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Research Article

The Impact of a Combined Pulmonary Rehabilitation and Resistance Training Program on Sarcopenia, Muscle Strength, and Functional Capacity in Patients with COPD: A Randomized Controlled Trial

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ABSTRACT
Background: Sarcopenia, the age-related loss of skeletal muscle mass and function, is a prevalent and impactful extrapulmonary manifestation in Chronic Obstructive Pulmonary Disease (COPD). It contributes significantly to reduced functional capacity, poor quality of life, and increased mortality. Pulmonary Rehabilitation (PR) is a cornerstone of COPD management, but the specific additive effect of structured resistance training on sarcopenic patients remains a key area of investigation.
Objective: To determine the prevalence of sarcopenia in a stable COPD cohort and to evaluate the efficacy of a standard PR program augmented with high-intensity resistance training on muscle strength and functional exercise capacity.
Methods: One hundred stable COPD patients (GOLD stages 2-3) were screened for sarcopenia using the EWGSOP2 criteria (low muscle strength confirmed by low muscle quantity/quality). Participants were randomly assigned to either the Control Group (CG, n=50) receiving standard PR (aerobic exercise, education, breathing techniques) or the Intervention Group (IG, n=50) receiving standard PR plus supervised, progressive resistance training for 8 weeks. Primary outcomes were changes in limb muscle strength (1-Repetition Maximum Leg Press) and functional capacity (6-Minute Walk Test, 6MWT). Secondary outcomes included handgrip strength and sarcopenia status.
Results: The prevalence of sarcopenia in our COPD cohort was 38%. At baseline, sarcopenic patients had a significantly lower 6MWT distance compared to non-sarcopenic patients (318±45m vs. 402±52m, $p<0.001$). Post-intervention, the IG showed significantly greater improvements than the CG in leg press strength (IG: +32.5 kg vs. CG: +10.2 kg, $p<0.001$) and 6MWT distance (IG: +55.8m vs. CG: +28.4m, $p<0.001$). A higher proportion of sarcopenic patients in the IG (68.4%) reversed their sarcopenia status compared to the CG (21.1%, $p<0.01$).
Conclusion: Sarcopenia is highly prevalent in COPD and is strongly associated with impaired functional capacity. Integrating targeted resistance training into a standard pulmonary rehabilitation program yields superior improvements in muscle strength and functional exercise capacity, and is highly effective in reversing sarcopenia in COPD patients.

Keywords: Copd, Sarcopenia, Pulmonary Rehabilitation, Resistance Training, 6-Minute Walk Test, Skeletal Muscle Dysfunction.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a major cause of global morbidity and mortality, characterized by persistent respiratory symptoms and airflow limitation. Beyond its pulmonary pathology, COPD is recognized as a systemic disorder, with skeletal muscle dysfunction being one of its most significant extrapulmonary manifestations [1]. This dysfunction ranges from impaired muscle metabolism and bioenergetics to the overt loss of muscle mass and strength, a condition known as sarcopenia [2].

Sarcopenia, traditionally associated with aging, is highly prevalent in COPD due to a confluence of factors including chronic systemic inflammation, oxidative stress, physical inactivity, corticosteroid use, and nutritional deficiencies [3]. The presence of sarcopenia in COPD patients has profound clinical implications, leading to exercise intolerance, increased dyspnea, higher exacerbation frequency, and reduced survival [4]. The Six-

Minute Walk Test (6MWT) is a widely used, reliable measure of functional capacity that is consistently shown to be adversely affected by skeletal muscle weakness in this population [5]. Pulmonary Rehabilitation (PR) is an evidence-based, multidisciplinary standard of care for COPD, proven to improve exercise capacity and quality of life [6]. While conventional PR includes aerobic endurance training, its effect on reversing the specific deficits of sarcopenia—namely, the loss of muscle strength and power—may be suboptimal [7]. Resistance training, designed to load the musculoskeletal system, is a potent stimulus for muscle protein synthesis and hypertrophy. Its integration into PR programs is logical, yet the specific benefits for patients identified as sarcopenic require further elucidation.

This study aimed to: 1) Determine the prevalence of sarcopenia in a cohort of 100 patients with stable COPD, and 2) Investigate whether a combined intervention of standard PR plus high-intensity resistance training is more effective than standard PR alone in improving muscle strength and functional capacity, particularly in those with sarcopenia.

METHODS

Study Design and Participants

A single-center, prospective, randomized controlled trial was conducted over 10 months. The study was approved by the Institutional Ethics Committee and all participants provided written informed consent.

One hundred patients with a confirmed diagnosis of COPD (GOLD stages 2-3) were recruited from the outpatient pulmonary clinic. Inclusion criteria were: age 40-80 years, clinical stability (no exacerbation in the preceding 4 weeks), and ability to perform exercise tests. Exclusion criteria included: severe cardiovascular disease, orthopedic/neurological limitations to exercise, active cancer, and long-term oxygen therapy.

Screening and Assessment of Sarcopenia

Sarcopenia was diagnosed according to the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) criteria [8]. The algorithm was applied as follows:

1. **Case Finding (SARC-F questionnaire):** All patients were screened.
2. **Assessment of Muscle Strength:** Handgrip strength (HGS) was measured using a Jamar dynamometer. Low strength was defined as HGS <27 kg for men and <16 kg for women.
3. **Confirmation of Low Muscle Quantity:** Appendicular Skeletal Muscle Mass (ASMM) was assessed using Bioelectrical Impedance Analysis (BIA). Low muscle quantity was defined as ASMM index (ASMMI) <7.0 kg/m² for men and <5.5 kg/m² for women. Patients with both low muscle strength and low muscle quantity were confirmed as having sarcopenia.

Randomization

After baseline assessments, the 100 participants were randomly assigned using computer-generated random numbers to one of two groups:

- **Control Group (CG, n=50):** Received standard pulmonary rehabilitation.
- **Intervention Group (IG, n=50):** Received standard pulmonary rehabilitation plus resistance training.

Interventions

Both groups underwent a supervised 8-week program, with sessions held three times per week.

- **Standard Pulmonary Rehabilitation (for both groups):** Comprised of 30 minutes of stationary cycling at 60-80% of peak workload, 15 minutes of treadmill walking, educational lectures (on disease management, nutrition, etc.), and diaphragmatic breathing techniques.
- **Resistance Training (IG only):** Following the PR session, the IG performed a progressive resistance training circuit. Exercises included leg press, knee extension, chest press, and seated row. The intensity was set at 60-80% of the one-repetition maximum (1-RM), which was assessed at baseline and at week 4. Participants performed 3 sets of 8-12 repetitions for each exercise.

Outcome Measures

Assessments were performed at baseline and after the 8-week intervention.

- **Primary Outcomes:**
  - **Muscle Strength:** Lower limb strength was measured as the 1-Repetition Maximum (1-RM) on a leg press machine.
  - **Functional Capacity:** The 6-Minute Walk Test (6MWT) was performed according to ATS guidelines, and the distance in meters (6MWD) was recorded.

- **Secondary Outcomes:**
  - **Handgrip Strength (HGS):** Measured as a marker of overall muscle strength.
  - **Sarcopenia Status:** Re-assessment post-intervention to determine the proportion of patients who no longer met the criteria for sarcopenia.

Statistical Analysis

Data were analyzed using SPSS version 26.0. Normality was assessed using the Shapiro-Wilk test. Continuous variables are presented as mean ± standard deviation. Between-group differences at baseline were analyzed using independent t-tests or Chi-square tests. The effects of the intervention were analyzed using a two-way repeated-measures ANOVA. A p-value of <0.05 was considered statistically significant.

Table 1. Baseline Characteristics of the Study Participants

Characteristic	Control Group (n=50)	Intervention Group (n=50)	p-value
Demographics			
Age (years)	67.4 ± 6.1	66.8 ± 5.9	0.61
Male, n (%)	32 (64%)	30 (60%)	0.68
Disease Severity			
FEV1 (% predicted)	52.3 ± 8.5	53.1 ± 9.0	0.65
GOLD Stage II, n (%)	28 (56%)	26 (52%)	0.70
GOLD Stage III, n (%)	22 (44%)	24 (48%)	0.70
Sarcopenia Status			
Sarcopenia, n (%)	19 (38%)	19 (38%)	1.00
Handgrip Strength (kg)	25.8 ± 6.2	26.1 ± 5.9	0.80
ASMMI (kg/m²)	6.8 ± 1.1	6.9 ± 1.0	0.62
Primary Outcomes (Baseline)			
1-RM Leg Press (kg)	68.5 ± 15.3	70.2 ± 14.8	0.57
6MWD (meters)	365 ± 58	372 ± 61	0.55

All 100 enrolled participants successfully completed the 8-week study protocol, and their data were included in the final analysis. As detailed in Table 1, the baseline characteristics of the two randomized groups were well-matched, with no statistically significant differences observed. The mean age was approximately 67 years in both groups, with a majority of male participants. Lung function, measured by FEV1 % predicted, was nearly identical, and the distribution of GOLD stage II and III patients was similar. Crucially, the prevalence of sarcopenia at baseline was 38% in each group (19 patients per group), confirming a successful randomization for this key variable. The baseline values for the primary outcomes, 1-RM Leg Press and 6-Minute Walk Distance (6MWD), were also not significantly different, ensuring that any post-intervention differences could be attributed to the treatment effect. An analysis of the entire cohort revealed the profound functional impact of sarcopenia, as patients with the condition had a significantly lower baseline 6MWD compared to non-sarcopenic patients (318 ± 45 m vs. 402 ± 52 m, $p < 0.001$).

Table 2. Changes in Outcome Measures Following the 8-Week Intervention

Outcome Measure	Control Group (n=50)	Intervention Group (n=50)	Between-Group Difference*	p-value
1-RM Leg Press (kg)				
Baseline	68.5 ± 15.3	70.2 ± 14.8	-	-
Post-Intervention	78.7 ± 16.1	102.7 ± 18.5	-	-
Change from Baseline	+10.2 ± 4.1	+32.5 ± 8.9	+22.3	<0.001
6MWD (meters)				
Baseline	365 ± 58	372 ± 61	-	-
Post-Intervention	393 ± 54	428 ± 59	-	-
Change from Baseline	+28.4 ± 12.5	+55.8 ± 15.2	+27.4	<0.001

Handgrip Strength (kg)				
Baseline	25.8 ± 6.2	26.1 ± 5.9	-	-
Post-Intervention	27.3 ± 5.8	29.9 ± 5.5	-	-
Change from Baseline	+1.5 ± 1.0	+3.8 ± 1.5	+2.3	<0.01
Reversal of Sarcopenia				
Sarcopenic at Baseline, n	19	19	-	-
No Longer Sarcopenic, n (%)	4 (21.1%)	13 (68.4%)	+47.3%	

The effects of the 8-week intervention on all outcome measures are summarized in Table 2. For the primary outcome of muscle strength, the group that received combined pulmonary rehabilitation and resistance training (Intervention Group) demonstrated a substantially greater improvement than the standard rehabilitation group (Control Group). The mean increase in 1-RM Leg Press was 32.5 kg in the Intervention Group, which was more than three times the 10.2 kg gain observed in the Control Group, a difference that was highly statistically significant ($p < 0.001$).

This superior improvement in strength translated directly to the other primary outcome, functional capacity. The Intervention Group increased their 6MWD by a mean of 55.8 meters, a change that nearly doubled the 28.4-meter improvement seen in the Control Group and far exceeds the established minimal clinically important difference. The between-group difference in the improvement was 27.4 meters, which was also highly significant ($p < 0.001$).

Significant benefits for the Intervention Group were also evident in the secondary outcomes. Handgrip strength, a marker of overall limb strength, improved by 3.8 kg in the Intervention Group compared to only 1.5 kg in the Control Group ($p < 0.01$). Most notably, the intervention had a dramatic impact on the clinical status of sarcopenia. Among the patients who were sarcopenic at baseline, 68.4% (13 of 19) in the Intervention Group no longer met the diagnostic criteria after the program, compared to only 21.1% (4 of 19) in the Control Group. This represents a significant reversal of the condition directly attributable to the combined training regimen ($p < 0.01$).

DISCUSSION

This randomized controlled trial yields two principal findings that underscore the critical relationship between skeletal muscle dysfunction and lung disease. First, we identified a high prevalence of sarcopenia (38%) in our cohort of patients with moderate to severe COPD, and this condition was strongly associated with a significant reduction in functional exercise capacity, as measured by the 6MWT. Second, and more importantly, we demonstrated that augmenting standard pulmonary rehabilitation with targeted, high-intensity resistance training is a profoundly more effective strategy for ameliorating this dysfunction than standard PR alone. The intervention group not only achieved superior gains in muscle strength and walking distance but also saw a significantly higher rate of sarcopenia reversal.

The high prevalence of sarcopenia in our COPD cohort aligns with the established literature on systemic manifestations of the disease. Our finding that 38% of patients met the EWGSOP2 criteria is consistent with a large cross-sectional study by Sepúlveda-Loyola et al. (2020), who reported a prevalence of 34% in a similar patient population and similarly identified sarcopenia as a key predictor of functional limitation [4]. The robust correlation we observed between sarcopenia and a reduced 6MWD at baseline (318m vs. 402m in non-sarcopenic patients) reinforces the concept that the skeletal muscle is a key "limiting organ" in COPD. This supports the work of Jones et al. (2013), who found that quadriceps strength was a more powerful predictor of 6MWD than the degree of airflow obstruction (FEV1) [5]. Our baseline data therefore confirm that the loss of muscle mass and strength is not merely a secondary observation but a central determinant of exercise intolerance and disability in these patients.

The most compelling evidence from our study pertains to the efficacy of the combined training modality. The dramatic improvement in lower limb strength in the intervention group (+32.5 kg vs. +10.2 kg in controls) directly translates

the physiological principle of training specificity into clinical practice. While standard PR improves cardiorespiratory endurance and whole-body efficiency, it provides a suboptimal stimulus for myofibrillar protein synthesis and hypertrophy. Our findings are strongly supported by the work of Troosters et al. (2010), who demonstrated that adding resistance training to a PR program resulted in significantly greater improvements in muscle force and mass compared to aerobic training alone [7]. Our study builds upon this by specifically focusing on patients characterized as sarcopenic, demonstrating that this combined approach not only improves strength but can effectively reverse the diagnostic criteria of the condition itself.

Furthermore, the superior gain in functional capacity in the intervention group, with a mean improvement in 6MWD of 55.8 meters, has clear clinical relevance. This improvement far exceeds the established minimal clinically important difference (MCID) of 30-35 meters [10]. The magnitude of this effect can be attributed to the direct impact of increased muscle strength on walking mechanics and endurance. A study by Maltais et al. (2014) provides a mechanistic basis for our results, showing that exercise training in COPD, particularly modalities that load the muscle, can reverse specific muscle abnormalities, including a shift in fiber-type distribution and improved oxidative capacity [2]. The significant reversal of sarcopenia status in 68.4% of our intervention group, compared to only 21.1% in the control group, provides a powerful clinical endpoint. It suggests that the combined regimen directly counteracts the core pathophysiological processes of muscle wasting, moving beyond symptomatic management to address the underlying extrapulmonary disease.

CONCLUSION

In conclusion, our findings robustly confirm that sarcopenia is a highly prevalent and functionally consequential comorbidity in COPD. The integration of progressive resistance training into the standard pulmonary rehabilitation model is not merely an additive enhancement but a transformative one. It directly targets the core deficit of skeletal muscle dysfunction, yielding superior improvements in strength and functional capacity that are both statistically significant and clinically meaningful. We therefore advocate for the routine assessment of sarcopenia in COPD management and the formal inclusion of structured resistance training as an essential, non-negotiable component of pulmonary rehabilitation for this patient population.

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