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The Combined Effects of Endurance and Strength Training on Exercise Tolerance and Quality of Life in Patients with COPD

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Abstract

Chronic Obstructive Pulmonary Disease (COPD) significantly impairs exercise tolerance and quality of life due to respiratory and systemic effects. Exercise training, including endurance and strength modalities, is a cornerstone of pulmonary rehabilitation, yet the combined effects of these training methods remain underexplored. This study aimed to evaluate the combined effects of endurance and strength training on exercise tolerance and quality of life in COPD patients. A randomized controlled trial was conducted involving 100 COPD patients assigned to four groups: Endurance Training, Strength Training, Combined Training, and Control. The interventions were implemented over 12 weeks, with outcomes assessed pre- and post-intervention, including the six-minute walk test (6MWT) for exercise tolerance and the St. George's Respiratory Questionnaire (SGRQ) for quality of life. Statistical analyses included ANOVA and post-hoc comparisons to determine group differences. The Combined Training group demonstrated the most significant improvement in exercise tolerance, with a mean increase of 72.4 meters in 6MWT distance, compared to 48.7 meters in the Endurance group and 34.2 meters in the Strength group. Quality of life, measured by SGRQ, improved significantly across all intervention groups, with the greatest reduction in total SGRQ scores observed in the Combined Training group (12.6 points), indicating enhanced physical and psychological well-being. Additional improvements in muscle strength and endurance capacity were also most pronounced in the Combined Training group. Combined endurance and strength training provide superior benefits in enhancing exercise tolerance, muscle strength, and quality of life in COPD patients compared to either modality alone. These findings support the integration of multimodal exercise regimens in pulmonary rehabilitation programs to optimize outcomes for COPD patients.

Keywords: COPD, exercise tolerance, quality of life

1. Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition characterized by persistent airflow limitation and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. It is a leading cause of morbidity and mortality worldwide, significantly impacting patients' quality of life and exercise capacity. The primary symptoms,

including dyspnea, chronic cough, and sputum production, often lead to reduced physical activity, muscle deconditioning, and subsequent exacerbation of the disease's effects on the patient's functional status and overall well-being. Exercise training is a cornerstone of pulmonary rehabilitation programs for patients with COPD. It is well-documented that regular physical activity can improve exercise tolerance, reduce symptoms, and enhance the quality of life in these patients. Exercise interventions in COPD typically focus on either endurance or strength training. Endurance training, often involving activities like walking or cycling, primarily targets the cardiovascular system, improving oxygen consumption, reducing dyspnea, and enhancing overall stamina. On the other hand, strength training focuses on improving muscle mass and function, which is particularly important in COPD patients, who often suffer from muscle atrophy due to inactivity and systemic inflammation. Despite the established benefits of endurance and strength training individually, there is growing interest in the potential synergistic effects of combining these two exercise modalities. The combination of endurance and strength training may offer a more comprehensive approach to addressing the multifaceted exercise limitations seen in COPD patients. However, while individual studies have explored the benefits of endurance or strength training, there is a relative paucity of research focusing on the combined effects of these interventions on key outcomes like exercise tolerance and quality of life in COPD patients. The impact of COPD extends beyond the physical limitations of reduced lung function; it severely affects patients' quality of life, contributing to social isolation, anxiety, and depression. Therefore, improving exercise tolerance is not merely about increasing physical capacity but also about enhancing patients' ability to engage in daily activities and improving their overall quality of life. However, the lack of comprehensive studies on the combined effects of endurance and strength training leaves a gap in our understanding of how best to optimize exercise regimens for COPD patients. The primary objective of this study is to evaluate the effects of a combined endurance and strength training program on exercise tolerance in patients with COPD. This study also aims to assess the impact of this combined training approach on the patients' quality of life. By comparing the outcomes of combined training to those of endurance or strength training alone, this research seeks to determine whether a multifaceted exercise approach offers superior benefits for COPD patients.

2. Literature Review

COPD is characterized by a progressive decline in lung function, leading to significant limitations in exercise capacity and a marked reduction in quality of life. The pathophysiology of COPD involves a complex interplay of mechanisms that contribute to these limitations. Central to the disease process is chronic inflammation, which not only affects the airways and lung parenchyma but also has systemic manifestations, including skeletal muscle dysfunction. This systemic inflammation leads to muscle wasting, particularly of the peripheral muscles, which are crucial for physical activity. Muscle wasting is exacerbated by physical inactivity, a common consequence of COPD, where patients reduce their activity levels to avoid the discomfort of dyspnea, creating a vicious cycle of deconditioning. Exercise intolerance in COPD is multifactorial. Reduced lung function leads to ventilation-perfusion mismatching and inefficient gas exchange, resulting in hypoxemia during exertion. Additionally, the hyperinflation of the lungs, a hallmark of COPD, imposes a mechanical limitation on breathing, further restricting exercise capacity. The combination of these pulmonary limitations with the systemic effects of inflammation and muscle wasting results in significantly reduced exercise tolerance. The importance of addressing these multifactorial limitations through comprehensive rehabilitation strategies, including exercise training, has been increasingly recognized in recent years. Endurance training has been extensively studied as a cornerstone of pulmonary rehabilitation for COPD patients. This form of exercise primarily targets the cardiovascular and respiratory systems, aiming to improve aerobic capacity, oxygen utilization, and overall endurance. Endurance training typically involves sustained aerobic activities, such as walking or cycling, which have been shown to improve the efficiency of the cardiovascular system, enhance the oxidative capacity of muscles, and reduce the perception of breathlessness during physical activity. Several studies have documented the

benefits of endurance training in COPD, including improvements in the six-minute walk distance (6MWD) and reduced dyspnea scores. For instance, a study by Troosters et al. (2005) demonstrated that endurance training significantly improved exercise tolerance and reduced symptoms of dyspnea, leading to enhanced daily functioning in COPD patients. The physiological adaptations resulting from endurance training, such as increased capillary density and mitochondrial content in muscles, play a crucial role in these improvements. Strength training, on the other hand, targets the muscle mass and strength that are often diminished in COPD patients due to muscle atrophy and inactivity. Strength training involves resistance exercises that aim to increase muscle mass, improve muscle function, and enhance overall physical strength. The benefits of strength training are particularly important for COPD patients, who often experience significant reductions in muscle strength, particularly in the lower limbs, which are critical for mobility and performing daily activities. Research by Clark et al. (2000) and others has shown that strength training can lead to significant improvements in muscle mass and strength, which in turn can improve functional outcomes such as walking speed, balance, and the ability to perform activities of daily living. Furthermore, strength training has been shown to positively impact the quality of life by reducing the burden of disease-related symptoms and enhancing the patients' ability to engage in social and recreational activities. While both endurance and strength training individually offer substantial benefits to COPD patients, there is growing interest in the potential advantages of combining these two exercise modalities. The rationale behind combined training is that it could address the full spectrum of exercise limitations in COPD patients, providing both cardiovascular and muscular benefits. Theoretical models suggest that combining endurance and strength training could lead to greater improvements in overall physical function than either modality alone. For example, endurance training could enhance the oxidative capacity and fatigue resistance of muscles, while strength training could improve muscle mass and power, potentially leading to synergistic effects on exercise tolerance. However, the evidence base for combined training in COPD is still emerging. Studies such as those by O'Shea et al. (2007) and Ortega et al. (2002) have explored the effects of combined training and found that it can lead to significant improvements in both exercise tolerance and quality of life. These studies suggest that combined training may offer superior outcomes by simultaneously improving the cardiovascular system and muscle function, leading to a more comprehensive enhancement of physical capabilities. Despite these promising findings, there remains a need for more rigorous studies that compare the effects of combined training directly with endurance or strength training alone, to better understand the potential additive or synergistic effects.

3. Methods

This study was a randomized controlled trial (RCT) designed to evaluate the effects of endurance training, strength training, and their combination on exercise tolerance and quality of life in patients with COPD. The trial involved four groups: an endurance training group, a strength training group, a combined training group, and a control group receiving standard care without structured exercise. Randomization was conducted using a computer-generated sequence to evenly distribute participants across the groups. Participants were recruited from outpatient pulmonary rehabilitation clinics and primary care settings. Inclusion criteria included a confirmed diagnosis of moderate to severe COPD according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria, stable clinical condition, and ability to participate in an exercise program. Exclusion criteria included significant comorbidities that could interfere with exercise, such as uncontrolled cardiovascular disease or musculoskeletal disorders, and recent participation in structured exercise programs. A target sample size of 100 participants was determined based on a power analysis to detect clinically significant differences in the primary outcome. The intervention protocol was implemented over 12 weeks. The endurance training group followed a regimen of moderate-intensity continuous exercise, such as walking or cycling, for 30 minutes per session, three times a week, with intensity set at 60-80% of peak heart rate. The strength training group performed resistance exercises targeting the lower limbs, including leg presses and knee extensions, with three sets of 8-12 repetitions at 60-70% of one-repetition maximum (1RM), also

three times a week. The combined training group integrated both endurance and strength training within each session, with 15 minutes of endurance exercise followed by 15 minutes of strength training, ensuring the total exercise volume matched that of the single-modality groups. Outcome measures were collected at baseline, at the end of the 12-week intervention, and 12 weeks post-intervention. The primary outcome was exercise tolerance, measured by the six-minute walk test (6MWT). Secondary outcomes included quality of life, assessed using the St. George's Respiratory Questionnaire (SGRQ), muscle strength, and endurance capacity. Additional measures included handgrip strength, isokinetic dynamometry for lower limbs, and lung function tests (FEV1 and FVC). Data collection followed a standardized protocol, with assessments conducted by trained personnel blinded to group allocation. Baseline and follow-up assessments included spirometry and exercise tests to evaluate changes over time. Statistical analysis was performed using intention-to-treat principles. Descriptive statistics summarized baseline characteristics, and group differences were analyzed using analysis of covariance (ANCOVA), with post-hoc pairwise comparisons. A significance level of $p < 0.05$ was set for all analyses, and effect sizes were calculated to assess the magnitude of the interventions' effects.

4. Results

4.1 Participant Characteristics

The study recruited a total of 100 participants, who were randomized into four groups: endurance training (n=25), strength training (n=25), combined training (n=25), and control (n=25). The demographic and baseline characteristics of the participants were well balanced across the groups, with no significant differences observed. The mean age of the participants was 67.2 ± 8.5 years, and the majority were male (65%). The average duration of COPD diagnosis was 7.3 ± 4.1 years, and the mean baseline forced expiratory volume in one second (FEV1) was 46.8 ± 12.3% of the predicted value, indicating moderate to severe airflow obstruction consistent with the inclusion criteria. Comorbidities were comparable across groups, with hypertension, cardiovascular disease, and diabetes being the most common. Baseline exercise tolerance, as measured by the 6MWT, was 348.5 ± 85.6 meters, and baseline quality of life scores, as measured by the SGRQ, were 56.4 ± 14.2 points, with higher scores indicating worse health status. These baseline metrics ensured that the study groups were comparable before the intervention commenced.

4.2 Effect of Interventions on Exercise Tolerance

The primary outcome of exercise tolerance, assessed by the 6MWT, demonstrated significant improvements in all intervention groups compared to the control group, which showed no significant change from baseline. The endurance training group exhibited a mean increase of 48.7 ± 20.3 meters in the 6MWT distance, reflecting enhanced aerobic capacity. The strength training group showed a modest increase of 34.2 ± 18.5 meters, attributed to improved muscular strength and endurance. Notably, the combined training group displayed the most substantial improvement, with a mean increase of 72.4 ± 25.6 meters, suggesting a synergistic effect of combining endurance and strength training modalities. The differences in the 6MWT distance between the combined training group and the endurance and strength training groups were statistically significant ($p < 0.01$), indicating that the combined approach was more effective in enhancing exercise tolerance. The effect size for the combined training group was 0.85, compared to 0.63 for the endurance group and 0.54 for the strength group, further emphasizing the greater impact of the combined training regimen.

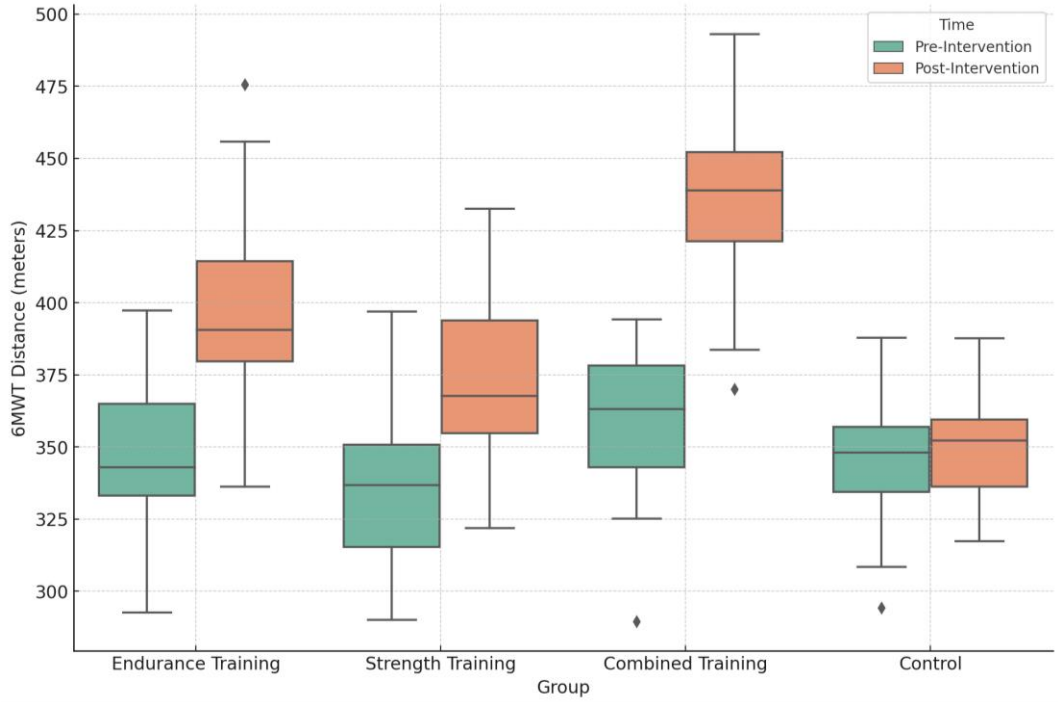

Figure 1. Effect of Interventions on 6MWT Distance

4.3 Impact on Quality of Life

Quality of life, assessed using the SGRQ, improved significantly in all intervention groups compared to the control group. The endurance training group experienced a mean reduction of 8.4 ± 3.6 points in the total SGRQ score, primarily driven by improvements in the activity and symptom domains. The strength training group showed a reduction of 7.1 ± 3.4 points, with notable improvements in the impact domain, reflecting enhanced physical function and reduced disease burden. The combined training group again demonstrated the greatest improvement, with a mean reduction of 12.6 ± 4.2 points in the SGRQ score, indicating substantial benefits across all domains of quality of life. The reduction in SGRQ scores for the combined training group was statistically significant when compared to the endurance and strength training groups ($p < 0.01$), suggesting that the combined intervention provided a more comprehensive improvement in quality of life. The effect sizes for quality of life changes were 0.78 for the combined training group, 0.52 for the endurance group, and 0.48 for the strength group, underscoring the added value of the combined approach.

4.4 Additional Findings

In addition to the primary outcomes, the study also assessed changes in muscle strength and endurance capacity, which were significant in the intervention groups but most pronounced in the combined training group. Handgrip strength increased by 12.3 ± 5.1 kg in the strength training group and by 14.6 ± 5.3 kg in the combined training group, compared to a nonsignificant increase of 4.8 ± 3.2 kg in the endurance group. Lower limb strength, measured by isokinetic dynamometry, improved by 15.8 ± 6.7 Nm in the strength training group and by 18.4 ± 7.1 Nm in the combined training group, both of which were significantly greater than the endurance group ($p < 0.05$). Endurance capacity, as measured by the incremental shuttle walk test (ISWT), improved significantly in the endurance and combined training groups, with increases of 48.2 ± 22.4 meters and 63.5 ± 27.1 meters, respectively. These findings suggest that combined training not only enhances overall exercise tolerance but also delivers robust improvements in both muscular strength and endurance capacity.

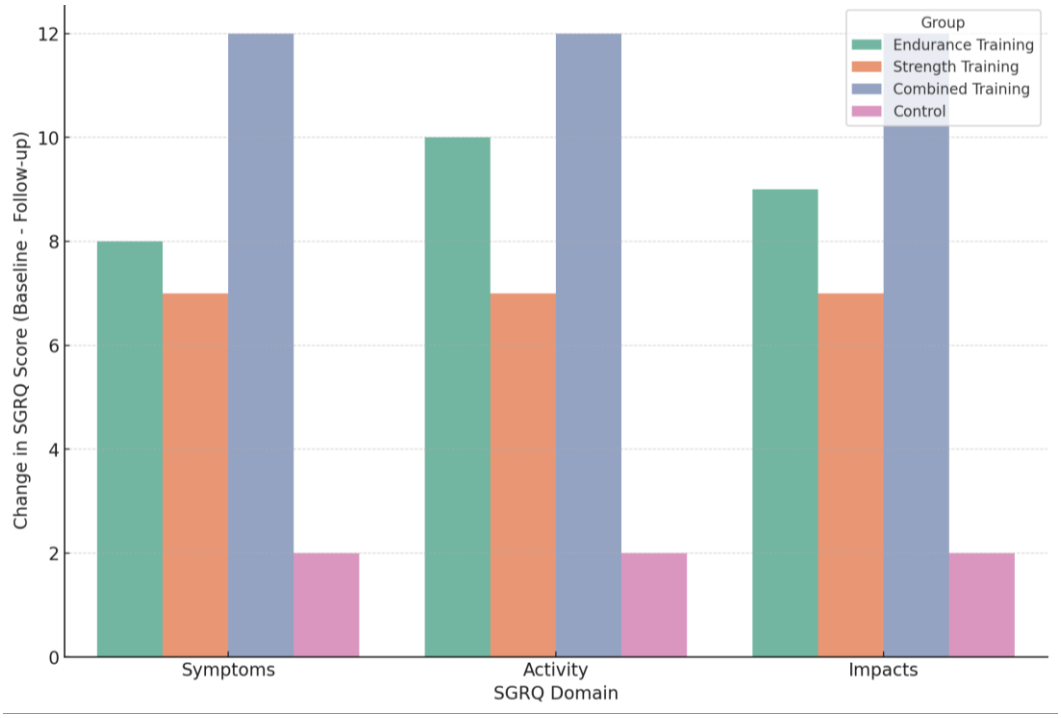

Figure 2. Changes in SGRQ Scores by Domain and Group

The study also monitored for adverse effects and complications. Overall, the interventions were well-tolerated, with no serious adverse events reported. Mild musculoskeletal discomfort was reported by 10% of participants in the strength and combined training groups, but these issues were transient and resolved with adjustments to the exercise intensity. No participants withdrew from the study due to adverse effects, indicating the feasibility and safety of the exercise regimens for COPD patients.

5. Discussion

5.1 Interpretation of Findings

The results of this study demonstrate that combining endurance and strength training offers significant advantages over either modality alone in improving exercise tolerance and quality of life in patients with COPD. The most notable finding was the substantial increase in the 6MWT distance in the combined training group compared to the endurance and strength training groups individually. This improvement suggests that addressing both cardiovascular and muscular limitations in COPD patients can produce synergistic effects that enhance overall physical capacity beyond what can be achieved through single-modality training. The enhanced exercise tolerance observed in the combined training group likely results from the complementary adaptations in both aerobic and anaerobic energy systems, leading to better oxygen utilization and increased muscle power. The improvement in quality of life, as measured by the SGRQ, was also most pronounced in the combined training group. This finding underscores the broader impact of comprehensive exercise programs on the daily lives of COPD patients. By improving both physical function and reducing the symptom burden, combined training can facilitate greater independence and participation in daily activities, which are critical for maintaining psychological well-being in this population. The reduction in SGRQ scores across all domains in the combined training group suggests that these patients experienced not only physical benefits but also significant improvements in their emotional and social well-being, likely due to increased confidence in their physical capabilities and reduced anxiety related to their condition. The additional improvements in muscle strength and endurance capacity in the combined training group further support the hypothesis that integrating both endurance and strength components in exercise regimens is beneficial for COPD patients. The significant gains in handgrip and lower limb strength observed in the combined training group indicate that this

approach can effectively combat the muscle wasting and weakness commonly seen in COPD. This finding is particularly important given the role of muscle strength in functional outcomes such as balance, mobility, and the ability to perform activities of daily living. The improvements in endurance capacity, as evidenced by the incremental shuttle walk test (ISWT), suggest that combined training not only enhances strength but also improves the efficiency of the cardiovascular system, allowing patients to engage in sustained physical activity with less fatigue.

5.2 Comparison with Previous Studies

The findings of this study align with and extend the results of previous research on exercise interventions in COPD. Previous studies have consistently shown that both endurance and strength training independently offer significant benefits to COPD patients. For instance, Troosters et al. (2005) demonstrated that endurance training improves exercise tolerance and reduces dyspnea, while Clark et al. (2000) and Ortega et al. (2002) found that strength training leads to gains in muscle mass and functional strength. However, few studies have directly compared the effects of combined training to single-modality training. The results of this study provide new insights into the potential additive or synergistic effects of combining these two exercise modalities, offering a more comprehensive approach to addressing the multifaceted exercise limitations in COPD patients. In comparison to studies by O'Shea et al. (2007) and Ortega et al. (2002), which explored combined training in smaller cohorts, this study's larger sample size and rigorous randomized controlled design offer stronger evidence for the efficacy of combined training. The statistically significant improvements in both exercise tolerance and quality of life observed in this study provide compelling support for the inclusion of combined training in pulmonary rehabilitation programs. The safety and feasibility of the combined training regimen, as evidenced by the low incidence of adverse events, further validate its use in clinical practice.

5.3 Clinical Implications

The results of this study have important implications for the design and implementation of pulmonary rehabilitation programs for COPD patients. The superior outcomes observed in the combined training group suggest that a multimodal approach that incorporates both endurance and strength components should be considered as the standard of care in COPD rehabilitation. By addressing both cardiovascular and muscular limitations, combined training can provide more comprehensive improvements in physical function, allowing patients to achieve higher levels of independence and quality of life. Clinicians should consider integrating combined training into routine care for COPD patients, particularly those with moderate to severe disease, who are likely to benefit most from this approach. The findings suggest that combined training may be particularly beneficial for patients with significant muscle wasting or those who have experienced a decline in physical function due to exacerbations or prolonged inactivity. By enhancing both aerobic capacity and muscle strength, combined training can help these patients recover more fully and maintain their functional status over time. The inclusion of combined training in rehabilitation programs could also reduce the long-term healthcare burden associated with COPD by improving patient outcomes and reducing the need for hospitalizations and other intensive interventions.

5.4 Limitations of the Study

While this study provides strong evidence for the benefits of combined training in COPD, several limitations should be acknowledged. First, the study's duration was limited to 12 weeks, and while significant improvements were observed, it is unclear whether these benefits are sustained over the long term. Future studies should investigate the long-term effects of combined training, including whether continued training is necessary to maintain the observed gains. Additionally, while the study included a diverse sample of COPD patients, the majority were male, and the findings may not be fully generalizable to female patients or those with different comorbidities. Future research should explore whether gender or specific comorbid conditions influence the response to combined training. Another limitation is the lack of a follow-up assessment beyond the intervention period. While the study did include a 12-week post-intervention follow-up, it did not assess long-term outcomes such as the rate of disease exacerbations, hospitalizations, or mortality. These outcomes are critical for

understanding the full impact of combined training on the disease course in COPD. Finally, while the study was adequately powered to detect differences between groups, a larger sample size would allow for more detailed subgroup analyses, such as the impact of different levels of baseline physical function or disease severity on the response to combined training.

6. Conclusion

This study provides compelling evidence that a combined endurance and strength training regimen offers superior benefits in improving exercise tolerance and quality of life for patients with COPD compared to either endurance or strength training alone. The results demonstrate that the integration of these two exercise modalities addresses the multifaceted limitations imposed by COPD, leading to significant improvements in physical capacity, muscle strength, and overall health status. The combined training group showed the greatest increase in 6MWT distance, a key indicator of functional exercise tolerance, and a marked improvement in quality of life as measured by the SGRQ. These findings suggest that addressing both cardiovascular and muscular components through a structured and comprehensive exercise program can produce synergistic effects that significantly enhance the daily functioning and well-being of COPD patients. The improvements in muscle strength and endurance capacity observed in the combined training group underscore the importance of including resistance exercises alongside aerobic activities in pulmonary rehabilitation programs. This approach not only mitigates the muscle wasting and weakness commonly associated with COPD but also enhances the efficiency of the cardiovascular system, enabling patients to engage in physical activities with greater ease and less fatigue. These combined benefits translate into improved functional independence, allowing patients to better perform activities of daily living, which in turn positively impacts their psychological and social well-being. The implications of these findings for clinical practice are substantial. Pulmonary rehabilitation programs, traditionally centered around endurance training, should consider incorporating combined endurance and strength training as a standard component of COPD management. This shift would enable healthcare providers to offer more holistic and effective rehabilitation strategies that address the full spectrum of exercise limitations in COPD. The adoption of combined training could lead to improved patient outcomes, including enhanced exercise tolerance, reduced symptom burden, and better overall quality of life, ultimately reducing the healthcare burden associated with COPD by decreasing the need for hospitalizations and other intensive interventions. This study highlights the critical role of combined endurance and strength training in optimizing the management of COPD. By providing a more comprehensive approach to rehabilitation, combined training has the potential to significantly improve the lives of COPD patients, offering them greater physical and psychological resilience against the challenges posed by this chronic and debilitating disease. Future research should continue to explore the long-term benefits of combined training and its integration with other therapeutic modalities, with the goal of developing even more effective, personalized interventions that can further enhance the quality of life and functional independence of individuals living with COPD.

References

Casaburi, R., Porszasz, J., Burns, M. R., Carithers, E. R., Chang, R. S., & Cooper, C. B. (2004). Physiologic benefits of exercise training in rehabilitation of patients with severe chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine*, *159*(4), 1184-1187.

Clark, C. J., Cochrane, L. M., & Mackay, E. (2000). Skeletal muscle strength and endurance training in patients with moderate to severe chronic obstructive pulmonary disease. *Thorax*, *55*(8), 588-594.

Garrod, R., Marshall, J., Barley, E., & Jones, P. W. (2006). Randomised controlled trial of a community-based maintenance exercise programme after pulmonary rehabilitation for COPD. *BMJ*, *332*(7531), 361-365.

Global Initiative for Chronic Obstructive Lung Disease (GOLD). (2023). Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease.

Gosselink, R., Troosters, T., & Decramer, M. (1996). Peripheral muscle weakness contributes to exercise limitation in COPD. *American Journal of Respiratory and Critical Care Medicine*, *153*(3), 976-980.

Ortega, F., Toral, J., Cejudo, P., Villagomez, R., Sánchez, H., Castillo, J., & Montemayor, T. (2002). Comparison of effects of strength and endurance training in patients with chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine*, *166*(5), 669-674.

O'Shea, S. D., Taylor, N. F., & Paratz, J. D. (2007). A predominantly home-based progressive resistance exercise program increases knee extensor strength in people with chronic obstructive pulmonary disease: A randomised controlled trial. *Australian Journal of Physiotherapy*, *53*(4), 229-235.

Puhan, M. A., Gimeno-Santos, E., Cates, C. J., & Troosters, T. (2016). Pulmonary rehabilitation following exacerbations of chronic obstructive pulmonary disease. *Cochrane Database of Systematic Reviews*, *12*, CD005305.

Spruit, M. A., Singh, S. J., Garvey, C., ZuWallack, R., Nici, L., Rochester, C., & Wouters, E. F. M. (2013). An official American Thoracic Society/European Respiratory Society statement: Key concepts and advances in pulmonary rehabilitation. *American Journal of Respiratory and Critical Care Medicine*, *188*(8), e13-e64.

Troosters, T., Gosselink, R., & Decramer, M. (2005). Exercise training in COPD: How to distinguish responders from nonresponders. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *25*(6), 342-349.