EFFECTS OF NMES IN PATIENTS WITH REFRACTORY HEART FAILURE

M. Bijak (1), W. Mayr(1), M. Quittan(2), A. Sochor(2), R. Pacher(3), E. Unger(1), D. Rafolt(1), H. Lanmueller(1), S. Sauermann(1), G. Freilinger(4)

(1) Department of Biomedical Engineering and Physics,
(2) Department of Physical Medicine and Rehabilitation
(3) Department of Radiology, (4) Department of Plastic and Reconstructive Surgery
all University of Vienna, University Hospital (AKH), Vienna, Austria

Abstract

Skeletal muscle strength and mass are severely impaired in patients with chronic heart failure.

The aim of the study was to determine the impact of Neuromuscular Electrical Stimulation (NMES) on the thigh muscles of this group of patients. Forty-two subjects with stable disease course were assigned randomly to a stimulation group (SG, mean age: 59y) and a control group (CG, mean age: 57y). A modified version of a space approved eight-channel electrical stimulation device was used to exercise SG for eight weeks.

Control parameters were isometric and isokinetic thigh muscle strength and muscle cross sectional area (CSA). An increase in muscle strength of 22.7% for knee extensors and 35.4% for knee flexors could be demonstrated in SG while CG remained unchanged or decreased by 8.4% in extensor strength. CSA increased in SG by 15.5% and in CG by 1.7%.

NMES of thigh muscles in patients with refractory heart failure is effective in increasing muscle strength and bulk.

Introduction

In long-term space flights reduced gravity causes muscle atrophy, orthostatic hypotension and reduction in blood volume. Physical activity and daily training are used as countermeasure [1]. As alternative a stimulation system for leg muscles was developed and transferred to space station MIR where two cosmonauts used it on a regular basis for 6 hours per day. After returning to the earth both reported a better muscle status and a shorter rehabilitation time in comparison to previous space flights [2,3].

The introduced study is based on these findings and investigates the effects of NMES on non-healthy subjects with reduced physical abilities.

Methods

Forty-two patients with an established diagnosis of severe chronic heart failure, making them listed for heart transplantation, were included in the 17 month lasting study at the Department of Physical Medicine and Rehabilitation, University hospital Vienna.

Randomization to the NMES group (SG) or the control group (CG) was done after baseline measurements in accordance with a block-wise randomization list. The personnel performing all measurements was not aware of the patients group assignment. All patients were reviewed once a week to check the skin and the equipment and to encourage adherence to the stimulation program. The CG patients were asked about their medical condition and encouraged to continue their usual activities of daily living. The overall duration of follow-ups was 8 weeks.

The stimulation device offers four independent channels with transformer isolated constant voltage outputs. Each channel is controlled by a micro-controller (PIC 16C57, Microchip, Chandler, AZ, USA) allowing independent adjustment of pulse width, stimulation frequency and stimulation amplitude. Variation of the amplitude can be easily done with a rotary knob while alteration of pulse width and frequency required a special tool. All control elements and connection cables are consequently color coded to ease the handling. For safety reasons the device is powered with a rechargeable battery that is charged externally in a commercially available device (Fig. 1).

Multi-usable hydrogel surface electrodes (130cm^2, Bentronic, Munich, Germany) were placed bilaterally on the thighs to stimulate quadriceps and hamstring

Fig. 1: Four channel surface stimulator

	NMES (n=17)		Control group (n=16)	
Age	59 (±6)		57 (±8)	
BMI	22.7 (±3.2)		25.7 (±3.9)	
	Baseline	8 weeks	Baseline	8 weeks
Knee ext. IMPT [Nm]	109.5 (±37.9)	130.9 (±40.3)*	124.7 (±41.6)	115.8 (±42.3)
Knee ext. IKPT [Nm]	85.9 (±27.8)	103 (±28.9)*	103.8 (±39.4)	94.0 (±37.6)*
Knee flex. IMPT [Nm]	57.5 (±25.0)	69.2 (±26.4)*	60.1 (±18.9)	56.4 (±18.4)
Knee flex. IKPT [Nm]	44.3 (±19.0)	55.2 (±18.7)*	52.5 (±20.5)	49.5 (±18.3)
CSA [cm2]	98.5 (±27.6)	111.3 (±24.2)*	104.4(±21.6)	106.4 (±22.8)

Tab 1: Isometric peak torque (IMPT) and isokinetic peak torque (IKPT) of knee extensor and knee flexors, cross sectional area (CSA) of mid-thigh muscles for NMES group and control group. Body mass index (BMI).
All values mean (±SD); * $p<0.001$

muscles.

Biphasic impulses with duration of 0.7ms+0.7ms and a frequency of 50Hz were applied in a 2s on and 6s off regime. The amplitude was set to achieve a strong tetanic contraction, corresponding to 25 to 30% of maximum voluntary contraction. After the patient was introduced to the handling of the equipment stimulation started at home with 30 minutes per day, 5 days a week and increased to 60 minutes per day after 2 weeks.

Muscle strength was evaluated with the leg extension apparatus of Cybex 6000 dynamometer (Cybex, Henley, USA). After a warm up with increasing effort consisting of 3 sets of sub-maximal isometric and isokinetic repetitions, 3 reciprocal knee extension and flexion movements with an angular speed of 60 degrees per second were performed with maximal effort. The highest value achieved was regarded as peak torque. After 4 minutes rest the maximal isometric strength of extensor and flexor muscles was measured at a knee angle of 60° by pushing and pulling as hard as possible against the fixed lever arm for 3 seconds.

The CSA of the mid-thigh was evaluated by computer tomography using a single slice technique and a semiautomatic segmentation with automatic fat tissue and bone exclusion.

As secondary outcome measures we used a muscle fatigue protocol, the NYHA functional classification, the functional assessment of activities of daily living related to leg muscle strength (ADL score), and parts of the Medical Outcome Study Short Form 36 questionnaire. The detailed results are published in [4].

Results

33 patients completed the study, nine dropped out for several non NMES- related reasons.

Baseline measurements of both isometric and isokinetic muscle strength did not differ significantly between SG and CG. After eight weeks SG showed increased isometric and isokinetic muscle strength of both extensors and flexors ($p<0.001$) while CG remained unchanged. Increase of CSA was in SG significant ($p<0.001$) as well (Tab. 1). Isometric muscle strength of both muscle groups adjusted for total muscle CSA did not show significant differences in the observed groups.

Conclusions

NMES proved to be an effective and safe therapy to revert leg muscle wasting, enhance leg muscle strength and improve activities of daily living in patients with severe heart failure awaiting transplantation. NMES has no side effects, can be administered by the patients at home and is economical. Therefore, the present study leads us to conclude that NMES of thigh muscles should be a promising adjunct to drug therapy in patients with severe heart failure.

References

[1] V.A.Convertino, Exercise as a countermeasure for physiological adaption to prolonged spaceflight, Med Sci Sports Exerc, 28/8, 999-1014, 1996

[2] W. Mayr et al, FES as a Countermeasure against Muscular Atrophy in long-term Space Flights – First Application on Board of MIR-Station, „5th Annual Conference of the IFESS“, Aalborg, Proceedings, 27-30; 2000

[3] W. Mayr et al, Myostim - FES to prevent from muscle atrophy in microgravity and bed-rest: Preliminary report, Artif. Org., 23/5, 428-431, 1999

[4] M. Quittan et. al., Improvement of thigh muscles by neuromuscular electrical stimulation in patients with refractory heart failure, Am J Phys Med Rehabil, 2001

Acknowledgments: We thank the Austrian Federal Ministry of Education, Science and Culture for funding this study.