

Respiratory response to BiPAP aided upper limb exercise in hypercapnic COPD patients

Abstract

Study design: Experimental study design

Background: Application of inspiratory support, through proportional assisted ventilation, or continuous positive airways pressure ventilation, may potentially lead to enhanced training intensity. Therapies that are aimed to enhance physical activity levels have the potential to benefit patient group. However, beneficial effects of BiPAP aided performance of upper limb activities have been poorly documented.

Purpose of the study: To investigate the beneficial effects of BiPAP aided performance of upper limb activities along with oxygen therapy in improving gas exchange, fatigue and dyspnoea in Hypercapnic COPD patients.

Method: 30 Hypercapnic COPD patients were selected for both groups. Subjects in group A performed 20 minutes upper limb activity regimen without BiPAP where as subjects in group B performed the same regimen with BiPAP. Subjects underwent ABG analysis before and immediately after intervention.

Results: Within Groups analysis showed that there was a significant rise in dyspnoea, fatigue and PaCO₂ scores in both groups ($p < 0.001$). PaO₂ and pH scores showed significant reduction in group A whereas there was a significant increase in PaO₂ score and a decrease in pH scores in group B. Between groups analysis showed significantly higher rise in dyspnoea, fatigue, PaCO₂ in Group A as compared to that in Group B ($p \leq 0.05$). pH scores showed significant reduction in group A as compared to that in Group B ($p \leq 0.001$). There was significantly higher rise in PaO₂ score in Group B as compared to Group A ($p \leq 0.001$).

Conclusion: The results yielded a clinically significant improvement in patients' blood gas exchange parameters and less increase in dyspnoea and fatigue in BiPAP aided Hypercapnic patients.

Keywords: BiPAP, hypercapnic, COPD, blood gas; dyspnoea

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Saini Kirti, Sonia, Kalra Sheetal
Dashmesh College of Physiotherapy, India

Correspondence: Kalra Sheetal, Dashmesh College of Physiotherapy, SGT group of Institutions, Gurgaon, India, Email pawaria_sonia@yahoo.co.in

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Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a major cause of death and disability worldwide. Many people suffer from this disease for years and die prematurely of it or due to its complications.¹ About three million people died worldwide due to COPDs in 2005 and WHO predicts that it will be the fourth leading cause of death world wide by 2030.²

COPD is characterized by airflow limitation and reduced exercise capacity. Airflow limitation is usually progressive and associated with symptoms such as dyspnoea, excessive sputum production and chronic cough.² Dyspnoea and fatigue are the two most common symptoms experienced by patients with COPD.³ While dyspnoea has been traditionally considered the primary symptom in COPD patients, recent attention to measures of fatigue have shown both dyspnoea and fatigue to be important symptoms in this population.⁴

COPD patients have a decreased exercise capacity and reduced activity level compared to healthy controls.⁵ They often complain of severe exertional dyspnoea and have limited ventilator reserve during exercise.⁶ The ventilation capacity further decrease with the development of acute or chronic Hypercapnic respiratory failure (HRF).⁷ Exercise intolerance is one of the most distressing

consequences of COPD. Presence of limitation in physical activity or exercise in COPD patients is due to dyspnea.⁸

The upper limbs (ULs) are used extensively in daily life for carrying out activities in daily living (ADLs). As the disease progresses, the patients have thoraco abdominal asynchrony which increases the oxygen consumption and increase the minute ventilation (VE) during efforts of the ULs without support.⁹ Exercise training for patients with COPD has traditionally emphasized lower-extremity exercise (e.g. walking, cycling); however, many patients with COPD report disabling dyspnoea for daily activities involving the upper extremities (eg lifting, grooming) at work levels much lower than for lower extremity exercise.¹⁰

Non invasive ventilation (NIV) refers to the provision of ventilatory support through the upper airway, with the use of a face mask. Non-invasive mechanical ventilation (NIV), administered in the form of continuous positive pressure ventilation support ventilation (bi-level positive airways pressure or proportional assisted ventilation), unload the respiratory muscle.¹¹

Hence the application of inspiratory support, through proportional assisted ventilation, or continuous positive airways pressure ventilation, may potentially lead to enhanced training intensity. So, the

aim of present study was to investigate the beneficial effects of BiPAP aided performance of upper limb activities along with oxygen therapy in improving gas exchange, fatigue and dyspnoea in Hypercapnic COPD patients.

Methods

Study design

The study had an experimental (Pretest-Posttest) design.

Subjects

30 subjects were taken and divided into two groups:

Group A- were given upper extremity exercises and received O₂ by mask.

Group B- were given upper extremity exercises and received O₂ through BiPAP.

Inclusion criteria included age group 40-60years, male and female subjects, COPD patients with hypercapnia, patients having dyspnoea, patient on domiciliary oxygen therapy.

Exclusion criteria included subjects unable to tolerate >1hr of BiPAP, SpO₂<88% with FiO₂ ≥0.5; resting SBP<90 or >160mmHg & diastolic<60 or >100mmHg, unstable angina or previous MI, resting HR >120/min, decreased sensorium.

Procedure

A written informed consent was taken from all the subjects. All the subjects selected for the study for both groups underwent initial assessment. Variables dyspnoea, fatigue and ABG parameters were evaluated before and immediately after the intervention.

Intervention

Subjects in group A performed 20minutes upper limb activity regimen without BiPAP where as subjects in group B performed the same regimen with BiPAP.

The patients in both groups were continuously monitored with respect to VO₂, VCO₂, heart rate (HR), and dyspnoea index according to the Borg scale both at rest and during the execution of the following four activities of daily living (ADLs).

i. Sweeping the floor using a broom with nylon bristles for 5min on a previously determined rubber surface. The movements of the individuals during this activity was constricted to a small area due

to the limited extension of the tube that connected the metabolic system to the face mask of the individual for the collection of information about the metabolic and ventilator variables.

- ii. Erasing a blackboard for 5min with the blackboard placed in front of the individual. The subject started this activity with the dominant upper limb semi-flexed at the elbow but allowed to switch arms if he becomes fatigued.
- iii. Lifting pots weighing 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0kg with both arms simultaneously extended in order to pick up the pots that are at waist level, and then lift them above the head and put them down on a surface at that level. The arms were then lowered without a weight, and the individual performed the opposite effort, picking up the pot above his head and putting it down at waist level. The exercise was started by lifting the lightest pot and continued with progressively heavier pots until the series get completed. The series were repeated as many times as necessary to complete 5min, and the number of series completed were not taken into consideration.
- iv. Screwing in and out a bulb from four sockets placed at the height of the eyes, starting with the dominant arm semi-flexed at the elbow. However, switching arms during this activity was permitted depending on fatigue. This activity was performed over a period of 5min, and numbers of bulb changes were not taken into account.

Outcome measures

ABG parameters were measured by blood sampling. Dyspnoea and Fatigue were measured by modified borg,s scale.

Result

There was no significant difference in baseline pulmonary functions and demographics in subjects in both the groups (Table 1). Within Groups analysis showed that there was a significant rise in dyspnoea, fatigue and Pa CO₂ scores in both groups (p<0.001). PaO₂ and pH scores showed significant reduction in group A whereas there was a significant increase in PaO₂ score and a decrease in pH scores in group B (Table 2) (Table 3).

Between Group analysis showed significantly higher rise in dyspnoea, fatigue, PaCO₂ in Group A as compared to that in Group B (p≤0.05). pH scores showed significant reduction in group A as compared to that in Group B (p≤0.001). There was significantly higher rise in PaO₂ score in Group B as compared to Group A (p≤0.001). (Table 4).

Table 1 Subjects baseline characteristics represented as Mean ± SD.

Variables	Group A(n=15) Mean ± S.D	Group B(n=15) Mean ± S.D	T-value
Age (Years)	53.20±4.02	54.53±4.49	0.721NS
BMI (Kg/m ²)	22.81±1.99	23.27±2.17	1.020NS
Gender Male/Female	10/5	12/3	0.248/0.252NS
Modified Borg Score (Dyspnoea)	0.867±0.640	1.067± 0.704	0.814NS
Modified Borg Score (Fatigue)	0.800±0.676	0.933±0.594	0.574NS
PaO ₂	68.320±1.307	69.413±4.661	0.875NS
PaCO ₂	51.053±2.213	52.027±4.860	0.706NS

Table continued...

Variables	Group A(n=15) Mean ± S.D	Group B(n=15) Mean ± S.D	T-value
PH	7.35±0.01	7.35±0.01	1.122NS

*Significant at $p \leq 0.05$ **Highly significant at $p < 0.001$

NS, non significant

Table 2 Within Group Analysis Group A

Variables	Pre exercise Mean±SD	Post exercise Mean±SD	T- value
Dyspnoea	0.867±0.640	2.467±0.990	6.287**
Fatigue	0.800±.676	1.800±0.676	10.247 **
PaCO ₂	51.053±2.213	57.913±3.820	7.936**
PaO ₂	68.320±1.307	62.013±2.276	5.205**
pH	7.35±0.01	7.33±0.01	15.62**

*Significant at $p \leq 0.05$ **Highly significant at $p < 0.001$

NS, non significant

Table 3 Within Group analysis Group B

Variables	Pre exercise mean±SD	Post exercise mean±SD	T- value
Dyspnoea	1.067±0.704	1.533±0.640	2.824*
Fatigue	0.933±0.594	1.400±0.507	2.824*
PaCO ₂	52.027±4.860	52.253±4.982	3.302**
PaO ₂	69.413±4.661	79.747±5.049	13.459**
pH	7.35±0.01	7.34±0.01	16**

*Significant at $p \leq 0.05$ **Highly significant at $p < 0.001$

NS, non significant

Table 4 Between Group Analysis

Variables	Group A Mean±SD	Group B Mean±SD	T- value
Dyspnoea	2.467±0.990	1.533±0.640	2.824*
Fatigue	1.800±0.676	1.400±0.507	2.779*
PaCO ₂	57.913±3.820	52.253±4.982	3.302*
PaO ₂	62.013±2.276	79.747±5.049	6.351**
pH	7.33±0.01	7.34±0.01	6.349**

*Significant at $p \leq 0.05$ **Highly significant at $p < 0.001$

NS, non significant

Discussion

Non invasive positive pressure ventilation has been shown to be an important adjunct to pulmonary rehabilitation in Hypercapnic severe COPD patients who complain exertional dyspnoea and show desaturation during lower limb exhaustive exercises and also during 6MWT. But the effect of NPPV in Hypercapnic severe COPD patients while performing upper limb activities of daily living has not been investigated much. So the present study was conducted to analyze the impact of NPPV via portable BiPAP on respiratory responses including arterial blood gas tension (PaO₂, PaCO₂ and pH), dyspnea and fatigue.

Unsupported arm exercise is typical of activities of daily living. Unsupported arm exercise capacity has been shown to be reduced in both COPD subjects and healthy when compared with leg exercise and supported arm exercise.¹² Present study included an activity regimen that considered of sweeping, erasing the board, lifting weights and changing bulbs. Patients in both Groups A & B performed these activities at their own rhythm (frequency and repetitions), as we wanted to measure their own respiratory responses as close as possible as to how they would do it in the real world. To avoid the effect of any confounding factors on unsupported arm exercise, oxygen therapy was given to all subjects, irrespective of the groups and was standardized to achieve SaO₂ >92-93%. The result of the present study shows that there is a significant impact of ventilator assistance via portable BiPAP, on the performance of upper limb activities in Hypercapnic COPD patients.

Change in dyspnoea and fatigue

The high values on Modified Borg scale after 20minutes of activity as seen in the both the Groups may be explained by following reasons:

- i. Lifting weights required a great deal of physical effort by the patients, as it involved a wide amplitude of the upper limb movements particularly shoulder
- ii. Changing bulbs is complex activity in addition to requiring the simultaneously elevated and unsupported upper limbs, it also requires a fine motor coordination of the hand
- iii. The maintained unsupported and elevated positions of upper limbs throughout the execution of the task require active participation of scapular belt muscles to maintain the activity. It has been shown that activities requiring a higher level of concentration lead patients with COPD to engage in short periods of apnea during these activities and are associated with dis-synchronous breathing.¹³

The dyspnoea reported by all the subjects after the activity supports the literature findings that point out that performance of activities involving the upper extremity of body patients with COPD may displace the respiratory functions of scapular belt muscles to a more anti-gravitational function, increasing the work done by diaphragm and the ventilator demand due to superimposed loads of dynamic hyperinflation.

These findings are in congruence with the findings of Mc Keough et al.,¹⁴ who found that unsupported arm positioning above 90 degree places the chest wall in inflated position, the rib cage is expanded by passive stretch of muscles such as pectoralis major, minor and serratus anterior increase functional residual capacity and decreases

inspiratory capacity.¹⁴ O' Donnell et al.,¹⁵ also explained that breathing at higher lung volumes may further restrict the ability to progressively increase tidal volume, thus indicating mechanical constraints would have contributed to ventilator constraints in severe COPD. Inspiratory muscle load would have decreased due to the effects of hyperinflation, leading to impaired contractility of diaphragm and respiratory muscles and would have contributed to fatigue, by contracting against higher loads.¹⁵

It is conceivable that sustained muscle tension decreases blood flow. The reduced arm blood flow cause muscle fatigue, thereby, shortening the length of time for any arm activity. Older studies have already shown that exercises with the arms, increase the sympathetic tone and lactate concentration, suggesting that working in a position that keeps the arm muscles under for the diaphragm muscle, blood flow may progressively decrease and approach zero at 75% of maximum trans diaphragmatic pressures.

Subjects in Group A would have reached high ventilation to accomplish their tasks and blood flow may have been "stolen" from the arm muscles and redistributed to the ventilator muscles, contributing to the fatigue of the arm muscles and expressed by the high Borg index.

However, subjects in Group B had a comparatively less increase in Modified Borg scores with a mean increase of 0.466 (p<0.05), i.e. 43.67% for dyspnoea and 0.467 (p<0.05), i.e. 47.02% for fatigue than group A who showed mean increase in dyspnoea of 1.60 (p<0.001), i.e. 184% and fatigue by a mean of 1.00 (p<0.001) i.e. 125.0%. Our result findings are supported by a study of Andrea Rossi et al 2006 while studying the effect of PSV and other modes on simple arm elevation. PSV was found to increase in ventilation (23%), tidal volume (48%), reduced frequency of breathing (18%), decrease in PEEP (59%), diaphragmatic effort (77%) as compared to arm elevation without PSV.¹⁶

Polkey et al.,¹⁷ observed that the addition of 30minutes of BiPAP with via oro nasal mask with adjustments in the IPS and inspiratory time to optimize patient comfort during exhaustive treadmill exercises reduces the slowing of inspiratory muscle relaxation rate.¹⁷

Changes in PaO₂, PaCO₂ and pH

Subjects in Group A who performed the activity regimen without BiPAP showed an increase in PaCO₂ by a mean of 6.86 (p<0.001) i.e. 13.43%, decrease in PaO₂ by a mean of 6.307 (p<0.001) i. e. 9.23% and pH by 0.02(p<0.001) i.e. 0.27 %. The findings of our study are in agreement with results of O' Donnell et al.,¹⁸ who found increase in PaCO₂ (71mm Hg, p<0.05) with a strong statistical correlation between exercise induced increase in PaCO₂ and simultaneous increase in dynamic end expiratory lung volume (r²=0.62, p<0.005) among twenty clinically stable advanced COPD with varying degree of hypoxemia. The same authors also found strong co-relation between exercise arterial oxygen desaturation & exercise induced change in CO production which primarily reflects worsening of alveolar hyperventilation as a result of dynamic mechanical restriction.¹⁸

Based on the above discussed research findings, it can be suggested that unsupported arm exercises result in dynamic hyperinflation or increases end expiratory lung volume which alters the breathing pattern, expansion of dead space ventilation & reduction of CO₂ elimination. The development of acute dynamic hyperinflation increases inspiratory muscle load, either due to inspiratory muscle

fatigue, thereby, contributing to ineffective CO₂ elimination produced from the whole body and thus worsening gas exchange.

Increase in PaCO₂ in already Hypercapnic COPD patients may lead to further abnormal physiological mechanisms. But upper limb activities are necessary to perform the activities of daily living. To augment the unsupported arm exercise capacity, we used noninvasive positive pressure ventilation via portable BiPAP by alleviating the abnormal respiratory response.

In Group B PaCO₂ markedly decreased by a mean of 0.223 (p<0.05) i.e. 0.42%, PaO₂ substantially increased by a mean of 10.33 (p<0.001) i.e. 14.88% and pH increased by a mean of 0.01 (p<0.001) i.e. 0.14%. When BiPAP with IPAP of 8-18cm H₂O and EPAP of 4-6cm H₂O was added to supplemental oxygen during the activity regimen.

During exercise in Hypercapnic COPD, alveolar ventilation is inadequate in relation to CO₂ production. The decrease in PaCO₂ in Group B would have occurred due to increase in overall minute ventilation, or alternatively, improvement in ventilation perfusion relationships.

Brochard et al.,¹⁹ found a good correlation between the reduction in respiratory muscles activity due to IPS and on other hand, the lower VO₂ of contracting ventilator muscles.¹⁹

Duiverman et al.,²⁰ augmented with these findings, showing the improvement in fatigue domain of CRQ score, MRF-28 total score and MRF-28 cognition score and daytime PaCO₂ after noncturnal application of BiPAP with exercise training for four weeks in comparison to exercise training alone in total population of 72, Hypercapnic severe COPD patients.²⁰

Based on the above evidences, we can conclude that workload is reduced by unloading of respiratory muscles with the application of BiPAP for 20minutes which would have further contributed in reduction of fatigue. NPPV reduces breathlessness and allows a better limb exercise by redistribution of blood flow from the respiratory to skeletal muscles.

Limitations

- Sample was small.
- The results of the study were subjected to patient's effort and motivational factor.
- Study duration was short.
- Due to unavailability of resources, it was not possible to continue the monitoring of arterial blood gas perimeters after study design.

Relevance to clinical practice

The finding of the present study suggested to have important clinical implication. It was found that institution of BiPAP with individualized prescription during activity program resulted into elevation of dyspnoea and fatigue scores.

Institution of BiPEP during daily activities of upper limb, can be practiced in addition to other interventions to improve exercise capacity in the pulmonary rehabilitation program in addition to its use while at rest or during the sleep.

Future research

It is needed to evaluate the effects if BiPAP on other physiological

variables such as minute ventilation (V_E), Breathing Frequency (B_f), after performing activities of daily living in Hypercapnic patients.

Future studies are also needed to address the impact of skeleton muscle impairment and should include subgroup analysis in order to identify patients who benefits from BiPAP after activities of daily living compared with those who do not.

Future studies should address the impact of BiPAP during different types of activities like stair climbing in Hypercapnic COPD patients.

Conclusion

The results obtained from this study in patients with Hypercapnic stable COPD, a 20minute BiPAP aided upper limb activity program yielded a clinically significant improvement in patients' blood gas exchange parameters and less increase in dyspnoea and fatigue. Moreover, this improvement was significantly higher than the patients receiving only oxygen supplementation. Hence research hypothesis i.e. the use of BiPAP during upper limb activities has a significant impact on the respiratory responses in stable Hypercapnic COPD patients has been accepted.

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None.

Conflict of interest

The author declares no conflict of interest.

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