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The Effect of Pulmonary Rehabilitation on Echocardiographic Parameters and Quality of Life in Patients with Primary Lung Disease

ABSTRACT

Background: The authors aimed to evaluate the effects of pulmonary rehabilitation (PR) on respiratory and echocardiographic parameters in patients with primary lung disease.

Methods: This retrospective cohort study included 55 patients who were admitted to the authors' hospital between January 2018 and December 2019 with respiratory complaints, diagnosed with primary lung disease and underwent PR. Echocardiographic parameters, respiratory parameters, 6-minute walk distance (6-MWT), body mass index, Modified Medical Research Council (mMRC) dyspnea score, and quality of life measurement score values measured before and after PR were retrieved from the patient database.

Results: After PR, a significant improvement was observed in systolic pulmonary artery pressure (PABs), Tricuspid annular plane systolic excursion (TAPSE), TAPSE/PABs, and 6-minute walk test (6-MWT) compared to before PR. As the effectiveness of PR at quality of life was evaluated with the SF-36 test, improvement was found in all variables in the asthma group. However, a statistically significant improvement was found in parameters other than general health and pain in the chronic obstructive pulmonary disease (COPD) group.

Conclusion: Pulmonary rehabilitation in patients with chronic lung disease is associated with improvement in both respiratory and cardiac functions and quality of life.

Keywords: Pulmonary rehabilitation, echocardiography, right ventricular functions, chronic obstructive pulmonary disease, asthma

ORIGINAL INVESTIGATION

INTRODUCTION

Pulmonary rehabilitation (PR) is a treatment designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote long-term adherence to health-promoting behaviors. Pulmonary rehabilitation is a comprehensive intervention that includes individualized exercise training, education, and behavior modification following a thorough patient assessment.[1,2] Pulmonary rehabilitation has demonstrated physiological, symptom-reducing, psychosocial, and health economic benefits in multiple outcome areas for patients with chronic respiratory diseases (COPD,[3] interstitial lung disease,[4] bronchiectasis,[5] cystic fibrosis,[6] asthma,[7] pulmonary hypertension,[8] lung cancer,[9] lung volume reduction surgery,[10] and lung transplantation[11]).

Patients with chronic respiratory diseases experience disabling symptoms (including dyspnea and fatigue) and exercise intolerance have low physical activity levels and impaired quality of life. Pulmonary rehabilitation reduces patients' symptoms and improves limb muscle function, exercise capacity, emotional function, quality of life, knowledge, and self-efficacy. Pulmonary rehabilitation is implemented by a dedicated, interdisciplinary team, including physicians, and other health care professionals; the latter may include physiotherapists, respiratory therapists, nurses, psychologists, behavioral specialists, exercise physiologists, nutritionists, occupational therapists, and social workers.[1,2]

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Pulmonary rehabilitation programs (sessions) may be conducted in hospital, outpatient, or home settings. Most of the research has involved outpatient PR programs with 1 to 3 visits per week over a period of at least 8 weeks. The essential components of PR include an initial center-based assessment conducted by a healthcare professional, an exercise test performed at the time of assessment, a field exercise test, quality-of-life measurement, dyspnea assessment, evaluation of nutritional and occupational status, endurance and resistance training, an individually prescribed and progressively adjusted exercise program, and a multidisciplinary team that includes healthcare professionals experienced in exercise prescription and progression. Additionally, healthcare professionals must be adequately trained to deliver the components of the implemented rehabilitation model.[12]

Studies showed improvements in exercise capacity and some items of pulmonary function tests (PFT), Saint George Respiratory Questionnaire (SGRQ) scores, and BODE indexes of patients after PR programs.[13,14] Diaphragmatic thickness at the end of expiration also significantly improved after PR and was positively correlated with functional performance.[14]

Cardiac effects of PR are not well-known (except pulmonary hypertension) compared to the pulmonary effects of PR in patients with chronic respiratory disease. There is a limited number of studies on the cardiac effects of PR, and these studies were generally limited to the idiopathic pulmonary hypertension and chronic thromboembolic pulmonary hypertension groups. In these studies, the 6-minute walk distance (6-MWT), which is a mortality predictor of pulmonary hypertension and is used in the diagnosis and treatment of pulmonary hypertension, was utilized as the basic parameter.[15] In this study, the authors aimed to investigate the effects of PR on respiratory and echocardiographic parameters as well as health related quality of life in subjects with primary pulmonary disease.

METHOD

Study Design

This retrospective cohort study was conducted in accordance with the guidelines recommended in the Declaration of Helsinki. The present study was approved by an Institutional Review Board (29/4/2020/71). Artificial intelligence (AI)–assisted technologies (such as Large Language Models [LLMs], chatbots, or image generators) were not used at any stage of the presented study.

HIGHLIGHTS

- Pulmonary rehabilitation in patients with chronic lung disease is associated with improvement in both respiratory and cardiac functions and quality of life.
- After PR, significant improvement was found in PABs, TAPSE, TAPSE/PABs, and 6-MWT compared to before PR.
- When the effectiveness of PR at quality of life was evaluated with the SF-36 test, improvement was found in all variables in the asthma group.

Study Participants

We enrolled adult subjects who presented with respiratory symptoms to the chest diseases clinic secondary to primary lung disease and underwent PR between January 2018 and December 2019. Exclusion criteria were acute pulmonary embolism, acute pulmonary edema, and acute coronary syndrome. Patients who had a change in their medical treatment during the PR period were also excluded from the study (n=10). In addition, patients who did not undergo echocardiographic evaluation before and after respiratory physiotherapy were not included in the study (n=13). A total of 55 patients were included in the study.

Data Collection

Respiratory and echocardiographic data of the patients before and after PR were retrieved from the hospital electronic database.

Body mass index (BMI) was calculated using the formula of body weight (kg)/height^2 (m^2). Biochemical analyses were conducted on venous blood samples taken after 12 hours of fasting.

Echocardiography

Echocardiographic evaluation was performed before and after PR by the same operator with a Philips Vivid 3 device. Ejection fraction was calculated using the modified Simpson's method. Pulmonary arterial pressure was calculated using the peak velocity on the tricuspid valve in apical 4-chamber imaging. TAPSE was evaluated using M mode echocardiography in the lateral tricuspid annulus.

Pulmonary Function Testing

All patients performed a PFT (Cosmed Pony FX Desktop Spirometer—MIR Intermedical Spirolab Spirometer) according to American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines. Pulmonary function testings were forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), and FEV1/FVC.

Six-Minute Walk Test

The 6-MWT was performed in accordance with the ATS/ERS guidelines, and parameters such as dyspnea (mMRC scale), oxygen saturation (SpO_2), blood pressure, and pulse rate were measured at the beginning and end of the test. Each patient was asked to walk at his or her own pace to cover the maximum distance possible in the allotted time. The distance covered by the patient in 6 minutes was recorded and reported in meters.

Psychometric Evaluation

The Survey Short Form 36-item questionnaire (SF-36) was used to assess quality of life. Processing the answers of a participant comprises the calculation of 10 scores corresponding to 8 scales measuring several aspects of perceived health and 2 summary components (physical and mental). The Hospital Anxiety and Depression Scale (HADS) was used for detecting states of depression and anxiety in patients (HADS; scores range from 0 to 42, with higher scores indicating worse symptoms). The Asthma Control Test (ACT) was used to measure the control in asthma patients. The ACT is a patient-completed questionnaire and consists of

5 items evaluating different dimensions of asthma control over the preceding 4 weeks (limitation of activities, shortness of breath, awakenings at night, use of reliever medication, and own perception of asthma control). Each question has 5 response levels, resulting in scores of 1-5. The sum of all scores gives the total ACT score, ranging from 5 (poorest asthma control) to 25 (optimal asthma control). The COPD assesment test (CAT) was used to measure symptom control in COPD patients. There are 8 questions in total in the scale, which is scored as an increasing Likert scale between 0 and 5. The Turkish validity and reliability study of the scale was conducted by Yorgancıoglu et al[16] and reported to be appropriate.

Pulmonary Rehabilitation Program

The patients attended a structured, comprehensive PR program including 16 sessions over 8 weeks. Pulmonary rehabilitation program was institution-based and performed under the supervision of a qualified physiotherapist at a hospital. The PR program consisted of stretching of upper and lower extremity muscles, breathing exercises, supervised endurance and resistance training, self-management, and patient education. Breathing exercises lasted for 30 minutes in each session; diaphragmatic and pursed-lip breathing were performed on patients with COPD. A stationary cycle ergometer exercise was performed for 30 minutes, twice a week, to determine the training heart rate. The training heart rate was calculated using the results of the 6-MWT, according to the following formula: [(max HR − resting HR) × (60% or 70%)] + resting HR (moderate to high-intensity exercise training). The training was performed under the supervision of a physiotherapist, and the heart rate was monitored continuously.

Statistical Analysis

SPSS, version 17.0 (SPSS Inc., Chicago, Ill, USA) was used for performing all statistical analyses of the present study. A level of $P < .05$ was defined as statistically significant. One-sample Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the distribution of the data. Normally distributed continuous variables are defined as the mean and SD, and non-normally distributed continuous variables are defined as the median and interquartile range. Categorical variables are described as numbers and percentages. To compare sample characteristics before and after PR, paired t-tests and Wilcoxon Signed-Rank tests were conducted for normally distributed parameters and non-normally distributed parameters, respectively.

RESULTS

A total of 55 patients, 27 of whom were women, were included in the study. The mean age, height, weight, and BMI of the sample were 57.35 (±12.76), 161.95 (±9.48), 80.7 (±15.67), and 30.99 (±6.50), respectively. About 32 (58.18%) of the participants had asthma, and 23 (41.82%) had COPD. About 26 (47.3%) of the participants were active smokers. This table also presents the same features for both conditions (asthma and COPD) separately. While women are more frequent in the asthma group, men are more frequent in the COPD group. Active smoking is more common in the COPD group. Mean BMI was higher in the asthma group [33.14 (±7.13)] compared to the COPD group [27.99 (±3.97)] (Table 1).

Table 1. General Characteristics of the Study Population

Variables	Total = 55	Asthma, n (%) 32 (58.18%)	COPD, n (%) 23 (41.82%)
Gender (male/female) %	28 (50.9) / 27 (49.1)	6 (18.8) / 26 (81.2)	22 (95.7) / 1 (4.3)
Age (years)	57.35 (±12.76)	54.06 (±13.13)	61.91 (10.94)
Height (cm)	161.95 (±9.48)	158.25 (±9.52)	167.09 (6.74)
Weight (kg)	80.7 (±15.67)	82.47 (±17.48)	78.23 (±12.70)
BMI (kg/m^2)	30.99 (±6.50)	33.14 (±7.13)	27.99 (±3.97)
Cigarette smokers (n, %)	26 (47.3)	7 (21.9)	19 (82.6)
Cigarette (Pocket/year)	40 (35)	0 (0)	40 (35)

A statistically significant difference was found between the PABs, TAPSE, and TAPSE/PABs values of the population before and after PR (Table 2).

Improvement was observed in the PFT parameters of the patients. However, since these values were performed with different devices, the values were not included in the study.

A statistically significant difference was found between the 6-MWT, mMRC scale, ACT, physical function, physical roll

Table 2. Functional and Echocardiographic Parameters of the Entire Population Before and After Pulmonary Rehabilitation

Variables	Pre	Post	*P*
EF (%)	60 (0)	60 (0)	.439
PABs (mm Hg)	27.91 (±6.07)	23.67 (±3.60)	.006
TAPSE (mm)	21.64 (±5.75)	23.56 (±4.11)	<.001
TAPSE (mm)/sPAB (mm Hg)	0.81 ± 0.28	1.01 ± 0.24	<.001
6-MWT	407.29 (±106.79)	501.81 (±144.95)	<.001
mMRC scale	2 (1)	1 (2)	<.001
ACT (only Asthma)	16.53 (±3.93)	20.34 (±4.31)	<.001
SF-36 Physical function	59 (±24.24)	73.91 (±24.30)	<.001
SF-36 Physical roll function	6 (100)	75 (50)	<.001
SF-36 General health	41.84 (±24.94)	52.87 (±21.82)	.003
SF-36 Mental health	59.13 (±20.44)	75.42 (±15.27)	<.001
SF-36 Pain	74 (58)	100 (28)	.006
SF-36 Vitality	51.55 (±20.48)	67.91 (±16.77)	<.001
Anxiety	6.45 (±3.67)	4.85 (±3.60)	<.001
Depression	5.31 (±3.88)	3.42 (±3.36)	<.001

EF, Ejection Fraction, PABs, Systolic Pulmonary Artery Pressure, TAPSE, Tricuspid Annular Plane Systolic Excursion, mMRC, Modified Medical Research Council, 6-MWT, six-minute walk distance; SF-36, Short Form 36-item questionnaire.

Table 3. Functional and Echocardiographic Parameters of the Astma and COPD Groups Before and After Pulmonary Rehabilitation

	Asthma, n (%); 32 (58.18%)			COPD, n (%); 23 (41.82%)		
Variables	**Pre**	**Post**	***P***	**Pre**	**Post**	***P***
EF (%)	60 (5)	60 (5)	.405	60 (0)	60 (0)	.99
PABs (mm Hg)	28.06 ± 6.73	23.34 ± 4.29	<.001	27.70 ± 5.17	24.13 ± 2.34	.006
TAPSE (mm)	21.38 ± 5.59	23.63 ± 4.04	.023	22.00 ± 6.07	23.48 ± 4.31	.127
TAPSE (mm)/sPAB (mm Hg)	0.81 ± 0.29	1.04 ± 0.26	<.001	0.82 ± 0.26	0.98 ± 0.22	.006
6-MWT	396.06 ± 83.84	489.91 ± 134.15	<.001	431.64 ± 129.05	519.14 ± 161.02	<.001
mMRC scale	1.5 (1)	1 (1)	<.001	2 (2)	1 (2)	.004
ACT (only asthma)	16.53 ± 3.93	20.34 ± 4.31	<.001	–	–	–
SF-36 Physical function	45.41 ± 23.49	70.00 ± 25.37	.003	62.61 ± 25.31	79.35 ± 22.12	<.001
SF-36 Physical roll function	0 (100)	75 (50)	.006	50 (100)	100 (25)	.005
SF-36 General health	42.69 ± 24.87	57.13 ± 18.49	.002	40.65 ± 25.53	46.96 ± 24.98	.316
SF-36 Mental health	56.13 ± 21.71	74.75 ± 16.89	<.001	63.30 ± 18.16	76.35 ± 12.99	.003
SF-36 Pain	62 (47)	74 (38)	.007	100 (26)	100 (16)	.503
SF-36 Vitality	48.28 ± 21.08	67.81 ± 17.96	<.001	56.09 ± 19.13	68.04 ± 15.36	.009
Anxiety	7.09 ± 4.04	5.56 ± 3.93	.011	5.57 ± 2.92	3.87 ± 2.90	.004
Depression	5.69 ± 4.48	3.69 ± 3.69	.009	4.78 ± 2.86	3.04 ± 2.87	.018

EF, Ejection Fraction, PABs, Systolic Pulmonary Artery Pressure, TAPSE, Tricuspid Annular Plane Systolic Excursion, mMRC, Modified Medical Research Council, 6-MWT, six-minute walk distance; SF-36, Short Form 36-item questionnaire.

function, general health, mental health, pain, vitality, anxiety, and depression values of the population before and after PR (Table 2).

Meanwhile, the same statistics were made separately for each disease (asthma and COPD) (Table 3); in asthma patients, the results were similar to the entire population's results. However, in COPD patients, there was a statistically significant difference between pre- and post-PR values of PABs, TAPSE/PABs, 6-MWT, mMRC scale, physical function, physical roll function, mental health, vitality, anxiety, and depression. In contrast, in COPD patients, EF, TAPSE, general health, and pain were not statistically significantly different before and after the PR.

DISCUSSION

This multidisciplinary study has shown that PR improves echocardiographic parameters as well as health-related quality of life in subjects with primary pulmonary disease and may be a potential approach to prevent the development of pulmonary hypertension in such patients. In this study, 16 sessions of PR over 8 weeks were applied to patients who were symptomatic despite optimal asthma or COPD treatment. Physical and psychosocial parameters and cardiac functions were evaluated before and after PR. The echocardiographic evaluation of the cardiac effects of PR distinguishes this study from other studies.

In this study, the 6-MWT, which is one of the important parameters used in the follow-up and treatment of pulmonary hypertension, improved significantly after PR. This improvement is statistically significant in both asthma and COPD groups. When PR efficacy was evaluated with the SF-36 test, improvement was observed in all variables in the asthma group. However, this level of efficacy was not achieved in the COPD group. These results may be related to the higher disease awareness and treatment adherence in the asthma patient group. The BMI of the asthma group is higher than that of the COPD group. This may explain the greater improvement in poor quality of life in the asthma group. The study concluded after 8 weeks of PR. However, increased physical activity and improved mental well-being following PR are expected to lead to weight loss, suggesting that long-term improvements may be even more pronounced—especially in the asthma group with a higher BMI. In overweight patients with asthma, neutrophilic inflammation has been shown to be more pronounced, which may be mitigated by weight loss and exercise.[17] Although asthmatic patients might display a slightly lower baseline exercise capacity, this difference is generally not significant, and those with lower exercise capacity may experience a relatively greater benefit from PR.[1] Moreover, the typically younger age and better treatment and exercise compliance in asthmatic patients may further enhance PR outcomes.

In contrast, many COPD patients experience exercise-induced desaturation, which can negatively affect exercise capacity and increase pulmonary vascular resistance during exertion.[18] Exercise training itself appears to improve right heart function through mechanisms such as myocardial remodeling, increased capillarization, and reduced systemic inflammation.[19] However, because COPD is a chronic and progressive disease, the development of right heart dysfunction in these patients is often long-standing and irreversible. This may explain the less pronounced improvement in right ventricular function in response to short-term PR.[20] Additionally, respiratory exercises in PR can improve oxygenation and indirectly benefit right heart performance, while enhanced peripheral muscle strength may facilitate better capillarization and venous return.[19,20] Moderate-to-high-intensity exercise training has also been associated with increased endurance by delaying the onset of lactic acidosis, thereby reducing acidosis and hypercapnia—all of which favorably impact right heart pressures.[21]

There is limited research on the cardiac effects of PR. There is controversy regarding the effects of exercise in patients with severe pulmonary hypertension. In the past, some physicians have even recommended avoiding physical exercise in this patient group.[19,22] However, studies on patient coronary artery disease and severe left heart failure have shown that exercise has positive effects on endothelial function, exercise capacity, and quality of life.[8,23,24] Improvements in functional capacity and respiratory functions were demonstrated with a medically supervised treadmill program in group 1 pulmonary hypertension patients.[25] In a multicenter study evaluating the effects of exercise training in PAH/CTEPH patients, improvements were observed in 6-MWT, quality of life, WHO functional class, and peak oxygen consumption during exercise after exercise programs conducted both in and out of the hospital.[26]

In this study, no change was observed in left heart functions after PR, which is consistent with other studies. However, after PR, sPAB decreased, and TAPSE and TAPSE/sPAB ratios increased. This is an indicator of improvement in right ventricular functions after PR. Since right ventricular longitudinal contraction provides 80% of right ventricular function, TAPSE is an important marker in the assessment of right ventricular function.[27] However, the geometry of the right ventricle is relatively difficult to understand compared to the symmetrical left ventricle. Therefore, the incorporation of echocardiographic parameters other than TAPSE and systolic pulmonary artery pressure, and the use of cardiac MR into the clinical practice should be accelerated.[28] There are studies evaluating the effects of PR on right ventricular function with different imaging modalities. In a study examining the effects of PR on right heart function using cardiac MRI, a significant reduction in patients' dyspnea complaints was observed after PR, while a slight reduction in RV GLS and RV mass was observed.[29] In another study investigating the effects of intensive endurance exercise in athletes, a decrease in RV fractional area change and tricuspid annular plane systolic excursion was observed following intensive exercise.[30] It is widely accepted that the cardiac effects of PRare related to exercise intensity. However, there is no consensus on the exercise program to be applied according to the severity of the disease and the type of disease.

The mechanism of the beneficial effects of PR on pulmonary hypertension PABs and TAPSE is not fully understood. There are some theories regarding the mechanism of action of PR on pulmonary hypertension. Improvement in exercise capacity after PR was associated with regression in muscle atrophy, improvement in muscular metabolism, and gas exchange. However, the improvement in ventilation capacity also has an effect on this process.[31] It has been stated that it is associated with changes in inflammatory mediators, endothelial nitric oxide synthase activity, and decreased vascular oxidative stress in this patient group.[31]

Study Limitations

The limited number of patients included in this study and the absence of a control group limit the impact of the study on clinical practice. However, considering the positive results of PR, the presence of a control group that did not receive PR would cause ethical problems. Pulmonary function tests were performed before and after PR in the patients who participated in this study, and improvement was observed in the PFT parameters of the patients. However, since these values were performed with different devices, the values were not included in the study. The possible positive effects of weight loss in patients during the PR process could not be evaluated.

Another limitation is that the PR intensity applied in the study could not be classified and the cardiac effects of PR intensity were not evaluated. In addition, the fact that fractional area change was not calculated in the evaluation of right ventricular function in patients represents another limitation of the study. Moreover, there were no Brain Natriuretic Peptide measurements in this study.

CONCLUSION

In patients with primary lung disease, a significant improvement was achieved in the pulmonary, cardiac, physical, and psychological functions of the patients with PR.

Ethics Committee Approval: This study was conducted in accordance with the rules recommended in the Declaration of Helsinki and approved by the Ethics Committee of Balıkesir University Faculty of Medicine (Approval No: 71, Date: 29.4.2020).

Informed Consent: Written informed consent was obtained from the patients who agreed to participate in the study.

Peer-review: Externally peer reviewed.

Author Contributions: Concept – D.E.A., O.S., F.E., S.S.O.; Design – E.A., O.S., F.E.; Supervision – E.A., A.N.; Resources – D.E.A., O.S., A.N.; Materials – D.E.A., O.S., F.E., S.S.O.; Data Collection and/or Processing – D.E.A., O.S., F.E., S.S.O.; Analysis and/or Interpretation – D.E.A., O.S., S.S.O.; Literature Search – D.E.A., O.S., S.S.O., A.N.; Writing – D.E.A., O.S., S.S.O., A.N.; Critical Review – D.E.A., O.S., S.S.O., A.N., E.A., F.E.

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REFERENCES

1. Spruit MA, Singh SJ, Garvey C, et al. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *Am J Respir Crit Care Med*. 2013;188(8):e13-e64. [CrossRef]
2. Rochester CL, Vogiatzis I, Holland AE, et al. An official American Thoracic Society/European Respiratory Society policy statement: enhancing implementation, use, and delivery of pulmonary rehabilitation. *Am J Respir Crit Care Med*. 2015;192(11):1373-1386. [CrossRef]
3. Arnold MT, Dolezal BA, Cooper CB. Pulmonary rehabilitation for chronic obstructive pulmonary disease: highly effective but

often overlooked. *Tuberc Respir Dis (Seoul)*. 2020;83(4):257-267. [CrossRef]
4. Dowman L, Hill CJ, Holland AE. Pulmonary rehabilitation for interstitial lung disease. *Cochrane Database Syst Rev*. 2014;10:CD006322. [CrossRef]
5. Lee AL, Hill CJ, McDonald CF, et al. The short- and long-term effects of exercise training in non–cystic fibrosis bronchiectasis: a randomized controlled trial. *Respir Res*. 2014;15(1):1-10. [CrossRef]
6. Kriemler S, Kieser S, Junge S, et al. Effect of supervised training on FEV1 in cystic fibrosis: a randomised controlled trial. *J Cyst Fibros*. 2013;12(6):714-720. [CrossRef]
7. Osadnik CR, McDonald VM, Jones AP, et al. Pulmonary rehabilitation versus usual care for adults with asthma. *Cochrane Database Syst Rev*. 2022;8(8):CD013434. [CrossRef]
8. Chan L, Chin LMK, Kennedy M, et al. Benefits of intensive treadmill exercise training on cardiorespiratory function and quality of life in patients with pulmonary hypertension. *Chest*. 2013;143(2):333-343. [CrossRef]
9. Morano MT, Araújo AS, Nascimento FB, da Silva GF, Mesquita R, Pereira ED. Preoperative pulmonary rehabilitation versus chest physical therapy in patients undergoing lung cancer resection: a pilot randomized controlled trial. *Arch Phys Med Rehabil*. 2013;94(1):53-58. [CrossRef]
10. Granger CL, McDonald CF, Berney S, Chao C, Denehy L. Safety and feasibility of an exercise intervention for patients following lung resection: a pilot randomized controlled trial. *Integr Cancer Ther*. 2013;12(3):213-224. [CrossRef]
11. Gloeckl R, Halle M, Kenn K. Interval versus continuous training in lung transplant candidates: a randomized trial. *J Heart Lung Transplant*. 2012;31(9):934-941. [CrossRef]
12. Zhang Z, Tian Y, Yang J. Effects of pulmonary rehabilitation therapy combined with conventional drugs on BODE and pulmonary function indexes in elderly patients with interstitial pneumonia. *Pak J Med Sci*. 2022;38(6):1703-1707. [CrossRef]
13. Güneş S, Genç A, Aytür YK, Çiftçi F, Hayme S, Kaya A. Effects of pulmonary rehabilitation on diaphragm thickness and contractility in patients with chronic obstructive pulmonary disease. *Turk J Med Sci*. 2022;52(1):89-96. [CrossRef]
14. Miyamoto S, Nagaya N, Satoh T, et al. Clinical correlates and prognostic significance of six-minute walk test in patients with primary pulmonary hypertension: comparison with cardiopulmonary exercise testing. *Am J Respir Crit Care Med*. 2000;161(2 Pt 1):487-492. [CrossRef]
15. Yorgancıoğlu A, Polatlı M, Aydemir Ö, et al. Reliability and validity of Turkish version of COPD assessment test. *Tuberk Toraks*. 2012;60(4):314-320. [CrossRef]
16. Badesch DB, Abman SH, Ahearn GS, et al. Medical therapy for pulmonary arterial hypertension: ACCP evidence-based clinical practice guidelines. *Chest*. 2004;126(1 Suppl):35S-62S. [CrossRef]
17. Telenga ED, Tideman SW, Kerstjens HA, et al. Obesity in asthma: more neutrophilic inflammation as a possible explanation for a reduced treatment response. *Allergy*. 2012;67(8):1060-1068. [CrossRef]
18. Christensen CC, Ryg MS, Edvardsen A, Skjønsberg OH. Relationship between exercise desaturation and pulmonary haemodynamics in COPD patients. *Eur Respir J*. 2004;24(4):580-586. [CrossRef]
19. Hambrecht R, Wolf A, Gielen S, et al. Effect of exercise on coronary endothelial function in patients with coronary artery disease. *N Engl J Med*. 2000;342(7):454-460. [CrossRef]
20. Hilde JM, Skjørten I, Grøtta OJ, et al. Right ventricular dysfunction and remodeling in chronic obstructive pulmonary disease without pulmonary hypertension. *J Am Coll Cardiol*. 2013;62(12):1103-1111. [CrossRef]
21. Atakan MM, Li Y, Koşar ŞN, Turnagöl HH, Yan X. Evidence-based effects of high-intensity interval training on exercise capacity and health: a review with historical perspective. *Int J Environ Res Public Health*. 2021;18(13):7201. [CrossRef]
22. Gaine SP, Rubin LJ. Primary pulmonary hypertension. *Lancet*. 1998;352(9129):719-725. [CrossRef]
23. Hambrecht R, Fiehn E, Weigl C, et al. Regular physical exercise corrects endothelial dysfunction and improves exercise capacity in patients with chronic heart failure. *Circulation*. 1998;98(24):2709-2715. [CrossRef]
24. Hornig B, Maier V, Drexler H. Physical training improves endothelial function in patients with chronic heart failure. *Circulation*. 1996;93(2):210-214. [CrossRef]
25. Grünig E, MacKenzie A, Peacock AJ, et al. Standardized exercise training is feasible, safe, and effective in pulmonary arterial and chronic thromboembolic pulmonary hypertension: results from a large European multicentre randomized controlled trial. *Eur Heart J*. 2021;42(23):2284-2295. [CrossRef]
26. Gleditsch J, Jervan Ø, Haukeland-Parker S, et al. Effects of pulmonary rehabilitation on cardiac magnetic resonance parameters in patients with persistent dyspnea following pulmonary embolism. *Int J Cardiol Heart Vasc*. 2022;40:100995. [CrossRef]
27. Aloia E, Di Maio M, De Caterina AR, et al. TAPSE: an old but useful tool in different diseases. *Int J Cardiol*. 2016;225:177-183. [CrossRef]
28. Albert RK, Spiro SG, Jett JR. *Clinical Respiratory Medicine: Expert Consult—Online and Print*. Philadelphia, PA: Elsevier Health Sciences; 2008.
29. La Gerche A, Connelly KA, Mooney DJ, MacIsaac AI, Prior DL. Biochemical and functional abnormalities of left and right ventricular function after ultra-endurance exercise. *Heart*. 2008;94(7):860-866. [CrossRef]
30. Coats AJ, Adamopoulos S, Radaelli A, et al. Controlled trial of physical training in chronic heart failure. Exercise performance, hemodynamics, ventilation, and autonomic function. *Circulation*. 1992;85(6):2119-2131. [CrossRef]
31. Kojda G, Cheng YC, Burchfield J, Harrison DG. Dysfunctional regulation of endothelial nitric oxide synthase (eNOS) expression in response to exercise in mice lacking one eNOS gene. *Circulation*. 2001;103(23):2839-2844. [CrossRef]