compare the changes with each group.

Results:-

Table (1) and fig (1) show the mean, standard deviation, maximum minimum of age, weight, height and BMI of the two different groups. These data include.

Group		Age (yr.)	Weight (Kg)	Height (cm)	BMI (Kg/m^2)
Treatment Group	Mean S.D. Max. Min.	47.4 5.6 55 36	75.1 6.09 85 60	158.5 5.7 170 150	29.9 1.9 34.2 26.6
Control Group	Mean S.D. Max. Min.	47.5 5.7 55 36	75 6.6 85 60	160.2 5.9 150 172	29.3 1.6 33.7 26.7
Significance		P>0.05**	P>0.05**	P>0.05**	P>0.05**

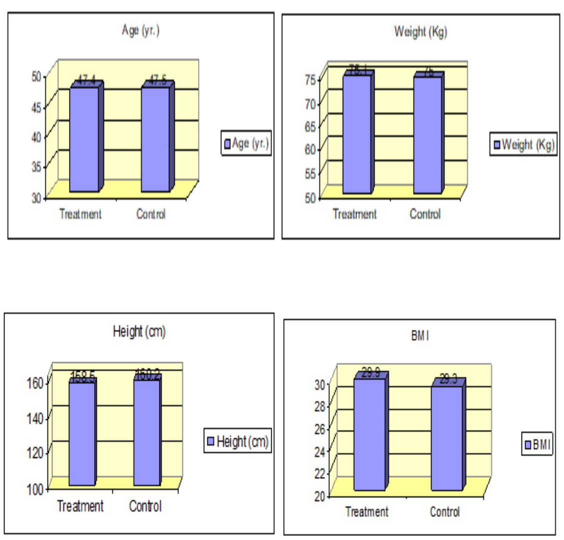

Table (2): Statistical analysis for muscle strength of the right quadriceps before and after the treatment program.

Group / Parameter	Treatment Group	Control Group	t-value	P-value
Before program	9.7±2.9	10.2 ± 2.4	-0.63	P>0.05**
After program	16.2 ± 3.9	10.1± 2.51	6.75	P<0.05*
t-value	-16.1	0.37		
% of changes	% 67.29	% 0.98		
P-value	P<0.05 *	P>0.05**		

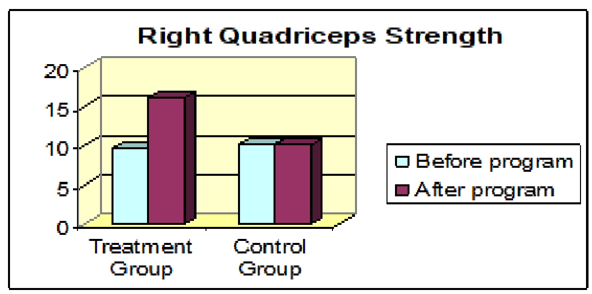

Fig (10): Statistical analysis for muscle strength of the right quadriceps before and after the treatment program.

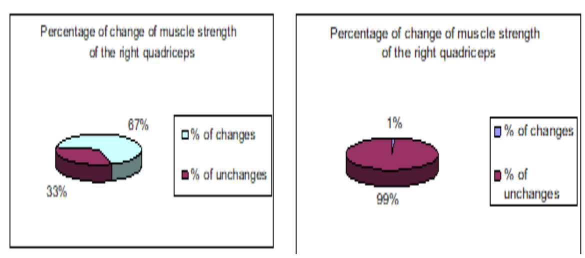

Fig (11): Percentage of change of muscle strength of the right quadriceps before and after treatment for study and control group

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Table (3): Statistical analysis for muscle strength of the Left quadriceps before and after the treatment program.

Group / Parameter	Treatment Group	Control Group	t-value	P-value
Before program	9.6±3.01	10.01 ± 2.56	-0.58	P>0.05**
After program	16.28 ± 3.89	10.2± 2.45	6.83	P<0.05*
t-value	-17.1	-0.49		
% of changes	%69.58	% -1.89		
P-value	P<0.05 *	P>0.05**		

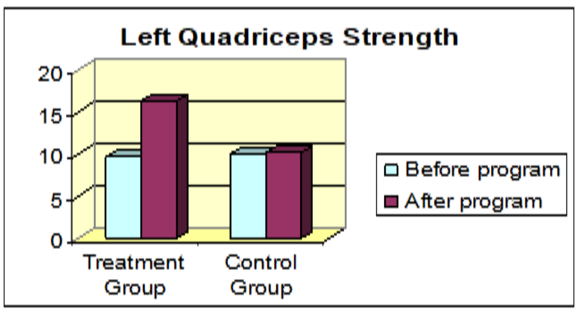

Fig (12): Statistical analysis for muscle strength of the Left quadriceps before and after the treatment program.

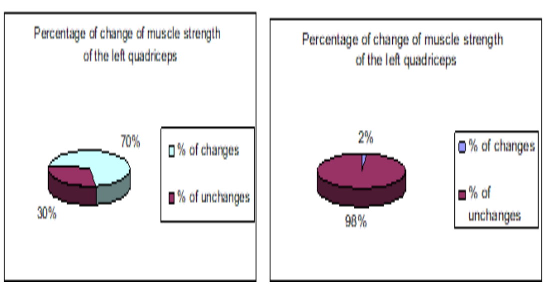

Fig (13): Percentage of change of muscle strength of the left quadriceps before and after treatment for study and control group

Table (4): Statistical analysis for muscle strength of the right Calf muscle before and after the treatment program.

Group / Parameter	Treatment Group	Control Group	t-value	P-value
Before program	5.56±1.49	5.37 ± 0.9	0.51	P>0.05**
After program	10.36± 2.5	5.37± 1.29	9.3	P<0.05*
t-value	-20.8	0.00		
% of changes	%86.33	%0.00		
P-value	P<0.05 *	P>0.05**		

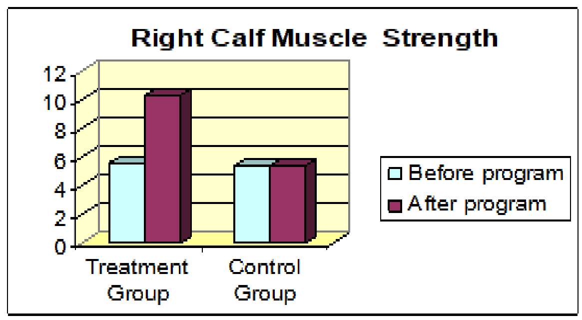

Fig (14): Statistical analysis for muscle strength of the right Calf muscle before and after the treatment program

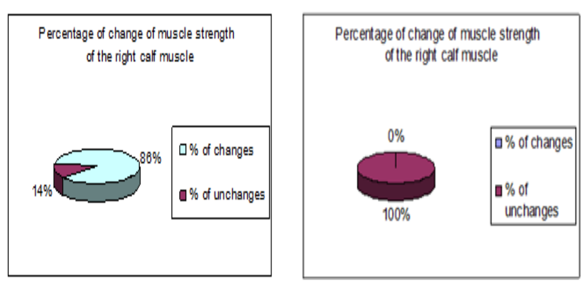

Fig (15): Percentage of change of muscle strength of the right calf muscle before and after treatment for study and control group

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Table (5): Statistical analysis for muscle strength of the Left Calf muscle before and after the treatment program.

Group / Parameter	Treatment Group	Control Group	t-value	P-value
Before program	5.56±1.53	5.37±1.29	0.47	P>0.05**
After program	10.4±2.38	5.37±0.97	10.38	P<0.05*
t-value	-22.08	0.00		
% of changes	%87.05	%0.00		
P-value	P<0.05*	P>0.05**		

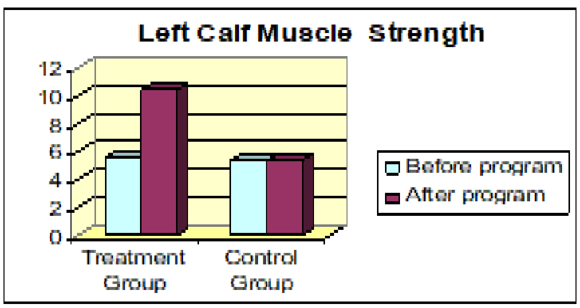

Fig (16): Statistical analysis for muscle strength of the Left Calf muscle before and after the treatment program

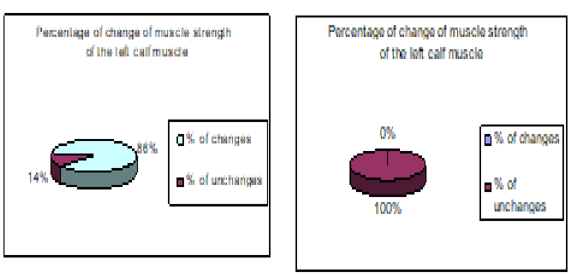

Fig (17): Percentage of change of muscle strength of the left calf muscle before and after treatment for study and control group

Table (6): Statistical analysis for Doppler ultrasound of right lower limb between the study group and control group before and after the treatment program

Group / Parameter	Treatment Group	Control Group	t-value	P-value
Before program	115.43±20.9	108.31±18.4	1.26	P>0.05**
After program	136.32±21.9	109.98±18.2	4.59	P<0.05*
t-value	-12.25	-5.4		
% of changes	%18.09	% 1.5		
P-value	P<0.05*	P>0.05**		

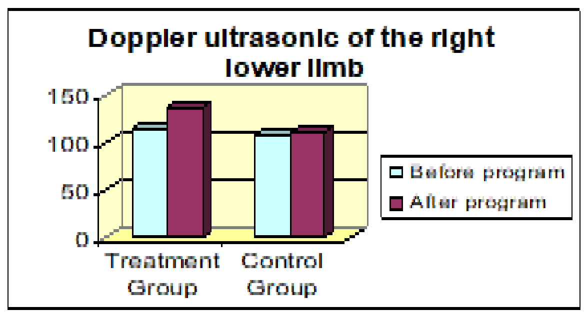

Fig (18): Statistical analysis for Doppler ultrasound of right lower limb between the study group and control group before and after the treatment program

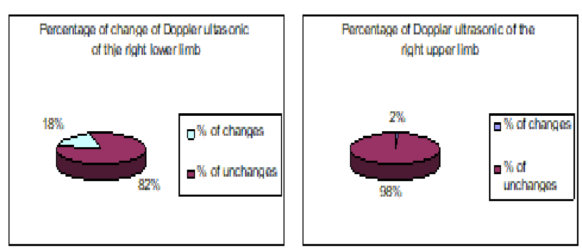

Fig (19): Percentage of Dopplar ultrasonic of the right upper limb before and after treatment for study and control group

Table (7): Statistical analysis for Doppler ultrasound of Left lower limb between the study group and control group before and after the treatment program

Group / Parameter	Treatment Group	Control Group	t-value	P-value
Before program	114.5±19.9	110 ± 18.7	0.8	P>0.05**
After program	133.8 ± 22.2	110.9± 18.6	3.9	P<0.05*
t-value	-14.67	-7.7		
% of changes	%16.85	%0.81		
P-value	P<0.05 *	P>0.05**		

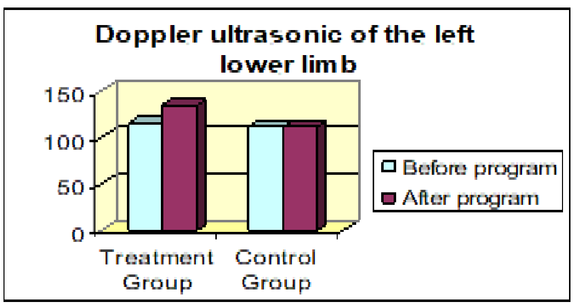

Fig (20): Statistical analysis for Doppler ultrasound of Left lower limb between the Study group and control group before and after the treatment program

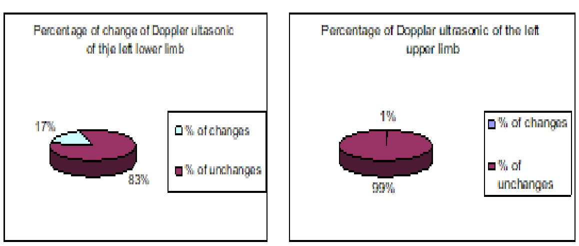

Fig (21): Percentage of Dopplar ultrasonic of the left upper limb before and after treatment for study and control group

Discussion:-

Our present investigation was designed to investigate whether low frequency electrical stimulation of quadriceps and calf muscles has a beneficial effect on muscles strength and blood flow in patients with chronic heart failure (CHF) or not, with the hypothesis that there may be no effect of low frequency electrical stimulation on neither muscle strength nor blood flow in patient with chronic heart failure (CHF) classes III-IV.

Fifty patients diagnosed with CHF, classified as New York Heart Association (NYHA) classes lll to lV, on optimal medical treatment (angiotensin converting enzyme inhibitor(ACEI,) betablockers , diuretics) were randomly selected from Cairo university hospitals (cardiology department) randomly assigned into two groups, study group thirty patients and, control group twenty patients, Each subject of the study group received Electrical stimulation for one hour/day, five days a week, for three consecutive weeks in addition to medical treatment, on the other hand each subject of the control group received medical treatment only , Pre and post program muscles strength and blood flow velocity assessment was done for each subject of both groups.

This is very similar to that used by **(Maillefert, *et al*., 1998)** (28) who first reported a significant improvement of exercise capacity parameters in fourteen patients with CHF after five weeks of LFES, namely an improvement of functional capacity, and a 6 minute walking test. In the same study, a nuclear magnetic resonance test showed a significant increase in the muscle mass of the triceps surae muscle

Similarly, **Vaquero, *et al., 1998*** (39) found a significant increase in functional capacity in CHF patients after eight weeks of electrical stimulation of the lower limbs. The beneficial influence of LFES on muscle strength was reported.

(Egginton and Hudlick ,1999),(10) stated that Chronic low frequency electrical stimulation has been shown to decrease fatigue in fast twitch muscles after a much shorter period of stimulation than that needed for decreased muscle fatiguability achieved by endurance training **,**Improved resistance towards fatigue preceded increased activity of oxidative enzymes and occurred concomitantly with increased capillary supply. a dissociation between muscle endurance and oxidative capacity has also been demonstrated, where stimulation increased fatigue resistance within five to seven days without accompanying changes in the activity of oxidative enzymes, , an increase in the activity of oxidative enzymes has been described in tibialis anterior muscle after ten days of stimulation.

Lewis et al., 2001, (27) Demonstrated that LFES is well tolerated, safe, and results in significant improvement in markers of functional capacity. There was improvement in quality of life for both groups when examined together, and there was a trend towards improved quality of life when LFES and bicycle groups were examined separately. LFES appeared to produce similar improvements in exercise capacity as bicycle training for the patients participating in the study, and it is a potentially attractive form of therapy since it requires less motivation and can be performed whilst a subject is sedentary. As such, it may be suitable for those Patients who are either unwilling or unable to perform more conventional forms of exercise**.**

Similarly, **(Quittan et al ., 2001)** (37) compared Conventional training and LFES training are different, however. More muscle groups are utilised in conventional exercise regimes and there are significant changes in central haemodynamic variables during conventional exercise. Electrical muscle stimulation targets a smaller number of muscle groups, so LFES is well tolerated, safe, although only a crude assessment of central response to local muscle stimulation, it is in keeping with other investigators who have identified no change in cardiac output and only small changes in heart rate during periods of LFES. Whilst this supports the safety of this form of muscle training in CHF patients, further work to investigate both central and local haemodynamic effects of muscle stimulation in a heart failure population is required., although LFES may be benefit in combination with conventional exercise, or as a bridging therapy until a patient regains sufficient functional capacity to exercise conventionally.

Similar experiences have already been reported in the studies by **(Harris, *et al*., 2003)** (14) and **(Nuhr, *et al*, .2004)** (30) According to **(Maillefert,. *et al*1998)** (28) and **(Vaquero, *et al., 1998***) (39) LFES does not cause any significant change in cardiac output and heart frequency. During the eight weeks of stimulation we did not observe any life threatening side effects of LFES on blood pressure or heart rate.

While also confirming the previous findings of increased capillary supply in muscles stimulated for two to four days, capillary supply started to increase at four days with a 40% increase seen at seven days**.** at seven days, the total capillary surface area available for substrate delivery and metabolite exchange was increased by 30% and this may help to explain the improved muscle performance previously demonstrated that capillary growth is stimulated by sustained high blood flow induced by infusion of vasodilators (13).

The contribution of LFES on vascular remodeling observed in the significant increase of the inner diameter of the right femoral artery after electrical stimulation. The significant increase in blood velocity in the femoral artery during stimulation may reflect the importance of the global vascular benefit for the peripheral muscle mass after LFES. This finding may also be considered as a sign of improved adaptation of the local muscle vasculature to the exercise workload (3).

Wiesinger .,et al, 2001 (40) stated that fifteen patients with (CHF) (NYHA class III&IV) had three weeks of LFES, five days /week, one hour /day. Significantly increased both muscle strength and blood flow velocity. It was concluded that LFES may improve the structural and functional patterns of skeletal muscles and may be useful in the treatment of patients with severe chronic heart failure the beneficial effects of chronic low-frequency stimulation of thigh muscles in patients with advanced chronic heart failure were described also**.**

It is possible to suppose that stimulation-induced changes of blood flow velocity are most probably related to the modification of endothelial functions by long-term electrical stimulation, and thus may be NO dependent. The significant increase of the blood flow velocity in femoral artery during stimulation observed in our study may reflect the importance of achieved global vascular benefit for the peripheral muscle mass after three weeks of LFES (24).

This finding is similar to those of previous studies investigating the effects of (LFES) in spinal cord-injured. These results could be attributed to LFES-induced changes in muscle fiber type. Indeed, a decrease in the percentage of type IIb fibers (i.e., glycolytic fibers) and an increase in the percentage of type I and IIa fibers (i.e., oxidative fibers) also improvements of excitation- contraction coupling may be involved : twitch times depend on rates of calcium release, rates of calcium uptake, and myofilament cross bridge kinetics. were previously found in CHF patients after several weeks of LFES training. (4).

These findings agree with results from numerous studies and also confirm our observations on LFES-induced changes in skeletal muscles of normal human subjects Moreover, the changes in the enzyme profile of the present study resemble previous observations on exercise-trained CHF patients, suggesting an improved capacity of aerobic-oxidative energy metabolism (35).

(Quittan et al 2001) (37), reported an increase in muscle strength using a frequency of 50 Hz. The stimulation protocol in was rather intense (60 min/day), and was targeted to relatively large muscle masses in both legs (both the quadriceps and calf muscles), which could explain the significant increase in muscle strength (even with lower frequency)

These results are very similar to those observed in another study; thirty patients with CHF and NYHA class II-III were randomly assigned to a rehabilitation program using either electrical stimulation of skeletal muscles or bicycle training; five

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weeks of (LFES) applied simultaneously to the quadriceps and calf muscles of both legs (thirty minute/day for five days/week); and bicycle training((thirty minute /day for five days/week) aerobic exercise led to significant (increase functional capacity, distance walked in 6 minutes, and of HRmax) in both groups., the improvement in functional capacity seems to be mediated through the improvement in transport mechanisms, which itself appears to be the result of improved maximal workload and exercise duration. (14).

(Nuhr et al., 2004) (30) Published the results of another study population comprised twenty-four patients with stable, chronic congestive heart failure. (NYHA functional classes II, III). The patients were randomized to enter either a classical bicycle training program, or an electrical stimulation program. Symptom limited spiroergometry was examined before and after training. The patients in the bicycle group (group 1) underwent (five daily sessions of twenty minute bicycle exercise), at 60–80% of their maximal heart rate. for five weeks, in the electrical stimulation group (group 2), low-frequency (10 Hz) LFES was applied to both quadriceps and calf muscles. (five daily LFES sessions of one hour were achieved) for five weeks. The following parameters were collected before and at the end of the rehabilitation program: distance walked in 6 minutes &symptom limited spiroergometry parameters& exercise duration and HRmax (maximal heart rate) using Doppler study of the common femoral artery flow: This study showed that: Improvement of exercise capacities in patients with chronic heart failure can be achieved either by classical bicycle training or by electrical stimulation

Similarly, **(Eicher et al 2004)** (11) Published another two randomized trials showed that both home-based electrical stimulation of the legs and classical exercise training can significantly increase muscle strength and quality of life and improve oxygen uptake after several weeks of stimulation in patients with CHF. These results were confirmed also in the present study. The increases in functional capacity and distance walked in 6 minutes, and also the exercise duration after eight weeks of LFES were very similar to the increases in these parameters in the bicycle group**.**

Deley, 2005, (7), compared LFES and conventional exercise training in a group of stable CHF patients. Bilateral quadriceps and calf muscles,: NMES, 10 Hz, biphasic On/off time: 12/8 s Pulse duration: 200 µs Amplitude set to highest tolerable for the patient 60 min/d, 5 d/wk., 5 wk. Conventional exercise: Aerobic exercise (treadmill, bicycle and arm cycling) at 60–70% peak HR; target exertion by Borg scale 13–15, 60 min/d, 5 d/wk., 5 wk. No adverse events reported. Significant increase in the NMES group: Peak VO2 (8.2%), 6MWTD (11.9%), Maximal knee extensor isometric contraction at 90º (9.7%) Significant increase in the bicycle group: Peak VO2 (21.8%), 6MWTD (15.3%), Maximal knee extensor isometric contraction at 90º (11.3%) Aforementioned improvements were not statistically significant between groups.

Karavidas, 2006, (21), published bilateral quadriceps, calf muscle: NMES, 25 Hz, biphasic On/off time: 5/5 s Intensity: visible muscle contraction not strong enough to elicit discomfort or joint movement 30 min/d, 5 d/wk., 6 wk. Control: Sensory electrical stimulation only 30 min/d, 5

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d/wk., 6 wk. No adverse events reported Significant increase in the NMES group: 6MWTD (11.9%), Quality-of-life score (18.4%), TNFα (17.5%), sICAM-1 (15.6%), sVCAM-1 (13.1%).Baseline brachial artery diameter (2.0%), Hyperemic brachial artery diameter (3.5%). Flow mediated dilatation, (29.6%).No change in the aforementioned variables in the control group Peak VO2 and LVEF did not significantly improve in either group.

LeMaitre, 2006, (26) Published bilateral quadriceps, calf muscles, :NMES 25 Hz, biphasic On/off: 5/5 s 30 min/d, 5d/wk., 6 wk. Bicycle: 30 min/d, 5 d/wk., 6 wk., 70% of maximum HR No adverse events reported Significant increase in the NMES group: Treadmill exercise time (s) (12%), 6MWTD (12%), Max quad strength (kg) (13%), Quadriceps fatigue index (17%); Significant increase in the bicycle group: Peak VO2 (16%), Treadmill exercise time (s) (27%), 6MWTD (13%), Max quad strength (kg) (13%), Quadriceps fatigue index (9%). Aforementioned improvements were not statistically significant between groups.

Petr Dobsak, et al., 2006, (33), compared the home-based (LFES) training and bicycle training; the results demonstrated that both methods could significantly influence the muscle strength, improve functional parameters and improve also the quality of life in patients with (CHF) (NYHA class II-III) Patients in the first group (n = 15) had eight weeks of home-based low-frequency electrical stimulation (LFES) applied simultaneously to the quadriceps and calf muscles of both legs (1 h/day for seven days/week); patients in the second group (n = 15) underwent eight weeks of (forty minute aerobic exercise) (three times a week).after the eight weeks. Period significant increases in several functional parameters were observed in both groups: maximal VO2 uptake, maximal workload, distance walked in 6 minutes, and exercise duration. These results demonstrate that an improvement of exercise capacities can be achieved either by classical exercise training or by home-based electrical stimulation. LFES should be considered as a valuable alternative to classical exercise training in patients with CHF.

(Kelsall et al., 2006) (23), reported that the contractions initiated by local electrical stimulation of the strength muscle may cause similar (or identical) vascular reactions as seen during physical exercise, namely the exercise-induced reactive hyperemia in working muscles. Thus, the previously mentioned beneficial effects of LFES on vascular function are most probably related to the effect of increased pulsatile flow on the vessel's endothelial layer. It is likely that the LFES induced changes in blood flow by long-term electrical stimulation are related to modification of endothelial function, and thus may be mostly NO-dependent, but as mentioned earlier**.**

(Petr Dobsak et al., 2006) (34), reported additional mechanisms cannot be excluded, especially the possible growth enhancement of new vessel collaterals, as occurs after physical exercise training. The contribution of LFES on vascular remodeling observed in this study may be seen in the insignificant increase of the inner diameter of the right femoral artery at the end of the sixth week of stimulation. The significant increase in blood velocity in the femoral artery during stimulation may

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reflect the importance of the global vascular benefit for the peripheral muscle mass after six weeks of LFES**.**

Deley, 2008, (8), stated that bilateral quadriceps and calf muscles, : NMES, 10 Hz, biphasic On/off time: 12/8 s Pulse duration: 200 µs Amplitude set to highest tolerable to patient 60 min/d, 5 d/wk., 5 wk. Treadmill exercise: Heart rate corresponding to ventilatory threshold on baseline exercise test 60 min/d, 5 d/wk., 5 wk. No adverse events reported Significant increase in the NMES group: Peak VO2 (12.2%), 6MWTD (13.8%) Significant increase in the bicycle group: Peak VO2 (16.7%), 6MWTD (16.5%) Aforementioned improvements were not statistically significant between groups the greatest improvements were realized by those with the lowest baseline exercise capacity in both groups.

Karavidas, 2008, (22) compared LFES and conventional exercise training in a group of stable CHF patients. Bilateral quadriceps and calf muscles,: NMES,25 Hz, biphasic On/off time: 5/5 s Amplitude set to elicit a muscle contraction without discomfort or significant movement at knee or ankle joints 30 min/d, 5 d/wk., 6 wk. Control: Same NMES protocol but amplitude set to a level that did not elicit a muscle contraction No adverse events reported Significant increase in the NMES group: 6MWTD (9.3%), Quality-of-life score (37.2%) No change in the aforementioned variables in the control group Nonsignificant trend toward a reduction in B-type natriuretic peptide only in the NMES group (6%, P =0.053)

Banerjee, 2009, (2) compared LFES and conventional exercise training in a group of stable CHF patients: Bilateral quadriceps, hamstrings, calf muscles, and gluteal muscles 4 Hz, rhythmic contraction Maximum current: 300 mA Intensity: 90% of heart rate reserve, determined individually 60 min/d, 5 d/wk., 8 wk. Washout phase: Return to habitual physical activity level No adverse events reported but inability to tolerate NMES was the drop out cause for 2 patients Significant increase in the NMES group: Peak VO2 (10%), 6MWTD (9.6%), maximal knee extensor isometric contraction at 90º (7.1%) No significant difference in the aforementioned variables between baseline and washout. The greatest improvements were achieved by those with the lowest baseline exercise capacity and strength. No changes in LVEF and diastolic function.

Deftereos, 2010, (6), reported in the study that: Bilateral quadriceps and calf muscles,: NMES 25 Hz On/off time: 5/5 s 30 min/d, 5 d/wk., 6 wk. Bicycle: 30 min/d, 5 d/wk., 6 wk., 70 % of maximal HR No adverse events reported Significant increase in the NMES group: 6MWTD (10%), Peak VO2 (6%), endothelial function FMD (38%), Endothelium-independent vasodilation (1.4%), Significant increase in the bicycle group: 6MWTD (13%), Peak VO2 (14%), endothelial function (48%), endothelium-independent vasodilation (2%). Significantly higher FMD value after bicycle training compared to NMES Significantly higher 6MWTD and Peak VO2 after bicycle training compared to NMES LVEF did not significantly improve in either group

Araujo, 2012, (5), reported in the study that NMES: bilateral quadriceps 20 Hz, Pulse duration: 200 µs 60 min x 2/d, daily until hospital discharge Control: 60 min x 2/d, daily until hospital discharge but the electrostimulation device was turned off.

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No adverse events reported Significant improvement in the NMES group: 6MWTD (127%), lactate decreased (33%) No change in the aforementioned variables in the control group

Similarly, **Dobsak, 2012**, (9), reported in the study that NMES: bilateral quadriceps and calf muscles, 10 Hz, biphasic On/off time:20/20 s Intensity: 60 mA 60 min x 2/d, 7d/wk., 12 wk. ET: 12 wk. total with bicycle: 40 min 2 wk., 20 min in the last 10 wk. and resistance training 20 min last 10 wk. No adverse events reported Significant beneficial effects in the NMES group: Peak VO2 (9.8%), Big-endothelin pmol/L (-25%), CRP mg/L (-65.3%) Significant beneficial effects in the aerobic ET group: Peak VO2 (11.2%), Big-endothelin pmol/L (-8.2%), CRP mg/L (-60%) Aforementioned improvements were not statistically significant between groups No changes in LDL, HDL and glucose level Positive effect after 12 weeks of ET or NMES on arterial stiffness and autonomic balance in patients with moderate CHF

Karavidas, 2013, (20) reported in the study that NMES: Bilateral quadriceps and calf muscles, 25 Hz On/off time: 5/5 s Intensity: visible muscular contraction 30 min/d, 5 d/ wk., 6 wk. Placebo: same regimen, 5 Hz, without visible muscular contractions No adverse events reported Significant beneficial effects in the NMES group: 6MWTD (23.8%), FMD (73.6%), improvement in quality of life and depression assessed by KCCQ, MLHFQ scores, BDI questionnaires and Zung self-rated depression scores. Placebo group: no change in FMD, A tendency toward a lower mitral E/e' wave ratio was observed in the NMES group Significant difference between groups: FMD, 6MWTD, quality of life and depression BNP nonsignificant change in plasma BNP levels was observed between both groups

In agreement**, Labrunee, 2013,** (25), reported that: NMES, left leg quadriceps and triceps surae muscle, 25 Hz Duration: 5 min On/off time: 3/3 s TENS: left leg quadriceps and triceps surae muscle Current non polarized, 80 Hz, Duration: 5 min On/off time: 3/3 s cross over, randomized and sham controlled No adverse events reported Significant beneficial effects in the NMES group: reduce MSNA Significant beneficial effects in the NMES group: reduce MSNA No variation of blood pressure, heart rate or respiratory parameters was observed after stimulation

In agreement, **Parissis, 2014,** (32) reported that bilateral quadriceps and calf muscles,: NMES: 25 Hz On/off time: 5/5 s Intensity: visible muscular contraction to pain threshold 30 min/ d, 5 d/ wk., 6 wk. Placebo: Bilateral quadriceps and calf muscles, 5 Hz (did not lead to palpable contractions 30 min/ d, 5 d/ wk., 6 wk. No adverse events reported significant beneficial effects in the NMES group: FMD (120%), KCCQ, MLHFQ scores, BDI questionnaires and Zung self-rated depression scores. Significant difference between groups: FMD, quality of life and depression

On the other hand**, Soska, 2014**, (35), reported that bilateral extensors muscle,: NMES, 10 Hz, On/off time: 20/20 s 60 min x 2/ d, 7 d/wk., 12 wk. AT: Bicycle, 10 min+40 min +10 min, 3x/wk., to individual anaerobic threshold, first 2 wk. AT 20 min and resistance training 20 min for the following 10 wk. AT + NMES: identical AT + identical NMES, 12wk No adverse events reported Significant beneficial effects in the NMES group: Peak VO2 8.3%), Duration of exercise min (9.4%), quality of life MLHF score (-16.6%) Significant beneficial effects in the AT group: Peak VO2 (15.2%), Duration of exercise min (19.8%), quality of life MLHF score (-27.9%) Significant beneficial effects in the AT+NMES group: Peak VO2 (15.3%), Duration of exercise (min) (10.7%), quality of life MLHF score (-29.1%) The results of the three studied rehabilitation training protocols did not significantly differ statistically. It can be stated that aerobic ET combined with EMS adds no statistically significant benefit

Palau, 2016, (31), concluded that NMES: bilateral quadriceps and gastrocnemius muscles, 10-50 Hz On/off time: 5/5 s Intensity: pain threshold 45 min/d, 2 d/wk., 12 wk. IMT: 20 min x 2/d, 7 d/ wk., 12 wk. IMT + NMES: identical IMT + Identical NMES Standard treatment: no IMT, NMES Ongoing

Similarly, **Kadoglou, 2017,** (19) concluded that bilateral quadriceps and gastrocnemius muscles, : NMES 25 Hz On/off: 5/5 s Intensity: visible muscular contraction 30 min/d, 5 d/ wk., 6 wk. Placebo: 5 Hz, not leading to a visible or palpable contraction No adverse events reported Significant beneficial effects in the NMES group: 6MWT, hospitalization rate. Patients after NMES had no difference compared to non-NMES patients in terms of survival The hospitalization rate was significantly lower in the NMES group before and after adjustment for major prognostic factors

Similarly, **Forestieri, 2017**, (12) concluded that bilateral quadriceps and calf muscles,: NMES, 40 Hz, On/off: 10/20 s Intensity: visible muscular contraction 60 min x2/day, daily, 2 wk. Control: breathing exercises and global active exercises of the upper and lower limbs in bed No adverse events reported Stimulation group exhibited a significantly higher increase compared to the control group in terms of 6MWT. NMES group: significantly higher dose reduction of dobutamine compared to the control group

On the other hand, **Iliou, 2017,** (16) concluded that NMES+ET: 20±5 low frequency NMES for quadriceps muscles after aerobic training and/or additional physical activities, 10Hz biphasic current, Pulse duration 200µs, On/off: 20/40 s, ET: 20±5 physical training sessions, 4–8 weeks Session: 30–60-minute period of aerobic exercise training on a bicycle or treadmill NMES on top of ET does not demonstrate any significant additional improvement in exercise capacity in moderately severe and stable CHF patients.

Ploesteanu R L, et al 2018, (36), concluded that research conducted in the last two decades suggests that neuromuscular electrical stimulation of the lower limb muscles (NMES) may be a "bridge" to conventional exercise or an alternative for patients with advanced chronic heart failure (CHF), non-compliant or non-responsive to physical training. Through stimulating the work of the skeletal muscles, NMES increases the functional capacity, muscle mass and endurance in patients with CHF. A beneficial effect of NMES on functional capacity, vascular endothelial function, quality of life and aerobic enzymes activity has been shown. A significant benefit of this novel therapy in heart failure is the fact that the procedure can be home-based, after prior guidance of the patient.

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On the contrary, **Jirka Cops et al. 2020,** (18), Published The importance of physical activity has become evident since a sedentary lifestyle drives cardiovascular disease progression and is associated with increased morbidity and mortality. The favorable effects of exercise training in chronic heart failure (HF) and chronic kidney disease (CKD) are widely recognized and exercise training is recommended by European and American guidelines. However, the application of exercise intervention in HF patients hospitalized for acute decompensation or acute worsening in cardiac function has not been explored extensively and, as a result. Acute HF is often accompanied by signs and symptoms of congestion, termed acute decompensated heart failure (ADHF), which leads to worsening renal function (WRF) and eventually negatively affects both thoracic and abdominal organs. Therefore, we first provide a comprehensive overview of the impact of exercise training in hospitalized patients demonstrating acute decompensating HF.

Conclusion:

The present study showed that acetylcholine (Ach) Iontophoresis produced statistically significant improvement in microcirculation in type 2diabetic neuropathy. The present study has shown that the endothelium- dependent vasodilations are impaired in diabetic patients predisposed to foot ulceration and that neuropathy is the main factor associated with this abnormality.

References:-

1. **Alf Inge Larsen and Kenneth Dickstein , (2004):** Can sedentary patients with heart failure achieve the beneficial effect of exercise training without moving? Eur Heart J. (25): Number 2
2. **Banerjee, P. Caulfield, B. Crowe, L. Clark, A. L.:** Prolonged Electrical Muscle Stimulation Exercise Improves Strength, Peak VO2, and Exercise Capacity in Patients With Stable Chronic Heart Failure,‖ J. Card. Fail. 2009; 15:319–326.
3. **Brendle, DC. Joseph, LJ. Corretti, MC. Gardner, AW. Katzel, LI. (2001):** Effects of exercise rehabilitation on endothelial reactivity in older patients with peripheral arterial disease. Am J Cardiol; 87:324 329.
4. **Crevenna, R. Posch, M. Sochor, A. (2002):** Optimizing electrotherapy a comparative study of 3 different currents. Wien Klin Wochenschr; (114): 400-4.
5. **de Araújo, C. J. S. Gonçalves, F. S. Bittencourt, H. S. dos Santos, N. G. Junior, S. V. M. Neves, J. L. B. Fernandes, A. M. S. Junior, R. A. dos Reis, F. Guimarães, A. C. Junior, E. Carvalho, V. O.:** Effects of neuromuscular electrostimulation in patients with heart failure admitted to ward,‖ J. Cardiothorac. Surg. 2012;7:124.
6. **Deftereos, S. Giannopoulos, G. Raisakis, K. Kossyvakis, C. Kaoukis, A. Driva, M. Pappas, L. Panagopoulou, V. Ntzouvara, O. Karavidas, A. Pyrgakis, V.**

Rentoukas, I. Aggeli, C. Stefanadis, C.: Comparison of muscle functional electrical stimulation to conventional bicycle exercise on endothelium and functional status indices in patients with heart failure,‖ Am. J. Cardiol. 2010;106:1621–1625.

7. **Deley, G. Kervio, G. Vergès, B. Hannequin, A.. Petitdant, M. Grassi, B Casillas, J. (2005):** Comparison of low-frequency electrical stimulation and conventional exercise training in patients with chronic heart failure,‖ Eur J Cardiovasc Prev Rehabil.;12:226–33.
8. **Deley, G. Eicher, J. C. Verges, B. Wolf, J. E. Casillas, J. M.**; Do low-frequency electrical myostimulation and aerobic training similarly improve performance in chronic heart failure patients with different exercise capacities?,‖ J. Rehabil. Med.2008; 40:219–224.
9. **Dobšák, P. Tomandl, J. Spinarova, L. Vitovec, J. Dusek, L. Novakova, M. Jarkovsky, J. Krejci, J. Hude, P. Honek, T. Siegelova, J. Homolka, P.:** Effects of Neuromuscular Electrical Stimulation and Aerobic Exercise Training on Arterial Stiffness and Autonomic Functions in Patients With Chronic Heart Failure,‖ Artif. Organs. 2012; 36:920–930.
10. **Egginton and O. Hudlick.a (1999):** early changes in performance, blood flow and capillary fine structure in rat fast muscles induced by electrical stimulation Journal of Physiology 515.1, pp. 265—275 265
11. **Eicher, J.C. (2004):** Rehabilitation in chronic congestive heart failure; comparison of bicycle training and muscle electrical stimulation. SCRIPTA MEDICA (BRNO)– 77 (5–6): 261–270.
12. **Forestieri, P. Bolzan, D. W. Santos, V. B. Moreira, R. S. L. de Almeida, D. R. Trimer, R. de Souza Brito, F. Borghi-Silva, A. de Camargo Carvalho, A. C. Arena, R. Gomes, W. J. Guizilini, S.:** Neuromuscular electrical stimulation improves exercise tolerance in patients with advanced heart failure on continuous intravenous inotropic support use—randomized controlled trial,‖ Clin. Rehabil. 2017;32:66-74.
13. **Hambrecht, R.Gielen, S. Linke, A. (2000):** Effects of exercise training on left ventricular function and peripheral resistance in patients with chronic heart failure: a randomized trial. JAMA; (283): 3095-10.
14. **Harris, S. LeMaitre, JP. Mackenzie,G. (2003):** A randomised study of home-based electrical stimulation of the legs and conventional bicycle exercise training for patients with chronic heart failure. Eur Heart J (24):871–8.
15. **Hunt, SA. Abraham, WT. Chin, MH. et al (2005) :**Guideline Update for the Diagnosis and Management of Chronic Heart Failure in the Adult: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines.Circulation. ; 112:e154.
16. **Iliou, M. C. Vergès-Patois, B. Pavy, B. Charles-Nelson, A.**

Monpère, C. Richard, R. J. C. Verdier, J. C. and on behalf for the CREMS-HF (Cardiac REhabilitation and electrical MyoStimulation-Heart Failure) study group: Effects of combined exercise training and electromyostimulation treatments in chronic heart failure: A prospective multicentre study,‖ Eur. J. Prev. Cardiol. 2017; 24:1274–1282.

17. **JANâIK, J . (2002);** Low frequency electrical stimulation of skeletal muscle in patient with chronic heart failure; Circulation Journal .75 (4).
18. **Jirka Cops, Sibren Haesen, Bart De Moor, Wilfried Mullens, Dominique Hansen.**: Exercise intervention in hospitalized heart failure patients, with emphasis on congestion-related complications: a review: 2020, 25(2):257-26
19. **Kadoglou, N. P. Mandila, C. Karavidas, A. Farmakis, D. Matzaraki, V. Varounis, C. Arapi, S. Perpinia, A. Parissis, J.:** Effect of functional electrical stimulation on cardiovascular outcomes in patients with chronic heart failure,‖ Eur. J. Prev. Cardiol. 2017;24;833-839.
20. **Karavidas, A. Driva, M. Parissis, J. T. Farmakis, D. Mantzaraki, V. Varounis, C. Paraskevaidis, I. Ikonomidis, I. Pirgakis, V. Anastasiou-Nana, M. Filippatos, G**.: Functional electrical stimulation of peripheral muscles improves endothelial function and clinical and emotional status in heart failure patients with preserved left ventricular ejection fraction,‖ Am. Heart J. 2013;166:760–767.
21. **Karavidas, A. I. Raisakis, K. G. Parissis, J. T. Tsekoura, D. K. Adamopoulos, S. Korres, D. a Farmakis, D. Zacharoulis, A. Fotiadis, I. Matsakas, E. Zacharoulis, A.:** Functional electrical stimulation improves endothelial function and reduces peripheral immune responses in patients with chronic heart failure.,‖ Eur. J. Cardiovasc. Prev. Rehabil. 2006;13:592–597.
22. **Karavidas, A. Parissis, J. Arapi, S. Farmakis, D. Korres, D. Nikolaou, M. J. Fotiadis, N. Potamitis, X. Driva, I. Paraskevaidis, E. Matsakas, G. Filippatos Kremastinos, D. T.:** Effects of functional electrical stimulation on quality of life and emotional stress in patients with chronic heart failure secondary to ischaemic or idiopathic dilated cardiomyopathy: A randomised, placebo-controlled trial,‖ Eur. J. Heart Fail. 2008;10:709–713.
23. **Kelsall, CJ. Brown, Kent, J. Kloehn, M. Hudlicka, O. DOBSAK, P.:** (2006): endothelial dysfunction is restored in ischaemic muscles by chronic electrical stimulation. . Circulation Journal Vol.70, 2006 J Vasc Res 2004; (41): 241– 251.
24. **Kojda, G. Cheng, YC. Burchfield, J. Harrison, DG. (2001):** Dysfunctional regulation of endothelial nitric oxide synthase (eNOS) expression in response to exercise in mice lacking one eNOS gene. Circulation;103(23):2839–44.

Corresponding Author: Dr. Ibrahim Abu Zaid

25. **Labrunée, M. Despas, F. Marque, P. Guiraud, T. Galinier, M. Senard, J. M. Pathak, A.:** Acute electromyostimulation decreases muscle sympathetic nerve activity in patients with advanced chronic heart failure (EMSICA study),‖ PLoS One. 2013;8:1–8.
26. **LeMaitre, J. P. Harris, S. Hannan, J.. Fox, K. A. A Denvir, M. A.:** Maximum oxygen uptake corrected for skeletal muscle mass accurately predicts functional improvements following exercise training in chronic heart failure,‖ Eur. J. Heart Fail. 2006;8:243–248.
27. **Lewis, EF. Johnson, PA. Johnson, W. Collins, C. Griffin, L. Stevenson, LW. (2001):** Preferences for quality of life or survival expressed by patients with heart failure. J Heart Lung Transplant;(20):1016–24
28. **Maillefert, J. F Eicher, J. C. Walker, P. Dulieu, V. Rouhier-Marcer, I. Branly, F. M. Cohen, M Brunotte, F. Wolf, J. E. Casillas, J. M. Didier, J. P.:** Effects of low-frequency electrical stimulation of quadriceps and calf muscles in patients with chronic heart failure. J. Cardiopulm. Rehabil. 1998;18:277–82.
29. **MIFKOVL, (2004):** Improvement of muscular performance in patient with chronic heart failure after some weeks of low frequency electrical stimulation; SCRIPTA MEDICA BRNO, 77 (5-6) December **.**
30. **Nuhr, MJ. Pette, D. Berger, R. (2004):** Beneficial effects of chronic low-frequency stimulation of thigh muscles in patients with advanced chronic heart failure. Eur Heart J; (25): 136-43.
31. **Palau P, Domínguez E, López L, Heredia R, González J, Ramón JM, Serra P, Santas E, Bodí V, Sanchis J, Chorro FJ, Núñez J:** Inspiratory Muscle Training and Functional Electrical Stimulation for Treatment of Heart Failure With Preserved Ejection Fraction: Rationale and Study Design of a Prospective Randomized Controlled Trial,‖ Clin. Cardiol. 2016;39:433–439.
32. **Parissis, J. Karavidas, A. Farmakis, D. Papoutsidakis, N. Matzaraki, V. Arapi, S. Potamitis, N. Nikolaou, M. Paraskevaidis, I. Ikonomidis, I. Pyrgakis, V. Kremastinos, D. Lekakis, J. Filippatos, G.:** Efficacy and safety of functional electrical stimulation of lower limb muscles in elderly patients with chronic heart failure: A pilot study,‖ Eur. J. Prev. Cardiol. 2015;22:831–836.
33. **Petr Dobsak, (2006):** Electrical Stimulation of Skeletal Muscles An Alternative to Aerobic Exercise Training in Patients With Chronic Heart Failure? Int Heart J 47 (3).
34. **Petr Dobsak, (2006):** Low – Frequency Electrical Stimulation Increases Muscle Strength and Improves Blood supply in patients With Chronic Heart Failure; Circulation Journal ,70 (4).
35. **Pette, D.(2002):** The adaptive potential of skeletal muscle fibers. Can J Appl Physiol;(27):423.

Corresponding Author: Dr. Ibrahim Abu Zaid

36. **Ploesteanu RL, Nechita AC, Turcu D, Manolescu BN, Stamate SC, Berteanu M:** Effects of neuromuscular electrical stimulation in patients with heart failure – review: J Med Life, 11(2):107-118, 2018.
37. **Quittan, M. Wiesinger, GF. Sturm, B. Puig, S. Mayr ,W.Sochor, A.(2001)** : Improvement of thigh muscles by neuromuscular electrical stimulation in patients with refractory heart failure: A single-blind, randomized, controlled trial. Am J Phys Med Rehabil; (80): 206 –214.
38. **Soska, V. Dobsak, P. Pohanka, M. Spinarova, L. Vitovec, J. Krejci, J. Hude, P. Homolka, P. Novakova, M. Eicher, J.-C. Wolf, J.-E. Dusek, L. Siegelova, J.:** Exercise training combined with electromyostimulation in the rehabilitation of patients with chronic heart failure: A randomized trial.,‖ Biomed. Pap. Med. Fac. Univ. Palacky. Olomouc. Czech. Repub. 2014;158:98–106.
39. **Vaquero, A. Chicharro, J. Gil, L. Ruiz, M. Sánchez, V. Lucía, A. Urrea, S. Gómez, M.:** Effects of Muscle Electrical Stimulation on Peak VO 2 in Cardiac Transplant Patients,‖ Int. J. Sports Med. 1998;19:317–322.
40. **Wiesinger, GF. Crevenna, R. Nuhr, MJ. Huelsmann, M. Fialka-Moser, V. Quittan, M.(2001):** Neuromuscular electric stimulation in heart transplantation candidates with cardiac pacemakers. Arch Phys Med Rehabil; (82): 1476-7.

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