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Physiological Effects of Pulmonary Rehabilitation in Patients with Chronic Obstructive Pulmonary Disease (COPD)

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is a long-term illness, which is associated with continued airflow blockage, body-wide inflammation, and impairments. The pharmacological treatment offers symptomatic relief with sufficient lack of response to extrapulmonary impairment. Pulmonary rehabilitation (PR) has become one of the versatile interventions which address physiological, functional, and psychosocial aspects of COPD.

Objectives: This study was designed to assess physiological outcomes of eight-week pulmonary rehabilitation program in patients with COPD in terms of lung functioning, exercise capacity, muscle strength, and quality of life.

Methods: The study was a prospective interventional study that was carried out in two tertiary care restorative hospitals in Lahore, Pakistan, between March 2023 and March 2024. A total of 100 COPD patients (62 men, 38 women; mean age 59.4 8.7 years) were enrolled, according to GOLD criteria, and were considered to be in a stable condition clinically. All the subjects were subjected to a well-organized PR program that included supervised aerobic and resistance training, breathing re-education, nutritional education, and mental health assistance. The baseline and post completion assessment was done on pulmonary function tests, six minutes walk distance (6MWD), quadriceps strength, and St. Georges Respiratory Questionnaire (SGRQ) scores. Paired t-tests were used to analyze data with a significance of $p < 0.05$.

Results: FEV1 and FVC increased to 54.8 and 75.6, respectively ($p < 0.001$ and $p = 0.002$, respectively), compared to 49.6 and 72.1, respectively, before rehabilitation. The average 6MWD was improved by 68.2 meters ($p < 0.001$). There was an improvement in the strength of quadriceps by 18.5% ($p < 0.001$). The overall scores on SGRQ declined by 21.3 points, which is a significant improvement in the quality of life ($p < 0.001$).

Conclusion: PR is a very effective intervention that leads to improvements in the physiological, exercise and quality of life among COPD patients. It is highly suggested to be integrated into the common COPD management.

Keywords: Pulmonary rehabilitation, COPD, lung function, exercise capacity, quality of life.

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a chronic respiratory disease that is typified by persistent airflow obstruction, chronic airway inflammation, and non-pulmonary systemic effects. It is one of the health challenges facing the globe, and it is one of the top causes of morbidity and mortality in the world [1]. The Global Initiative of Chronic Obstructive Lung Disease (GOLD) estimates that COPD has over 300 million cases and is a major health care issue, disability, and causes of premature deaths. In Pakistan and other developing countries with low- and middle-income levels, the rates of prevalence are

increasing based on high rates of smoking, exposure to indoor biomass fuels, and late diagnosis. The patients usually complain of dyspnea, persistent cough, sputum, gradual loss of exercise capacity, which cumulatively affect daily operations and quality of life [2,3].

COPD pathophysiology consists of the airflow obstruction caused by airway remodeling, hypersecretion of mucus and emphysematous alveoli destruction along with systemic outcomes (skeletal muscle wasting, cardiovascular dysfunction, and metabolic changes) [4,5]. Pharmacological treatment with bronchodilators and corticosteroids is effective in relieving symptoms and reducing exacerbations but does not stop the disease progression and reverse extra-pulmonary manifestations. Hence, the holistic management plans that focus on pulmonary and systemic impairments are necessary [6].

PR has become an essential element of non-pharmacological COPD treatment. It is an interdisciplinary, multidisciplinary intervention, which incorporates supervised exercise training, breathing retraining, nutritional advice, and psychological intervention. PR has as its primary physiological objectives an increase in ventilatory efficiency, gas exchange, and an increase in functional exercise capacity [7]. In addition, PR has systemic benefits through countering skeletal muscle deconditioning, decreasing the intensity of inflammatory responses, and increasing cardiovascular fitness. Numerous randomized controlled trials and meta-analyses have shown again and again that PR positively affects lung mechanics, six-minute walk distance (6MWD), peripheral muscle strength, and healthcare use [8,9].

Although there is substantial evidence based on the developed healthcare systems, the data on South Asian populations is scarce. The differences in genetic predisposition, environmental exposures, nutritional status and healthcare infrastructure make it necessary to conduct region-specific studies. Moreover, although symptomatic and psychological advantages of PR are well-voiced, its direct physiological impact on the state of lung functioning, muscle activity, and exercise capacity on the COPD patients in Pakistan has to be assessed systematically [10].

The current study was thus aimed at determining the physiological effect of 8 weeks pulmonary rehabilitation intervention in COPD patients. The proposed study will offer clinically relevant information on the role of PR as an integrative intervention in the management of COPD because it will examine its impact on pulmonary function, exercise capacity, muscle strength, and quality of life [11].

MATERIALS AND METHODS

The proposed interventional study was carried out in the Departments of Pulmonology and Rehabilitation Medicine of two major tertiary care hospitals in Lahore, Pakistan between March 2023 and March 2024. The two institutions were required to provide ethical approval and information written consent was signed by all the participants prior to their participation in the study. One hundred clinically stable patients who had a proven diagnosis of chronic obstructive lung disease (COPD) were recruited. The diagnosis was confirmed based on the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification, where post-bronchodilator FEV1/FVC ratio are below 0.70. Patients who used to have acute exacerbations in the last four weeks before recruitment and could attend supervised exercise sessions were eligible patients aged between 40 and 75 years. Patients were ruled out in case of unstable cardiovascular disease, severe musculoskeletal and neurological conditions, active malignancy, or had undergone thoracic or abdominal surgery in the past that may have restricted their participation in the rehabilitation.

Eight-week pulmonary rehabilitation program was done to all registered participants and it was planned and overseen by a multidisciplinary team that comprised of pulmonologists, physiotherapists, nutritionists and psychologists. The program was presented three times on a week, and each session took about ninety minutes. The condition involved in each rehabilitation session was aerobic activity (walking the treadmill and stationary cycling) at a starting level of 50-60% of the individual peak work rate and gradually increased according to an individual tolerance and involved resistance training with light dumbbells and elastic bands that emphasized both lower and upper limb muscles. In the incorporation of breathing retraining to facilitate ventilatory efficiency and minimize exertional dyspnea, breathing retraining methods, especially diaphragmatic breathing and pursed-lip breathing methods were utilized. Optimization of dietary intake, proper caloric balance, and protein supplementation were conducted in form of nutritional counseling. Counselling and stress management plans were also provided to assist in reducing anxiety and depression that are normally related to COPD. Throughout the study, all the patients remained on the pharmacological treatment regimen prescribed to them. Rehabilitation adherence was also checked by means of attendance history and follow-up evaluation.

At baseline, physiological results were measured and at the end of the rehabilitation program. Functional pulmonary tests were done using a standard spirometer, and forced expiratory volume in the one second (FEV1), forced vital capacity (FVC), and forced expiratory volume in one second/forced vital capacity (FEV1/FVC) ratio were measured and compared to the predicted results in the percentage. The six-minute walk distance (6MWD) test on a flat indoor corridor was used to identify the exercise capacity as recommended by the American Thoracic Society. The evaluation of quadriceps muscle strength was done with the help of handheld dynamometry, and the maximum of three attempts was taken as final. The St. George Respiratory Questionnaire (SGRQ) was used to

measure the quality of life related with health by measuring the severity of symptoms, activity limitations, and the psychosocial impact where a high score indicates poorer quality of life.

All the data gathered were keyed into SPSS version 26.0 with the view of statistical analysis. The values of continuous variables were represented as standard deviation and mean. Paired t -tests were used to compare pre- and post-rehabilitation measurements. The subgroup analyses involved the investigation of sex-based differences in response to pulmonary rehabilitation. All comparisons were judged to be significant in a p-value less than 0.05.

RESULTS

A total of 100 patients completed the pulmonary rehabilitation successfully where 62 of the patients were males with 38 being females. The average age of the participants was 59.4 years 8.7 years. The prevalent patients were categorized as GOLD stage II-III and 28% patients were in GOLD stage IV. The male and female ratio of patients was relatively the same to perform a comparative analysis of results.

Demonstrations of pulmonary function revealed that there were significant improvements on pulmonary functioning after rehabilitation. The baseline FEV1 was 49.6 plus 9.4 percent anticipated and after rehabilitation was 54.8 plus 8.9 percent ($p < 0.001$). The forced vital capacity (FVC) increased to 75.6 ± 9.7% (72.1 ± 10.3), whereas the FEV1/FVC ratio increased to 0.61 ± 0.05 (0.58 ± 0.06). These findings, as demonstrated by Table 1, affirm that there are remarkable changes in airway patency and dynamics of expiratory flows.

There was an increase in exercise capacity. There was an improvement of mean six-minute walk distance (6MWD) between the baseline of 349.2 ± 52.6 meters to the post-rehabilitation of 417.4 ± 56.4 meters ($p < 0.001$). Compared to females, male patients showed better baseline and post-rehabilitation distance, although both groups had positive clinically significant improvements. The summarization of the findings is presented in Table 2.

Peripheral muscle performance also showed marked improvement. Quadriceps strength increased from 245.3 ± 37.6 Newtons at baseline to 290.7 ± 41.2 Newtons after eight weeks of training, reflecting an average gain of 18.5% ($p < 0.001$). The improvement in lower limb strength is shown in Table 3.

The quality of life on health matters also increased significantly. The average total of the St. George Respiratory Questionnaire (SGRQ) scored at 66.3 (13.2) at the baseline and 45.0 (11.8) at post-rehabilitation and is a clinically significant change. There was also a domain-specific improvement, as the symptom scores reduced by 14.7, activity scores reduced by 18.7, and impact scores reduced by 15.9. Table 4 describes these results in more detail.\

Table 1: Changes in Pulmonary Function After Pulmonary Rehabilitation (n = 100)

Parameter	Baseline (Mean ± SD)	Post-PR (Mean ± SD)	Mean Change	p-value
FEV1 (% predicted)	49.6 ± 9.4	54.8 ± 8.9	+5.2	<0.001
FVC (% predicted)	72.1 ± 10.3	75.6 ± 9.7	+3.5	0.002
FEV1/FVC ratio	0.58 ± 0.06	0.61 ± 0.05	+0.03	0.001

Table 2: Six-Minute Walk Distance (6MWD) Before and After Pulmonary Rehabilitation

Group	Baseline (m)	Post-PR (m)	Mean Change (m)	p-value
Male (n=62)	361.8 ± 55.4	436.2 ± 59.8	+74.4	<0.001
Female (n=38)	328.6 ± 49.3	386.7 ± 52.1	+58.1	<0.001
Total (n=100)	349.2 ± 52.6	417.4 ± 56.4	+68.2	<0.001

Table 3: Quadriceps Muscle Strength Before and After Pulmonary Rehabilitation (n = 100)

Measure	Baseline (N)	Post-PR (N)	% Change	p-value
Quadriceps strength	245.3 ± 37.6	290.7 ± 41.2	+18.5%	<0.001

Table 4: St. George's Respiratory Questionnaire (SGRQ) Scores Before and After Pulmonary Rehabilitation (n = 100)

Domain	Baseline (Mean ± SD)	Post-PR (Mean ± SD)	Mean Difference	p-value
Symptoms	61.4 ± 12.8	46.7 ± 11.3	-14.7	<0.001
Activity	72.9 ± 14.1	54.2 ± 13.2	-18.7	<0.001
Impact	64.8 ± 13.5	48.9 ± 12.6	-15.9	<0.001
Total	66.3 ± 13.2	45.0 ± 11.8	-21.3	<0.001

The combined findings prove pulmonary rehabilitation yielded substantial physiological effects in a variety of domains. Lung performance was better, there was an improvement in exercise capacity, muscle strength was regained and quality of life was significantly improved. The results of Tables 1 to 4 are strong indications of the efficacy of pulmonary rehabilitation as an all-inclusive means of therapy in the management of COPD.

DISCUSSION

The findings of this study demonstrate that the concept of pulmonary rehabilitation (PR) is extremely significant and improves the physiological performance of patients with

chronic obstructive pulmonary disease (COPD) [11]. The presence of multidimensional PR benefits was supported by the positive change in the parameters of the pulmonary functioning, the ability to exercise, the strength of the peripheral muscles, and the quality of life. These results are consistent with the results of the world to reveal PR as a basis of COPD treatment particularly in patients with moderate to severe COPD who still have persistent symptoms despite the best pharmacological interventions [12].

The evidence of the airway mechanics and more efficient expiratory flow is expressed by the increase in pulmonary functions in particular FEV1 and FEV1/FVC ratio. Although reverse airway obstruction is not among the main objectives of PR, breathing retraining, pursed-lip and diaphragmatic breathing can reduce dynamic hyperinflation and enhance gas exchange and allow more effective ventilation [13]. The minor but significant shifts in spirometric results in the study are in line with other studies, which have indicated PR to enhance ventilatory and reduce the sense of dyspnea. These results justify the use of non-pharmacological interventions as a supplement to medical intervention since they can be used in overcoming the physiological limitations that cannot be resolved by airway obstruction [14,15].

Exercise capacity, in the form of the six minutes walk distance (6MWD), was one of the most important ones. The present study of 68.2 meters increase is higher than the previously established clinically significant change threshold of 30 to 54 meters which had been established among COPD populations [16]. This finding demonstrates that PR can have a great positive impact on functional capacity that allows patients to perform their daily activities with ease and less fatigue. The advantages were also evident in both genders, but in the present instance, the slight but significant improvements were observed in males, which is likely due to the fact that in such a situation, the muscle mass and tolerance to high-intensity exercises were larger. These findings suggest that the sex differences may influence the amplitude of the reaction, however, overall, PR benefits may be applied to the patients universally [17,18].

Peripheral muscle strength particularly the quadriceps muscle functioning also improved significantly. This observation is important as the skeletal muscle dysfunction is a recognized systemic manifestation of COPD and it is directed by chronic inflammation, deconditioning, oxidative stress, and corticosteroid therapy [19]. The fact that the quadriceps strength of our cohort was restored nearly 20 percent by resistance training is critical in the importance of resistance training in reversing muscle atrophy and improving the exercise tolerance. The improvements in 6MWD, fatigue reduction, and increase in activities of daily living directly result as a consequence of the increased performance of the muscles. Our research validates findings of other researchers that PR is a systemic effect which is propagated into the physiological deficiency of the whole body with COPD [20,21].

Another way of confirming the holistic value of PR is the gains of quality of life that will be experienced in this study. Reduction in St. George Respiratory Questionnaire (SGRQ) scores exceeded the maximum change which is four units in each domain and a substantial reduction in symptomatic and positive activity performance and a psychosocial burden [22]. Such results bring out the notion that PR does not only lead to enhancement of measurable physiological processes, but also is transferred into meaningful transformation on the daily lives of the patients. This may have been possible because of the integrated nature of psychological support and nutritional counseling through the rehabilitation program as the all-inclusive PR concentrates on the physical, nutritional and emotional aspects of patients with COPD [23].

The positive aspects of this work are the prospective design of the study, sufficient sample size, and consideration of various areas of physiological and psychosocial functioning. Nevertheless, there are some shortcomings that should be noted. First, the time span of the study was reduced to eight weeks and the sustainability of the improvements was not checked in the long run [24]. Second, the sample size was not made powerful enough to investigate sex-specific differences in PR outcomes even though both sexes were used in the study. Third, the researchers carried out the study at a tertiary care hospital in an urban region, which might reduce the ability to generalize the results to rural populations or patients with low access to organized rehabilitation interventions. Notwithstanding these shortcomings, the results are a strong indication towards the use of PR as an intervention in mainstream COPD management in resource constrained healthcare systems like that of Pakistan [25].

CONCLUSION

Pulmonary rehabilitation has important physiological effects on COPD patients, such as lung and exercise capacity and muscle performance and health-related quality of life. The steady improvements in various areas will testify that PR proves to be a powerful, holistic intervention which covers both the pulmonary and systemic concerns of the disease. Since PR is safe, economical, and multidimensional, it needs to be implemented into the management of COPD patients regular like pharmacological therapy. The growth of PR services in low- and middle-income countries can be promising in terms of disease burden reduction, patient outcomes, and quality of life improvement of millions of people living with COPD.

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Authors' contributions:

K.B. – Study conception, design, and supervision.

H.U.K. – Data acquisition and statistical analysis.

M.N.S. & F.G – Literature review and manuscript drafting.

A.J. – Data interpretation and results formulation.

S.Y.A. – Proofreading and formatting of the manuscript.

M.L. – Final review, editing, and approval of the manuscript.

All authors read and approved the final version of the manuscript.

Data Availability Statement: The data used in this study are available upon reasonable request from the corresponding author, subject to ethical and institutional guidelines.

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