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EFFECT OF PULMONARY REHABILITATION ON STATIC LUNG FUNCTIONS IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS-A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT Aim of present study was to find out the effect of pulmonary rehabilitation on static lung functions in COPD patients. Residual volume and total lung capacity are the indicators of dynamic hyperinflation associated with COPD. Pulmonary rehabilitation is one of the most important tool in the non-pharmacologic management of COPD patients.

40 diagnosed COPD patients were randomly divided into two groups. Control group received conventional chest physiotherapy maneuvers and the experimental group received conventional chest physiotherapy as well as they were enrolled into pulmonary rehabilitation program. Residual volume and total lung capacity were measured at day one, day tenth and at the end of fourth week of treatment.

The results showed statistically significant improvement in residual volume of experimental group whereas there were no significant changes in the values of total lung capacity.

Thus, pulmonary rehabilitation is an effective tool in improving residual volume in patients with COPD and thus help in reducing dynamic hyperinflation associated with COPD.

KEYWORDS : Chronic obstructive pulmonary disease, Pulmonary Rehabilitation, Residual Volume, Total Lung Capacity

Chronic Obstructive Pulmonary Disease (COPD) is an umbrella term that includes a variety of progressively debilitating lung diseases[1]. The World Health Organization estimates that COPD will rank as the world's third-largest killer by 2030. In the United States, COPD is already the nation's third-leading killer[2].

GOLD (Global initiative for Chronic Obstructive Lung Disease) has defined COPD as, "a common preventable and treatable disease characterized by persistent airflow limitation that is usually progressive and associated with an enhanced inflammatory response in the airways and the lungs to noxious particles or gases"[1].
The burden of Chronic Obstructive Pulmonary Disease (COPD) is increasing globally as well as in India. COPD is one of the major causes of mortality and morbidity across the globe. The prevalence of COPD globally is 9-10% in people aged 40 years and above.[3]

In developing countries, the overall changing lifestyle because of the socioeconomic development and urbanization. This changing lifestyle is one of the leading cause of increased burden of non-communicable disease, COPD being one of the most prevalent. Many studies have reported smoking (active as well as passive) to be the most common causative factor for COPD.[4]

In India, though smoking continues to be the leading cause for COPD, the disease is common in non-smokers in the rural population. Biomass fuel is identified as a prime source of disease in non-smokers. In India large population in rural area uses biomass fuel for cooking (chulha). The fumes of the biomass fuel are responsible for the compromise in respiratory function in this population. Females are at increased risk of this as the exposure is more to females as they are engaged in cooking with biomass fuel regularly. Passive smoking of this biomass fuel is also found to be significant in development of the disease. Thus the burden of COPD in India is increasing progressively.[7,8]

Along with these factors indoor and outdoor pollution is also a significant contributor to the increased risk associated with COPD. Industrialization and global warming are responsible for the environment pollution. Increased exposure to irritants have deleterious effects on respiratory function and found to be one of the most common causes in the development of COPD.[9]

The chronic airflow limitation in COPD results in altered lung function parameters. Flow limitation results in decreased forced expiratory volume in one second, decreased peak expiratory flow rate. Because of air trapping and dynamic hyperinflation there is increase in residual volume and total lung capacity at the cost of decreased functional residual capacity.[13] With hyperinflation without air trapping there is increase in TLC along with increase in residual volume. When air trapping and hyperinflation both are present, there is increase in residual volume and TLC is also increased. These abnormalities result in increased RV/TLC ratio. RV/TLC ratio is considered to be the indicator of dynamic hyperinflation. The normal RV/TLC ratio is 20% in younger population to 35% in older adults.[14] Gary T. Ferguson stated that lung hyperinflates in COPD in response to the air trapping.[15]

In COPD there is decreased exercise capacity usually because of dyspnea.

Dyspnea can be because of peripheral muscle dysfunction, consequence of dynamic hyperinflation, defective gas exchange or increased respiratory load. Sometimes two or more factors act at the same time. This results in more marked decrease in exercise capacity and thus functional limitation. These changes are also aggravated by age related changes and decline in respiratory function. Also, there is effect of detraining (deconditioning) because of limitation of functional capacity. The vicious cycle continues and that results in poor quality of life of the patient.[16]

Pulmonary Rehabilitation is found to be an important intervention in the management of COPD.[17] The American Thoracic Society and European Respiratory Society has defined Pulmonary Rehabilitation as, "Pulmonary rehabilitation is a comprehensive intervention based on a thorough patient assessment followed by patient-tailored therapies, which include, but are not limited to, exercise training, education, and behavior change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence of health-enhancing behaviors."[18] It has shown to improve dyspnea, quality of life and reduce hospital admissions in patients with chronic respiratory disease.

Pulmonary Rehabilitation is implemented by a interdisciplinary team including a chest physician, a physiotherapist, an occupational therapist, a nursing care professional, a psychiatrist, a dietician and the other health care professionals as required. Exercise Training is a cornerstone in the Pulmonary Rehabilitation program. It is best available means of overcoming peripheral muscle dysfunction.

Exercise Training improves muscle function and thus improve functional capacity without improvement in lung function. Improvement in muscle function results in decreased ventilatory requirement for a given submaximal work because of increased oxidative capacity of muscles. This decreases exertional dyspnea and improves symptoms and thus improves Quality Of Life.[18]

A Cochrane review done by McCarthy B et al strongly support inclusion of pulmonary rehabilitation as part of the management and treatment of patients with COPD. It has also shown that pulmonary rehabilitation is is an effective tool in improving health related the quality of life.[19]

Before exercise training is incorporated, exercise capacity is assessed by doing exercise testing. Usually in COPD patients submaximal exercise testing is done. 6MWT is the most feasible and cost effective submaximal exercise testing tool. 6MWT evaluates the walking capacity of the patient. Walking is found to be the best exercise training modality as it mimics most of the functional activities of the day. Exercise training includes endurance training, resistance training and flexibility/postural training in a pulmonary rehabilitation program. Exercise testing prior to implementation of actual exercise program also helps in evaluating the need for supplemental oxygen therapy during the training. Monitoring the oxygen saturation by invasive techniques or pulse oximetry helps identifying the level of desaturation at given submaximal effort.[20]

Endurance training is usually given in the form of walking, can be ground walking or treadmill walking. For patients having difficulty in maintaining balance or any musculoskeletal disorder limiting treadmill walking static cycling is considered. Patients with cardiac limitations are evaluated prior to testing so that appropriate exercise training mode can be selected. This training is usually given at 40-60% of the maximum heart rate. The intensity of training may vary from patient to patient depending upon the initial level of fitness and the other associated comorbid conditions. The usual prescription of exercise training is 4-5 days per week, 20-60 min per day, at RPE (rate of perceived exertion) 12-14 (somewhat hard) and with intensity of 60-70% of 1RM.[21]

Endurance training has shown to improve cardiopulmonary function and thus improve symptoms related to physical activity. Endurance training has also shown to improve state of psychological well being and promote good mental health and thus helps overcoming anxiety and depression related to COPD.[22]

Resistance training for all major muscle groups is indicated 2-3 times a week with 10 repetitions for each muscle group performed against gravity, once or twice a day.

Resistance training improves the oxidative capacity of muscles. There is hypertrophy of each muscle fiber unit though number of motor fiber unit in the muscle remains the same. Also, there are neural adaptations of muscles to resistance training which help in improvement of muscle function. Endurance training in combination with resistance training has shown more improvements in quality of life compared to endurance training alone.[23]

Along with resistance and endurance training, flexibility training is the most important component of exercise training for a patient in pulmonary rehabilitation program. With advanced disease, patient adapts a specific posture so as to overcome symptoms. A COPD patient is usually in slouched posture (to avoid dyspnea). This results in tightness of some muscles and overstretching of some muscles resulting in overall postural imbalance. Prolonged postural deviation leads to severe physiological limitations resulting in altered PFTs. Therefore, flexibility training becomes an important component of exercise training. Stretching exercises started at the early stage help in preventing postural deviations and thus should be a part of exercise training sessions. Flexibility training is indicated everyday for a patient with COPD.[24]

Along with physical benefits, pulmonary rehabilitation has shown significant improvements in FEV1, FEV1/FVC, PEFR and quality of life. The effect of pulmonary rehabilitation in reducing the dynamic hyperinflation is not well estabilishd. A study done by Kaku Yoshimi et al has shown reduction in RV values and no significant change in TLC.[25]

Pulmonary rehabilitation relieves symptoms, improves muscle strength, cardiopulmonary endurance and improves quality of life in COPD patients. It also improves dynamic pulmonary functions like FEV1, FEV1/FVC, PEFR. But, recovery of static pulmonary functions remains questionable.

The dynamic hyperinflation is a characteristic finding of COPD. Clinical findings of which include flattening of dome of diaphragm, increased RV values than predicted, increased TLC than predicted and thus increased RV/TLC ratio. Because of lack of evidence, recovery of these lung functions remains questionable.

Thus the present study was undertaken to see if with pulmonary rehabilitation program is there any change in these lung functions.

AIM

To find the effect of pulmonary rehabilitation on static lung functions in COPD patients

OBJECTIVES

- To find the effect of pulmonary rehabilitation on Residual Volume in COPD patients
- To find the effect of pulmonary rehabilitation on Total Lung Capacity in COPD patients
- To find the effect of pulmonary rehabilitation on RV/TLC in COPD patients

MATERIALS AND METHODS

- 40 stable COPD patients from the in patient department of pulmonary medicine, Smt. Kashibai Navale Medical College, were selected and recruited in the study. Subjects were randomly assigned to experimental and control group using cluster sampling method. Subjects were selected as per the inclusion and exclusion criteria. Patients with recent MI, patients who are on continuous oxygen therapy, those who are in the category of severe COPD according to the GOLD criteria were excluded.

• **Materials:** Notebook, Pen, Body Plethysmography unit, Mouth piece, Wheelchair (required for transferring the patient to body plethysmography unit)

INCLUSION CRITERIA:

Subjects diagnosed as COPD admitted in the chest medicine ward of Smt. Kashibai Navale Medical college and General Hospital willing to participate in the study

EXCLUSION CRITERIA:

- Global Organization for Lung Disease (GOLD) criteria – severe and very severe
- Patients who are on O2 therapy
- Recent MI
- Unstable angina
- Patients were enrolled after the confirm diagnosis of COPD was made by the pulmonary physician and the subject was hospitalized. Written informed consent was taken from the subjects after the purpose and procedure of the study was explained in detail. Subjects were randomly assigned to control and experimental groups. Each subject was randomly asked to pick a chit with pre-assigned number. Odd numbered candidates were included in control group and even numbered candidates were included in experimental group.
- Patients in the **control group** received conventional chest physiotherapy which included diaphragmatic breathing exercise, sputum clearance techniques, dyspnea management , nebulization and positioning as required. At the time of discharge patients were explained in detail about the dyspnea management and sputum clearance technique. Follow up was kept for once in a week on OPD basis. RV, TLC and RV/TLC readings were taken on day 1,

day 10 and at the end of fourth week.

- Patients in the **experimental group** received the pulmonary rehabilitation program which included endurance training, resistance training and flexibility training as follows. The training was formulated according to the ATS guidelines.

Endurance training (30 min)	20 min of training in the form of walking/cycling Target training 40 to 60% of target HR 3 days/week
Resistance training	1 set of 10 repetitions for all the shoulder, hip and knee For 2 days/week, starting with 60 % of 1 RM
Flexibility exercise	stretching to pectorals, hamstrings, calves, quadriceps and biceps 5 days/week

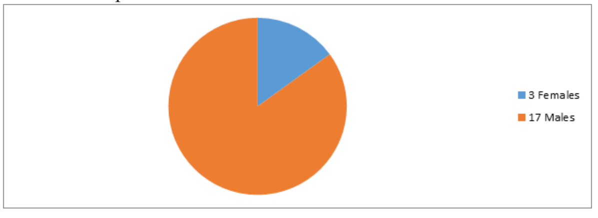
Patients in the experimental group received supervised exercise program till the time of discharge. At the time of discharge patients were given in detail exercise program for everyday and telephonic follow-up was kept. Patients were called for follow up on OPD basis at least once in a week or at the maximum thrice a week.

The RV, TLC and RV/TLC readings were taken in the body plethysmography unit on day 1, day 10 and the end of fourth week.

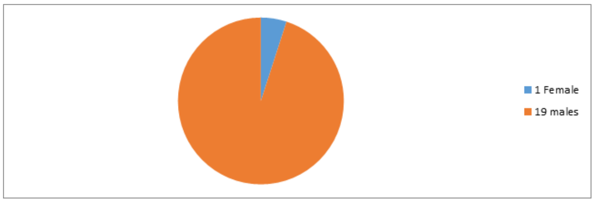
Statistical Analysis

Demographic Data:

Control Group:

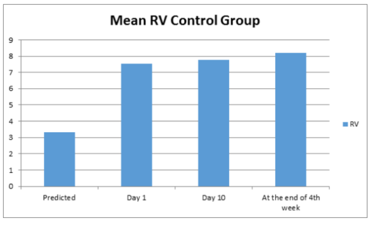


Graph 1: Distribution of males and females in control group

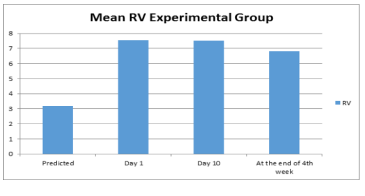


Graph 2: Distribution of males and females in experimental group

Distribution of RV

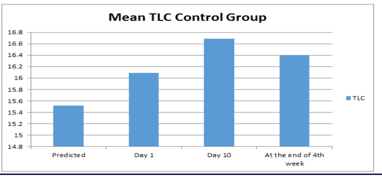


Graph 3: Distribution of mean RV in control group

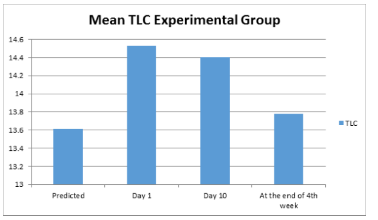


Graph 4: Distribution of mean RV in experimental group

Distribution of TLC

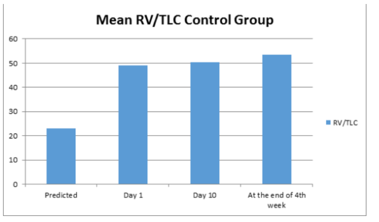


Graph 5: Distribution of mean TLC in control group

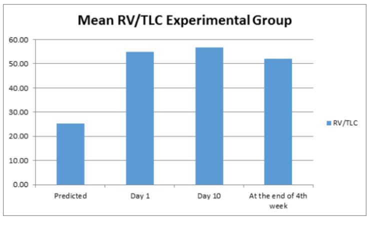


Graph 6: Distribution of mean TLC in experimental group

Distribution of RV/TLC



Graph 7: Distribution of mean RV/TLC in control group



Graph 8: Distribution of mean RV/TLC in Experimental group

Results

The study consisted of 2 groups control and experimental consisting of 20

subjects in each group. Subjects were in the range of 57 yrs to75 yrs with average age 63yr ± 4.6 yr.

Distribution of RV, TLC and RV/TLC was noted at day 1, day 10 and at the end at of 4th week. Unpaired t-test was used to compare means between the groups and analysis of variance was used to compare the means within the group after testing for normality. Table 1 depicts the results for RV.

Table 1: Distribution of RV between the groups with respect to time

Variable	Control	Experimental	t-test	P
Day 1	7.5 ± 2.1	7.5 ± 2.7	0.002	0.961
Day 10	7.8 ± 1.9	7.5 ± 2.8	0.135	0.715
at the end of 4th week	8.2 ± 2.3	6.8 ± 1.7	4.317	0.045*
F	0.986	0.855		
P	0.325	0.687		

It was observed that mean RV did not differ between control group and the experimental group on day 1 and day 10. However statistically significant difference was noted in mean at the end of 4th week where mean RV of experimental group was significantly low in experimental group as compared to control group ($p<0.05$)

It was also noted that the mean RV increased gradually in control group where as it decreased gradually in experimental group. However the difference was not statistically significant.

Table 2: Distribution of TLC between the groups with respect to time

Variable	Control	Experimental	t-test	P
Day 1	16.1 ± 5.1	14.5 ± 6.1	0.755	0.39
Day 10	16.7 ± 5.7	14.4 ± 6.4	1.421	0.241

at the end of 4th week	16.4 ± 5.2	13.8 ± 4.8	2.716	0.108
F	0.034	0.164		
P	0.854	0.687		

It was observed that though mean TLC of experimental group was lower than that of control group at day 1, day 10 and at the end of 4th week, the difference was not statistically significant. Similarly there was no difference in mean TLC within control group or experimental group.

Table 3: Distribution of RV/TLC between the groups with respect to time

Variable	Control	Experimental	t-test	P
Day 1	49.0 ± 13.9	55.0 ± 16.4	1.557	0.22
Day 10	50.3 ± 16.1	56.9 ± 19.2	1.371	0.25
at the end of 4th week	53.4 ± 19.3	52.2 ± 12.1	0.053	0.819
F	0.678	0.311		
P	0.414	0.579		

It was observed that though mean RV/TLC did not differ between control group and the experimental group on day 1 and day 10 and at the end of 4th week.

It was noted that mean RV/TLC increased gradually in control group, however the difference was not statistically significant. No such trend was seen in experimental group.

DISCUSSION

This study consisted of 40 subjects with 20 in each group. The experimental group consisted of 20 subjects and received the pulmonary rehabilitation program and the control group received the conventional chest physiotherapy. The pursuit of the present study was to see if rehabilitation is helping in reducing the RV, TLC and RV/TLC values in COPD patients. The statistical analysis was done for all the three parameters for both the groups.

The changes in the residual volume of experimental group are statistically significant. In COPD, there is dynamic hyperinflation. It occurs when patients commence inhalation before full exhalation has been achieved. Consequently, there is air trapping which increases with each successive breath. Thus the end expiratory lung volume (EELV) is not occurring at the same point of equilibrium between the chest wall and lung recoil. This end expiratory lung volume is now occurring at a earlier stage called Positive End Expiratory Pressure (PEEP), before patient can achieve the relaxation volume.

Also, there is increase in cholinergic (vagal) tone, inflammation and plugging in COPD resulting in limited expiratory airflows. The time required for expiration is insufficient and thus FRC is increased. This increase in FRC slowly contributes to increased RV. Therefore RV/TLC and RV are considered to be the indicators of dynamic hyperinflation in COPD.

In this study, as the pulmonary rehabilitation group has shown statistically significant decrease at the end of fourth week. These results are consistent with a retrospective study done by Kaku Yoshimi et al, which consisted of 31 subjects and they assessed the all the COPD patients in an outpatient pulmonary rehabilitation department for various lung function indices and quality of life.

The results say that the quality of life and lung functions like FEV1, FVC were significantly improved following a pulmonary rehabilitation program. Whereas in static lung functions, only residual volume showed statistically significant changes whereas, TLC and RV/TLC did not show significant changes.

The pulmonary rehabilitation program of the present study included cardiopulmonary endurance training, strength training and flexibility training.the breathing strategies which focused on expiratory training might have helped the patient to reduce the air trapping and thus the residual volume.

Flattening of diaphragm is one of the characteristic of hyperinflation.[26] The flexibility training included the thoracic mobility exercises along with diaphragmatic breathing which might have helped the subjects to overcome the dynamic hyperinflation and thus decrease in residual volume. This explanation is also supported by the study above mentioned. One of the reference article of the present study on pathogenesis of lung hyperinflation by Philippe Gangnon et al stated that the decline in residual volume, total lung capacity and the ratio of two is because of the overall decline in health because of decreased exercise tolerance, dereased peripheral muscle strength and decreased respiratory muscle strength.[31]

The rehabilitation program in this study included training for cardiopulmonary endurance, peripheral muscle strengthening and also diaphragmatic breathing exercise. These training might have helped in an enhanced lung function of the patients.

The changes in Total Lung Capacity and the ratio of RV/TLC .is not statistically significant in both the groups after a detailed statistical analysis. Now looking at the trend of improvement of RV, the significant change is seen at the fourth week but not in the values taken at 10th day. This shows that duration of the program is an important factor to bring about the changes in these lung functions. Thus 4 weeks may be an insufficient time duration to bring about the statistically significant changes in TLC.

The TLC is the maximal volume of inspired air. TLC is determined by the balance of lung recoil plus chest wall recoil on the one hand, and muscle strength and effort on the other hand. As the lung recoil is reduced with COPD and also with advanced age, TLC is increased in these subjects. The reduction in lung recoil and chest wall recoil may be may not be affected by the pulmonary rehabilitation program and thus may not have contributed to enhanced function.

On the other hand, TLC is a function of respiratory muscle strength and efforts, which increase with respiratory rehabilitation program as per the evidence but quantification of strength was out of scope of this study and thus percentage increase in strength and TLC could not be analyzed.

In the present study, the rehabilitation program was unsupervised after discharge from the hospital. The duration of hospital stay was not fixed. Supervised programs with probably for longer duration may show improvements in TLC and RV/TLC ratio.

Considering the inclusion criteria of the present study, only mild and moderate COPD patients were included in the study and thus the baseline changes in TLC values compared to predicted values was not much significant. as TLC was near normal or slightly increased in all the patients, probably it has not shown any trend or improvement.

CONCLUSION

Pulmonary rehabilitation is found to be beneficial for COPD patients by improving the residual lung volume and hence helping in overcoming the dynamic hyperinflation associated with the disease.

LIMITATIONS OF THE STUDY

Duration of the study was short and the program was unsupervised after discharge from hospital. Also, respiratory muscle training was not considered as a part of pulmonary rehabilitation program

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