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*Original Research Article*

# Effect of Threshold Positive Expiratory Pressure on Dynamic Hyperinflation & Dyspnea in COPD: A Randomized Cross Over Trial

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## ABSTRACT

**Background:** Hyperinflation seen in COPD patients puts excess loads on ventilatory muscles exercise intolerance and limits physical activity. Physiotherapeutic management mainly emphasizes on increasing providing positive end expiratory pressure devices (PEEP). Threshold PEP is a device generating this pressure. Aim of the study is to evaluate efficacy of Threshold PEP in reducing dynamic hyperinflation & dyspnea during exercise.

**Material and Methods:** Thirty two patients were screened out of which twenty seven were included who were clinically stable with mean age of (64.63 ± 4.83) of either gender Male (n=20), Female (n=12). Patients included were into moderate to severely affected category (GOLD). Crossing over of patients in either group was done & sequence of therapy was allocated by block randomization. After recruitment initial assessment including PFT, RPE, 1RM & vitals was done. Patients performed same exercise with the device in experimental group & without device in control group. Patients performed knee extension exercise with weights (30% of 1RM) firmly strapped to ankles in high sitting position. Both legs were exercised alternately, with approximately 15 repetitions per leg per minute. A washout period of 60 minutes was given between interventions. Number of repetitions, time duration of exercise, PFT (Inspiratory capacity, slow vital capacity) breathlessness by RPE & vitals were measured in both the group pre – post intervention.

**Results:** A statistically significant difference was found in the inspiratory capacity in experimental group (0.52 ± 0.10) compared to (-0.11 ± 0.10) in control group. The RPE scores were lesser on experimental group post intervention (-0.61 ± 0.19) as compared to controls (0.9 ± 0.2). The duration of exercise in experimental group (94.85 ± 43.03) was more than controls

(78.22 ± 35.39) .The number of repetitions in experimental group (93.55 ± 35.43) was higher than controls (71.55 ± 25.28).
**Conclusion:** Threshold positive expiratory pressure (PEP) improves inspiratory capacity & slow vital capacity by reducing dynamic hyperinflation during exercise. This helps in alleviating dyspnea during training & improves exercise performance in COPD patients.
***Keywords:*** Dynamic hyperinflation, COPD, threshold positive expiratory pressure (PEP), Physiotherapy, dyspnea , exercise training

## INTRODUCTION

Chronic Obstructive pulmonary disease (COPD) is a preventable and treatable disease with some significant extra pulmonary effects that may contribute to the severity in the individual patients. Its pulmonary component is characterised by airflow limitation that is not fully reversible. The airflow limitation is usually progressive and is associated with an abnormal inflammatory response of the lung to the noxious particles. [(1)]

COPD affects 4% to 6% of population and fourth leading cause of death throughout the world. [(2)] In India COPD constitute nearly 25% to 30% of cases. [(3)] The prevalence rates varied from 1.4% to 4.08% in males & 2.5% to 2.7% in southern India. [(4)]

Predominantly cough, sputum production, wheezing, and dyspnea typically on exertion are the clinical manifestations seen in COPD patients. Among these dyspnea is slow but progressive in onset and occurs late in the course of the disease. [(5)]

In patients with significant COPD, alveolar destruction reduces outward radial traction on the airways, allowing airway collapse, trapping air in alveoli, and resulting in dynamic hyperinflation and reduced Inspiratory capacity (IC). Lung emptying in expiration becomes incomplete because it is interrupted by next inspiration leading to air trapping. This phenomenon leads to hyperinflated lungs in COPD patients. [(6)] Hyperinflation puts excess loads on ventilatory muscles which further exacerbate shortness of breath causing exercise intolerance and limited physical activity. [(7)]

Hyperinflation of the lung is defined as an elevation above normal of the resting functional residual capacity (FRC) or end expiratory lung volume (EELV). Hyperinflation has two components, static & dynamic. Static hyperinflation is present irrespective of breathing movements. Dynamic hyperinflation occurs when patient commences inhalation before full exhalation has been achieved. The degree of dynamic hyperinflation at any moment in time varies depending on the degree of airflow limitation and the rate of breathing. [(7)]

Currently various strategies to treat dynamic hyperinflation include pharmacological management, surgical management, & physiotherapeutic management. [(8)] Multiple studies have shown beneficial effects in managing dynamic hyperinflation with the use of Bronchodilators. Surgical management which comprises of lung volume reduction surgery is restricted to selected candidates and has high mortality rates. Another promising approach is placement of one way endobronchial valve by bronchoscopy. [(9)]

However physiotherapeutic management mainly emphasizes on increasing providing positive end expiratory pressure devices (PEEP). Purse lip breathing is one method by which PEEP is created. It is found to be beneficial in reducing dynamic hyperinflation, dyspnea & improve exercise endurance. [(9)]

Different Positive expiratory pressure (PEP) devices are used which help in lung expansion therapy. They are mainly of three types; Flow resistor, Threshold resistor & Vibratory PEP. PEP therapy involves active expiration against a variable flow resistance. It helps move secretions in larger airways by filling under aerated airways segments via collateral circulation & prevents airway collapse. Thus plays a vital role in avoiding lung hyperinflation. [10]

In a recent study it has been found that Conical-PEP devices decrease pulmonary volumes and hyperinflation in patients who are breathing close to total lung capacity. [11] they act by increasing expiratory time, decreasing respiratory rate and dynamic hyperinflation thereby reducing dyspnea associated with COPD. Another study using Threshold PEP found improvement in dyspnea levels immediately following activity. [9]

However, there is paucity of data suggesting effectiveness of Threshold PEP on dynamic hyperinflation and performance in COPD during exercise. So the aim of the study is to evaluate efficacy of Threshold PEP in reducing dynamic hyperinflation & dyspnea during exercise.

## MATERIALS AND METHOD

### Subjects

We included patients with moderate to severe COPD 60 to 70 years and exclusion Criteria were history of acute exacerbation of COPD, Mechanical ventilation within past one week, unstable cardiovascular disease in last 3 months. Any musculoskeletal impairment limits limb mobility, peripheral vascular disease, and who cannot understand the instructions.

### Procedure

The study was presented to the scientific committee & time bound Research Ethical committee of KMC Mangalore Manipal University & approval was obtained. Patients were referred by pulmonary care physicians to the physiotherapy department. The purpose of the study was explained to the patients and their informed consent forms were obtained. The Patients were selected based upon inclusion and exclusion criteria. Patients who met inclusion criteria were allotted either to control or experimental groups through block randomisation.

After randomisation, initial assessment including PFT ($FEV_1$ FVC, IC, SVC) (Appendix C), Rating of perceived exertion according to Modifies Borg's dyspnea scale, 1RM (repetition maximum) for quadriceps muscle were done. Vital parameters (Pulse rate, saturation & respiratory rate) of the patients were recorded before intervention.

### Experimental group

In the experimental group, patients performed knee extension exercise with Threshold PEP device & with weights (30% of 1RM) firmly strapped to ankles in high sitting position. Exercise was terminated if complains of Breathlessness $\geq$ 5/10 on Borg's scale, leg discomfort, or any other unpleasant symptoms were experienced by patient. Both legs were exercised alternately, with approximately 15 contractions per leg per minute with Threshold PEP. (Expiratory resistance of 10-15 cm of $H_2O$).Expiratory resistance was calculated as 10% of PEmax by P Morgan's instrument. Both legs were exercised alternately, with approximately 15 repetitions per leg per minute. Number of repetitions done by patient & time duration of exercise was measured.

### Control group

In control group, patients performed the knee extension exercise with normal breathing & weights (30% of 1RM) firmly strapped to ankles in high sitting position.

Exercise was terminated on complains of breathlessness ≥ 5/10 on Borg's scale, leg discomfort, or any other unpleasant symptoms were experienced by patient. Both legs were exercised alternately, with approximately 15 repetitions per leg per minute. The number of repetitions performed & the duration to which patient performed the exercise were noted.

Post intervention PFT (Inspiratory capacity, slow vital capacity) breathlessness RPE modified Borg's scale, respiratory rate & pulse rate were measured in both the groups. This was followed by a wash out period of 60mins in which patient were made to lie down in supine so that vitals come to normal. After washout period crossing over of patient groups was done.

**Statistical analysis**

Statistical analysis was performed using the statistical package for social sciences (SPSS version 16.0) for Windows. Paired t test was used to compare pre and post treatment spirometry measures, saturation, respiratory rate & pulse rate within each group. Unpaired t test was used to compare pre and post treatment spirometry measures, saturation, respiratory rate & pulse rate between group analyses. A *p*-value <0.05 was considered statistically significant.

## RESULTS

Randomisation was done wherein 32 subjects were included in the study & 27 subjects were evaluated. Five Subjects were prematurely withdrawn from the study. Of which three were unable to generate sufficient force for interpretation of spirometry, one had an episode of exacerbation and one denied to continue with the assessment.

The following table1 shows baseline demographic values, baseline spirometry values, smoking & medical history.

**Table 1: Table showing baseline characteristics of patients:**

| **Characteristic** | | **Mean ± SD** |
|---|---|---|
| Age in years | | 64.63 ± 4.83 |
| Gender | | Male (n=20) |
| | | Female (n=12) |
| BMI | | 21.15 ± 2.71 |
| $FEV_1$ | Moderate COPD | (n=20) 60.76 ± 8.49 |
| | Severe COPD | (n= 12) 45.9 ± 10.67 |
| $FEV_1$/FVC [%] | | 58.21 ± 13.52 |
| Smoking history | Pack year [No. of smokers = 20] | 26 ± 15.6 |
| Medications | LABA + Glucocorticosteroids | 15 ± 3 |
| | Anticholinergics + SABA | 12 ± 2 |
| | Other Bronchodilators | 5 ± 1 |

Table 2 showing improvement as well as statistically significant difference in inspiratory capacity & slow vital capacity in the experimental group. There is decrement seen in values of (IC) of control group. Table 3: Showing the mean difference between the groups before & after exercise. Improvement is seen in IC. Difference in IC was highly statistically significant & rest were insignificant. The table 4, shown differences in pre, post exercise in both the groups. The rating in perceived exertion (RPE) by Modified Borg's dyspnea scale shows significant improvement in experimental group post exercise.

**Table 2: shows spirometry values pre, post exercise & its difference in control & experimental groups**

| Group | Outcome | Pre Exercise | Post exercise | Difference (Post minus Pre) | *p*- Value |
|---|---|---|---|---|---|
| **Control group** | (IC) | 1.59 ± 0.62 | 1.48 ± 0.71 | -0.11 ± 0.10 | 0.004 |
| **Experimental group** | (IC) | 1.66 ± 0.58 | 2.18 ± 0.81 | 0.52 ± 0.10 | 0.0 |
| **Control group** | (SVC) | 2.10 ± 0.75 | 2.10 ± 0.68 | 0.00 ± 0.57 | 0.9 |
| **Experimental group** | (SVC) | 2.10 ± 0.68 | 2.40 ± 0.91 | 0.32 ± 0.07 | 0.0 |
| **Control group** | $FEV_1$ | 1.19 ± 0.55 | 1.21 ± 0.54 | 0.18 ± 0.04 | 0.66 |
| **Experimental group** | $FEV_1$ | 1.29 ± 0.52 | 1.38 ± 0.66 | 0.08 ± 0.09 | 0.36 |
| **Control group** | $FEV_1/FVC$ | 58.06 ± 14.9 | 56.35 ± 14.42 | -1.71 ± 0.99 | 0.09 |
| **Experimental group** | $FEV_1/FVC$ | 58.21 ± 13.52 | 60.62 ± 14.67 | 2.41 ± 1.37 | 0.09 |

**Table 3: Showing difference between experimental & control groups of spirometry values.**

| Outcome measure | (Exp-Control) Mean difference between groups | t – value | Significance (*p*) |
|---|---|---|---|
| **Inspiratory capacity (pre exercise)** | 0.07 | 0.41 | 0.67 |
| **Inspiratory capacity (post exercise)** | 0.7 | 3.37 | 0.001 |
| **Slow vital capacity (pre exercise)** | 0.00 | -0.56 | 0.57 |
| **Slow vital capacity (post exercise)** | 0.32 | 1.37 | 0.17 |
| **$FEV_1$ (Pre exercise)** | 0.1 | 0.7 | 0.49 |
| **$FEV_1$ (Post exercise)** | 0.17 | 1.02 | 0.31 |
| **$FEV_1/FVC$ (Pre exercise)** | 0.15 | 0.03 | 0.97 |
| **$FEV_1/FVC$ (Post exercise)** | 4.27 | 1.08 | 0.28 |

**Table 4: Showing pre, post exercise of variables in control & experimental groups**

| Group | Outcome | Pre Exercise | Post exercise | Difference (Post minus Pre) | *p*– Value |
|---|---|---|---|---|---|
| **Control group** | RPE | 1.48 ± 0.77 | 2.38 ± 1.1 | 0.9 ± 0.2 | 0.00 |
| **Experimental group** | RPE | 1.48 ± 0.77 | 0.87 ± 0.8 | -0.61 ± 0.19 | 0.00 |
| **Control group** | Respiratory Rate | 18.41 ± 3.92 | 22.81 ± 3.4 | 4.4 ± 0.45 | 0.00 |
| **Experimental group** | Respiratory Rate | 16.52 ± 3.04 | 22.89 ± 3.9 | 6.37 ± 1.54 | 0.00 |
| **Control group** | Pulse rate | 77.7 ± 10.69 | 87.11 ±11.25 | 9.4 ± 1.26 | 0.00 |
| **Experimental group** | Pulse rate | 76.15 ± 11.27 | 86.00 ±11.28 | 9.8 ± 0.84 | 0.00 |
| **Control group** | $SpO_2$ | 91.19 ± 4.18 | 87.44 ± 4.3 | -3.7 ± 0.45 | 0.00 |
| **Experimental group** | $SpO_2$ | 92.26 ± 4.04 | 90.11 ± 5.14 | -2.14 ± 0.48 | 0.00 |

Table 5 showing mean difference between experimental & control groups of RPE, respiratory rate, pulse rate & saturation scores. The negative value in post exercise RPE scores suggests lower Ratings by the patient in experimental group. No significant difference in other variables seen.

**Table 5: Difference between experimental & control values pre, post exercise shown**

| Outcome measure | (Exp- Control) Mean difference between groups | t – value | Significance (*p*) |
|---|---|---|---|
| **RPE (Pre exercise)** | 0.0 | 0.00 | 1.00 |
| **RPE (Post exercise)** | -1.51 | -5.63 | 0.00 |
| **Respiratory Rate (Pre exercise)** | -1.89 | -1.97 | 0.05 |
| **Respiratory Rate (Post exercise)** | 0.08 | 0.07 | 0.94 |
| **Pulse rate (Pre exercise)** | -1.55 | -0.52 | 0.6 |
| **Pulse rate (Post exercise)** | -1.11 | -0.36 | 0.72 |
| **$SpO_2$ (Pre exercise)** | 1.07 | 0.95 | 0.34 |
| **$SpO_2$ (Post exercise)** | 2.67 | 2.06 | 0.04 |

The table 6 showing mean values of Duration of exercise & number of repetitions in both the groups. Values in Experimental group are higher than that of controls.

**Table 6: Showing mean values of duration of exercise, number of repetitions in both groups & difference between them.**

| Secondary outcome measures Post intervention | Mean value | |
|---|---|---|
| | Experimental | Control |
| Duration of exercise | 94.85 ± 43.03 | 78.22 ± 35.39 |
| No. of repetitions | 93.55 ± 35.43 | 71.55 ± 25.28 |

## DISCUSSION

The present study shows Threshold PEP improves inspiratory capacity by reducing dynamic hyperinflation during exercise. Threshold PEP device, also alleviate dyspnea during training & improved exercise performance in COPD patients.

In this study, exercise capacity of subjects in both the groups was assessed by dynamic knee extension exercise. This was considering following reasons; firstly prevalence of quadriceps muscle affection in COPD & secondly ease of measurement of ventilatory parameters, saturation & vitals in test position. This exercise involved usage of large muscle groups & appeared to place significant load on cardiovascular & respiratory system. The use of 30% of 1 RM leg weights to quadriceps muscle corresponds to 70% of their age-predicted maximum heart rate. [12]

In experimental group use of Threshold PEP device significantly improved inspiratory capacity by 33% and slow vital capacity by 25%. This confirms that it has a substantial effect on exerciseinduced hyperinflation. Breathing through the Threshold PEP device set at 10 - 15 cm $H_2O$, may have generated a net increase in intraluminal pressure thereby increasing the transpulmonary pressure. The intraluminal pressure may have exceeded the airway collapsing pressure further, along the airway length with PEEP present. This may have moved the equal pressure point proximally to less collapsible airways, preventing dynamic airway collapse and gas trapping during exhalation. [9]

Hence blowing through this device might have improved lung emptying with each exhalation. This may have led in reduction of Functional residual capacity (FRC) giving opportunity for recruitment of tidal volume & inspiratory capacity thereby giving more room to breathe. The device may also have helped complete exhalation of $V_T$ to the relaxation volume & reduce EELV (End expiratory lung volume) to resting FRC, thus further steady rise of IC was possible. [13]

Another possible mechanism which may have improved inspiratory capacity was, building up of equilibrium between outward recoil of the chest wall & inward recoil of lungs. Deflation of lung to the relaxation volume occurring with the Threshold PEP device must have reduced elastic loading on the inspiratory muscles. [13] This improved elastic loading might have put, already flattened Diaphragm at mechanical advantage and hence helped maximal inspiratory force. The Threshold PEP device may also have prolonged duration of exhalation, this may have enabled better alveolar emptying, thereby creating a mechanical advantage for subsequent inhalation to improve inspiratory capacity. [11]

Earlier study showed improvement in inspiratory capacity; thereby showing reduced dynamic hyperinflation with the use of Conical PEP during exercise. [11] It has been suggested that an improvement in IC (Inspiratory Capacity) of equal to or greater than 10% of the predicted value corresponds with a real improvement in exercise performance. [14]

In the control group probable reasons for reduction in IC during exercise in control group are increased drive to breathe, inability to generate increased tidal volumes & increased breathing frequency. Increased breathing frequency can lead to exacerbation of DH, which may have limited the time for exhalation leading to intrinsic PEEP and further DH. [9] Another reason for reduced inspiratory capacity post exercise could be because; the backward pressure generated during normal/purse lip breathing is insufficient to avoid air trapping.

Another possibility could be uncontrolled exhalation, due to lack of maintained intraluminal pressure at the set threshold pressure throughout the expiratory cycle. This may have generated high airway expiratory pressures further leading to collapse of airways. This can be because the transmural pressure might have surpassed pressure support by the lung parenchyma. [10]

Spirometry tests also included $FEV_1$ & $FEV_1/FVC$, as other primary outcome measures. These were mainly carried out to categorise patients into moderate & severe group. We didn't find any significant change in both the outcome measure in both the groups. PEEP generated may not have altered these parameters probably as the intervention was given for a very short duration.

Dyspnea was another primary variable evaluated using Modified Borg scale. The dyspnea rating was lower in experimental group as compared to controls. This suggests that PEEP applied during exhalation may alleviate breathlessness during exercise. The Threshold PEP device probably produced a substantial increase in

Tidal volume ($V_t$) along with a reduced ventilatory rate and minute ventilation. [9] This reduction in minute ventilation must have improved perception of dyspnea.

Probably ventilation at low lung volumes with Threshold PEP may have improved force generating capacity of inspiratory muscles by increasing sarcomere fiber length. [14, 15] This resulted in reduced effort for volume displacement, more harmonious relationship between central neural drive & mechanical response, thereby reducing dyspnea sensation. [15] Another reason for lesser dyspnea scores can be improved airway conduction at all lung volumes. This may have led to release of cholinergic tone thereby relieving Dyspnea. [15]

In the control group, the dyspnea levels were high post exercise. Inability to generate increased tidal volumes could be a reason; to compensate patients may have increased their breathing frequency. Increased breathing frequency could have further exacerbated DH limiting the time for exhalation leading to intrinsic PEEP & dyspnea. Another possibility could be constrained Vt expansion by the progressive encroachment of EELV and the finite TLC (Total lung capacity). Therefore, patients must have experienced dyspnea during exercise, as there is "no room to breathe". [13]

Although other factors which may have an impact on the cognitive sensation of dyspnea including the mechanical status of the chest integration of respiratory afferent activity, respiratory motor drive, affective state, attention, experience and learning which existed in our patients, could not be neglected.

To further examine the effects of Threshold PEP device on exercise capacity, we used secondary outcome measure of saturation, respiratory rate & heart rate. Saturation was assessed wherein; we found significant drop post exercise in both the groups. This suggests that PEEP created by the device might not have corrected ventilation perfusion mismatch. Probably, decrease in saturation was also seen because of competition between ventilatory & locomotor muscles for available oxygen demand, particularly during exercise. [15] Increased demand during exercise might have led to hypoxia & persistent pulmonary vasoconstriction, causing drop in saturation. [16]

Respiratory rate & pulse rate were increased in both the groups. The possible reason can be lack of adaptability of the device by patients. Co- ordination of both activities i.e. blowing though the device & dynamic knee extension may have led to anxiety in patients. It was a onetime intervention & there was no change in normal physiological response following exercise in subjects.

The duration of exercise & number of repetitions were noted. Both the variables were higher in experimental group. This suggests that usage of Threshold PEP improved endurance & performance of patients.

Limitations of study is outcome measures like Residual volume, total lung capacity were not used. These measures are found to provide better accuracy in getting inspiratory capacity. Small sample size & shorter duration of study are other limiting factors. The chances of observer bias could not be eliminated as tester was not blinded.

Future studies can incorporate effect of device during other training activities like upper limb training, bicycle ergometry etc. In addition long term study with follow up can be carried out. Studies with larger sample size can be implemented.

## CONCLUSION

We conclude that Threshold positive expiratory pressure (PEP) improves inspiratory capacity & slow vital capacity by reducing dynamic hyperinflation during exercise. This helped in alleviating dyspnea during training & improved exercise performance in COPD patients.

*Conflict of interest*

The authors have no conflicts of interest to disclose

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