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Impact of combined Russian current and threshold PEP on dyspnoea and functional capacity in patients with COPD: a randomised controlled trial

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Abstract

Introduction. Expiratory muscle weakness and dyspnoea are common in patients suffering from chronic obstructive pulmonary disease (COPD) and negatively affect their exercise capacity. We aimed to highlight the combined effect of Russian current and a threshold positive expiratory pressure (PEP) device on expiratory muscle strength, dyspnoea, and functional capacity in patients with COPD.

Methods. A total of 60 males with COPD were involved in this controlled randomised trial (age ranged 55–65 years and median body mass index [BMI] was 28.68–25.96) and randomly assigned into two equal groups (30 for each), to receive combined Russian current and PEP device (study group) or PEP device only (control group), for three sessions per week over a ten-week period. Maximum expiratory pressure (MEP), dyspnoea (modified Borg scale – MBS), and functional capacity (6-minute walk test) were assessed before and after the intervention.

Results. There was statistically significant improvement in all measured variables (MEP, MBS, and 6-minute walk test) in either the study group or the control group according to Wilcoxon's sign rank test (all were $p < 0.001$ and $p < 0.01$, respectively), however, the study group showed a more significant improvement compared to the control group according to the Mann–Whitney *U*-test ($p < 0.001$).

Conclusions. Combined Russian current and PEP device had a superior beneficial effect on improving dyspnoea and functional capacity by boosting the expiratory muscle strength in COPD patients, which could be implemented in their management, although further studies are needed to evaluate its maintenance effect.

Key words: chronic obstructive pulmonary disease, dyspnoea, exercise tolerance, respiratory muscle weakness, Russian current

Introduction

Chronic obstructive pulmonary disease (COPD) is a prevalent progressive respiratory disease that causes respiratory muscle dysfunction [1] which is the third leading cause of death worldwide [2]. Both inspiratory and expiratory muscles are involved similarly in COPD and experience structural and functional changes [3], which are potent drivers of dyspnoea and physical activity limitation [4].

Several studies focused on the inspiratory muscle dysfunction, mainly the diaphragm, however, the expiratory muscle is activated at the end of expiration during both rest and exercise [5, 6] to compensate for diaphragm dysfunction and lung hyperinflation, and therefore also yields to progressive weakness [7].

Strong expiratory muscle is important not only to maintain respiratory function in COPD but also for inducing effective cough, which delays further deterioration of lung function, dyspnoea, and quality of life [8]. As a result, maintaining expiratory muscle strength in COPD patients has become a must incorporate into pulmonary rehabilitation programs for these patients [9].

Positive expiratory pressure devices (PEP) provide resistive training of the expiratory muscles and were recommended for patients with multiple conditions, such as those with pulmonary or neurological disorders [10]. In patients with COPD, threshold PEP proves its effectiveness in decreasing the labour of breathing, enhancing expiratory muscle strength, relieving dyspnoea, and improving exercise tolerance [11].

Furthermore, a clinically relevant goal of threshold PEP is to improve gas exchange, minimise/prevent exacerbation, lower the impact of COPD episodes on these patients, and improve their morbidity rate [12]. The clinical efficacy of threshold PEP is comparable to that of conventional chest physiotherapy, which means it represents a simple and potent strategy in the management of COPD [13].

When threshold PEP is combined with another modality/technique, it can result in considerable improvements in dyspnoea, pulmonary function, and exercise tolerance compared to when it is used alone [14]. Russian current is a popular and well-tolerated type of neuromuscular electrical stimulation (NMES) that develops muscle strength with little pain, effort, or metabolic demand [15]. It is beneficial in patients with chronic illnesses that make typical exercise programs difficult for them to participate in, such as chronic heart or respiratory insufficiency [16].

The application of Russian current in COPD is currently confined to treating peripheral muscular dysfunction caused by a significant reduction in oxygen flow, which contributes to exercise intolerance and poor quality of life [17]. Respiratory muscles are skeletal muscles that are similarly impacted and weaken [18]. As a result, the Russian current application could help with respiratory muscle dysfunction in a similar way.

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Russian current involves the application of medium frequency electrical current (2,500 Hz) delivered in a variety of health care settings, which induces skeletal muscle contraction [19]. Furthermore, Russian current improves COPD patients' expiratory muscular strength, functional capacity, and overall health. It also speeds up the rehabilitation process and lowers the expense [20].

The application of Russian current to the expiratory muscles (abdominal muscles) causes phasic contraction, which improves diaphragm strength by forcing the ribs into an oblique and downward position. This gives the diaphragm a mechanical advantage, making contraction easier and decreasing inspiratory flux [21].

Unfortunately, there is a scarcity of evidence supporting the use of Russian current alone or in combination with threshold PEP for selective expiratory muscle training in COPD patients, and more study is needed.

The goal of this study was to see how effective the combination of Russian current and threshold PEP was at improving expiratory muscle strength in COPD patients, with the hypothesis that this combined technique would provide a superior improvement in expiratory muscle strength, dyspnoea, and functional capacity.

Subjects and methods

Participants

This was a single-blinded prospective study that was carried out at (hidden for reviewing), after trial approval from the Faculty of Physical Therapy Ethical Committee of (hidden for reviewing) and was registered on clinical trial.gov (hidden for reviewing). Informed consents were obtained from each eligible participant before enrolment in the study, which was consistent with the Declaration of Helsinki and CONSORT guidelines [22].

Selection criteria

Patients were eligible if they were 55–65-year-old males with a body mass index (BMI) of 25.0 to 29.9 kg/m^2, diagnosed as moderate COPD (Stage II-GOLD criteria) [1], had no history of acute infection or exacerbation within two months prior to the study and had not previously participated in any selective respiratory muscle exercise programs. Patients were excluded if they had chest infection, implanted pacemaker, open injury that interfered with Russian current application or cognitive difficulties that limit them in following the program. Patients who had chronic metabolic, renal, cardiovascular, musculoskeletal, or neurological diseases, in addition to having systemic corticosteroids or medications affecting our results in the preceding 4 weeks, were also excluded.

After baseline assessment, all participants were randomly assigned to one of two groups – the study group (received Russian current + threshold PEP device) or the control group (received the threshold PEP device only) (Figure 1) – by an independent statistician who was not involved in the study, using the web-based Research Randomizer software (https://www.randomizer.org/). The physiotherapist in our trial was informed of the group assignment, but the outcome assessor was kept anonymous.

G*Power software (version 3.1.9.2), Germany – University of Kiel, was used to estimate the study sample size for the primary outcome (MEP) based on a pilot study of 15 patients with the same eligible criteria and an effect size (d) = 0.78 at a 5% significant level and a power of 80% [*t* tests: difference between two independent means (two groups)] that revealed a final sample size of 30 individuals per group with an expected 5% dropout rate.

Procedures

Threshold PEP device protocol

Both groups (study and control) received EMT through a threshold PEP device (threshold PEP positive expiratory pressure device, Philips, USA, with an adjustable calibration from 5 to 41 cm H_2O). The training protocol consisted of three 30-min. sessions per week over 10 weeks, with a training load equal to 50% of each patient's predetermined MEP. The patients were told to wear a nose clip at rest and blow quickly and forcefully through the device after taking a deep breath.

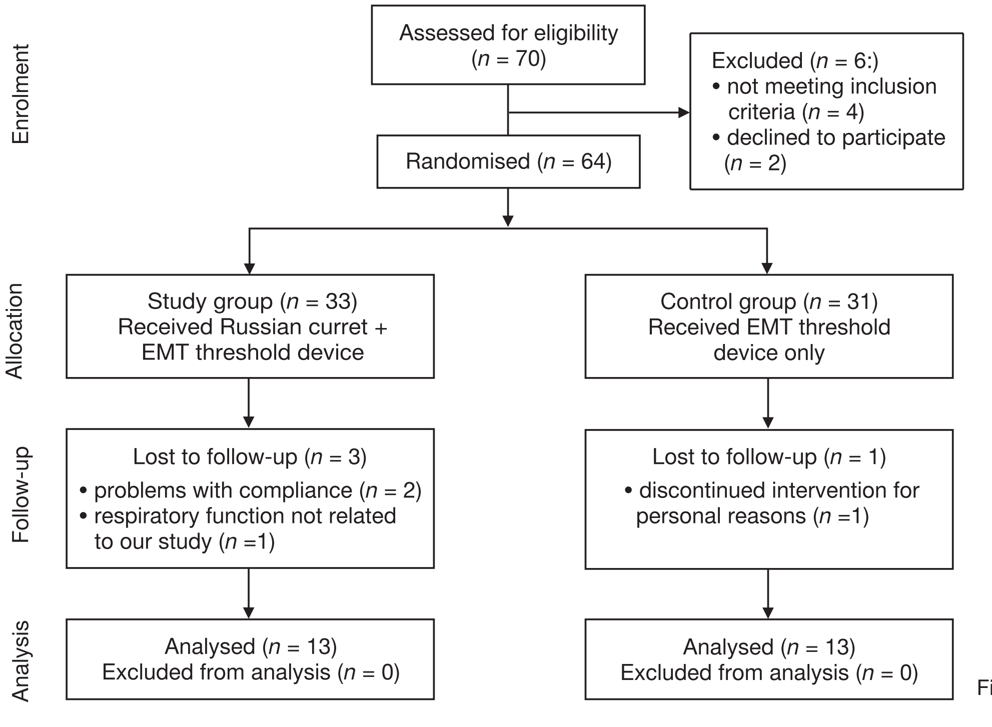

Figure 1. Study flowchart

The training load was measured each session to ensure that the target expiratory pressure was maintained. The session total work time was intially18 min and consisted of repeated cycles of 3 min work: 2 min rest, with the work intervals gradually increasing and the rest period decreasing weekly until achieving 30 min working time in the last week of the intervention [9].

Patients in the control group used the threshold PEP device under supervision for the first session only and completed the remaining sessions during the study period at home. All participants had a training log to keep track of their training days and number.

Russian current application

In our centre, the study group was exclusively treated with a threshold PEP device and Russian current, and their adherence was tracked by a face-to-face interview. The Russian current (Chattanooga Tran-Sport Unit, CT-2738 Mexico) was applied on the abdominal muscles' motor points (oblique and rectus abdominal muscles) through 2 channels (2 electrodes for each) firmly secured with tape after adding electrode gel to enhance the electrical current conductivity. The patients' heads were lifted and supported at 35° in a dorsal decubitus position during each session.

For a total of 25 min, the device emitted a medium frequency current (2,500 Hz) that was modulated according to the sequence of the structured program. Each Russian current session was carried out after the threshold PEP application (10 min rest in between) which began and ended with 5 min of 5 Hz muscle conditioning and relaxation, respectively, and 15 min for muscle training (10 min of 40 Hz for slow muscle fibres and 5 min of 120 Hz for fast twitch muscle fibres) at the highest tolerable intensity which produced a visible contraction [23], 3 sessions per week for 10 weeks. During the session, the patients were told not to volitionally contract their abdominal muscles.

Outcomes

MEP

The expiratory muscle strength was assessed by measuring MEP with a MicroRPM Respiratory Pressure Meter (Micro Direct, Lewiston, USA) according to the American Thoracic Society (ATS) and the European Respiratory Society (ATS/ERS) criteria [24], in which each patient was instructed to inhale deeply up to their total lung capacity (TLC) then forcefully expire through the manometer's mouth adaptor and hold for 1 second. This manoeuvre was repeated 3 to 8 times and the highest value that did not differ by more than 5 cm H_2O was recorded [25]. The results were calculated as percentages of the predicted values.

Dyspnoea (Modified Borg scale)

Modified Borg scale (MBS) is a validated measure for assessing the daily perception of dyspnoea and describes almost the entire range of dyspnoea from none (Grade 0) to extreme breathlessness (Grade 10) [26].

Functional capacity (6MWT)

The 6MWT was carried out according to the ERS guidelines for estimating the functional capacity of the participants, with the walked distance (m) covered over the 6-minute period being recorded [27].

Statistical analysis

The data was statistically analysed using the SPSS version 25 statistical package (IBM Corp., Armonk, NY). Categorical data were presented as absolute frequency (*n*) and relative frequency (%). The Shapiro-Wilk test was conducted to determine the normality of the data distribution ($p > 0.050$ indicating a normal distribution). The Mann–Whitney *U*-test was used for non-normally distributed continuous data. Within-group and between-group differences were described as mean ± standard deviation (*SD*) for normally distributed continuous data with no significant outliers or median (IQR; 25^{th} percentile – 75^{th} percentile) while the chi-square test or Fisher's exact test was used for comparing categorical data. The Wilcoxon signed-rank test and the Mann–Whitney *U*-test were used to determine within-group and between-group differences for non-normally distributed data. A *p*-value ≤ 0.05 was considered statistically significant.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Clinical Trial Registration: www.ClinicalTrials.gov, identifier NCT04704479.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

A total of 70 males with moderate COPD were screened. Six patients were excluded as they did not meet the inclusion criteria or declined to participate. As a result, the remaining 64 participants were randomised to one of two groups: study group ($n = 33$; received Russian current and threshold PEP device) or control group ($n = 31$; used only threshold PEP device). Four patients were dropped from the study for various reasons (lost to follow-up, deterioration of respiratory function not related to our study or compliance issues), leaving a total of 60 patients (30 for each group) who completed the study and were included in the data analysis with no adverse intervention events reported in either group. Dropout reasons were reported, and the data was analysed using the intention-to-treat (ITT) principle. All patients who completed the study in both groups had similar baseline characteristics ($p > 0.05$; Table 1).

Expiratory muscle strength (MEP)

As presented in Table 2, both groups had a substantial increase in MEP % pred., according to Wilcoxon's sign rank test ($p < 0.01$ for the control group and $p < 0.001$ for the study group), however, these improvements were statistically significant in the study group compared by the control group ($p < 0.001$).

Dyspnoea (MBS)

Both groups' MBS scores were significantly improved ($p < 0.01$ for the control group and $p < 0.001$ for the study group), however the study group's significant reduction in MBS score was greater than the control group's ($p < 0.001$) (Figure 2).

Table 1. Baseline characteristics of study participants

Characteristics		Study group (*n* = 30)	Control group (*n* = 30)	χ^2 / *Z*	*p*-value
Age (years)	median (IQR)	59.00 (57.00–62.00)	59.50 (57.00–62.00)	–0.067	0.947
	range	55.00–65.00	55.00–64.00		
BMI (kg/m²)	median (IQR)	27.50 (25.88–28.88)	27.30 (26.13–28.55)	–0.259	0.796
	range	25.10–29.70	25.30–29.50		
MEP Pred. (%)	median (IQR)	67.74 (62.48–72.43)	65.95 (63.88–68.86)	–0.444	0.657
	range	61.50–74.01	63.20–71.53		
6-MWTD (m)	median (IQR)	404.50 (393.75–431.25)	397.50 (389.75–425.75)	–1.102	0.271
	range	387.00–455.00	383.00–451.00		
MBS	median (IQR)	7.00 (7.00–8.00)	7.00 (6.00–8.00)	–0.638	0.523
	range	6.00–8.00	6.00–8.00		
Smoking behaviour					
Current	*N* (%)	12 (40.0%)	9 (30.0%)	1.162	0.559
Previous		8 (26.7%)	7 (23.3%)		
Never		10 (33.3%)	14 (46.7%)		

Data presented as *N* (%) for categorical data, median (IQR) and range (min-max) for continuous data.
categorical data: χ^2 test; continuous data: Mann–Whitney *U*-test
BMI – body mass index
MEP Pred. – maximum expiratory pressure
6-MWTD – 6-minute walk test distance
MBS – modified Borg scale

Table 2. Effect of combined Russian current and threshold PEP device on expiratory muscle strength (MEP)

Variable		Study group (*n* = 30)	Control group (*n* = 30)	*Z*[b]	*p*-value[b]
MEP Pred. (%)	pre-intervention	67.74 (62.48–72.43)	65.95 (63.88–68.86)	–0.444	0.657
	post-intervention	106.50 (101.50–115.25)	96.50 (88.75–104.25)	–4.172	< 0.001**
	p-value[a]	< 0.001*	< 0.01*		

data presented as median (IQR)
[a] Wilcoxon's sign rank test, [b] Mann–Whitney *U*-test
* statistically significant at $p < 0.05$ according to Wilcoxon's sign rank test
** statistically significant at $p < 0.05$ according to Mann–Whitney *U*-test
MEP Pred. – maximum expiratory pressure

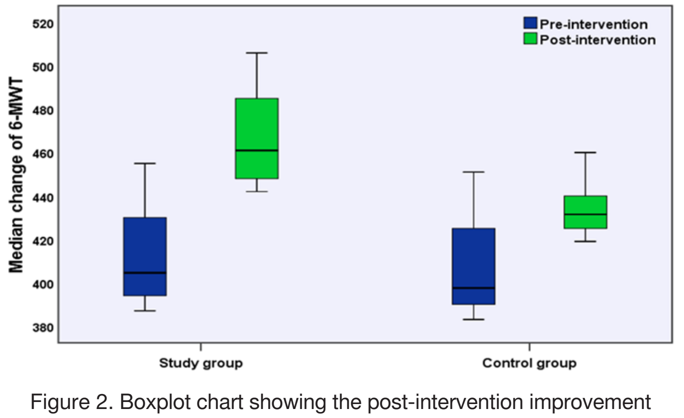

Figure 2. Boxplot chart showing the post-intervention improvement in the median of dyspnoea (MBS) score compared to the pre-intervention score within both study and control groups. A bigger significant change occurred in the study group over the control group ($p < 0.001$)

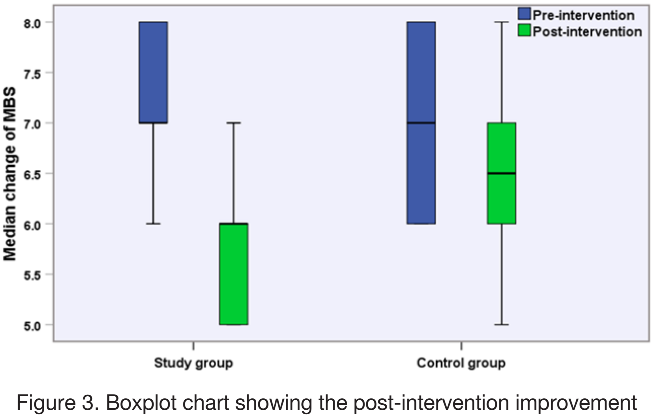

Figure 3. Boxplot chart showing the post-intervention improvement in the median of functional capacity (6-MWTD) score compared to the pre-intervention score within both study and control groups. A bigger significant change occurred in the study group over the control group ($p < 0.001$)

Functional capacity (6-MWTD)

The improvement of 6-MWTD notably differed in the study group (increasing) over the control group with stronger statistical significance in favour the study group ($p < 0.001$) (Figure 3).

Discussion

The findings of our study demonstrated that 10 weeks of Russian current implementation combined with a threshold PEP device improved expiratory muscle strength, functional capacity, and incapacitated dyspnoea among moderate COPD patients.

The degree of improvement was greater in the study group (received Russian current + threshold PEP device) than in the control group (threshold PEP device only). These benefits were achieved by enhancing the strength of the expiratory muscles with a targeted combined intervention that had considerable impact [28].

Russian current as a form of NMES plays a considerable role in COPD patient management, concerning different situations and severities, in the ICU, inpatient, and outpatient rehabilitation [29] but most of these studies evaluated the effect of NMES on peripheral muscle strength in COPD [17], and few studies reported its effect on the respiratory muscles [8]. Indeed, in this study, we focused on selective strengthening of the weak expiratory muscles among COPD patients.

Our results revealed remarkable improvements in functional capacity after NMES ($p < 0.001$), which is consistent with Morris et al. [30], who found that the 6MWT distance was improved after NMES strengthened the lower extremity (LE) muscles.

Chaplin et al. [31], in a comparative study between two different NMES frequencies (35 Hz low – 50 Hz high) applied on quadriceps muscles of hospitalised COPD patients with acute exacerbation, improved the quadriceps muscle isometric strength and endurance walking time after 30 minutes of daily NMES to both quadriceps, independent of the used frequency.

Moreover, Mota et al. [9] reported an improvement in the walking distance in COPD which significantly correlated with changes in MEP after 5 weeks of expiratory muscle training by an expiratory threshold device. Nevertheless, our results are more robust, as we had a larger sample size (60 patients) compared to Mota et al. (18 patients).

In addition, a retrospective study by Coquart et al. [32] found that NMES significantly improved exercise capacity and overall health-related quality of life (HRQoL) in COPD patients, regardless of the severity of the airway obstruction.

In contrast to the aforementioned studies in the discussion, Henoch et al. [33] claimed NMES could lower HRQoL with little effect on exercise capacity. This disparity is likely due to the fact that Henoch results was influenced by a variety of other factors such as dyspnoea, obstruction, smoking, and BMI. These variables were bolstered in our investigation by careful selection of the criteria for the individuals who were included.

Our findings were compatible with Weiner et al. [8] regarding the significant impact of expiratory muscle training (EMT) in increasing exercise tolerance and maximal work. Even though these results were confirmed by another study conducted by the same author, the benefits of EMT were lower than the results of inspiratory muscle training (IMT) or similar to those of combined IMT and EMT. This supports our hypothesis that selective training of the expiratory muscles by more than one intervention would provide superior improvement and clinically relevant changes regarding pulmonary function, exercise capacity, and dyspnoea.

Banerjee et al. [34] speculated that NMES improved the stimulated muscle function by enhancing the sensitivity of neural synapses, leading to better motor unit synchronisation during contraction. Russian current induces stronger and more synchronised motor nerve stimulation, resulting in increased muscle strength [35, 36]. This evidence may explain the benefits of strengthening the weak expiratory muscles in breaking the vicious cycle in COPD patients by desensitisation of dyspnoea.

In relation to the considerable reduction in dyspnoea in the current study, Suzuki et al. [37] discovered evidence of EMT's role in reducing the respiratory effort in healthy individuals, whereas Weiner et al. [8] observed no statistically significant difference in dyspnoea following an EMT program. We postulate that Russian current would improve the abdominal muscle tone, reduce thoracic air trapping by elevating the diaphragm (primary muscle of inspiration), and compensate for inspiratory muscle activity during expiration, hence alleviating dyspnoea [30].

Expiratory muscle training with an expiratory threshold device can be skewed by training because it is a volitional manoeuvre; therefore, combining it with a standard approach that does not provoke dyspnoea, such as NMES, to optimise the expiratory muscle strength is appropriate for patients with musculoskeletal dysfunction or exercise intolerance who also have high ventilatory stress, such as in COPD.

Abdominal exercises, according to prior research, not only improve abdominal muscle strength but also alter the diaphragm and inspiratory muscle function. According to Shao et al. [38], abdominal muscle exercise, as a major muscle of expiration, resulted in an increase in MEP and a significant increase in maximal voluntary ventilation in healthy individuals, which is similar to our findings. In addition, after abdominal exercise, DePalo et al. [39] found a significant increase in transdiaphragmatic pressure, maximum inspiratory and expiratory pressures in healthy adults.

The results of our study agree with the study by Vieira et al. [40] in which 8 weeks of NMES applied bilaterally on the quadriceps muscles promoted a significant reduction in dyspnoea during exercise that was accompanied by improvements in FEV1 and exercise tolerance (6MWT) in COPD patients. Our point of view regarding these findings relies on the effect of Russian current on the expiratory muscles' local metabolism or aerobic adaptation.

The results of this study showed that combined Russian current and threshold PEP device application to strengthen weak expiratory muscles improved the expiratory muscle strength, dyspnoea, and functional capacity in COPD patients, achieving a major goal for their treatment. Russian current is a safe and effective approach for COPD patients that can be implemented in their rehabilitation programs either in outpatient clinics or in home-based rehabilitation programs. We hope that our research will assist physiotherapists in determining the applicability of this intervention in the COPD population and will add to their understanding of how to manage these patients.

Limitations

There are a few limitations worth mentioning. First, air trapping (as measured by functional residual capacity and residual volume) was not taken into account. Second, due to a lack of resources, coughing capacity and MIP were not assessed, and patient follow-up after the trial intended to determine the long-term effects of our intervention was not undertaken. Finally, despite the favourable results of this study, the generalisability of the results to different populations may be limited due to the subject selection criteria and the procedure.

Conclusions

Based on our existing findings, Russian current, when combined with a traditional pulmonary rehabilitation program, is a practical and effective way to improve physical performance and dyspnoea in COPD patients by strengthening the weak expiratory muscles, rather than relying on a threshold PEP device alone. Future research is needed to clarify the influence of Russian current on other outcomes in COPD patients, as well as the standard approach based on the desired physiological effect. This study suggests that patients may gain more from the combination trainings than from the threshold PEP device alone.

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Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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