

Transcutaneous electrical diaphragmatic stimulation by Russian current in COPD patients

Estimulação elétrica transcutânea diafragmática pela corrente russa em portadores de DPOC

Estimulación diafragmática eléctrica transcutánea por corriente rusa en pacientes con EPOC

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ABSTRACT | Chronic Obstructive Pulmonary Disease (COPD) causes losses in lung mechanics, interfering in performance, mobility and conformity of the diaphragm, and traditional diaphragmatic electrical stimulation is able to generate benefits to the lung patient. Could Russian current be another option? We aimed to identify changes after transcutaneous diaphragmatic electrical stimulation through the Russian current in individuals with COPD. Prospective and nearly experimental study with inclusion criteria: drug stability, smoking interruption, COPD degrees III and IV and lifestyle maintenance. Anthropometric and functional measurements have been evaluated. Diaphragmatic stimulation occurred by Endophasys R ET 9701 for four months, twice a week, 30 sessions. Therapy time and frequency for each session were: 18 min. (20 to 30 Hz) and 12 min. (70 to 100 Hz), respectively. For data analysis Student's t-test was applied ($p < 0.05$). Thirteen individuals participated in the COPD treatment being 11 (84.6%) male, all white, aged 68.46 ± 11.11 years and with tobacco load of 74.03 ± 56.2 per year. At the end of the intervention, there were changes on minute volume from $14.47 \text{ min} \pm 4.72$ to 13.03 ± 4.00 l/min; BODE index from 3.92 ± 2.10 to 3.23 ± 1.87 and distance on the 6-minute walk test from 336 ± 76.36 to 402.76 ± 51.29 m. As a conclusion, diaphragmatic electrical stimulation through Russian current promotes significant benefits to COPD patients, providing respiratory and functional improvement.

Keywords | Diaphragm; Electrical Stimulation; Respiratory Therapy.

RESUMO | A doença pulmonar obstrutiva crônica (DPOC) ocasiona prejuízos na mecânica pulmonar, interferindo na atuação, mobilidade e conformidade do diafragma. A estimulação elétrica diafragmática tradicional é capaz de gerar benefícios ao pneumopata; poderia a corrente russa ser outra opção? Objetivou-se identificar as alterações após estimulação diafragmática elétrica transcutânea pela corrente russa em indivíduos portadores de DPOC. Trata-se de estudo prospectivo, quase experimental, com os seguintes critérios de inclusão: estabilidade medicamentosa, cessação tabágica, DPOC grau III e IV e manutenção do estilo de vida. Foram avaliadas medidas antropométricas, respiratórias e funcionais. A estimulação diafragmática se deu pelo Endophasys R ET 9701 por quatro meses, duas vezes por semana, com 30 sessões. O tempo de terapia e frequência para cada sessão foram: 18 min. (20 a 30 Hz) e 12 min. (70 a 100 Hz), respectivamente. Para análise dos dados foi aplicado teste "t" de Student ($p < 0,05$). Participaram do tratamento 13 DPOC, sendo 11 (84,6%) do sexo masculino, todos brancos com idade de $68,46 \pm 11,11$ anos e carga tabágica de $74,03 \pm 56,2$ maços-ano. Ao final da intervenção houve mudanças no: volume minuto de $14,47 \pm 4,72$ para $13,03 \pm 4,00$ L/min.; índice BODE de $3,92 \pm 2,10$ para $3,23 \pm 1,87$; e distância no teste de caminhada de 6 minutos (TC6) de $336 \pm 76,36$ para $402,76 \pm 51,29$ m. Concluiu-se que a estimulação elétrica diafragmática por meio da corrente russa promove

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benefícios significativos ao portador de DPOC, proporcionando melhora respiratória e funcional.

Descritores | Diafragma; Estimulação Elétrica; Terapia Respiratória.

RESUMEN | La enfermedad obstructiva crónica (EPOC) perjudica la mecánica pulmonar, interfiriendo en la acción, movilidad y conformidad del diafragma. La estimulación diafragmática eléctrica tradicional es benéfica a los portadores de enfermedades pulmonares, ¿es posible ser otra opción la corriente rusa? El propósito de este trabajo es identificar los resultados tras la estimulación diafragmática eléctrica transcutánea por corriente rusa en pacientes con EPOC. Se trata de un estudio prospectivo, casi experimental, con los siguientes criterios de inclusión: la estabilidad de fármaco, el abandono del tabaco, la EPOC grados III y IV y el mantenimiento del estilo de vida. Se evaluaron medidas antropométricas, respiratorias

y funcionales. La estimulación diafragmática fue realizada por el Endophasys R ET 9701 durante cuatro meses, dos veces semanales, con 30 sesiones. El tiempo de terapia y la frecuencia de cada sesión fueron los siguientes: 18 min. (20 a 30 Hz) y 12 min. (70 a 100 Hz), respectivamente. En el análisis de datos se empleó la prueba t de Student ($p < 0,05$). Del estudio participaron 13 portadores de EPOC, siendo 11 (84,6%) varones, blancos, cuya edad fue de $68,46 \pm 11,11$ años y el tiempo del tabaco fue de $74,03 \pm 56,2$ paquetes-año. Al final de la intervención ocurrieron cambios: en el volumen minuto de $14,47 \pm 4,72$ a $13,03 \pm 4,00$ L/min.; en el índice BODE de $3,92 \pm 2,10$ a $3,23 \pm 1,87$; y en la distancia de la prueba de caminata de 6 minutos (TC6) de $336 \pm 76,36$ a $402,76 \pm 51,29$ m. Se concluye que la estimulación diafragmática eléctrica por corriente rusa es benéfica a los portadores de EPOC y les proporciona mejoras respiratoria y funcional.

Palabras clave | Diafragma; Estimulación Elétrica; Terapia Respiratoria.

INTRODUCTION

Primary organs affected by chronic obstructive pulmonary disease (COPD) are the lungs and, over time, there are changes on the thorax and adjacent structures, partly, due to muscle weakness^{1,2}. The lungs lose their elastic retraction and the diaphragm presents mechanical disadvantage, causing changes in shape and geometry of the chest wall, which leads to chronic reduction of the diaphragmatic apposition area with abnormal lowering and horizontality, as well as lower vertical excursion during inspiration, changing the diaphragm structure, in addition to increased amount of type I fibers, decrease of type II fibers and increase of oxidative capacity of all fibers, however, insufficient to restore the ability to generate power and endurance at normal levels³⁻⁶.

Transcutaneous electrical diaphragmatic stimulation (TEDS) is aimed at retraining and recruiting the largest number of intact muscle fibers generating specific muscle contraction, thus promoting strengthening of muscles and preventing muscle hypotrophy, specially in patients with neuromuscular disorders and ventilatory weaning. In the last one mentioned, it can improve the contractile dysfunction, in addition to be indicated to induce breathing⁶⁻⁸.

As observed, TEDS effects are related to respiratory variables. However, there is a differentiation between

equipment and electrical current parameters, and even intervention protocols⁹.

Nowadays, some electric current equipment used for diaphragmatic stimulus are no longer produced, such as Phrenics, which was suitable for functional reeducation through diaphragmatic and intercostal stimulation. Then, there was the intention to review equipment that could cause this electrical stimulation, provide physical improvement and also improve COPD signs and symptoms. Therefore, Russian current was thought as a therapeutic resource for being beneficial to musculature, which promotes increase in resistance and strength of skeletal muscles, removing atrophies and weaknesses from sound muscles, meaning, Russian current is a proposal to conduct TEDS.

Establishing a relation between Russian Current and Phrenics, there are differences in frequency, pulse width (burst) and work cycle modulation, and Russian current differentials are: sinusoidal wave format, depolarized average frequency (2.500 Hz and can be modulated at 30 Hz), with low frequencies (5 to 100 Hz) and variable duration of phases, with 4 ms pulse width and 20%, 35% and 50% variable work cycle. Russian current application favors proprioceptive stimulation and also increases the contraction threshold, which provides a higher intramuscular tension, thus improving muscular tonus^{10,11}. Being a medium frequency current, it presents a higher current penetration through the adipose tissue,

impedance capability, which can be beneficial to COPD patients.

The topic addressed in this research is relevant, since it brings a therapeutic innovation on the transcutaneous electrical diaphragmatic stimulation in individuals with COPD, especially regarding its action on structural and hemodynamic changes.

Anyway, so far, research on the effects of transcutaneous electrical diaphragmatic stimulation through the Russian current in COPD patients have not been found. The aim of this research was to evaluate influence of transcutaneous electrical diaphragmatic stimulation through the Russian current in individuals with chronic obstructive pulmonary disease.

METHODOLOGY

This research was nearly experimental and prospective, approved by the Committee for Ethics and Research of the Universidade do Sagrado Coração (No. 203/10), with intentional sampling with an estimation of 20 subjects according to a previous study.⁹ Nineteen COPD patients from Bauru city were chosen, although five were excluded for their respiratory condition exacerbation and one for not being able to attend the sessions. These patients were approached by pulmonologists from Bauru State Hospital and a by television campaign.

Inclusion criteria for treatment were: drug stability, smoking interruption, COPD classification levels III and IV¹ and lifestyle maintenance. The exclusion criteria were: unstable pathology, metallic prosthesis, cardiac pace-maker and dermic injury⁸.

Specific respiratory assessment consisted of information about history of the disease, drug survey, anthropometry, physical and functional assessment. Volunteers have identified their respiratory clinical symptoms through MRC scale and Borg scale. After the initial investigation, volunteers remained 5 minutes in sitting posture for the measurement of systemic arterial pressure (AP), pulmonary auscultation, respiratory frequency (RF), peripheral oxygen saturation (SpO₂) – Onyx 9500 and pulse frequency (PF), measurement of maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) levels – Comercial Médica; tidal volume (TV), slow vital capacity (SVC) and minute volume (MV) – Wright spirometer; respiratory volumes and

capacities – Spiro USB – Spida 5 (United Kingdom)¹²; weight and height allowed to calculate the body mass index (BMI).

The next day, volunteers were subjected to the six-minute walk test (6MWT)¹³ to calculate the BODE index¹⁴.

On the third day, the intervention was initiated through the transcutaneous electrical diaphragmatic stimulation by the Russian Current Endophasy R ET 9701 (KLD®, SP, Brazil)^{6,7,9,10,15}. The electrodes were placed on their chests bilaterally following the midaxillary line on the height from the seventh to the eighth intercostal space⁸.

According to the ventilatory rate of each patient, the individual parameter⁷ was established, as contraction time: from 1 to 6 seconds; relaxation time: twice the contraction time; current modulating frequency: 2.500 Hz; therapy time and frequency: 18 minutes on a frequency between 20 and 30 Hz and 12 minutes on a frequency between 70 and 100 Hz; current percentage: 20 to 50%, starting on 20% and increasing progressively each 10 full sessions, with maximum possibility up to 50%. The treatment had 30 sessions, twice a week.

Normality of data distribution was confirmed by the Shapiro-Wilk test. Data were expressed in a descriptive manner by standard deviation mean± and absolute and relative values. Student's t-test was used for dependent variables paired for comparison between before and after treatment variables ($p < 0.05$) by using the SPSS 17 software (IBM, Chicago, Illinois).

RESULTS

Among the 13 patients, 11 (84.6%) were male, white and aged 68.46 ± 11.11 , body weight 70.78 ± 14.85 kg, height 1.67 ± 0.06 m and BMI 25.13 ± 4.61 kg/m².

Among them, one has never smoked and the others were smokers for 34.69 ± 12.03 years, and the tobacco load was 74.03 ± 56.2 packets per year.

All of them (100%) used bronchodilators; five (38.46%) for control and prevention of hemorrhagic episodes; four (30.76%) for the cardiovascular system; five patients (38.46%) were physically active (light physical activity/twice a week).

Table 1 shows initial and final values of vital and anthropometrical signs of COPD patients submitted to diaphragmatic electrical stimulation.

Table 1. Values of vital, respiratory and anthropometrical signs of patients at the beginning and at the end of the intervention

Variables	Initial	Final	p-value*
SBP (mmHg)	161.0±15.5	126.6±18.4	0.4852
DBP (mmHg)	100.0±11.5	80.3±13.3	0.6415
PF (bpm)	82±18.3	78.5±16.5	0.8421
SpO ₂ (%)	95.5±0.7	94.5±3.6	0.5595
Borg – dyspnea	2.4±1.6	2.2±1.3	0.387
RF (rpm)	17±5	16.0±4.3	0.4764
BMI (kg/m ²)	25.3±0.1	24.9±4.9	0.6708

* Comparison between the starting time with the final time

SBP: systolic blood pressure; DBP: diastolic blood pressure; PF: pulse frequency; BPM: beats per minute; SpO₂: peripheral oxygen saturation; RF: respiratory frequency; BMI: body mass index

It can be noted that there was no statistically significant difference of the variables studied when compared the initial moment with the final one.

On table 2, there are the values of respiratory variables and the BODE index before and after the physical therapy intervention.

Table 2. Initial and final values of respiratory function and the BODE index

Variables	Initial	Final	p-Value
FEV ₁ /FVC%	49.7±14.6	48.0±14.7	0.4692
FEV ₁	35.7±9.7	37.3±10.9	0.2439
FEF 25-75%	17.3±8.0	17.3±9.2	1
PEF	39.5±10.7	44.6±13.0	0.0570
FVC	57.9±12.8	62.3±12.4	0.0616
MIP	64.0±22.1	61.4±25.8	0.7191
MEP	83.7±18.5	83.4±20.5	0.956
MV	14.4±4.7	13.0±4.0	0.0191*
SVC	3.0±0.8	3.3±0.8	0.8844
RF (rpm)	17±5	16±4.3	0.4764
TV	0.8±0.2	0.8±0.2	0.1984
BODE	3.9±2.1	3.2±1.8	0.006*

* p< 0.05 for comparison between the initial and the final moment

FEV₁: forced expiratory volume in one second; FEF 25-75%: medium forced expiratory flow; PEF (l/sec): peak expiratory flow; FVC (l): forced vital capacity; MIP (cmH₂O): maximum inspiratory pressure; MEP (cmH₂O): maximum expiratory pressure; MV (l/min): minute volume; RF (rpm) = respiratory rate; SVC (l): slow vital capacity; TD (l): tidal volume

We observed statistically significant changes (p<0.05) with reduction of minute volume (l/min) from 14.47±4.72 to 13.03±4.00 and BODE index from 3.92±2.10 to 3.23±1.87.

During the walk test, the average of initial distance covered by the patients was 336±76.36 m, while at the end it was 402.76±51.29 m, which is a 66.76 m difference (p<0.05).

DISCUSSION

This research contributes to science due to innovation by using Russian current as a diaphragmatic stimulator

and for further clarification on its effects on COPD individuals.

Afonso et al.¹⁶ report that males have a higher probability of risk in COPD development. COPD prevalence is higher in individuals over 40 years old, being smoking its main modifiable risk factor. The sample studied represents this profile, and 84.6% were male, with 68.46±11.11 average age and 92.3% were ex-smokers. The study of Carlos et al.¹⁷ performed in animal models confirmed the effects induced by exposure to cigarette smoke. At first, such research seems to be repetitive, however, it contributed to the observation of main effects such as oxidative damage on the diaphragm muscle and, obviously, morphological changes on the lung tissue, pointing out that the diaphragm becomes vulnerable to exposure of cigarette smoke and that is the reason of respiratory repercussions, especially for smokers.

COPD patients present differences on type I and type II fibers, which indicates aerobic adaptation of the diaphragm regarding the disease and insufficiency to restore the ability to generate strength and endurance at normal levels, thus increasing its mechanical load.^{5,6,18} On animal models, the diaphragmatic electrical stimulation at 50 Hz frequency; TON/TOFF (contraction/relaxation time): 2/2 s; pulse duration: 0.4 ms, intensity: 5 mA to 1 mA with increase every three minutes for 20 minutes, by surface electrode, during seven days, caused changes in prevalence of diaphragm muscle fibers of Wistar male rats. Type I fibers reduced 19.5% and type II fibers increased almost 50%.¹⁹

Cancelliero et al. performed the transcutaneous electrical stimulation with two different protocols on 21 healthy women. Sessions happened twice a week for six weeks, totalizing twelve sessions. The devices used were Dualpex (Phrenics) and Dualpex 961. These devices, respectively, led to a MEP increase of 44.7% and 60.9%, while MIP had an increase of 32.9% and 63.2%. The two protocols have improved the respiratory muscle strength, considering that the initial pressure average was MIP – 63.36 and MEP – 76.93. According to the authors, the increase in both pressures happened due to overlapping of the stimulated region. Also, the electrical current applied generates a wide electric field that would be sufficient to stimulate other muscle groups⁹. In the same context, Nohama, Jorge and Valenga developed an instrument for diaphragmatic stimulation in COPD patients. This was the only research that applied this technique specifically in COPD, similar

to the present research. However, 10 sessions lasting 20 minutes each happened. In this study, MIP increased from 66.67 ± 12.11 to 91.67 ± 25.03 (delta D: 25) and MEP from 92.50 ± 10.84 to 116.67 ± 8.16 (D:24). The improvement on MIP contributed to decrease sensation of dyspnea, potentialize the respiratory muscles capacity and enhance functional capacity. The improvement on MEP was justified by the respiratory muscle adaptation, which optimized the strength-tension relation. In this study, there was also an increase in SpO₂ and RF reduction, however they were not presented, which limits our discussion.

Another study involved 14 older adults and TEDS, Dualpex 994 Frenics, during two weeks, once a day, totalizing 10 sessions lasting 30 minutes each. Again this technique occasioned increase on MIP, MEP and also on tidal volume. In this research, MIP and MEP values were lower than in other studies. MIP changed from 42.14 ± 12.67 to 55.71 ± 12.84 and MEP from 63.21 ± 19.18 to 83.57 ± 20.52 , and tidal volume increased from 411.43 ± 79.79 to 453.24 ± 164.93 mL.²¹ Debastiani and Aroca verified that the TEDS application in institutionalized older people, after 10 sessions of 20 minutes, provided an increase of up to 25% on MIP.²²

Unlike previous findings, the present study identified a decrease in MIP and MEP values, although these data were not statistically significant. Increase in these pressures was expected, mainly in MIP, which expresses inspiratory muscular strength, since electrical stimulation was directed to the main inspiratory muscle, however, it did not happen. For future studies, dosages, application time and more accurate evaluation techniques must be reviewed.

Furini and Longo report that when 10 to 30% of maximum muscular voluntary contraction is used, it can occur a 20% increase of blood circulation that happens around one minute after the beginning of electrical stimulation and this increase can last for up to five minutes after suspension.¹⁰ Another study with respiratory electrical stimulation in patients with polyneuromyopathy found that electrostimulation can lead to increased blood pressure and cardiac debit.²³ Cancellero, Costa and Silva²⁴ conducted an experimental study on rats, and after TEDS five sessions, they observed that this resource did not interfere in the cardiac electrical dynamic and caused a significant elevation of 42.85% on glycogen concentration in the diaphragm muscle, which demonstrates its effectiveness in improving muscle energy conditions.

In the present research, regarding clinical relevance, the average value of blood pressure arterial systemic measures had important reductions and can be classified as normal, which is still a benefit for patients who often have heart and kidney compromises due to respiratory distress.

Ghedini et al.²⁵ carried out a diaphragmatic electrical stimulation directly through single channel electrodes (Dualpex 961 Phrenics – depolarized current, with rectangular waveform, alternating symmetrical pulse type, 25 Hz frequency [cycles/sec] and 0.07 ms squall width.) on rabbits. Several intensities were administered and the relationship between the volume of expired air and the applied current intensity could be assessed. During the procedure it was possible to achieve expiratory volumes up to 149% of basal value.

Despite the methodological differences of these studies, such as the type of experimental model (humans and animals) with different intervention periods, in this research, reduction of the MV was evidenced, which in normal circumstances, from 5 to 6 L/min, contributes to obtain a respiratory efficient work. Electrical stimulation contributed to decrease MV, being a positive effect, as patients had a high MV if compared with reference values.

The distance walked in the 6MWT is a sensitive parameter for detecting clinical changes, and the BODE provides a multifactorial assessment^{1,18}. Pinto-Plata et al.²⁶ stated that the distance walked in the 6MWT is a most significant mortality marker when compared with FEV₁, BMI or in the presence of co-morbidities, which reinforces significance for assessing functional capacity of patients in daily life activities.

After the treatment intervention, there was a decrease of BODE Index from 3.92 ± 2.10 to 3.23 ± 1.87 , causing a significant difference, which was not influenced by the BMI. This finding is entirely positive, as it indicates that through the intervention there was a reduction in the probability of mortality occurrence in the group of COPD patients.

Specifically for the six-minute walk test, Redelmeier et al. determined a referential for clinical improvement when comparing distances (before and after intervention), this differential value must be 54 meters²⁷. At our study, the initial distance walked by patients during the six-minute walk test was 336 ± 76.36 m, while the average of the final distance walked by patients was 402.76 ± 51.29 m. That is, these patients gained functional capacity, which reflects positively on their daily life activities, on aerobic capacity to

practice activities, and on functional status of the cardiovascular and/or respiratory system as well as on morbidity and mortality indexes²⁸. For this parameter it is possible to monitor the effectiveness of treatment and establish the prognosis of these individuals²⁹. It can be observed that in a short time it is possible to obtain favorable results through the Russian current electrical stimulation.

There is unanimity among authors about TEDS being an effective tool to improve respiratory functional performance, however, only this research used Russian current as a therapeutic resource.

Based on the beneficial results found, we expect to encourage more studies to be performed on this type of protocol as a treatment method for COPD patients with a large number of volunteers, a large control group and evaluation equipment with a higher value precision. Due to specific characteristics of the volunteers, it was not possible to form the control group, since the number of subjects was scarce, and the few that were available refused to remain in this group in case they were selected.

CONCLUSION

Diaphragmatic electrical stimulation through Russian current generates significant benefits to COPD patients, since it interferes on respiratory and functional components.

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