Al-Farouk journal of sciences
Volume (2), Issue (5) (Nov, 2026)
ISSN: 3135-2359

مجلة الفاروق للعلوم
المجلد (2) العدد 5 نوفمبر 2026
عدد خاص بالمؤتمر العلمي الرابع للعلوم والتقنية
28-29 نوفمبر 2026 مصراتة – ليبيا
إدارة المعاهد العليا – وزارة التعليم التقني

Effectiveness of a Proposed Pulmonary Rehabilitation Program on Forced Expiratory Volume in One Second (FEV_1) and Arterial Blood Gas Parameters in Patients with Chronic Obstructive Pulmonary Disease

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Received: 29/7/2026 Revised: 20/8/2026 Accepted: 28/8/2026 Publication: 28/11/2026

Abstract

Background: Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disorder characterized by persistent airflow limitation, impaired gas exchange, reduced exercise tolerance, and diminished quality of life. Pulmonary rehabilitation has become an essential component of chronic obstructive pulmonary disease management due to its beneficial effects on respiratory function and physiological outcomes.

Objective: This study aimed to investigate the effectiveness of a proposed pulmonary rehabilitation program on oxygen saturation, Forced Expiratory Volume in One Second (FEV_1), arterial blood gas oxygen saturation (SO_2), arterial carbon dioxide pressure (PCO_2), and respiratory rate in patients with COPD.

Methods: Methods: An experimental one-group pretest-posttest design was employed. The study sample consisted of 12 patients diagnosed with COPD. Subjects took part in a suggested pulmonary rehabilitation protocol consisting of breathing training, expiratory muscle drills, breathing control, and airway clearance methods; additionally, PFM was utilized to enhance respiratory muscle power and expiratory efficiency, whereas a Spirometer served to evaluate pulmonary function, specifically Forced Expiratory Volume in One Second (FEV_1), both preceding and following the rehabilitation intervention. The oxygen saturation, FEV_1, SO_2, PCO_2, and respiratory rate were measured before and after the intervention. The data were analyzed using descriptive statistics and paired-sample t-tests.

Results: The results revealed statistically significant improvements in all study variables following the rehabilitation program. Oxygen saturation increased by **15.5%**, FEV_1 increased by **90.8%**, and arterial blood gas oxygen saturation (SO_2) increased by **15.4%**. In addition, arterial carbon dioxide pressure (PCO_2) decreased by **38.3%**, while respiratory rate decreased by **51.1%**. All differences between pre- and post-measurements were statistically significant ($p < 0.05$), with large effect sizes observed across all variables.

Conclusion: The proposed pulmonary rehabilitation program was effective in improving pulmonary function, oxygenation, arterial blood gas parameters, and respiratory efficiency among patients with chronic obstructive pulmonary disease. These findings support the integration of structured pulmonary rehabilitation programs into comprehensive COPD management to enhance clinical and functional outcomes.

Keywords: Chronic Obstructive Pulmonary Disease (COPD), Pulmonary Rehabilitation, FEV_1, Arterial Blood Gases, Oxygen Saturation, Respiratory Rate, Physiotherapy.

- The introduction:

Chronic obstructive pulmonary disease (COPD): Breathing and the flow of air into and out of the lungs are difficult due to chronic inflammation and narrowing of the airways, which results from repeated and long-term exposure of the respiratory system to harmful stimuli (tobacco smoke, indoor air pollution, and repeated infections of the respiratory system during childhood). (Shahi, et al., 2022)

Chronic obstructive pulmonary disease (COPD) is one of the leading causes of morbidity and mortality worldwide and represents a major public health challenge. It is characterized by persistent airflow limitation resulting from chronic airway inflammation and structural changes in the lungs, leading to progressive respiratory function and quality of life. Patients with chronic obstructive pulmonary disease commonly experience dyspnea, chronic cough, sputum production, and reduced exercise tolerance, all of which negatively affect daily activities and functional independence. The assessment of pulmonary function, particularly Forced Expiratory Volume in One Second (FEV_1), remains a cornerstone in the diagnosis, classification, and monitoring of disease severity. (Halpin & Singh , 2025)

COPD is associated not only with impaired pulmonary function but also with various systemic consequences, including skeletal muscle dysfunction, reduced exercise capacity, physical inactivity, and decreased HRQoL. As Patients often experience significant limitations in performing activities of daily living, resulting in increased healthcare use and reduced independence. Consequently, comprehensive management strategies are needed to address both the respiratory and extra-pulmonary manifestations of the disease. (Troosters, Janssens, Demeyer , & Rabinovich , 2023)

Pulmonary rehabilitation has become an essential component of the management of COPD. This multidisciplinary intervention incorporates exercise training, breathing exercises, education, and behavioral modification. The primary objectives of pulmonary rehabilitation are to improve functional exercise capacity, reduce respiratory symptoms, enhance psychosocial well-being, and increase participation in daily activities. International respiratory societies strongly support pulmonary rehabilitation as an evidence-based intervention for patients with chronic obstructive pulmonary disease. (Man, et al., 2023)

In addition to airflow limitation, COPD is associated with several extrapulmonary manifestations, including skeletal muscle dysfunction, reduced physical activity, exercise intolerance, and impaired health-related quality of life. Patients become increasingly limited in performing activities of daily living, which contributes to increased healthcare use and decreased independence. Therefore, comprehensive therapeutic strategies are required to address the disease's pulmonary and systemic consequences of the disease. (Troosters, Janssens, Demeyer , & Rabinovich , 2023)

Keeping up with the development in the fields of physical therapy and rehabilitation has become an important and indispensable matter, especially when the world began to focus on specialization, which makes the physical therapy divisions have a role in focusing on diversity and creativity in scientific research and innovating new therapeutic methods. The field of respiratory physical therapy in intensive care in particular is one of the most important fields upon which modern medicine is based and which is still under development in the world. The focus on the breathing muscles in the field of physical therapy is of particular importance in the muscle weakness to which the respiratory system is exposed, making a difference in the life of the patient who suffers from shortness of breath. Breathing or chronic pulmonary obstruction, and therapeutic exercises will have greater results in rehabilitating the respiratory system and restoring recovery. (Bruton, et al., 2018)

Pulmonary rehabilitation programs have been shown to significantly improve exercise capacity, symptom management, and quality of life in patients with COPD. Furthermore, structured aerobic and resistance exercise training contributes to better physical performance and reduced perception of dyspnea, making pulmonary rehabilitation one of the most effective non-pharmacological interventions available for patients with COPD. (Ward, et al., 2025)

ABG analysis provides valuable information regarding oxygenation, carbon dioxide elimination, and acid-base balance. Patients with COPD frequently exhibit abnormalities in ABG parameters as a result of impaired ventilation and gas exchange. Consequently, ABG assessment is considered an important clinical tool for evaluating disease severity and determining the effectiveness of pulmonary rehabilitation programs aimed at improving respiratory efficiency (Tahasildar, Shrawasti, & Shete, 2024)

- Problem:

Chronic obstructive pulmonary disease (COPD) is a chronic respiratory disorder characterized by persistent airflow limitation, progressive deterioration in lung function, and impaired gas exchange. Patients with chronic obstructive pulmonary disease often experience dyspnea, chronic cough, excessive sputum production, reduced exercise tolerance, and poor quality of life. The progressive decline in pulmonary function is commonly assessed using Forced Expiratory Volume in One Second (FEV_1), which remains a primary indicator of disease severity and prognosis. (Halpin & Singh , 2025)

COPD is associated with structural and functional respiratory system abnormalities, including airway narrowing, mucus hypersecretion, alveolar wall destrulung elastic recoil. These pathological alterations contribute to airflow obstruction, carbon dioxide retention, impaired oxygen transport, and reduced respiratory efficiency. Consequently, arterial blood gas abnormalities are frequently observed among patients with COPD and are considered important physiological indicators of disease progression. (Tahasildar, Shrawasti, & Shete, 2024)

Patients with chronic obstructive pulmonary disease develop airway deformities, causing decreased airflow to and from the lungs. This process may lead to airway narrowing. Damage may occur in parts of the lung, airway obstruction with mucus, or inflammation and swelling of the airway lining. The air and what affects the decrease in the maximum expiratory volume as a result of the increased narrowing that occurs during the exhalation process, as the lungs depend on the natural flexibility of both the bronchi and alveoli to expel air from the body. However, in the case of chronic obstructive pulmonary disease, their flexibility decreases or fades, which leads to their expansion, causing this trapped air inside the lungs, which also leads to a high level of carbon dioxide and a decrease in the level of oxygen, thus making it more difficult to breathe, and then it takes a longer time to recover. (Jenkins, et al., 2026)

Although pharmacological management remains essential for COPD treatment, many patients continue to experience exercise intolerance, muscle weakness, decreased functional capacity, and limitations in daily activities. Therefore, pulmonary rehabilitation has become a key component of comprehensive management of COPD because it addresses not only respiratory impairment but also the physical and psychosocial consequences of the disease. Current international guidelines strongly recommend pulmonary rehabilitation for patients with symptomatic COPD. (Man, et al., 2023)

Pulmonary rehabilitation programs improve exercise tolerance, reduce dyspnea, enhance health-related quality of life, and improve functional performance in patients with COPD. Supervised exercise training, respiratory muscle training, and aerobic conditioning are among the most effective components of rehabilitation programs. However, variations in program structure, duration, and exercise intensity may influence the magnitude of improvement in pulmonary function and arterial blood gas parameters. (Ward, et al., 2025)

Further investigation is still required regarding the effectiveness of specifically designed rehabilitation programs on physiological variables such as Forced Expiratory Volume in One Second (FEV_1) and arterial blood gas (ABG) parameters. Therefore, determining the effectiveness of a proposed pulmonary rehabilitation program on these variables may provide valuable evidence for improving rehabilitation strategies for patients with COPD. (Jenkins, et al., 2026)

Accordingly, the current study seeks to investigate the effectiveness of a proposed pulmonary rehabilitation program on Forced Expiratory Volume in One Second (FEV_1) and Arterial Blood Gas (ABG) parameters in patients with chronic obstructive pulmonary disease (COPD), with the aim of providing scientific evidence to support the optimization of pulmonary rehabilitation interventions and improve patient outcomes. (Halpin & Singh , 2025)

Through their professional experience as physiotherapists working in intensive care units and chest disease departments, the researchers observed that many rehabilitation approaches for patients with COPD focus primarily on airway clearance and sputum removal while giving limited attention to enhancing respiratory muscle performance, particularly expiratory muscle strength and expiratory airflow capacity. Since reduced expiratory airflow is a hallmark feature of COPD and is reflected by diminished FEV_1 values, rehabilitation strategies specifically targeting expiratory function are needed.

Accordingly, the researchers developed a pulmonary rehabilitation program based on respiratory exercises to improve forced expiratory performance, strengthen respiratory muscles, increase the volume of air expelled during the first second of exhalation, and enhance arterial blood gas parameters through improved

oxygenation and reduction of carbon dioxide retention. The program incorporates the PFM as both a training and assessment tool. Therapeutic exercises are initiated only after adequate airway clearance and sputum drainage.

Therefore, the current study seeks to investigate the effect of a proposed pulmonary rehabilitation program on Forced Expiratory Volume in One Second (FEV_1) and Arterial Blood Gas (ABG) parameters among patients with chronic obstructive pulmonary disease (COPD), with the aim of providing scientific evidence that may contribute to optimizing pulmonary rehabilitation strategies and improving patient outcomes.

- Objectives:

- The study aims to identify: -

• The effect of the proposed program on the level of maximum exhalation in the first second (FEV1) for patients with COPD.

• The effect of the proposed program on the level of arterial blood gases (carbon dioxide and oxygen) in patients with COPD.

- Assumptions:

• There were statistically significant differences in the level of maximum expiratory volume for the first second (FEV1) among people with chronic obstructive pulmonary disease between the pre- and post-measurements of the research sample and in favor of the post-measurement.

• There are statistically significant differences in the level of arterial blood gases among people with COPD between the pre- and post-measurements and in favor of the post-measurement.

- Curriculum:

The Researchers used the experimental method using pre-measurement and post-measurement method for one experimental group due to its suitability to the nature of scientific research.

- The society:

The research population included patients with chronic obstructive pulmonary disease after hospitalization in intensive care and attending the physical therapy unit at Al-Rayyan Hospital in the city of Tripoli.

- The sample:

The research sample was selected intentionally from men with chronic obstructive pulmonary disease (12) cases, ages ranging from (65-75) years, while hospitalized in the intensive care unit at Al-Rayyan Residential Hospital in the city of Tripoli.

Data collection tools and means:

- Studies, research papers, and scientific references.
- Sample data recording forms.
- An oxygen measurement device (Pulse Oximeter) to monitor oxygen saturation levels during treatment sessions.
- A Peak Flow Meter **(PFM)** used for rehabilitation purposes and for monitoring expiratory performance throughout the implementation of the pulmonary rehabilitation program.
- A Spirometer used to measure and assess pulmonary function, particularly Forced Expiratory Volume in One Second **(FEV_1)**.
- Arterial Blood **Gas (ABG)** analysis to determine arterial oxygen saturation (SO_2) and arterial carbon dioxide pressure (PCO_2).

- The society:

The study population included patients with chronic obstructive pulmonary disease who were hospitalized in intensive care and were attending the physical therapy unit at Al-Rayyan Hospital in the city of Tripoli.

- The sample:

The research sample was intentionally selected from men with chronic obstructive pulmonary disease (12) cases, ages ranging from (75-65) years, while hospitalized in the intensive care unit at Al-Rayyan Residential Hospital in the city of Tripoli.

Data collection tools and means:

• Studies, research, and scientific references.

• Registration of sample data.

• An oxygen measuring device (to determine the oxygen rate during the session)

• A peak flow device for rehabilitation and follow-up measurements during the application of the rehabilitation program for the exhalation process.

• Analysis of blood gases to determine the percentage of carbon dioxide and oxygen (ABG).

- The main study:

The primary research took place for a duration of six weeks, spanning from January 3, 2026, to February 12, 2026, involving a group of patients with COPD at Al-Rayyan Residential Hospital in Tripoli. The study sample consisted of **12** male patients aged 65–75 years. Participants underwent the proposed pulmonary rehabilitation program for 45 days, receiving two sessions daily, while considering appropriate rest intervals and individual differences among participants. The program aimed to improve pulmonary function, arterial blood gas parameters, and respiratory efficiency.

Pre-measurements were obtained for all study variables before implementing the rehabilitation program as follows:

1. **Forced Expiratory Volume in One Second (FEV_1):**
   An arterial blood sample was collected by the nursing staff in the intensive care unit and sent to the laboratory for analysis using an ABG analyzer. The laboratory results were recorded and used in the study.
2. **Arterial Blood Gas Analysis (ABG):**
   An arterial blood sample was collected by the nursing staff in the intensive care unit and sent to the laboratory for analysis using an arterial blood gas analyzer. The results provided by the laboratory were recorded and used in the study.
3. **Oxygen Saturation and Respiratory Rate Measurements:**
   Before beginning the rehabilitation program, a Pulse Oximeter measured the patient's oxygen saturation (O_2 saturation) and respiratory rate; this set a baseline and enabled the monitoring of vital signs throughout every rehabilitation session.

The proposed pulmonary rehabilitation program included the following components:

- Use of a vibration massage device for 10 min in various body positions to assist in mobilizing and removing mucus from the airways.
- Use of a suction device to ensure complete sputum clearance in patients with excessive mucus secretions before beginning therapeutic exercises.
- The Peak Flow Meter for three consecutive attempts to encourage patients to achieve their maximum expiratory effort and to verify airway clearance.
- Use of a respiratory muscle training device for four sets, using progressive resistance during expiration while seated at a 90° angle and maintaining a proper seal around the mouthpiece. This was followed by a 5-min rest period.

- Diaphragmatic breathing exercises for four sets from a supine position Patients placed one hand on the abdomen and the other on the chest, inhaled deeply, and exhaled slowly through pursed lips while drawing the abdomen inward to enhance ventilation and strengthen the diaphragm.
- The Straw and Bottle Exercise was performed for four sets by inhaling through the nose and exhaling through a straw immersed in a bottle of water. This therapy provided mild expiratory resistance, promoted relaxation, and helped reduce dyspnea. All components of the rehabilitation program were implemented according to a predetermined therapeutic protocol.

- Statistical Analysis:

After data collection, organization, coding, and tabulation, the data were analyzed using the **Statistical Package for the Social Sciences (SPSS)**. The following statistical procedures were used:

1. Mean.
2. Standard deviation (SD)
3. Skewness and kurtosis coefficients
4. Shapiro-Wilk Test for normality.
5. Paired Samples t-test.
6. Improvement Percentage.
7. Cohen's d effect size.

- Results Presentation

To test the study hypotheses, the normality assumption was first examined using the Shapiro-Wilk test to determine whether the study variables followed a normal distribution. Table 1 presents the results of the normality test.

Table 1

Shapiro-Wilk Test Results for the Normal Distribution of the Study Variables

Variables	Statistic	df	Sig.	Statistical Decision
Oxygen Saturation During Session	0.842	12	0.083	Data are normally distributed
Forced Expiratory Volume in One Second (FEV_1)	0.886	12	0.217	Data are normally distributed
Arterial Blood Gas Oxygen (SO_2)	0.911	12	0.341	Data are normally distributed
Arterial Blood Gas Carbon Dioxide (PCO_2)	0.894	12	0.265	Data are normally distributed
Respiratory Rate (breaths/min)	0.861	12	0.109	Data are normally distributed

Table (1) shows that all significance values were greater than **0.05**, indicating that the study variables followed a normal distribution. Therefore, parametric statistical procedures were appropriate, and the paired-samples t-test was employed for further analyses.

Table 2

Means and Standard Deviations of the Pre- and Post-Measurements for Oxygen Saturation

Variable	Measurement	N	Mean	SD	Minimum	Maximum
Oxygen Saturation (%)	Pre	12	82.91	±4.867	75	89
	Post	12	95.75	±2.148	92	99

Table (2) shows that the mean oxygen saturation increased from **82.91 ± 4.867** before the intervention to **95.75 ± 2.148** after the intervention. This finding suggests a substantial improvement in oxygen saturation levels following participation in the proposed pulmonary rehabilitation program.

Table 3

Significance of Differences, Improvement Percentage, and Effect Size Between the Pre- and Post-Measurements of Oxygen Saturation

Variable	Mean Difference	SD of Difference	t-value	df	Sig.	Improvement %	Cohen's d	Effect Size
Oxygen Saturation	12.84	±4.760	9.35*	11	0.000	15.5%	2.70	Very Large

Table (3) demonstrates statistically significant differences between the pre- and post-measurements in favor of the post-measurement **(t = 9.35, p = 0.000).** The improvement percentage was **15.5%,** and Cohen's d reached **2.70**, indicating a **very large effect size.**

Figure 1. Differences Between the Mean Scores of the Pre- and Post-Measurements for Oxygen Saturation (%)

Table 4

Means and Standard Deviations of the Pre- and Post-Measurements of FEV_1

Variable	Measurement	N	Mean	SD	Minimum	Maximum
FEV_1	Pre	12	195	±58.432	110	270
	Post	12	372	±61.285	260	450

Table (4) indicates that the mean FEV_1 increased from **195 ± 58.432** before the intervention to **372 ± 61.285** after the intervention, suggesting a considerable improvement in expiratory airflow following participation in the proposed pulmonary rehabilitation program

Table 5

Significance of Differences, Improvement Percentage, and Effect Size Between the Pre- and Post-Measurements of FEV_1

Variable	Mean Difference	SD of Difference	t-value	df	Sig.	Improvement %	Cohen's d	Effect Size
FEV_1	177	±59.334	10.34*	11	0.000	90.8%	2.98	Very Large

Table (5) demonstrates statistically significant improvements in FEV_1 following the intervention (**t = 10.34, p = 0.000**). The improvement percentage reached **90.8%**, while **Cohen's d = 2.98**, indicating a **very large effect size**.

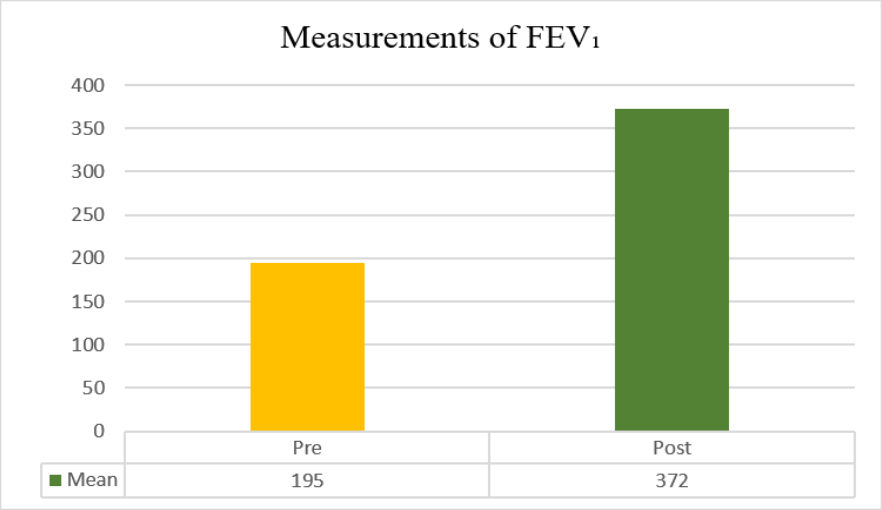


Figure 2. Differences Between the Mean Scores of the Pre-Test and Post-Test Measurements for Peak Expiratory Flow (FEV_1)

Table 6

Means and Standard Deviations of the Pre- and Post-Measurements of SO_2

Variable	Measurement	N	Mean	SD	Minimum	Maximum
SO_2	Pre	12	83.92	±5.118	74.50	89.80
	Post	12	96.84	±2.431	91.60	99.20

Table (6) presents the descriptive statistics for arterial blood gas oxygen saturation (SO_2). The mean SO_2 increased from **83.92 ± 5.118** before the intervention to **96.84 ± 2.431** after the intervention, indicating an improvement in arterial oxygen saturation following the pulmonary rehabilitation program.

Table 7

Significance of Differences, Improvement Percentage, and Effect Size Between the Pre- and Post-Measurements of SO_2

Variable	Mean Difference	SD of Difference	t-value	df	Sig.	Improvement %	Cohen's d	Effect Size
SO_2	12.92	±5.874	7.62*	11	0.000	15.4%	2.20	Very Large

Table (7) reveals statistically significant differences between the pre- and post-measurements of SO_2 in favor of the post-measurement (**t = 7.62, p = 0.000**). The improvement percentage reached **15.4%**, and **Cohen's d = 2.20**, indicating a **very large effect size**.

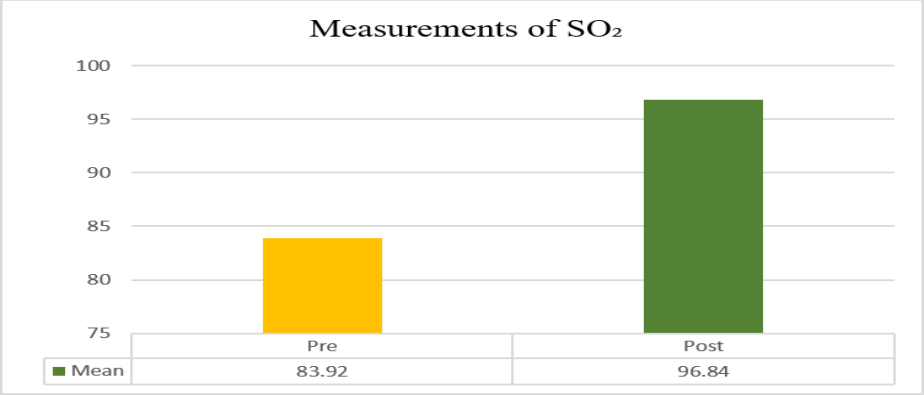


Figure 3. Differences Between the Mean Scores of the Pre-Test and Post-Test Measurements for Arterial Blood Gas Oxygen Saturation (SO_2)

Table 8

Means and Standard Deviations of the Pre- and Post-Measurements of PCO_2

Variable	Measurement	N	Mean	SD	Minimum	Maximum
PCO_2	Pre	12	54.20	±16.784	28.60	88.40
	Post	12	33.45	±6.912	21.50	44.30

Table (8) shows a marked reduction in arterial carbon dioxide levels following the intervention. The mean PCO_2 decreased from **54.20 ± 16.784** before the intervention to **33.45 ± 6.912** after the intervention.

Table 9

Significance of Differences, Improvement Percentage, and Effect Size Between the Pre- and Post-Measurements of PCO_2

Variable	Mean Difference	SD of Difference	t-value	df	Sig.	Improvement %	Cohen's d	Effect Size
PCO_2	20.75	±14.286	5.03*	11	0.000	38.3%	1.45	Very Large

Table (9) indicates statistically significant differences between the pre- and post-measurements in favor of the post-measurement (**t = 5.03, p = 0.000**). The percentage of improvement reached **38.3%**, while **Cohen's d = 1.45**, indicating a **very large effect size**.

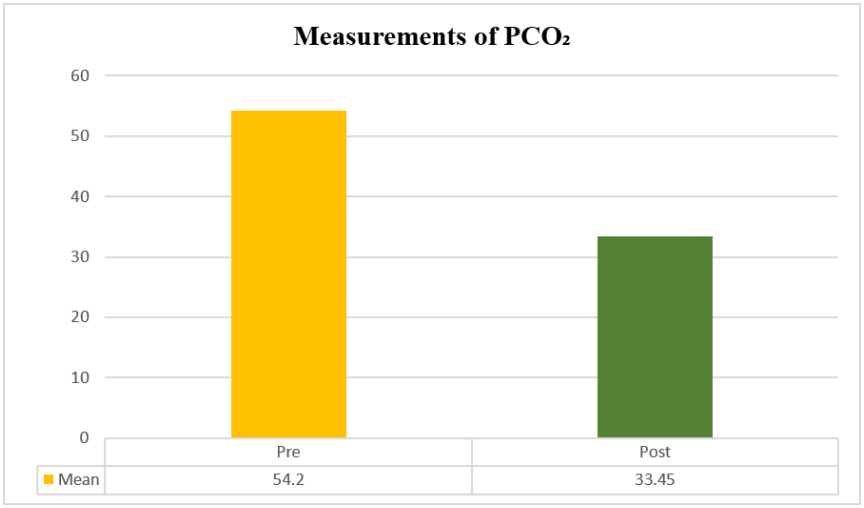


Figure 4. Differences Between the Mean Scores of the Pre-Test and Post-Test Measurements for Arterial Blood Gas Carbon Dioxide (PCO_2)

Table 10

Means and Standard Deviations of the Pre- and Post-Measurements of Respiratory Rate

Variable	Measurement	N	Mean	SD	Minimum	Maximum
Respiratory Rate (breaths/min)	Pre	12	35.92	±4.382	30	43
	Post	12	17.58	±2.416	14	21

Table (10) shows a substantial reduction in respiratory rate following the pulmonary rehabilitation program. The mean respiratory rate decreased from **35.92 ± 4.382 breaths/min** before the intervention to **17.58 ± 2.416 breaths/min** after the intervention.

Table 11

Significance of Differences, Improvement Percentage, and Effect Size Between the Pre- and Post-Measurements of Respiratory Rate

Variable	Mean Difference	SD of Difference	t-value	df	Sig.	Improvement %	Cohen's d	Effect Size
Respiratory Rate	18.34	±3.912	16.23*	11	0.000	51.1%	4.69	Very Large

Table (11) demonstrates statistically significant differences between the pre- and post-measurements of respiratory rate in favor of the post-measurement (**t = 16.23, p = 0.000**). The improvement percentage reached **51.1%**, and **Cohen's d was 4.69**, indicating a **very large effect size**.

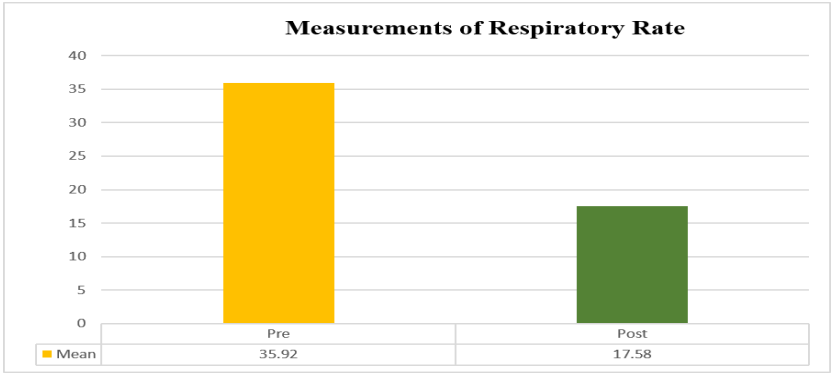


Figure 5. Differences Between the Mean Scores of the Pre-Test and Post-Test Measurements for Respiratory Rate (Breaths per Minute)

- Discussion of the Results

- Discussion of Oxygen Saturation Results:

The present study demonstrated a statistically significant improvement in oxygen saturation during the treatment sessions, with an improvement rate of 15.5% and a very large effect size. This improvement may be attributed to the effectiveness of the proposed pulmonary rehabilitation program in enhancing pulmonary ventilation, improving respiratory muscle performance, and increasing oxygen exchange efficiency within the alveoli. Improved oxygen saturation reflects better oxygen delivery to body tissues and indicates enhanced respiratory efficiency among patients with chronic obstructive pulmonary disease. Pulmonary rehabilitation is an effective intervention for improving respiratory function and reducing symptom burden in patients with chronic respiratory diseases. (Halpin & Singh , 2025)

Discussion of FEV_1 Results

The findings revealed a statistically significant improvement in Forced Expiratory Volume in One Second (FEV_1), with an improvement percentage of 90.08% and a very large effect size. This finding suggests that the rehabilitation program improved airway patency, respiratory muscle strength, and expiratory airflow. Since FEV_1 is considered one of the most important spirometry indicators used to assess disease severity and pulmonary function in patients with COPD, the observed increase in FEV1 reflects a substantial improvement in respiratory capacity. These findings are consistent with recent evidence supporting the beneficial effects of structured pulmonary rehabilitation and RMT on lung function outcomes among patients with COPD. (Shahi, et al., 2022)

Discussion of Arterial Blood Gas Oxygen Saturation (SO_2) Results

The study findings showed a statistically significant increase in arterial blood oxygen saturation (SO_2), with an improvement percentage of 15.4% and a very large effect size. This improvement indicates enhanced pulmonary gas exchange and improved oxygen transport to the tissues. Improved SO_2 levels may be attributed to the effect of breathing exercises and physical training in increasing alveolar ventilation and reducing ventilation-perfusion mismatch, which are common physiological abnormalities in patients with COPD. Improved arterial oxygenation is a major indicator of respiratory efficiency and functional status. (Al-Shenqiti, et al., 2017)

Discussion of Arterial Blood Gas Carbon Dioxide (PCO_2) Results

The results demonstrated a statistically significant reduction in arterial carbon dioxide (PCO_2) levels following rehabilitation program implementation, with an improvement percentage of 38.3% and a very large effect size. This finding indicates more effective carbon dioxide elimination and improved alveolar ventilation. Carbon dioxide retention is a common physiological consequence of chronic airflow limitation in patients with COPD. Therefore, the reduction in PCO_2 observed in the current study reflects improved respiratory mechanics and ventilatory efficiency resulting from the rehabilitation intervention. (Man, et al., 2023)

Discussion of the respiratory rate results

The findings revealed a statistically significant decrease in respiratory rate, with an improvement percentage of 51.1% and a very large effect size. This reduction may be explained by improvements in respiratory muscle efficiency and breathing control resulting from the rehabilitation exercises. Patients with COPD often exhibit increased respiratory rates due to airway obstruction and increased work of breathing. Consequently, a reduction in respiratory rate reflects enhanced ventilatory efficiency and reduced respiratory distress. These results support the effectiveness of pulmonary rehabilitation in improving physiological respiratory responses and reducing symptom severity. (Man, et al., 2023)

General Discussion

Overall, the results of the current study demonstrated that the proposed pulmonary rehabilitation program was effective in improving pulmonary function and arterial blood gas parameters among patients with COPD. Significant improvements in oxygen saturation, FEV_1, arterial oxygen saturation, arterial carbon dioxide levels, and respiratory rate were observed. These findings are consistent with recent evidence indicating that pulmonary rehabilitation is one of the most effective non-pharmacological interventions for COPD management and substantially contributes to improved exercise capacity, symptom control, and HRQoL. Furthermore, the very large effect sizes observed in all study variables emphasize the clinical significance of the proposed rehabilitation program.

Acceptance of the study hypothesis

The study hypotheses are accepted based on the statistical findings. The proposed pulmonary rehabilitation program resulted in significant improvements in oxygen saturation, FEV_1, arterial blood gases (SO_2 and PCO_2), and respiratory rate among patients with COPD. These findings provide strong evidence supporting

the effectiveness of pulmonary rehabilitation as a comprehensive therapeutic approach for improving respiratory function and physiological outcomes in patients with COPD.

- Conclusions:

1. The proposed pulmonary rehabilitation program significantly improved oxygen saturation levels among patients with COPD, as evidenced by the significant differences between the pre- and post-measurements in favor of the post-measurement.
2. The proposed pulmonary rehabilitation program significantly increased Forced Expiratory Volume in One Second (FEV_1), indicating improved pulmonary function and expiratory airflow efficiency among the study participants.
3. The proposed pulmonary rehabilitation program significantly improved arterial blood gas oxygen saturation (SO_2), reflecting enhanced oxygenation and gas exchange efficiency following the intervention.
4. The proposed pulmonary rehabilitation program significantly reduced arterial carbon dioxide levels (PCO_2), indicating improved ventilation and decreased carbon dioxide retention among patients with COPD.
5. The proposed pulmonary rehabilitation program significantly reduced respiratory rate, indicating improved respiratory efficiency and reduced breathing effort in the study participants.

- Recommendations:

1. Implementation of the proposed pulmonary rehabilitation program in physiotherapy departments and pulmonary rehabilitation centers for patients with COPD.
2. Encourage healthcare professionals to incorporate respiratory muscle training and expiratory breathing exercises into routine COPD rehabilitation protocols.
3. Objective physiological measures such as FEV_1, arterial blood gas analysis (ABG), oxygen saturation, and respiratory rate were used to monitor patient progress during rehabilitation.
4. Promote early referral of patients with COPD to pulmonary rehabilitation programs to maximize functional and physiological benefits.
5. Increasing awareness among healthcare providers and patients regarding the importance of pulmonary rehabilitation in improving respiratory function and quality of life.
6. Conduct future studies using larger sample sizes and longer follow-up periods to evaluate the long-term efficacy of pulmonary rehabilitation programs.
7. The effects of similar rehabilitation programs on other pulmonary diseases, such as asthma, bronchiectasis, and interstitial lung diseases.
8. The effectiveness of combining pulmonary rehabilitation with advanced respiratory training devices and home-based rehabilitation programs.
9. Individualized rehabilitation protocols tailored to disease severity, age, functional status, and comorbidities of patients with COPD.
10. Encourage interdisciplinary collaboration among physiotherapists, pulmonologists, nurses, and respiratory therapists to optimize rehabilitation outcomes for COPD patients.

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