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Effect of visual feedback aerobic exercise training on lung hyperinflation in chronic obstructive pulmonary disease patients – A randomized control trial

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Abstract:

CONTEXT: Lung hyperinflation is defined as an abnormal increase in the volume of air remaining in the lungs at the end of normal expiration caused by the permanently destructive changes of emphysema and expiratory flow limitation. All the rehabilitation exercise programs have some reinforcement on hyperinflation mechanism directly or indirectly without any associated feedback.

AIMS: This study aims to study the effect of visual biofeedback training on lung hyperinflation in chronic obstructive pulmonary disease (COPD) patients.

SUBJECTS AND METHODS: 104 mild to moderate (global initiative for chronic obstructive lung disease) COPD patient of age group 40–60 years were recruited and randomly allocated to control and experimental group using random reviewer software 3.3 versions. The baseline and postoutcomes were analyzed by an external observer who is blinded. The visual training group receives biofeedback training on expiratory flow limitation. Both experimental and control group receives aerobic exercise training of 50%–60% of maximum heart rate intensity where all received cycling as a mode for 20–40 min with a warm and cool-down period. All the patients were trained for 4 days a week for 8 weeks.

STATISTICAL ANALYSIS USED: Descriptive statistics, independent sample *t*-test, and repeated measures of analysis of variance.

RESULTS: Residual volume and total lung capacity significantly reduced statistics $F = 12.23$ with $P < 0.001$ between the group. Breath hold time and maximum expiratory pressure showed increase response with significant statistics of $F = 8.53$ with $P < 0.05$ between the group.

CONCLUSION: Visual feedback exercise training is one of the effective training methods to relieve the hyperinflation in stable COPD patients thereby improves exercise tolerance and quality of life.

Keywords:

Hyperinflation, total lung capacity, residual volume

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Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous disorder characterized by dysfunction of the small and large airways, as well as the destruction of the lung parenchyma, and its vasculature is highly variable combinations.[1-3] Expiratory flow limitation is the pathophysiological hallmark of COPD, but dyspnea (breathlessness) is the most prominent and distressing symptom.[2]

The COPD patients have difficulties in doing the activities which they used to do at the same extent of the similar profile of an individual because of profuse exacerbation or dyspnea. The routine daily activity is affected by dyspnea which is a troublesome symptom of COPD, and it progresses over time to incapacitating levels.[4] Limitations on activity often lead to feelings of social isolation and psychological problems and reduce a patient's perceived quality of life (QOL), which further diminishes the resulting inactivity and physical deconditioning. The underlying mechanisms behind the activity limitation and dyspnea are complex, which is further complicated by aging and comorbidity that are common in patients with COPD.[5]

Lung hyperinflation is defined as an abnormal increase in the volume of air remaining in the lungs at the end of normal expiration caused by the permanently destructive changes of emphysema and expiratory flow limitation.[6] A temporary increase in operating lung volumes after their resting value is identified as a key mechanism of expiratory flow limitation; this is referred to as lung hyperinflation which causes excessive overloading and functional weakness of the inspiratory muscle. Overall, the normal thoracic expansion is restricted during routine activities. Once the disease is progressed, the negative effects of hyperinflation will be irrevocable because the respiratory system adapts to the mechanical disadvantages caused by hyperinflation.[7]

Strategies to reduce hyperinflation: pharmacotherapy, oxygen therapy, and rehabilitative exercise training which includes conical positive end-expiratory pressure and pursed lip breathing exercise.[3] All the rehabilitation exercise programs have some reinforcement on hyperinflation mechanism directly or indirectly without any associated feedback.[8] There were numerous literatures found on the effects of aerobic training on COPD mainly on dyspnea control and exercise capacity. Therefore, this study is aimed at providing visual feedback to the patients and this will enhance their effort toward exercise in a goal-directed manner so as to improve the lung condition during the rehabilitative phase in the in-patient department of the hospital.

Subjects and Methods

104 stable COPD from Smt. Kashibai Navale Medical college and general hospital were recruited after written consent form. All the patients in the age group 40–60 years of Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria I to III, any patient having any musculoskeletal dysfunction, neurological, severe cardiac conditions inhibiting to perform the study were excluded from the study. The patients were randomly allocated into two groups: experimental and control group using Randomizer software version 2.3. (Urbaniak, G. C.& Plous, S- Computer Software 1999-2019). The experimental group received visual feedback and aerobic exercise whereas the control group received only aerobic training only and both group receives conventional chest physiotherapy for airway clearance. Blinding was done at two-level – one at the allocation level and another at the outcome assessor level. The sample size was estimated based on the standard deviation (SD = 1.3) between the mean of 2 observations of total lung capacity (TLC) sample (pilot study), the smallest difference of 2% and 20% of dropouts of patients at the end of the study.

Standard care was given in the form of bronchodilators and nutritional recommendation as prescribed by the primary physician. Health education was provided to all the patients in the form of posters for the management of COPD dysfunctions.[9] Daily attendance was maintained for all the exercising individuals in the form of logbook for the group.

Preparation for exercise program

Patients with COPD are deconditioned and have limited strength and flexibility; hence, a goal of 30-min low-intensity exercise as conditioning exercises will be given the single session a day for 2 weeks before moderate-intensity exercise was commenced so as to not to deter these individuals from participating in the program. Warm-up and Cooldown of 5–10 min were incorporated for efficient exercise training and safety procedure. As a precaution, hydration information and essential foot care were included in both the groups.[10]

Aerobic exercise prescription

The entire patient received a minimum 3 days/weeks of training session to a maximum of 4/week, with a tailored intensity of 40%–60% of heart rate reserve and as an adjuvant; the rate of perceived exertion was carried out. The duration of the exercise prescription was divided into the duration of each exercise session, as well as a total period of training required to have the desired effect for a week. The duration of each session was individually tailored for each patient. Patients will be required to accumulate a minimum of 150 min of moderate-intensity exercise duration each week. Program duration was kept to 6 weeks to have the desired effect with 2 weeks of familiarization.

Visual feedback training

Patient preparation

The patient was comfortably seated in a back-supported chair, and a noninvasive nasal or mouth mask was attached to the patient face. All the aseptic universal precaution were maintained during the procedure.

Procedure

The individual breathes through the Cosmed feedback system by holding the cheeks to reduce upper airway compliance tidal volume (TV) via mouth/nose. The information provided by the cosmed oscillation feedback about lung mechanics depends to a great extent on the frequency content of the TV that is applied to the lungs.[11] The software presents the user with a red sinusoidal tracking target which can be adjusted by the operator to have a breathing frequency similar to that of the individual being tested. A green tracking ball moves vertically to reflect the flow of the individual measured by a pneumotachograph. Thus, when the individual exhales, the ball will move upward, and it moves downward during inhalation, while the sinusoidal red wave scrolls horizontally. The individual tries to keep the green ball on the red track. The breathing rate is varied by adjusting the minute ventilation and TV. A zero offset allows the green ball to be placed exactly at the center level of the screen as shown in Figures 1 and 2.

Calibration

Every day before the training session, the wires, circuit, and the mask were calibrated as per the standard procedure of calibration. The software used was Laboratory Virtual Instrumentation Engineering Workbench (USA) having an autocalibration phenomenon which will detect the artifacts and rectify the necessary signal inputs.

Outcome measures

1. Pulmonary function test – TLC, residual volume (RV), functional residual capacity (FRC), forced expiratory volume in the 1 s (FEV1) and RV/TLC was analyzed by Q-Box from COSMED - Standalone Body Plethysmography (COSMED Italy C09068-01-99)
2. Respiratory muscle Strength – Pimax and Pemax by Q-Box from COSMED - Standalone Body Plethysmography (COSMED Italy C09068-01-99)
3. Exercise capacity - 6-min walk test (6MWT)
4. QOL – St George Respiratory Questionnaire (SGRQ).

Body plethysmography measurement

The individual performed the lung volume maneuver inside the Q box with relative open-closed shutter mechanism at a rate of 0.5–1 Hz which was of 30–60 breaths/min. The respiratory strength (Pimax and Pemax) was analyzed using occlusion maneuver. Three maneuvers were done to get an acceptable technical value which should be agreed within 5% of thoracic gas volume, and the mean value was reported.[12]

Exercise tolerance test

6MWT is relatively simple to perform and well tolerated. It is a valid and standardized measure to calculate the health status and exercise tolerance capacity of COPD.[3,6-8]

Quality of life

The SGRQ is a self-administered questionnaire that measures health status in patients with chronic airflow limitation.[13]

Ethical approval

An approval from Smt. Kashibai Navale Medical College and General Hospital Pune was taken before beginning the study. The study was registered under the Clinical trial of India - CTRI/2015/12/006425.

Statistical procedure

All the statistical analyses were performed using IBM SPSS statistics software version 20.0 for Windows (IBM Corp, New York, USA). Descriptive statistics was used to find the mean and SD of baseline variables.

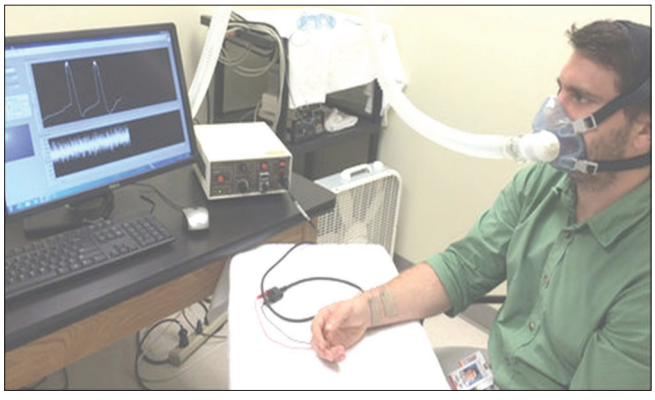

Figure 1: Visual feedback training

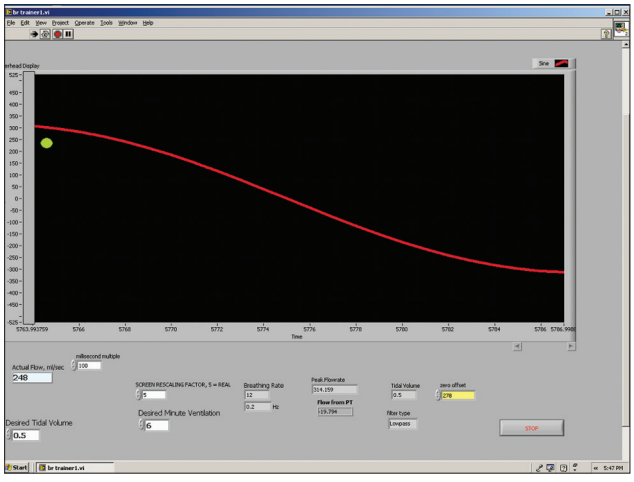

Figure 2: Visual feedback training with the target of flow

Independent sample *t*-test was used to compare the baseline comparison of control and experimental group, where Levene test of equality of variance was used to check the difference in the pre-intervention and post-intervention group analysis. Repeated measures of analysis of variance (RANOVA) were used to analyze the changes in outcome measures at multiple time periods between the experimental and the control groups.

Results

134 COPD patients were willing to participate in the study, of which 104 were eligible as per the inclusion and exclusion criteria. After obtaining written informed consent, all were randomly allocated into an experimental and control group. At the end of 8 weeks of training, 7 lost to follow-up in the experimental group and 6 lost follow-up in the control group due to various reasons, i.e., 8 lost to follow-up due deteriorating symptoms and 5 opted out due to work constraint. 45 patients in the experimental group and 46 patients in the control group completed the 8 weeks' training session. The outcomes measures were evaluated at the end of 4 weeks and 8 weeks of completion.

Table 1: The demographic data and comparison of both groups

Variables	Mean±SD		*t*	*P*
	Control group	Experimental group		
Age (years)	42.48±3.89	44.90±3.83	2.26	0.981
Gender (%)				
Male	40 (64.5)	38 (62)	-	-
Female	12 (35.5)	14 (38)	-	-
Height (cm)	160.34±8.02	161.94±6.83	0.067	0.535
Weight (kg)	60.72±4.94	59.96±8.49	0.035	0.577
BMI (wt/m^2)	25.52±2.2	26.02±2.5	0.089	0.85
Duration of COPD (years)	6.02±1.67	5.48±2.61	0.167	0.657
Category of COPD (%)				
Asthma	18 (35)	14 (27)	-	-
Emphysema	12 (23)	19 (36.5)	-	-
Chronic bronchitis	22 (42)	19 (36.5)	-	-
Smoking history				
Packs/year	16.14±2.8	15.84±3.1	-	-
Active smokers	40	38	-	-
Passive smokers	12	14	-	-
Gold stage				
A	21	19	-	-
B	23	22	-	-
C	8	11	-	-
D	0	0	-	-

Gold stage: Categorizing COPD based on FEV_1, recurrence and symptoms. SD: Standard deviation, BMI: Body mass index, *t*: Independent *t*-test value, COPD: Chronic obstructive pulmonary disease, FEV_1: Forced expiratory volume in 1 s

Baseline parameters

The mean age of control and experimental group patients was 42.48 ± 3.89 and 44.90 ± 3.83. Majority of the participants were of male candidates which constitute 63% on average in both the groups. Considering the gender, all the male populations were of active smokers; on the other hand, the females were of passive smokers and household smoke inhalers. All the active smokers have a smoking history of 15.5 packs year on average. The passive smokers and dose ratio were not estimated, and a logbook was maintained to record the duration of exposure. All the patients have a history of COPD < 10 years; moreover, on categorizing GOLD stages, majority fall under the Stage of A or B; only a few patients were of C Stage, in both the groups. Among the COPD group, the majority were of chronic bronchitis and asthma patients in both the study group. Independent sample *t*-test was used to compare the baseline variables of age, body mass index, and COPD severity; *P* value was insignificant in all the comparative analysis as shown in Table 1.

Changes in spirometry

The pulmonary functions were statistically analyzed by RANOVA, where the between-group difference was analyzed. The mean values of FRC%, TLC%, and RV% showed significant changes when comparing at baseline, 4th weeks, and 8 weeks, as summarized in Table 2.

Changes in 6-min walk test, respiratory muscle strength, and St George Respiratory Questionnaire

There was a statistically significant improvement in the mean 6MWT distance after 8 weeks of exercise training in both the groups. The experiment group showed a change of 203 m as compared to the control group of 144 meters from the baseline value. Both the mouth pressure namely inspiratory and expiratory showed significant change after the training session .Compared to inspiratory pressure ,expiratory mouth pressure showed higher significance of $P = 0.001$. The QOL of COPD patients was analyzed by SGRQ. There is a significant decrease in all the scale categories, namely –SGRQ symptom, activity, impact, and total scale as tabulated in Table 3.

Discussion

The present study demonstrates the positive effect of visual feedback training on hyperinflation in stable COPD patients after 8 weeks. This is the first kind of study to use visual biofeedback on expiratory flow limitation where a real-time view of expiratory flow was shown to the patient, thereby diminishing the hyperinflation effect. The result showed a decline of hyperinflation in the experimental group as compared to the control group as described in the results. Although there was an effective treatment for clinical improvements in patients with COPD, these benefits cannot be solely attributed to

Table 2: The mean and standard deviation comparison of pulmonary functions from baseline to 8 weeks of training in both groups

Pulmonary function parameters (%)	Mean±SD						*F*	*P*
	Baseline		End of 4 weeks		End of 8 weeks			
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group		
FEV_1	48.2±8.4	45.8±9.3	48.1±7.64	49.6±7.1	51.1±1.4	53.6±2.1	1.12 (DF 1, 3)	0.06
FRC	142.5±56.4	146.89±49.6	139.5±52.4	139.09±46.6	138.1±50.5	129.09±40.2	5.85 (DF 1, 3)	0.05*
TLC	108.23±24.5	115.5±26.8	106.63±23.4	114.5±25.9	105.3±22.1	106.2±20.89	6.34 (DF 1, 3)	0.05*
RV	161.9±36.2	166.2±39.2	158.9±35.3	159.2±36.4	147.9±32.53	131.2±25.84	13.24 (DF 1, 3)	0.006*
RV/TLC	48.12±8.12	49.1±2.8	47.8±9.2	47.5±4.8	43±6.2	40.2±4.5	6.54 (DF 1, 3)	0.06

*Significant at *P*<0.05. SD: Standard deviation, FEV_1: Forced expiratory volume in 1 s, FRC: Functional residual capacity, TLC: Total lung capacity, RV: Residual volume, *F*: *F* statistics of repeated measure analysis of variance, DF: Degree of freedom

Table 3: The mean and standard deviation comparison of respiratory muscle strength, 6 min walk test, and SGRQ from baseline to 8 weeks of training in both groups

Parameters	Mean±SD						*F*	*P*
	Baseline		End of 4 weeks		End of 8 weeks			
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group		
MIP (Pi Max (cm H_2O])	75.67±24.3	74.77±22.3	78.17±26.53	79.97±29.35	79.17±28.5	85.9±31.5	8.82 (DF 1, 3)	0.05*
MEP (Pe Max [cm H_2O])	82.12±22.48	82.58±21.14	85.2±25.8	88.5±25.4	86.12±20.87	94.5±29.4	11.2 (DF 1, 3)	0.001**
6MWT	375.67±52.3	382.77±44.3	410.17±66.53	420.97±55.35	519.17±28.5	585.9±31.5	15.12 (DF 1, 3)	0.001*
SGRQ symptom (%)	75.67±15.3	76.77±14.3	71.7±12.3	69.7±11.3	69.7±13.83	52.7±10.7	13.22 (DF 1, 3)	0.04*
SGRQ - activity (%)	65.87±12.8	63.67±10.3	59.8±11.8	57.7±12.3	57.8±12.1	51.4±10.1	11.85 (DF 1, 3)	0.05*
SGRQ - impact (%)	70.87±13.53	70.6±10.8	64.7±10.5	61.6±14.8	62.7±11.52	52.6±12.4	13.12 (DF 1, 3)	0.05*
SGRQ - total (%)	68.12±5.48	69.8±12.14	61.2±9.8	59.1±10.4	52.2±8.2	43.5±11.5	15.12 (DF 1, 3)	0.001*

*Significant at *P*<0.05, **Significant at *P*<0.001. SD: Standard deviation, MIP: Maximum Inspiratory pressure, MEP: Maximum expiratory pressure, 6MWT – 6 min walk test, SGRQ: St George Respiratory Questionnaire

the exercise training program. There could be multiple confounding factors which can attribute the clinical improvement. Nevertheless, the results of the study strongly suggest that visual feedback exercise training is effective and safe for patients with COPD and can be recommended as part of standard care in this population.

COPD is the second biggest cause of death in India where the smoking habit is the primary etiology of COPD leads to the destruction of airways and flares up the symptoms during exacerbation.[14] The prevalence is high among men as compared to the female which is consistent with this present study where the gender ratio is of 65%–35% (male: female). In the present study, predominantly, males are active smokers and females are passive smokers. The smoking history showed varying status, due to different pattern of smoking habits and a different constituent of tobacco, leading to varying smoking status among the group, thus the smoking habits were not taken into consideration.

The primary pulmonary function of hyperinflation, namely TLC and RV showed an off-putting effect after undergoing visual feedback training group. This result is consistent with the previous literature, namely Yoshimi *et al*., Lacasse *et al*., where a considerable change in RV and TLC were noted after 6 weeks of exercise training in COPD patients.[15-17] In the present study, FRC showed significant change after 8 weeks of training which correspond to the previous study done by Minoguchi *et al*., and Yamada *et al*., where they found a decrease in FRC after 6 weeks of respiratory training in moderate COPD patients.[16-18] Goldstein *et al*. and Bangi *et al*. demonstrated a significant increase of FEV1 after 8 weeks of pulmonary rehabilitation in mild to moderate COPD patients whereas in the current study FEV1 did not show any significant improvement which is inconsistent to the literature. On the other hand, studies by Yoshimi *et al*., Minoguchi *et al*., and Yamada *et al*. showed insignificant raise of FEV1, thus pulmonary function is largely controversial with relation to the exercise training.

The respiratory pressure showed significant improvement in the visual training group due to additional positive feedback. The visual feedback training helps the patients to understand the expiratory flow load thereby focus more on the prolonged expiratory training, where higher buccal pressure pushes the equal pressure point to the highest level whereby the constant load strain facilitates the expiratory process. Sánchez Riera *et al*. demonstrated that inspiratory muscle training (IMT) significantly increases respiratory muscle function and reduces dyspnea.[19]

Vivodtzev *et al*. found that the IMT-trained patients showed greater efforts and perform harder tasks without dyspnea after 8 weeks of aerobic exercise training.[20]

Thus, compelling evidence was favoring respiratory and aerobic exercise training, which is highlighted in the joint statement of American College of Chest Physicians and American Association of Cardiovascular and Pulmonary Rehabilitation Committee.[21]

The present study exhibits an increase of 6 min walk distance (6MWD) by 188 m after 8 weeks of a visual aerobic training program; on the other hand, in the control group, a change of 144 m indicates that both the groups are benefited with the aerobic exercise training [Table 3]. Lacasse *et al*. stated that the minimal increase in the 6MWD of 54 m[22] after 6 weeks of aerobic training in COPD patients. Bendtrup *et al*. did a meta-analysis where controlled 12-week study of outpatient pulmonary rehabilitation showed 6MWD increase by 180 m after 6 weeks, 113 m at the end of the program, and 96 m after 12 weeks program. Another study showed 6MWD increased by 171.75 m after the 6 weeks of outpatient pulmonary rehabilitation.[23] While Takigawa *et al*.[24] demonstrated a moderate improvement in 6MWD of 65 m at the end of 6–8 weeks of pulmonary rehabilitation. Shetty *et al*.[25] noted an increase of 178.41 m in 6MWD after outpatient pulmonary rehabilitation which was a primary home-based program which is of 6 months' duration. Overall the exercise capacity improved after the aerobic training due reconditioning of phasic muscle. Apart from it, the expiratory flow feedback facilitates the ventilatory muscle function by desensitizing dyspnea.[26]

In the present study, visual feedback exercise program exhibits improvement in every aspect of health-related domains of QOL. A considerable mean reduction in total score of SGRQ of 16.6 were noted in the present study as compared to 6.11 in the previous study done by Lacasse *et al*.[17] Similar to the previous literature, attendance adherence program was maintained which showed a high adherent of rehabilitation program contributed to the participants to achieve its optimal benefit. The poor attendance during pulmonary rehabilitation programs has determinately associated with smoking status, participating in a longer rehabilitation program, having multiple hospital admissions, and suffering repeated exacerbation.[27] The current study showed a significant improvement in the overall SQRQ score after 8 weeks of rehabilitation. The effect size exceeded the clinical level of significance after the rehabilitation program both in impact and activity components of QOL. The results coincide with the findings of the systematic review done by Puhan *et al*., where the SGRQ scores of impact and activity improved after the training session.[28]

Limitations

Confounding factors, namely varying pharmacological therapy, smoking status, socioeconomic status, lifestyle, physical activity level, and psychological status of the patient were not addressed in this study which may confound the results of the study.

Recommendations

Future studies will do to consider the confounding factors and with larger samples. . In addition to it; the expiratory flow variable and visual feedback training parameter, namely real-time flow and volume need to be studied for accurate measurement of end expiratory flow limitation.

Conclusion

Visual feedback exercise training provides real-time visual to the patient to analyze their air entrapment. The training session ameliorates dyspnea, thereby the exercise tolerance and QOL have improved in the present study. Considering the confounding factors mainly varying pharmacological therapeutics and uneven smoking habits larger-scale studies have to be addressed for the clinical effect of visual feedback exercise training. Thus, visual feedback exercise training is one of the effective training methods to relieve the hyperinflation in stable COPD patients thereby improves exercise tolerance and QOL.

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Conflicts of interest

There are no conflicts of interest.

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