

Muscle training program in patients with severe chronic obstructive pulmonary disease

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ABSTRACT

Objective: The objective of this study was to analyze the effects of a muscle training program with neuromuscular electrical stimulation (NMES) for lower limbs (LL) and active resisted exercises for upper limbs (UL) for patients with severe Chronic Obstructive Pulmonary Disease. **Methods:** With a sample of 5 subjects (65.2 ± 6.09 years), the initial and final evaluations were: One-Repetition-Maximum testing; Sit-to-stand test; perimetry of the thigh; 6-minute walk test; Saint George's Respiratory Questionnaire; Medical Research Council scale for dyspnea and the BODE index. The intervention was performed three times a week and was composed of 18 sessions of 30-minute NMES followed by 30 minutes of exercise for the UL based on the diagonal Kabat method. The NMES parameters were: 50Hz of frequency, 6s on and 8s off, increase slope of 2s and decrease slope of 2s, pulse width of 400 μ s, and intensity defined as patient tolerance and increased from 1 to 5mA each day. **Results:** The results have shown an increase in muscle strength ($p = 0.01$) and of muscle resistance ($p = 0.01$). There was an improvement tendency in the quality of life ($p = 0.16$) and in the cardiorespiratory fitness ($p = 0.11$). **Conclusion:** The association of physical exercises with diagonals and NMES can be a beneficial resource for the treatment of patients with severe COPD. It is suggested, however, the need for new researches with a wider sample size for assuring these benefits.

Keywords: Pulmonary Disease, Chronic Obstructive, Exercise Tolerance, Quality of Life

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INTRUDUCTION

The chronic obstructive pulmonary disease (COPD) may cause severe economic and social consequences, also composing, in an individual level, a substantial source of incapacity and low life quality of patients and their caregivers.¹ Per the World Health Organization,² 80 million individuals have moderate or severe COPD. The COPD is the fifth main cause of mortality around the world and, under recent estimates, it will reach the third position until 2030.

According to the Brazilian Society of Pneumology and Tisiology,³ the COPD is classically defined as a chronic and progressive reduction in the aerial flow, secondary to an abnormal inflammatory response of the lungs after the inhalation of toxic gases or particles. This inflammation promotes alterations of variable intensity in the bronchia (chronic bronchitis), bronchioles (obstructive bronchiolitis) and/or pulmonary parenchyma (emphysema).⁴ The diagnosis of COPD, confirmed by the pulmonary function test,⁵ must be considered in the presence of cough, catarrh production, dyspnea and/or history of exposure to risk factor for the development of the disease, such as smoking, environmental pollution, and occupational exposure to toxic gases or particles. These factors may override the recovery mechanism that restores the tissue structure damaged by some injuries.⁶

In addition to the structural and functional consequences induced in the lungs, the COPD also combines relevant systemic effects that have important repercussion over the quality of life and survival of the patients, including nutritional depletion and the skeletal muscles dysfunction, which contributes to intolerance to physical exercise,^{7,8} and for this reason, their participation in rehabilitation programs is hindered.

Due to this factor, the neuromuscular electrical stimulation may be a facilitating resource so that these patients may reach the minimal physical conditioning needed to participate in these programs.⁹ The neuromuscular electrical stimulation (NMES) is a technique in which an electrical current is applied to evoke muscle contractions and therefore promote functional movements and improvements in the physical performance.^{10,11}

In COPD, the peripheral muscle dysfunction (PMD) is characterized by structural and functional abnormalities.¹² The peripheral skeletal muscles undergo morphologic and metabolic alterations due to a combination of events in which the etiology seems to be

multifactorial, including the hypercapnia, oxidative stress, long-term use of corticosteroids, hypoxemia, nutritional depletion, systemic inflammation, the underuse atrophy, and the amino acids metabolism.⁸

Recent clinical guidelines on the treatment of COPD emphasize the role of physical exercise to disrupt the vicious circle of deconditioning. On this subject, the most recent guidelines about pulmonary rehabilitation recommend the physiotherapy programs to include exercises targeted at the upper limbs (UL) muscles for patients with COPD, due to its importance in their daily life activities.¹³ Many of these muscles are also accessory muscles of respiration, therefore activities with the arms elevated cause these muscles to reduce their participation as respiratory accessory, imposing more respiratory work to the diaphragm, what causes an increase in dyspnea and fatigue in these patients.¹⁴

OBJECTIVE

This study proposes the application of a training program with the aid of NMES for the lower limbs (LL) muscles and active resisted exercises for upper limbs muscles in patients with severe COPD as a manner to verify whether there are improvements in muscle strength and resistance, and in cardiorespiratory fitness of these patients.

METHODS

This is an experimental study, with quantitative approach, of patients of both genders recruited in the pneumology ambulatory of the Santa Maria University Hospital - Brazil (HUSM), and with clinical and functional diagnosis of severe and very severe COPD (levels III and IV of GOLD).⁵ This clinical trial was approved by the Independent Ethics Committee of the Federal University of Santa Maria - Brazil, under registration 0393.0.243.000-10.

The inclusion criteria of this study were: At spirometry, obtain the forced expiratory volume in one second (FEV1) < 65%, forced vital capacity (FVC) < 70%, and the ratio residual volume/total lung capacity (RV/TLC) > 40%; clinical stability; sedentary with exercise limitation (self-reported); age < 75 years. Patients with classes III and IV functional heart failure, renal and hepatic dysfunction, orthopedic and trauma diseases and/or neuromuscular deficit, cognitive deficit, paresthesia or tissue injuries at the electrode laying site,

use of pacemaker, diagnosis of HIV infection, or those who did not sign the informed consent form were excluded. 30 subjects were included per the inclusion criteria and, among them, 25 were excluded due to the exclusion criteria, yielding a total of 5 eligible subjects for the study.

The eligible patients underwent the following evaluations: anamnesis, physical exam, pulmonary function test (spirometry);¹⁵ the 6-minute walk test (6MWT);¹⁶ the Sit-to-stand test;¹⁷ the perimetry of the quadriceps muscle;¹⁸ the quadriceps muscle strength testing (One-Repetition-Maximum testing - 1MR);¹⁹ the Saint George's Respiratory Questionnaire (SGRQ) for quality of life;²⁰ and the upper limb incremental test.²¹ Along with them, the Medical Research Council scale (MRC)²² was also used to evaluate dyspnea and the BODE index was calculated (B - body mass index; O - airflow obstruction; D - dyspnea; E - exercise capacity).²³ The evaluations were applied sequentially by the same evaluator before the intervention, as well as after the intervention, during the reevaluation.

The intervention was performed in the Physiotherapy ambulatory of the Santa Maria University Hospital - Brazil (HUSM) for 6 weeks, totaling 18 sessions. The protocol was designed as 30 minutes of NMES in the quadriceps and 30 of functional exercise for upper limb, therefore performing a 1-hour session, with a frequency of three times a week.

The NMES was applied onto the quadriceps muscles of each patient with the KLD-bio-sistemas Neuromuscular Electrical Stimulator, model nms.0501, Endophasys. Self-adhesive electrodes were placed on the thighs, approximately 5cm below the inguinal fold, 5cm above the suprapatellar edge and in the ventromedial muscle, at the medial femoral condyle. Before the placement of the electrodes, the patient skin was cleaned with cotton previously soaked in 70% alcohol solution.

The NMES protocol was based on the study of Vivodtzev et al.²⁴ which aimed to minimize the effects of fatigue of the contractibility of the quadriceps muscles of patients with COPD, so described: the patient remained laid down in a stretcher, with the legs bent at 60° supported by a wedge pillow; the current used was the symmetric biphasic square pulse. The 60° flexion of the knees was used to optimize the muscle contraction, once, according to the literature, this is the angle in which the maximum force is produced by the quadriceps muscles.²⁵ The 5 initial minutes were performed as a warmup at a frequency of 5Hz with a pulse width of 400µs of reciprocal

electrical current. Along the next 25 minutes, the stimulator generated electrical pulses at a frequency of 50Hz with a pulse width of 400µs for 6s long, alternated with a resting period of 8s, also reciprocal, swapping the contractions of the lower limbs muscles. The applied intensity was defined as the patient's maximum tolerable intensity, being increased from 1 to 5mA each day. This strategy allowed a better tolerance of long exposure to electrical stimulation of patients with severe COPD.

During the NMES, the patients were requested not to do any active movement with the lower limbs so that the quadriceps movements were totally passive to the stimulation. By using an ankle weight, extra load was applied (in kilograms), beginning with 50% of the maximum load of the 1MR,¹⁹ and increased as the patient got used to the electrical current of the study. It was performed as a mean to enhance the patient strength without having to change the stimulation device parameters, what could cause discomfort to the patient.

The upper limb (UL) training had three stages: warmup, upper limb exercise and stretching.²⁶ The UL exercises were performed with dumbbells, with a load of 50% of the maximum weight as measured in the incremental test for UL.²¹ The first and the second diagonal of the Neuro-proprioceptive Facilitation Method²⁷ was used because of its functionality and the ability to recruit several UL muscle groups that are needed in the daily life activities. Each cycle of diagonal movement was performed for two minutes followed by a resting period of one minute, and, during the limb elevation, the patient was requested to exhale.

The analysis of the obtainable variables was conducted considering the percentages distribution and measures of central tendencies (mean, standard deviation). For the statistical analysis, the software SPSS (Statistical Package for the Social Science) version 13.0 was used. The Shapiro-Wilk test was performed for evaluating the distribution of the data. As the data was considered normal, the *t*-test was performed for comparing the variables and the chosen significance level was 5% ($\alpha < 0.05$).

RESULTS

As for the anthropometric characteristics, most patients were male (4/5), the mean age was 65.2 ± 6.09 years, and the body mass index was 23.84 ± 3.37 kg/m². The average cigarette consumption was 79 ± 41.29

packages/year. Out of the 5 patients, 3 were rated as GOLD III, and 2 as GOLD IV by the pulmonary function test.

The Table 1 presents the results of comparisons among the variables walk test, MRC, BODE, and quality of life before and after the training sessions. It is possible to observe an improvement tendency in the parameters of all the analyzed variables, however the results show there was no significant difference.

As for the perimetry, no substantial increase was found in the circumference of the thighs of both groups, in any of the measurements of 5cm, 10cm and 15cm performed in the study.

The results of the Sit-to-stand test and the quadriceps muscle strength testing (1MR) have shown a significant increase in the period after the intervention ($p = 0.001$). The mean repetitions of the Sit-to-stand test before the training was 22.40 ± 8.26 and after the training was 26.80 ± 7.39 . In the 1MR, the mean before and after the training was 15.60 ± 6.42 and 18.60 ± 5.77 kilograms respectively (Figure 1).

DISCUSSION

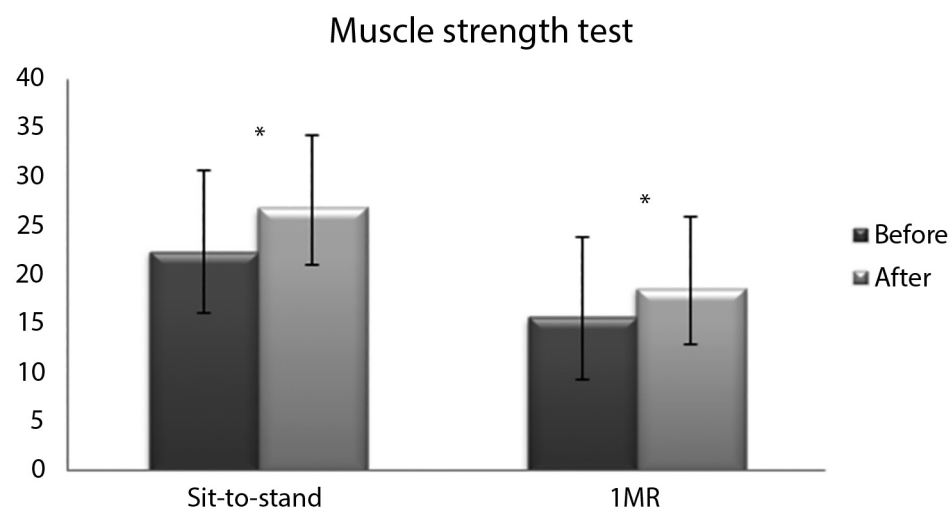
The main findings of this study, intervention with a program of muscle training with the aid of NMES in the quadriceps and physical exercises for the upper limbs, were the increase of strength and muscular resistance, evaluated by the 1MR and the Sit-to-Stand test.

The quadriceps muscle of patients with COPD is characterized by, in addition to muscle weakness,^{12,28} premature fatigability,²⁹ due to the reduction in the proportion of type-I fibers and oxidative enzymes.^{30,31} The findings of this study, as verified with the 1MR test, have shown that the NMES could increase the capacity to perform the knee extension with higher loads, as well as to improve the performance in the Sit-to-Stand test. Other studies have shown the strength increase in NMES programs can be related to the increase of the muscle activation, the electromyographic activity, i.e. neural activation, and the transversal anatomical section area.^{32,33} Moreover, the

Table 1. Results of comparison among the study variables, before and after the physical training*

	Before (n = 5)	After (n = 5)	<i>p</i>
6MWT (m)	266.20 ± 92.17	364.20 ± 83.92	0.11
MRC (points)	2.80 ± 0.83	2.20 ± 0.44	0.07
BODE (points)	6.20 ± 1.64	4.80 ± 0.83	0.07
QoL	51 ± 7.44	48.8 ± 7.19	0.16

n: number of subjects; 6MWT: Six-minute Walk Test; MRC: Medical Research Council; BODE: B - body mass index; O - airflow obstruction; D - dyspnea; E - exercise capacity; QoL: Quality of Life. The values are presented as mean ± standard deviation. * Student *t*-test $p < 0.05$ is significant.



* Statistically significant difference ($p = 0.05$)

Figure 1. Muscle strength tests results

neural adaptations occur in the first four training weeks with electrical stimulation and the alterations in the muscle density between the 4th and the 8th week.³²

By comparing the acute effect on strength of functional electrical stimulation with frequencies of 15Hz and 50Hz over the quadriceps muscle of aged patients, Sbruzzi et al.³⁴ found that 50Hz NMES reaches higher peak of isometric muscle torque. This study attributed this difference to the fact that the muscle strength is proportional to the stimulation frequency and to the number of recruited motor units. Therefore, the higher the frequency, the higher the motor recruitment, yielding higher muscle strength.³⁵

The NMES effects over the motor units depend on the stimulation frequency.³⁶ With a frequency as low as 20Hz, the work is directed to the type-I fibers,³⁷ which promote effective muscle contractions at a low metabolic cost, decreasing muscle fatigue.³⁸ With stimulation frequencies between 35 and 70Hz, it is possible to work the fast twitch muscle fiber - type II.³⁸ Possibly, this is the explanation why the 50Hz frequency yields higher torque peak when compared to the 15Hz frequency.³⁶

The maximum overload applied was equivalent to 50% of 1MR, with the use of ankle weights. Guedes & Guedes³⁹ emphasized that exercises overloaded above 40% of maximum strength yield enhancement of strength either by hypertrophy of fibers or by the increase of the recruitment of motor units. Oppositely, exercises with overloads lower than 40% of the maximum strength, emphasize resistance, even though they produce strength as well.

The perimetry, a method for evaluating the muscular trophism, is broadly applied either as therapy or as research, for it is considered practical, of low cost, and for non-invasively analyzing body mass.⁴⁰ The fact that we did not find significant difference in relation to trophism, besides the application of NMES being consistently considered related to an increase in body mass,⁴¹ it can be explained by the subjectivity of this measurement method to determine the muscular circumference when different muscle tensions is applied to the tape measure during the evaluation as well as the small number of subjects in the sample.

The average age of the participants was 65 years, therefore they were considered aged. Concerning this variable, it is important to consider that combined with the degenerative effects of COPD over peripheral muscles, the aging process on the muscular system progressively produces muscle density loss, specially of fast twitch type II fibers.⁴²

The cardiorespiratory fitness analyses, as measured by the 6MWT,¹⁶ have shown the patients walked longer distances at the end of the study. This difference, however, was not significant, what may also have been due to the insufficient number of subjects.

The findings on quality of life and desensitization of dyspnea have not been significant. On this matter, it is important to consider that along the therapy period, 3 out of the 5 patients had relevant symptoms of dyspnea, fever, and productive cough suggesting acute respiratory infection, probably due to seasonal temperature changes that occurred along the period of the year of the region the study was performed, where the weather is humid and cold.

Concerning BODE, the mortality predictor index, Pitta et al.⁴³ found higher mortality rate in insufficiently active subjects when compared to sufficiently active ones. In the present study, no significant difference was found after the training program, what can also be explained by the respiratory complications, once the BODE index is directly related to the dyspnea index.

As for the study limitations, the small sample size, the narrow data collection period, and the scarce financial resource as to increase the treatment period are among them. Nevertheless, the results we found encourage new researches on this muscle training program as part of the treatment given to patients with severe COPD.

CONCLUSION

The muscle training program applied in this research, by which NMES was used in lower limbs combined with training of upper limbs, has shown to be effective to increase muscle strength and resistance of patients with severe COPD. On this subject, new studies are suggested to be performed with longer follow up period and the inclusion of a broader number of subjects, as to possibly yield statistical relevance in the results of all variables analyzed.

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