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*Case Report*

# The Effect Of Expiratory Muscle Training In Chronic Heart Failure Patient: A Case Report

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## ABSTRACT

**Background:** Chronic systolic heart failure (CSHF) is a serious disease with very bad prognosis. Modern cardiovascular rehabilitation reduces the symptoms of CHF and thus improves the quality of life.
The main symptom presented by the patients with CHF is exercise-induced dyspnea and fatigue, which limits their ability to perform activities of daily life. Respiratory muscles function can be affected by heart diseases when the patients display weakness and respiratory muscle deterioration.
A specific respiratory muscles training program improves muscle strength, functional capacity and quality of life for CHF patients with weakened inspiratory and expiratory muscles.
**Aim:** In this set of case studies, the authors demonstrate the benefit of expiratory muscle training with the Threshold PEP® aid in a patient suffering from CHF and they compare the patient with another patient without respiratory intervention.
**Methods:** On the basis of dilated cardiomyopathy with left ventricular ejection fraction (EF LV) 30%, NYHA III, a resting initial and leaving spirometry and body plethysmography was performed on a 47-year-old patient with systolic CHF, blood gases levels were determined and the patient also completed a modified Medical Research Council dyspnea questionnaire. In accordance with the discovered occlusion expiratory pressure, an expiratory resistance in centimeters of water column (cm $H_2O$) was precisely set to meet the patient's needs. This expiratory resistance was then increased during the training. The respiratory training was drawn up for the period of 10 weeks.
**Results and Conclusion:** After ten-week long training with Threshold PEP® respiratory aid, a significant change in ventilatory parameters has occurred. That is why we can indicate that EMT is helpful to patients suffering from CHF. However, it is necessary to focus on these problems in more detail in the future.

***Key words***: heart failure, expiratory muscle, Threshold PEP®, cardiovascular rehabilitation.

## INTRODUCTION

The prevalence of chronic heart failure (CHF) is between 1-2% in European countries, while in patients over the age of 65, the incidence increases rapidly. [1] This disease is connected to a very serious prognosis; sources state 90% mortality in the next 8 years after the heart failure was diagnosed de novo. [2] The patients suffer from low exercise tolerance, dyspnea and increased fatigue. The quality of life is very low because of the symptoms accompanying the CHF. These manifestations are caused by weakening of skeletal limb and respiratory muscles because of inadequate oxygen supply to muscle tissue, which is caused by CHF. Abnormal ventilation response to training, periodical breathing and delay of oxygen trapping in tissue at maximum physical exercise associates with the adverse prognosis of CHF. [3]

The availability of cardiovascular rehabilitation for patients suffering from chronic heart failure is almost non-existent in our conditions. Lack of erudite physioterapists, who could reduce symptoms accompanying this serious disease in patients, either through adequately set physical activity or a special respiratory therapy, is one of the causes of the low availability. Dyspnea, caused by respiratory muscles myopathy, is the most limiting symptom. Reduction of dyspnea through direct activation of respiratory muscles by means of evaluated respiratory aid, Threshold PEP®, which is commonly used by patients suffering from respiratory diseases, is our main idea. The methodology of respiration therapy by means of any expiratory aids in patients with CHF has not yet been described in foreign countries. This approach has yet another advantage: The patients rehabilitate at home and visit the specialized doctor only for regular check-ups.

## METHOD

The described patients are treated for chronic systolic heart failure, while both of them had lived an active life, both work and private. After signing informed consent forms and approval of Ethical committee of University Hospital Brno, both described patients went through identical initial and leaving examinations: anamnesis, clinical examination, spirometry, plethysmography, blood gas levels were determined and the patients also completed the modified Medical Research Council dyspnea questionnaires. A six-minute walk test (6-MWT) was performed with both patients, also, the chest parameters in the mesosternale and xiphosternale level were measured. All initial examinations were performed in CHSS compensated condition with length of at least 3 months. Patient No.1 performed the ten-week expiratory muscles training with Threshold PEP®. Patient No.2 had no training intervention.

**Dyspnea assessment**

Dyspnea in daily life was evaluated by the mMRC scale which consists of five statements that describe almost the entire range of dyspnea from none (Grade 0) to almost complete in capacity (Grade 4). [4]

**Pulmonary function test**

Spirometric and plethysmographic examinations were performed in accordance with the American Thoracic Society and the European Respiratory Society (ATS/ERS) [5,6] recommendations. The parameters were measured three times on a computer-based spirometer and calibrated plethysmograph ZAN 500 Body II (Meβgreräte GmbH, Germany). The best value was registered and the results were interpreted in per cents of predictive value. We have evaluated the following parameters for the analysis: vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 second ($FEV_1$), inspiratory capacity (IC), peak expiratory flow (PEF), expiratory reserve volume (ERV), residual volume (RV) and the ratio of residual volume to total lung capacity (RV/TLC). [7]

**Maximal inspiratory and expiratory mouth pressure**

Maximal inspiratory mouth pressure ($PI_{MAX}$ ) was determined through a flanged mouthpiece in deep inspiration from functional residual capacity against a shutter with a minor air leak preventing undesirable glottis closure (ZAN 500 Body II, Meβgreräte GmbH, Germany). Maximal expiratory mouth pressure ($PE_{MAX}$) was measured at total lung capacity during a maximal expiratory effort. The highest pressure of 3 measurements with 10% variability was used for analysis. Two minutes of rest were allowed between the 2 manoeuvers when necessary. Mouth occlusion pressure ($P_{0.1}$) was assessed 100ms after the onset of inspiration during spontaneous breathing at rest. [6] PImax and $P_{0.1}$ are expressed as positive values, although they are negative pressures with respect to atmosphere (ZAN 500 Body II, Meβgreräte GmbH, Germany).

**Breathing pattern and respiratory drive assessment**

Measurements of the mouth occlusion pressure ($P_{0.1}$) were made 100 ms after the onset of inspiration at rest. [8,9] $P_{0.1}$ was the inspiratory pressure developed 100 ms after closure of a valve at the level of functional residual capacity (FRC) at rest (ZAN 500 Body II, Meβgreräte GmbH, Germany). The measuring was repeated 5 times and the average of 3 measurements differed by 5%[8].PI was expressed as an absolute value (kPa) and as percentage of PImax (PI/PImax). Minute ventilation (VE), tidal volume (VT), respiratory rate (f ), Ttot (total respiratory time) and duty respiratory cycle ($T_I$/Ttot), were calculated at rest. Tension Time index ($T_{TMUS}$) way calculated as $TT_{MUS} = PI/PI_{MAX} \times (T_I/T_{TOT})$. [7] PI is a quintuple of the pressure measured 100 milliseconds after the onset of inspiration ($P_{0.1}$), $T_I$ is the time of inspiration and $T_{TOT}$ is the length of the entire respiratory cycle.

**Measurement of thorax mobility**

Chest wall expansion was evaluated with the standard method. [10] A flat tape was wrapped around the patient's chest and with his arms down, the patient was asked to breathe out as much as possible while the measuring tape was drawn taut, and the chest circumference was measured. The tape was then released, and patient was asked to breathe in as deeply as possible. For the last measurement, patients were again asked to breathe out as much as possible. Measurements were made at the mesosternum level for the upper chest wall and at the xiphisternum for the lower chest wall. Difference between the maximum expansion of the chest during inspiration and expiration was recorded. All measurements were performed twice, and their average was used. [11]

**Training program with positive expiratory pressure**

The patient was advised to undertake a $10^{th}$ week expiratory muscles training program, which he was taught in the hospital and with which he continued at home. That program included expiratory muscles training with a device able to provide positive expiratory pressure (PEP) in the form of a resistive load ranging from 5 to 20 cm $H2O$ (Threshold PEP®, Respironics; Cedar Grove, NJ, USA) (Fig. 1). The home program included exercises of expiratory muscles with frequency of seven days per week (Table 1.)

**Patient No.1**

Patient No.1 is a 47-year-old male, initials N.M., who was diagnosed with heart failure in 2013 on the basis of post-inflammatory cardiomyopathy The patient N.M. has the BMI of 26.4, resting blood pressure (BP) of 115/70 and heart rate (HR) 65 per minute. Regarding the comorbidities, treated arterial hypertension is present in patient. Left ventricular ejection fraction (LV EF) is 30%, functional class is NYHA III. During the course of the entire training, the pharmacotherapy was administered in tolerable doses, respectively in accordance with the Czech Society of Cardiology (CSC) guidelines. The medication included ACE inhibitors, beta blockers, diuretics...With regard to non-pharmacological treatment, a Boston Incepta VR ICD CRT cardiac pacemaker was implanted to the patient. The patients had a sedentary employment, at the moment, he is in a disability retirement, however, he did actively engage in sports prior to the occurrence of the disease. Oncological diseases without cardinal signs present in the family anamnesis.

**Patient No.2**

The second patient is a 54-year-old male with BMI of 28, however, there was no intervention of expiratory muscles training. The data measured with the aforementioned methods can only be used for control. Hemodynamic parameters - BP 130/80 and HR 75. Heart failure on the basis of ischemic heart disease was diagnosed in 2014. EF LV determined at 28%, NYHA III functional class. For the whole period of 10 weeks, the patients' medication was in accordance with a CSC recommended procedure from 2011 for diagnostics and treatment of chronic heart failure, which included ACE inhibitors, beta blockers, diuretics.

The patient has a cardinal anamnesis, in 2003, he had a cardiac pacemaker implanted because of a wrong function of sinoatrial node (sinus sick syndrome), arterial hypertension, treated over a long period of time, belongs among other important comorbidities. The patient works as an electrician in a medical facility. The values of initial and leaving examinations are clearly stated in Table 3,4.

## RESULTS

In the patient with EMT (P1), an increase of all spirometric values has occurred, in the patient without training (P2), only FVC parameter increased; values of other parameters decreased, ERV decreased the most significantly. RV and RV/TLC decreased significantly in the P1.

**Table 1. Training program with respiratory device Threshold PEP®** [cm $H_2O$ – centimeter water]

| Week of training | Frequency of exercise/day | Number of expirations per one exercise | Training load (cm $H_2O$) |
|---|---|---|---|
| **1 – 2** | 3 | 20 | 5 |
| **3 – 4** | 4 | 20 | 10 |
| **5 – 6** | 5 | 20 | 15 |
| **7 – 8** | 6 | 20 | 20 |
| **9 – 10** | 7 | 20 | 20 |

**Figure 1. Threshold PEP®, Respironics; Cedar Grove, NJ, USA**

The patient No. 1 received verbal and written instructions (Table 2) to contact a cardiologist or a physiotherapist in case of a problem with training. The physiotherapist called the patient weekly for 10 weeks to check that the device was working and to ask about the patient's condition. At the end of the training period, the physical examination and pulmonary function tests were repeated.

**Table 2. Instructions for patient with expiratory muscle training (EMT)**

| Instructions for patients |
|---|
| • assume upright sitting position |
| • insert mouthpiece into mouth, the aid must be held vertically to mouth |
| • respiratory pattern: 2-second inspiration - 4-second apneic pause - 4-second expiration |
| • there has to be a resting pause for at least 2 minutes between the two series |
| • patients can drink unsweetened fluids can be during the exercise |
| • do not exercise immediately after eating and before sleep |
| • in case of spinning feeling and headache, palpitation, acute tachycardia or nausea, interrupt the training for the period of at least 15 minutes. |

**Table 3. Spirometry and pletysmography parameters**

| parameters | | P1 (with EMT training) | | P2 (without EMT training) | |
|---|---|---|---|---|---|
| | | pre | post | pre | post |
| spirometry | | | | | |
| | **VC [L]** | **3.9** | **4.47** | **4.36** | **3.98** |
| | VC % p.v. | 83 | 96 | 90 | 83 |
| | **IC [L]** | **3.67** | **3.91** | **3.54** | **3.41** |
| | IC % p.v. | 107 | 114 | 92 | 89 |
| | **FEV1 [L]** | **3.02** | **3.89** | **2.71** | **2.65** |
| | FEV1 % p.v. | 83 | 106 | 75 | 74 |
| | **FVC [L]** | **3.69** | **4.74** | **2.86** | **2.87** |
| | FVC % p.v. | 82 | 106 | 62 | 62 |
| | **ERV [L]** | **0.23** | **0.57** | **0.82** | **0.57** |
| | ERV % p.v. | 17 | 43 | 66 | 47 |
| | **PEF [L/s]** | **7.23** | **9.89** | **6.38** | **5.35** |
| | ERV % p.v. | 82 | 112 | 73 | 61 |
| bodypletysmography | | | | | |
| | **RV [L]** | **2.97** | **1.43** | **3.12** | **3.52** |
| | ERV % p.v. | 144 | 70 | 123 | 137 |
| | **RV/TLC %** | **45** | **24** | **42** | **47** |
| | RV/TLC % p.v. | 140 | 76 | 109 | 122 |

[key: % p.v. = % percents of predicted value; L = litres; VC = vital capacity; IC = inspiratory capacity; $FEV_1$ = forced expiratory volume in one second; FVC = forced vital capacity; ERV = expiratory reserve volume; PEF = peak expi ratory flow; RV = residual volume; RV/TLC = ratio of residual volume to total lung capacity]

**Table 4. Breathing pattern and inspiratory muscles performance parameters at rest, in patients, suffering from heart failure, with and without EMT**

| | P1 (with EMT) | | P2 (without EMT) | |
|---|---|---|---|---|
| | **pre** | **post** | **pre** | **post** |
| **VE [L/min]** | **10.52** | **19.21** | **8.37** | **20.27** |
| **VE % n.h.** | 88 | 160 | 70 | 169 |
| **f [breaths/min]** | **23** | **18** | **19** | **19** |
| **f % n.h.** | 142 | 110 | 122 | 122 |
| **VT [L]** | **0.46** | **1.09** | **0.43** | **1.04** |
| **VT % n.h.** | **77** | **181** | **72** | **173** |
| **Ti/Ttot** | **0.49** | **0.52** | **0.39** | **0.4** |
| **Ti/Ttot % n.h.** | 106 | 114 | 86 | 87 |
| **$P_{0.1}$ [kPa]** | **0.11** | **0.12** | **0.06** | **0.32** |
| **$P_{0.1}$ % n.h.** | 53 | 58 | 28 | 160 |
| **PI [kPa]** | **0.69** | **1.04** | **0.34** | **1.98** |
| **PImax [kPa]** | **5.47** | **8.04** | **7.22** | **5.34** |
| **PImax % n.h.** | 47 | 70 | 68 | 50 |
| **PEmax [kPa]** | **7.15** | **15.10** | **7.75** | **4.31** |
| **PEmax % n.h.** | 33 | 71 | 39 | 22 |
| **PI/PImax** | **0.126** | **0.129** | **0.047** | **0.37** |
| **$T_{TMUS}$** | **0.06** | **0.07** | **0.02** | **0.15** |

[key: VE = minute ventilation; f = respiratory rate per minute; VT = volume tidal; Ti/Ttot = ratio of duration of inspiratory time to total respiratory time; $P_{0.1}$ = mouth occlusion pressure, 100 ms after onset of inspiration; PI = mean inspiratory pressure; PImax = maximal inspiratory pressure; PEmax = maximal expiratory pressure; PI/PImax = mean inspiratory pressure/maximal inspiratory pressure; $T_{TMUS}$ = non-invasive tension-time index of the inspiratory muscles at rest; kPa = kilopascal; L/min = litres/minute]

In P1, parameters of respiratory rate (f) have decreased and thus improved, at PI, PImax, PEmax, an increase of pressure values has occurred, which predicts a sufficient strength of inspiratory and expiratory muscles. PEmax and PImax have shown a significant decrease of values (PEmax and PImax by 18% (Fig.2). The values registering neuronal activity of inspiratory muscles were normal. $T_{TMUS}$ parameter did not prove a ventilatory failure (range 0.06 – 0.15).

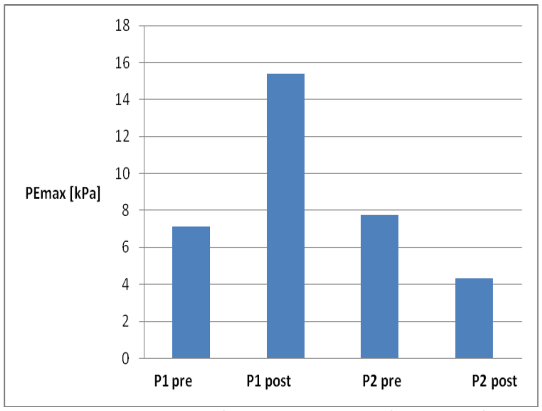
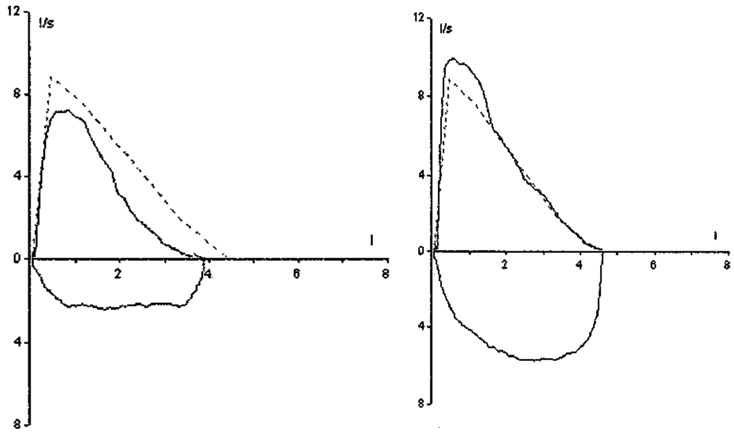



**Figure 2. Comparison of PEmax values before and after the training**
[key: PEmax = maximal expiratory pressure; P1 = patient 1; P2 = patient 2]




Pre Post

**Figure 3. Diagram of dependence of oxygen volume on time in Patient 1**

EMT led to an increase in chest expansion in were no changes of this parameter in evaluation of dyspnea perception in accordance with the modified MRC questionnaire (Table 5).

**Table 5. Circumference of rib cage and modified Medical Research Council of dyspnea perception**

| | P1 (with EMT) | | P2 (without EMT) | |
|---|---|---|---|---|
| **circumference** | pre | post | pre | post |
| **level of mesosternale** | 5 | 7.5 | 4 | 2.5 |
| **level of xiphosternale** | 5.5 | 6.5 | 1.5 | 2 |
| **mMRC** | 2 | 2 | 1 | 1 |
| **6- MWT [m]** | 444 | 504 | 436 | 405 |

## DISCUSSION

No technical paper has ever been written on the topic of direct activation of expiratory muscles in patients with systolic CHSS by means of sophisticated respiratory aids Threshold PEP®. A typical patient with HF has a lowered exercise tolerance and because of the clinical condition, the patient moves with difficulty due to the decrease of muscle strength caused by muscular myopathy. Respiratory muscles are largely affected by this pathology as well. Change in pH, primarily caused by increased level of $CO_2$ leads to stimulation of chemoreceptors, which causes tachypnea in these patients, increases tidal volume and generally stimulates inspirium with excessive engagement of respiratory muscles. We then consider such respiratory pattern to be significantly ineffective. Our group of authors proceeds from the assumption that from the point of view of difficulty, the expiratory muscles training is more beneficial to patients with CHSS than inspiratory muscles training, because inspiration is a significantly active event, because the elastic forces of soft tissue and muscles in the chest area are being overcome during inspiration. During expiration, these forces decrease and thus make it less difficult for the patients with CHSS; this way, we can achieve respiratory rate normalization and a decrease of demands on work of breathing. The ineffective expirium poses a significant problem for the patients with CHSS, because they themselves are unable to activate these muscles intentionally and effectively. We presume that securing ventilation at the expense of optimal functional engagement of respiratory muscles is the main cause of this dysfunctional respiratory behaviour. Expiratory muscles training leads to significant activation of these muscles, which intentionally causes a cerebral cortex motor centre stimulation with the goal to support their effective activity during breathing.

During expirium into the Threshold PEP® respiratory aid, a more significant depletion of alveolas of all retained $CO_2$ occurs; this event is also aided by opening of collateral airways and the patient does not need an inspirium of such volume to cover his or hers current respiratory demands any more. In addition, by an increase of inspiratory capacity, because of flattening and subsequent relaxation, the diaphragm is able to remove more $CO_2$ from the body and thus increase the total oxygenation.

During expiration against resistance, pressure conservation also occurs in the airways (PEEP), which ensures opening of alveolas, which is necessary to facilitate inspirium. Reinforcement of auxiliary expiratory muscles, suppression of pathological mechanism of muscular myopathy, but also influence on the change of breathing algorithm directly in CNS belong among our main theories for giving preference to EMT.

Expiratory muscles training with PEP increases $PE_{MAX}$ with potential increase of pulmonary functions parameters, exercise adaptation and physical efficiency, which requires adequate expiratory pressure. Significant increase of $PE_{MAX}$ parameter, which is an indicator of strength of expiratory muscles, is the most often stated result of expiratory muscles training in selected studies. Some studies state a decrease of dyspnea after expiratory muscles training in healthy probands and patients with COPD during physical activities, [12,13] and an increase of walk distance per time unit in patients with COPD. [14]

In our case study, we wanted to show the efficiency of expiratory muscles training in patient with HF, who manifested decreased tolerance to exercise, dyspnea and decrease of $PE_{MAX}$ parameter including pulmonary functions prior to the training. After the training, increase of the $PE_{MAX}$ parameter occurred, which was confirmed in the main study of the Cahalin et al. group. 2001. [15]

Laciuga et. al. discovered in her study that the immediate effect of short-term training of high expiratory pressure does not have a significant influence on the cardiorespiratory indicators (BP, HR, $SpO_2$) and that it does not require significant physical and respiratory effort in healthy individuals. In the training, we have applied a low intensity exercise of 5 - 20 cm of $H_2O$, because excessive expiratory resistance can lead to significant respiratory dysfunction, physical tiredness and deterioration of HF symptoms, such as exercise-induced dyspnea, arrhythmia, decrease of tidal volume with an increase of respiratory rate (known as rapid shallow breathing).

**Discussion regarding the pulmonary functional parameters.**

The spirometric values we measured are normal in both patients, but changes in PImax and PEmax strength parameters occur despite normal spirometry in VC, IC, FEV1 and FVC parameters. The most significant improvement occurred in the PEF parameter (by 30%) in P1, subsequently in the ERV parameter (by 26%) and $FEV_1$ (by 23%) in comparison with P2, where a decrease by 12% occurred in PEF, by 19% in ERV and by 1% in $FEV_1$. These parameters require expiratory muscles effort. We consider the decreased PImax and PEmax mouth pressure parameters to be predictors of inability to effectively activate the respiratory muscles, to which the CNS reacts with increased ventilation, manifested by a tachypnoea, which is a typical image of respiration in patients suffering from CHSS. Despite the normal spirometry, we can state a hypothesis that if increase in strength of inspiratory and expiratory muscles does not occur, as the disease will progress; the spirometric indicators will decrease as well, because they are also affected by the breathing effort, [16] which was proven in P2.

In patient No.1, after EMT, a decrease of RV (by 74%) as well as decrease of RV/TLC (by 64%) occurred, the IC value increased by 7%, respiratory rate decreased by 5 respiratory cycles per minute, which was probably caused by increased strength of expiratory muscles and by improved chest expansion. The results of the patient No.2 were opposite, RV increased by 14% and RV/TLC by 13% together with decrease of strength of expiratory muscles - $PE_{MAX}$ by 17%, ERV by 17% and PEF by 12% Higher value of RV/TLC increases elastic load created by soft tissues of the chest during breathing, the diaphragm flattens in its resting position and that predicts its fatigue. The patients are unable to increase their tidal volume and to fulfill the ventilatory requirements, it is necessary to increase the respiratory rate. [16] Tachypnoea causes degradation of RV/TLC and thus shortens the expiration period, it also decreases IC. As a result of inner positive end-expiratory pressure (PEEP), tachypnoea leads to dyspnea and increase of RV/TLC parameter.

The Threshold PEP® helps to prolong the expiration period and thus to reduce the volume of air at the end of expiration (PEEP), thus increasing the value of IC parameter. Balancing the inner elastic tension of soft tissues of the breastbone and inner elastic tension of pulmonary tissueis another possible mechanism of IC increase. Deflation of pulmonary tissue at expiration with the Threshold PEP® aid can reduce elastic tension to inspiratory muscles. [17] Newer studies show that improved IC leads to decrease of RV/TLC with use of positive expiratory pressure during physical exercise. [18] Decreased IC leads to the increase of ventilatory drive, which is shown by $P_{0.1}$ parameter, further to inability to create higher VT and to the increase of respiratory rate, which leads to decrease of the RV/TLC parameter, which shortens the expiratory period, as it was proven in patients with COPD. [19]

**Discussion regarding the maximal mouth occlussion pressure**

During the initial examination, decreased value of $PI_{MAX}$ was discovered in P No:1 (P No.1 = 47% n.v.), but after a 10-week training, an increase to 8.04 kPa (70% of n.v.) occurred; the value of 7.84 kPa in men between 20 and 54 years of age represents the lower boundary of normal condition (Hyatt). In case of P No.2, during the initial examination, the value of 7.72 kPa (68% kPa of n.v.) was registered, but during the leaving examination, decrease to 5.34 kPa (50% of n.v.), which represents weakening of inspiratory muscles, was discovered. Initial $PE_{MAX}$ values were decreased in both patients (P No.1 = 7.15

kPa (33% of n.v.); P No.2 = 7.75 kPa (39% of n.v.) because the lower boundary of normal condition is 14.61 kPa (Hyatt). After the training, in P No.1, an increase of $PE_{MAX}$ to 15.10 kPa (71% of n.v.) occurred, in P No.2, there was a decrease of $PE_{MAX}$ to 4.31 kPa (22% of n.v.).

Here we can assume that in both patients ≥ NYHA III. EMT can affect the strength of expiratory muscles in a positive manner and thus make the strength of inspiratory muscles and pulmonary parameters more effective. This assumption must be supported with a study performed on larger number of patients.

Two studies of Junior et al. and Peel confirmed significant decrease of the $PE_{MAX}$ value in patients with CHF in the III. stage in accordance with NYHA. [20,21]

**Discussion regarding the breathing pattern and ventilatory drive.**

Parameters of respiratory rate (f), minute ventilation (VE) and tidal volume (VT) were analysed to evaluate the respiratory pattern. In both patients, an increase of the resting VE was registered during the leaving examination (P1 19.21 l/min; P2 20.57 l/min), which we explain by an increase of tidal volume during the leaving examination (P1: 1.09 l, P2: 1.04 l), because in P1, the respiratory rate decreased from 23 to 18 cycles, P2 manifested no change. The $P_{01}$ parameter was examined for the purpose of evaluation of respiratory centres activity, it represents the strength of nerve impulse leading to a calm inspiration. During the initial examination, the values of both patients were within normal boundaries, but during the leaving examination, there was an increase to 0.32 kPa in P2, which represents a pathological value. [22] Values exceeding 0.3 kPa are connected to greater work of breathing and fatigue of inspiratory muscles, which are unable to generate corresponding strength. [2,12]

Threshold PEP® probably creates increased VT with decrease of respiratory rate and VE. Decrease of VE improves dyspnea perception. We presume that ventilation with low pulmonary volume with Threshold PEP® increases the strength of inspiratory muscles by expanding their sarcomeres, which harmonizes the relationship between respiratory drive and respiratory muscles response Insufficient adaptability to the training [22,23] is another hypothesis in case of failure to prove an improvement of ventilatory and strength parameters. Tension time index measuring ($T_{MUS}$) estimates the global function of inspiratory muscles and energy demands on breathing during given measuring. It is expressed as an average pressure, which is necessary for inspiration of corresponding tidal volume, related to maximal inspiratory pressure and multiplied by respiratory pattern, which expresses the period, during which the muscle contraction is being performed. [24] During the initial and leaving examination, the values were within normal levels in both patients, which does not suggest inspiratory muscles fatigue. During the initial examination, the value was physiological, however, during the leaving examination; an increase (0.15 kPa) was discovered in P2. $T_{TMUS}< 0.1$ is considered physiological, the value of >0,35 is an evidence of ventilatory insufficiency. [22] $P_I$/PImax expresses evaluation of respiratory capacity. $P_I$ designates the ratio of average inspiratory pressure during breathing to $PI_{MAX}$. The value of 0.3 of this ratio is considered critical. $P_I$ is determined by elastic and resisted exercise induced on inspiratory muscles. It is one of the determinants of energy demands of the breathing process. To ensure optimal endurance of respiratory muscles, it is necessary to create balance between energy supply and demand. If an increase of this parameter occurs, breathing-related energy demands increase, however, if these demands are not met, muscle fatigue occurs. [25,26]

In both patients, this parameter was within normal boundaries during the initial examination, but there was an increase to 0.37 in P2 during the leaving examination. Here, we presume that a relationship exists between increase of parameters $P_{01}$, $P_I/PI_{MAX}$ and $T_{TMUS}$ and a decrease of $PE_{MAX}$ and $PI_{MAX}$. Regarding the CHSS, no study to evaluate ventilatory drive parameters and respiratory muscles weakening was made so far, which provides space for further research.

**Discussion regarding chest expansion, 6-MWT and dyspnea rate.**

In patient No.2, decreased chest circumference on the mesosternale and xiphosternale level was discovered. During the leaving examination, a significant decrease of expansion in the mesosternale level (by 1.5 cm) was discovered. We can explain this decrease for example by respiratory muscles dysfunction, when decrease of $PI_{MAX}$ and $PE_{MAX}$ parameters occurs and this decrease caused patient's inability to activate inspiratory and expiratory muscles sufficiently.

In patient No.1, these parameters were not decreased significantly, but at the end of the training, increase of expansion in both aforementioned levels occurred. Here, we presume that this increase correlates positively with increase of parameters of pulmonary functions and maximal respiratory muscles strength. We have not found any study which would evaluate chest expansion in patients with heart failure in the available literature.

Bennett and Wood state an abnormal value for chest expansion in the level of fourth intercostal space to be a value lower than 2.5 cm at adult people.

However, subsequent studies prove this value not completely accurate, because in healthy people, chest expansion depends on other factors - for example age, gender, height, weight, somatotype. [27,28] Decreased chest expansion is often connected to occurrence of muscle imbalances, especially in the area of upper thoracic aperture, to abdominal muscles weakening and to restriction of thoracic fascia. Strength of inspiratory and expiratory muscles, with which maximal inspiration and expiration can be performed, will also have a special meaning for chest expansion. The chest expansion is evaluated during the maximal inspiration and expiration. Respiratory muscles training should be an integral part of therapy of patients, in which decreased respiratory muscles strength has been diagnosed. [29]

No subjective improvement of dyspnea perception occurred in both patients. However, in patient No. 1 with EMT intervention, a positive increase of distance by 60 m was discovered during the 6-MWT. In P2, a decrease by 31 m was discovered.

**Training programme discussion**

Breathing with Threshold PEP® with exercise in the range of 5 - 20 cm of $H_2O$ creates increased intraluminal pressure and thus increases transpulmonary pressure. Higher intraluminal pressure moves equal pressure point in proximal manner and thus prevents dynamic collapse of airways during expiration. [30] The effect of EMT in patients suffering from CHSS was proven in two studies, which concerned a combination of inspiratory muscles training (IMT and EMT). In one study, the patients performed a 12-week EMT with rate of 5 times per week for 30 - 40 minutes with the exercise of 5 -15% of $PE_{MAX}$. In this study, an increase of $PI_{MAX}$, $PE_{MAX}$, inspiratory muscles sustainability and 6-MWT parameters has occurred. [31,32] The same parameters were increased in P1, when the stress on Threshold PEP® was within 7 -

28% of $PE_{MAX}$, with gradual increase in exercise every 14 days. In the last month of training, the exercise was at 28% of $PE_{MAX}$ with gradual increase of number of expirations (range of 60-140 expirations/day). In the second study, a 12-week combined training was performed (respiratory exercises, training on the basis of normocapnic hyperpnoea and EMT). Training rate was 3 times per week in total period of 45 minutes/day. EMT was performed in the amount of 10 expirations with the period of 10 seconds during expiration with 15-second pauses in the amount of 10 series. An increase of $PI_{MAX}$, $PE_{MAX,}$ respiratory muscles endurance, 6 MWT, dyspnea and VE values has occurred. EMT is studies is a very small degree and that is the reason why our group also started to work on its integration into complete training programme for patients suffering from CHSS, because it was proven that in this group of patients was significant decrease of respiratory muscles strength.

## CONCLUSION

The main goal of this case study was to show the efficiency of EMT with low expiratory positive pressure on pulmonary parameters, strength parameters, ventilatory drive, dyspnea rate and chest expansion in patient with CHSS NYHA III. So far, no study regarding expiratory muscles training with low-pressure PEP (5-20 cm of $H_2O$) was ever made. On this case report, it can be shown that this type of training is a possible tool to improve pulmonary parameters VC, IC, $FEV_1$, ERV, PEF, RV, RV/TLC, respiratory muscles ($PI_{MAX}$, $PE_{MAX}$), ventilatory drive, chest expansion and functional capacity (increase in distance of 6-MWT).

Increase of expiratory air flow and decrease of dynamic hyperinflation of lungs during exercise and support of collateral ventilation is the principal effect of PEP-using aids. The effect manifests itself by prolonging expiration period and by a decrease of respiratory rate, which prevents the collapse of airways and thus also the decrease of RV/TLC (dynamic hyperinflation), [33] which leads to increase in dyspnea perception. A positive effect was proven during 6-minute walk test with simultaneous use of a PEP-using aid, when, in comparison with a control set, an increase of distance occurred during test with patients suffering from COPD. [34]

Future research works could focus on continual measurement of cardiac activity during training with Threshold PEP® aid, which will allow us to perform more detailed analysis of cardiac activity in patients with CHSS and their response to training. Subsequent studies could also verify positive effect of PEP-based aids during training and reconditioning in larger set of patients with heart failure as it was proven in studies in patients in heavy stages of COPD.

***Conflict Of Interest Statement***

The authors stated that there are no conflicts of interest regarding the publication of this article.

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