Neuromuscular Electrical Stimulation with Russian Current for Expiratory Muscle Training in Patients with Chronic Obstructive Pulmonary Disease

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Abstract. [Purpose] To analyze the effects of neuromuscular electrical stimulation (NMES) applied to the abdominal muscles of patients with COPD. [Subjects] A total of 22 patients in group A, mean age of 68.2 ± 6.4 years and in group B, 71.2 ± 10.1 years. [Methods] Randomized clinical trial. Patients with COPD were randomly and evenly divided into two groups: group A (NMES + conventional therapy) and group B (conventional physiotherapy) and respiratory muscle strength was measured by pressure manometry before and after the end of the experimental protocols. [Results] Maximum inspiratory pressure before and after the intervention of group A was −64 (44–74) cm H2O, respectively, and −68 (56–96) cmH2O, and in group B, −52 (46–92) cm H2O and −60 (50–72) cmH2O. Maximum expiratory pressure of group A was 84 (72–92) cmH2O and 112 (94–120), respectively, and in group B, 76 (60–100) cmH2O and 84 (60–108) cmH2O. [Conclusion] The results indicate that expiratory muscle training with Russian current together with conventional physical therapy during hospitalization improves the respiratory muscle strength of patients with COPD.

Key words: COPD, Electrical stimulation, Abdominal muscles

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is defined as a disease state characterized by the occurrence of airflow limitation which is not totally reversible1. The limitation is usually progressive, and is related to an abnormal inflammatory response of the lungs particles or harmful gases2–4. A set of pathological and structural changes in the lung, some significant extra-pulmonary effects and important co-morbidities must be taken into account when considering the seriousness of the disease and appropriate treatments.

Respiratory muscular weakening, with decreasing muscular strength and resistance is an important COPD clinical consequence5, 6, and affects muscles responsible for effective ventilatory-respiratory system functioning7. Though inspiratory muscular weakness is at least partially attributed to hyperinflation (causing mechanical damage to the inspiratory muscles), expiratory muscle weakness is a generalized myopathy characteristically observed in patients with COPD9.

Nowadays physical therapy for pulmonary rehabilitation includes: aerobic training for upper limbs8, 9 and lower limbs7, strength training10 and respiratory muscular strengthening exercises using Threshold®11, 12.

Neuromuscular electrical stimulation (NMES) has been used in a safe and effective way to improve peripheral muscular strength2, 13 in patients with chronic conditions such as congestive cardiac insufficiency and chronic respiratory insufficiency, and particularly patients with COPD particularly. Furthermore, other NMES benefits which can be cited are the improvement of cough efficiency, prevention of deep venous thrombosis and articular contractions, in addition to acceleration of the rehabilitation process, decrease of the number of medical appointments due to secondary conditions, reduced costs and increased life expectancy of these individuals14).

Some studies aimed at improving the ventilation process through muscular strengthening using NMES have already been carried out with almost unanimous success15–17. However, there is still much controversy about the methodology and procedure. Thus, in the present research we evaluated the effects of the training of abdominal muscles, which are accessories of the expiratory breathing phase, using electrical neuromuscular stimulation with Russian current on respiratory muscular strength of patients with chronic obstructive pulmonary disease.

MATERIALS AND METHODS

This study was a blind randomized clinical trial which was approved by the Universidade Luterana do Brasil Ethics Committee and Mãe de Deus Hospital. It was carried out during August and October 2011, at Santa Luzia Hospital in the municipality of Capão da Canoa and Nossa Senhora dos Navegantes Hospital in the municipality of Torres. Patients of all ages and both sexes, with International Classification of Diseases (ICD) 10 – J44.9 which corresponds to Chronic...
Obstructive Pulmonary Disease (COPD), were invited to participate in the study. Applicants received information about the research and signed a consent form written according to the guidelines concerning research involving human subjects included in the National Health Council number 196/96. The forms were handed in to the researcher and the patient in duplicate copies. Patients, who were not lucid, informed, or conscious; patients who had dysfunction, or were in post-surgery, those with abdominal incision, with dermatologic alterations in the abdominal region, with sensitivity alteration, pacemakers, or a record of epilepsy, and those who were receiving invasive mechanical ventilation were excluded from the research.

First, the patients were told about what would be done during the intervention period, and after they signed the consent form, the patients were surveyed for socio-demographic data, life habits, family and previous personal pathological events. Patients with COPD were randomly allocated by drawing from a sealed envelope to one of the two groups; group A (standard physical therapy and neuromuscular electrical stimulation with Russian current) and group B (only conventional physical therapy).

Patients from both groups were evaluated for respiratory muscular strength using a Comercial Médica® analog manometer, on a scale ranging from 0 to +120 cmH2O for maximum expiratory pressure (MEP) and 0 to −120 cmH2O for maximum inspiratory pressure (MIP) (8). Patients sat with their feet on the floor, and were provided a nose clip. The manometer had a mouth adaptor and patients were instructed to hold it firmly, pressing it against their lips. During measurement of maximum expiratory pressure, patients were asked to inflate the lungs up to the total lung capacity (TLC) and after a forced expiration, maintain maximum pressure for about a second. For maximum inspiratory pressure, the patients were instructed to perform maximum expiration up to the residual volume (RV) and maintain the pressure for about 1 second. Peak pressure was recorded and compared with reference values. Blood pressure (ABP), cardiac frequency (CF), respiratory frequency (RF) and oxygen peripheral saturation (Ops2) were checked before and after each measurement. Re-evaluation with a manometer was done for both groups before patients were discharged from hospitals.

Group A (N=11 patients), was treated with neuromuscular electrical stimulation with Neurodyn 10 Russian Current TM channels V2 0. Four channels with two electrodes each were positioned on the motor areas of the oblique muscles and rectus abdominis, using water-soluble gel to enhance electrical conductivity, and attached with adhesive tape. Therapy was carried out with the patient in dorsal decubitus (DD) with the head lifted to 35°. Vital signs were checked before and after each session of electrical stimulation. Parameters used for the Russian current were a carrier frequency of 2,500 Hz, with a frequency of 5 Hz for 5 minutes for the purpose of muscular conditioning, 40 Hz for 10 minutes for training of slow contraction muscular fibers, 120 Hz for 5 minutes for training of fast contraction muscular fibers, and finally with 5 Hz for 5 minutes for muscular relaxation. Decay and rise times were both 1 second, with an “On” time of 4 seconds and an “Off” time of 1 second, programmed according to the timing of inspiration and respiration, given that the moment and length of the contraction (On) was done in the expiratory phase of the patient and the Off time during the inspiratory phase. The patients had previously been instructed and trained to ventilate with pursed lips, lengthening the expiratory phase and holding it during the contraction induced by the device. The intensity was raised until a visible contraction was seen. The group received a total of 25 minutes of daily stimulation and two more daily conventional physiotherapy treatments.

Group B, (N=11 patients), received conventional physiotherapy only, which was conducted twice a day by in-service staff and physical therapists who were trained by the researcher and were not informed about the research groupings of the patients. Conventional therapy consisted of ventilation with pursed lips, vibrocompression, and huffing. Vibrocompression was sometimes applied with exercises of the upper limb diagonals during the expiratory phase with no weights, which progressed to graduated weights and bridging exercises. When the patient was still weak, usually at the beginning of hospitalization, he or she was asked to cooperate passive kinesiotherapeutic exercises for the upper limbs, performed by the professionals, which progressed to assisted (when the patient was asked to participate), active (when the patient did the exercises by themselves), and resisted (when the patient did the exercises by themselves with weights), until hospital discharge. All the exercises were done in two sets of ten repetitions, depending on the patient’s condition, with intervals of 2 minutes between the sets. Patients of both groups were each treated with the established protocol until hospital discharge.

The sample was based on a pilot-study carried out with 15 individuals with a medical diagnosis of COPD. Data was entered into an MS Excel 2007 spreadsheet, and analyzed using SPSS for Windows 15.0 (Statistical Package for Social Science). Data are presented as means ± standard deviation, or with the interquartile range Student’s t-test, and the Chi-Squared test, Mann-Whitney and Wilcoxon tests were used for statistical analysis. Significance was accepted for values of p≤0.05.

**RESULTS**

Between August and October 2011, 22 patients were enrolled in this study after signing a consent form. They were randomly an evenly divided between group A and group B. The average age of group A was 68.2 ± 6.4 years old, and that of group B was 71.2 ± 10.1 years old.

There was a 36% greater incidence of systemic arterial hypertension (SAH) in group A, while there was a 27% higher incidence of congestive heart failure associated with SAH in group B. Concerning hospital stay, group A presented a median of 4 (3.5 – 7) days, and group B presented a median of 9 (7.5 – 15.5) days.

The number of sessions of conventional physiotherapy are expressed by the median number, with group A receiving 10 (5–12) sessions and group B 12 (10 – 26) sessions. Group A received a median of 6 (3.5 – 7) sessions of electrical
neuromuscular stimulation with Russian current together with the conventional physiotherapy.

Table 1 presents the sample characterization. There were no significant differences between the groups. Therefore, the population can be characterized as homogeneous.

Table 2 shows the results for respiratory muscular strength before and after the experimental protocols. There were significant differences between group A compared to B, and also between the initial and final values of MIP (p=0.028), and MEP (p=0.006).

The MEP and MIP results are also shown graphically.

**DISCUSSION**

On account of the scarcity of data related to expiratory muscle training for patients with Chronic Obstructive Pulmonary Disease (COPD) receiving Neuromuscular Electrical Stimulation (NES), the present study aimed to enhance our knowledge about the topic.

We attempted to evaluate increases of the expiratory muscle strength after two interventions: NES with Russian current together with conventional physiotherapy, and conventional physiotherapy only.

There were no significant differences between the experimental groups; therefore the population was homogeneous, although it consisted mainly of females.

According to Langer et al.\(^{19}\) this gender bias probably related to the increasing numbers of female smokers seen in the last 30 years. A study carried out in developed countries showed that nowadays the occurrence of COPD is almost the same between men and women, and it possibly depicts changes in smoking habits\(^{21}\). One study suggested that women are more subject to smoking effects than men\(^{21}\). This is an important matter as the smoking rate is increasing among women in developed countries as well as in developing ones.

Concerning hospital stay, the Russian current group was in hospital for a shorter period, a fact that may be related to the benefits of NMS accelerating the rehabilitation process. COPD occurrence increases the total cost of patient care, especially that of hospitalized patients. In a study of the costs of COPD-related diseases, based on a 1987 U.S. report entitled National Medical Expenditure Survey, per capita expenditure due to hospitalization of patients with COPD was 2.7 times higher than spending on patients who did not suffer from COPD (US$5,409 compared to US$2,001)\(^{4}\).

The choice of NMS with Russian current was based on an Adel’s study\(^{22}\) which reported that in order to stimulate deep muscle fibers, electrical current must be used at a medium frequency. Medium frequency electrical current is a current with a frequency between 1 and 10 kHz, which

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n=11)</th>
<th>Group B (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) - average ± SD</td>
<td>68.2 ± 6.4</td>
<td>71.2 ± 10.1</td>
</tr>
<tr>
<td>Sex n(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5 (45)</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Female</td>
<td>5 (55)</td>
<td>8 (73)</td>
</tr>
<tr>
<td>Related Diseases- n(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAH</td>
<td>4 (36)</td>
<td>2</td>
</tr>
<tr>
<td>CHF</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>SAH + DM</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>AHS + CHF</td>
<td>0</td>
<td>3 (27)</td>
</tr>
<tr>
<td>SAH + DM + CHF</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>4 (36)</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Hospital days</td>
<td>8 (5–8.5)</td>
<td>9 (7.5–15.5)</td>
</tr>
<tr>
<td>Conventional Physiotherapy Session</td>
<td>10 (5–12)</td>
<td>12 (10–26)</td>
</tr>
<tr>
<td>Russian Current Session</td>
<td>6 (3.5–7)</td>
<td>0</td>
</tr>
</tbody>
</table>

Data are expressed as number (percentage) means standard deviation (SD) and median (interquartile range). Student’s test was used to analyze quantitative data and Chi-Square test for qualitative data. SAH=Sistemic Arterial Hypertension, CHF=Congestive Heart Failure, DM=Diabetes.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIP (cmH(_2)O)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>–64 (44–74)</td>
<td>–52 (46–92)</td>
</tr>
<tr>
<td>Final</td>
<td>–68 (56–96)</td>
<td>–60 (50–72)</td>
</tr>
<tr>
<td>MEP (cmH(_2)O)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>84 (72–92)</td>
<td>76 (60–100)</td>
</tr>
<tr>
<td>Final</td>
<td>112 (94–120)</td>
<td>84 (60–108)</td>
</tr>
</tbody>
</table>

Data are expressed as median and interquartile range. MIP=maximum inspiratory pressure; MEP=maximum expiratory pressure; cmH\(_2\)O= centimeters of water. Differences was examined with the Wilcoxon test.
is able to reach and stimulate deep muscles. In Kotz’s experiments, the best muscular contraction occurred with electrical stimulation, at a frequency of 25 kHz. Accordingly, we used the Neurodyn 10 V2 0 channels (Russian current stimulator) which works at a frequency of 25 kHz was used in this study. Pires concluded that neuromuscular electrical stimulation of low frequency causes greater muscular fatigue than electrical stimulation at a medium frequency. This conclusion implies the aim of neuromuscular electrical stimulation is to avoid muscular fatigue.

Group A patients, who underwent expiratory muscle training with NMES, presented statistically significant increases in respiratory muscle strength (RMS) compared to group B patients, who received conventional physiotherapy, indicating that expiratory muscle training with the use of NMES improves RMS. Suzuki et al. conducted expiratory muscle training and observed that there were no differences before expiratory muscle training between the training group and the control group in MIP or MEP. MEP increased significantly whereas MIP did not reveal in the training group. There were no significant changes in MIP and MEP in the control group.

The work of these authors suggests that respiratory muscle training itself is specific, that is, muscles that received training displayed significant increases in MEP only. Suzuki et al., in another study, developed a training method in which MIP, of the experimental group, made up of six normal individuals, increased after four weeks of training while MEP did not show statistically significant alterations; whereas MIP and MEP in the control group did not increase.

According to Leith and Bradley, normal individuals performed 5 weeks of respiratory muscle training to increase MIP and MEP. Do Valle et al. reported increases in MIP and MEP of sedentary individuals and athletes after a respiratory muscular strength training program. They also suggested that respiratory muscles can be evaluated and trained with greater efficiency through specific respiratory muscle strength and resistance training programs, and pointed out that respiratory muscles respond to specific training programs more efficiently.

Expiratory muscles were specifically trained in several configurations. Abdominal muscle training tends to increase expiratory muscle strength and improve cough efficacy in badly disabled patients with multiple sclerosis, improve the condition of dyspnea in children with neuromuscular disease, and decreasing the respiratory effort sensation during exercises in healthy individuals. The first complete study that explored expiratory muscle training (EMT) highlighted that there were changes in the expiratory muscle strength, during a six-minute walk, which were significant after EMT when compared to the controls; however, the increase did not result in any significant change in the sensation of dyspnea during daily activities. Weiner et al. compared EMT with inspiratory muscle training (IMT), and combined IMT and EMT, and showing that there were no additional benefits of EMT.

The major MEP and MIP increases observed in our study after respiratory muscular training (RMT) with the use of NMES, are similar to the results of Fernandes et al. who reported that RMT with ThresholdPEP, for a group of stroke patients increased maximum expiratory after five days of respiratory muscle training. In our study, patients who received expiratory and inspiratory muscle training showed statistically significant increases of MIP and MEP in relation to the control group.

The application of NMES with Russian current in our study resulted in a significant increase respiratory muscle strength, because abdominal muscles, during the expiratory phase, contribute in an indispensable manner to the activity and capacity of the diaphragm. The phasic contractions of the abdominal muscles strengthen the diaphragm muscle, and the strength and tons of the muscles push the ribs into a downward, and oblique position. This positioning confers a mechanical advantage on the diaphragm in the length-tension making its contraction easier. Also, the abdominal muscles influence the maintenance of adequate levels of pleural pressure, and the control of the inspiratory flux quality, pushing the diaphragm down during respiration. This pushing decreases the speed of the inspiratory flux making it more Laminar. Accordingly, we believe that, expiratory muscle training of the accessory abdominal muscles with NMES, resulted in the muscles being strengthened indirectly, favoring the strengthening of the inspiratory musculature, because it benefits mechanically.

Surprisingly, there is little data on expiratory muscles (abdominal muscles and internal intercostals muscles) for COPD patients. The improvement of expiratory muscle strength is significant for these patients, because they are more to muscular fatigue due to impaired abdominal musculature. One of the limiting aspects if our study was related to the difficulty of data collection for patients with Chronic Obstructive Pulmonary Disease (COPD). Another important limitation was a sub-diagnosis of COPD, because not all patients undergo spirometry. Similarly, physiotherapy prescription for COPD patients encounters some resistance and/or lack of knowledge about the importance of physiotherapy for this group of patients from other professionals.

REFERENCES

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