SCRIPTA MEDICA (BRNO) – 76 (5): 285–290, *November 2003*

INCREASE IN MUSCLE STRENGTH AFTER LOW-FREQUENCY ELECTRICAL STIMULATION IN CHRONIC HEART FAILURE

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A b s t r a c t

This study was designed to evaluate the effect of low-frequency electrical stimulation (LFES) of skeletal muscles in patients with chronic heart failure (CHF). A group of 14 patients with CHF, NYHA grades III to IV, were examined before and after 3 weeks of LFES of quadriceps muscles. Improvement in muscle strength was evaluated by dynamometry and blood flow velocity in the right femoral artery was assessed by pulsed-wave Doppler velocimetry. Three weeks of LFES significantly increased both muscle strength and blood flow velocity. It is 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.

K e y w o r d s

Chronic heart failure, Low-frequency electrical stimulation, Skeletal muscle, Dynamometry

INTRODUCTION

Chronic heart failure (CHF) is considered to be a complex condition that results from total hypoperfusion and is associated with neurohumoral activation. Sympathetic hyperactivation and the renin-angiotensin-aldosterone system may induce endothelial dysfunction in small and large vessels and may influence the distribution of terminal blood flow. These changes are characterised by impaired peripheral vascular dilatation in response to vasodilator stimuli and reduction of blood supply resulting in wasted skeletal muscles and depletion of skeletal muscle oxidative enzymes. The skeletal muscle metabolic integrity and muscle oxygen exchange are important determinants of exercise capacity; in chronic heart failure, both muscle metabolism and oxygen delivery are impaired and may contribute to exercise intolerance. During the last 10 years, many studies reported that physical training has beneficial effects on exercise capacity, ventilation, metabolic status, autonomic control of heart rate and other parameters (*1*). Furthermore, exercise programmes may also improve skeletal muscle performance and impaired endothelial functions *(2, 3).* However, at present most training protocols require systemic exercise and, therefore, cannot be used by all patients and especially not by those who have a severe grade of heart failure. There is growing evidence that low-frequency electrical stimulation (LFES) has positive effects on the metabolic and structural functions of strength muscles. In *in vitro* conditions, a LFES of 10 Hz influences the genome of stimulated skeletal muscle fibers and induces complete transformation of the myosin chains from the “fast” to the “slow” types. The latter are more resistant to fatigue (*4, 5*). LFES also has been shown to increase capillary density and to enhance blood supply in mammalian strength muscles (*6*). The aim of our study was to evaluate the effects of LFES on muscle strength and blood supply to muscles in patients with chronic heart failure.

MATERIALS AND METHODS

Patients

A group of 14 patients diagnosed with CHF, classified as NYHA grades III to IV, were included in the study. The mean age was 54±7 years. Their mean ejection fraction (EF) was 18.1±2 %. They all had undergone coronarography, were symptomatically stable and on optimal pharmacological treatment (ACEI, betablockers, diuretics) that remained unchanged throughout the study.

Low-frequency electrical stimulation

The stimulated muscles included quadriceps and calf muscles on both lower extremities. Special rectangular electrodes, 80x100mm (St.Cloud International, Chantonnay, France), were used. Electrical stimulation was performed for 1 hour/day, 7 days a week, for 3 consecutive weeks, using an Elpha 2000 dual-channel stimulator (Danmeter, Odense, Denmark). The stimulator delivered a biphasic current of 10 Hz frequency. The pulse duration was 200 msec with an “on-off” stimulus mode (20 s stimulation, 20 s pause). The maximal stimulation amplitude was 60 mA.

To determine the maximal muscle strength (F_{max}), an isometric dynamometry of quadriceps muscles was performed every week, using a PC-2 SDT dynamometer (Czech Republic).

Bood flow velocimetry measurement

To evaluate changes in peripheral perfusion, the standard pulsed-wave Doppler velocimetry of the right femoral artery was performed before and after the end of the three-week period of stimulation, using a Sonos 2000 echograph (Hewlett Packard, Andover, USA) (*7*). The measurements were performed before each session after 15 min of rest and after 15 min of stimulation. The mean value of blood flow velocity (cm/sec) was calculated from five measurements.

The experimental protocol was approved by the Hospital Ethics Committee and informed consent was obtained from each participant.

The Wilcoxon paired test was used for statistical analysis. The results were expressed as mean ± SD values. A *P* value <0.05 was considered significant.

RESULTS

Three weeks of low-frequency eletrical stimulation resulted in a significant increase in muscle strength in CHF patients. The mean (SD) results of maximal muscle strength by isometric dynamometry are shown in *Table 1*. All 14 patients tolerated the training procedure well and reported a considerable improvement in their management of everyday activities.

The improvement in muscle contratility was associated with a significant increase in blood flow velocity in the right femoral artery, as measured at 15 min of stimulation following 3 weeks of LFES. The values of blood flow velocity at rest before and after 3 weeks of stimulation did not differ (*Table 2*).

DISCUSSION

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. Chronic 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 (*8, 9*). The beneficial effects of LFES on vascular functions may be related to the effect of an increased blood flow in endothelium. It seems that electrical stimulation and

Table 1
Results of muscle strength measurements before and after 3 weeks of low-frequency electrical stimulation (LFES) in patients with chronic heart failure

Muscle strength	Before LFES	After LFES	Statistical significance
F_{max} (N)	203±89	251±110	$P<0.05$
F_{max} (%)	100±44	126±30	$P<0.05$

F_{max} (N), maximal muscle strength; N, Newtons .

Table 2
Blood flow velocity in the right femoral artery before and after 3 weeks of low-frequency eletrical stimulation (LFES)

	Before LFES	After LFES	Statistical significance
Before sessions after 15 min of rest (cm/sec)	12.9±5.2	13.2±4.7	Non-significant
At 15 min of muscle stimulation (cm/sec)	42.8±17.1	49.9±24.9	$P<0.03$

resulting muscle contractions induce similar vascular reactions as does physical exercise (*10*). In CHF patients before muscle stimulation, chronic structural vessel changes may be associated with sustained changes in endothelial function, and during exercise or muscle stimulation, they may be improved (*11*). The increase in blood flow through the femoral artery during muscle stimulation demonstrated in our study shows the importance of non-pharmacologial treatment in chronic heart failure. It is probable that LFES induces qualitative and quantitative changes in strength muscle fibers; these are probably related to the transformation of fast protein isoforms into their slow counterparts, with the subsequently enhanced activity of oxidative enzymes, improved oxygen consumption and growth of the terminal microvascular bed (*12*). The results of LFES protocols may be important in determining the profile of obtained changes and may account for more marked improvements in muscle strength (*13, 14*). The benefit of exercise in CHF patients is now well established. However, 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 haemodynamic variables. Electrical stimulation affects only a low number of muscle groups and makes the training safe even in patients with severe forms of CHF (*15*).

In conclusion, LFES can be considered a safe and well tolerated method that has no life-threatening side effects. LFES of the lower limbs may improve the skeletal muscle structural and functional patterns in chronic heart failure, including muscle strength and blood perfusion.

A c k n o w l e d g e m e n t

This work was supported by grant no. 5878–3 from the Internal Grant Agency of the Ministry of Health and grant no. MSM141100004 from the Ministry of Education, Youth and Sports, Czech Republic.

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ZVÝŠENÍ SVALOVÉ SÍLY VLIVEM NÍZKOFREKVENČNÍ ELEKTRICKÉ STIMULACE U CHRONICKÉHO SRDEČNÍHO SELHÁNÍ

S o u h r n

Cílem této studie bylo posouzení vlivu nízkofrekvenční elektrické stimulace (NFES) kosterních svalů u pacientů s chronickým srdečním selháním (CHSS). Skupina 14 pacientů s CHSS (NYHA III–IV) byla vyšetřena před a po 3-týdenní NFES čtyřhlavých svalů. Zlepšení svalové síly bylo měřeno dynamometrem a rychlost krevního proudu v pravé arteria femoralias byla měřena pulsním Dopplerovým velocimetrem. Po třech týdnech NFES došlo k signifikantnímu zvýšení svalové síly a ke zvýšení rychlosti průtoku krve. Dospěli jsme k závěru, že NFES může zlepšit strukturální a funkční vlastnosti kosterního svalstva u CHSS a může proto být užitečná při léčbě pacientů se závažným chronickým srdečním selháním.

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