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ORIGINAL ARTICLE

CHANGE OF VO_2 MAX AND MUSCLE MASS AFTER ONE-MONTH AND TWO-MONTH UPPER AND LOWER BODY EXERCISES IN STABLE CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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Abstract. Background: *Skeletal muscle dysfunction inevitably occurs due to systemic inflammation of Chronic Obstructive Pulmonary Disease (COPD), which manifests as muscle atrophy and dysfunction. It also exhibits decreases in muscle strength and endurance, leading to a deconditioned state and a reduction in maximal oxygen uptake (VO_2 max) in tissues. Exercise training can increase VO_2 max value. The main purpose of this study is to evaluate the benefits and compare the effectiveness of upper and lower body exercises given for one to two months in stable COPD patients.* ***Methods:*** *This quasi-experimental study was conducted on 25 stable COPD patients from December 2018 to May 2019 at the Physiotherapy Unit of Siti Hajar Hospital, Medan, Indonesia. All participants performed upper-body exercises and stationary bicycles for lower-body exercises twice a week for one month, then continued for two additional months. VO_2 max was calculated using the Nury Formula, specially developed for the Indonesian population, while muscle mass values were assessed using the OMRON Karada Scan scales. VO_2 max and muscle mass were measured before training (baseline) after one-month and two-month training. The statistical analysis used is the Repeated ANOVA test.* ***Results:*** *The baseline of mean muscle mass in COPD patients was 28.8 ± 2.43%. Muscle mass increased to 29.1 ± 2.34% in one month and 29.5 ± 3.01% after two months ($p < 0.05$). The mean value of VO_2 max before doing upper and low body exercises was 21.0 ± 3.08%. VO_2 was significantly increased after two-month training to 23.0 ± 3.6% ($p < 0.001$), but not after one-month training (VO_2 max: 21.32 ± 3.22%; ($p < 0.001$).* ***Conclusion:*** *Two-month upper and lower body training provides a greater impact in improving VO_2 max and muscle mass in stable COPD patients.*

Key words: *COPD, upper and lower body exercises, VO_2 max, muscle mass*

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INTRODUCTION

Exercise has been proven to be the most effective strategy for rehabilitation programs in reducing symptoms of shortness of breath and improving health status and exercise tolerance in patients with Chronic Obstructive Pulmonary Disease (COPD). COPD is a heterogeneous lung condition characterized by chronic respiratory symptoms (dyspnea, cough, sputum production, and/or exacerbations) due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction [1, 2, 3]. World Health Organization (WHO) states that COPD is the third leading cause of death worldwide, causing 3.23 million deaths in 2019 [2]. The prevalence of COPD in Indonesia has reached 5.6% of the total disease, with an estimated 8.5 million COPD cases [3].

The main problem experienced by COPD patients is exercise limitations. In addition to low oxygenation due to airway abnormalities, skeletal dysfunctions are a major concern in the pathophysiology of COPD. COPD patients will have skeletal muscle atrophy due to decreased muscle mass. The remaining muscle mass also turns out to be malfunctioning. Systemic inflammation and oxidative stress are thought to contribute to this abnormality. Both result in changes in the morphology of skeletal muscle fibers and capillaries. In the intracellular environment, there is a change in metabolic enzyme activity in the mitochondria of skeletal muscle resulting from the early activation of anaerobic metabolism in muscle cells, even when the patient is lightly active [4].

Muscle dysfunction is a condition characterized by disturbance in the strength and endurance of the skeletal muscles that impair the ability to carry out the physiological functions of the muscles [5]. Muscle dysfunction in the upper extremities can hinder the ability to carry out activities that require coordination of movements, such as grasping. Meanwhile, muscle dysfunction in the lower extremities will interrupt the patient's ability to move. According to the guidelines for the management of COPD, as outlined in GOLD 2023, a rehabilitation program with exercise has been proven to be the most effective strategy for reducing symptoms of shortness of breath and improving health status and exercise tolerance. Data on the differences in the effectiveness of one-month and two-month upper and lower body exercise to VO_2 max and muscle mass are still very limited. Therefore, the researchers aimed to assess the effectiveness of one-month and two-month upper and lower body exercises on muscle mass in stable COPD.

MATERIALS AND METHODS

The main purpose of this study is to evaluate the benefits and compare the effectiveness of upper and lower body exercises given for one to two months on maximal oxygen uptake (VO_2 max) and muscle mass in stable COPD patients, non-pharmacological treatment.

This study is a clinical trial with a quasi-experimental design for one group pre-post test. A total of 25 stable COPD patients enrolled in this study completed all exercise sessions from December 2018 to May 2019 at the Physiotherapy Unit of Siti Hajar Hospital Medan, Indonesia. All subjects were male, with the majority aged between 60 and 70 years (56% of the subjects). Clinical characteristics indicate that the majority of participants experienced severe airway obstructions, as evidenced by physical limitations as depicted by the mMRC scale. Additional characteristics of the subject are presented in Table 1.

Table 1. Demographic Characteristics of the Study Participants

Demographic Characteristics		N	%
Age	40-49 years	1	4.0
	50-59 years	4	16.0
	60-69 years	14	56.0
	≥70 years	6	24.0
Gender	Male	25	100.0
	Female	0	0.0
GOLD	GOLD 1	0	0.0
	GOLD 2	0	0.0
	GOLD 3	13	52.0
	GOLD 4	12	48.0
Brinkman Index	Light	1	4.0
	Moderate	8	32.0
	Severe	16	64.0
mMRC	0	4	16.0
	1	7	28.0
	2	6	24.0
	3	3	12.0
	4	5	20.0
BMI	Underweight	2	8.0
	Normoweight	7	28.0
	Overweight	6	24.0
	Obese	10	40.0

Abbreviations: COPD = Chronic Obstructive Pulmonary Disease, GOLD = Degree of Airflow Obstruction (% VEP1) based on the criteria for Global Strategy for Diagnosis and Management of COPD, mMRC = Modified Medical Research Council

The inclusion criteria for this study were stable COPD patients with no serious comorbidity, such as cardiovascular diseases, with very low ejection fraction (EF < 30%) and no serious musculoskeletal disease, including grade IV osteoarthritis, rheumatoid arthritis, etc. The exclusion criteria include the patients who did not complete all the training sessions due to any reason. All participants signed the informed consent after being informed of all the study protocols. The study procedure was approved by the Health Research Ethics Committee, Faculty of Medicine Universitas Sumatera Utara (No:700/TGL/KEPK FK USU-RSUP HAM/2018).

The participants filled out the questionnaire for their medical conditions and clinical characteristics. Vital signs, VO_2 max, and muscle mass were measured before the beginning of the study. The participants must have a good health status, including blood pressure below 140/90, heart rate < 100 bpm, respiratory rate < 24 breaths per minute, and oxygen saturation > 90%. Prior to exercise sessions, patients received 2.5 mg of inhaled salbutamol and 10 minutes of infrared radiation therapy to the chest to prevent exercise-induced exacerbations. Before starting upper and lower body exercises, a short-acting bronchodilator of 2.5 mg of salbutamol inhalation and 10 minutes of chest therapy by infrared radiation were administered to prevent exacerbations during exercise. During the training session, frequent evaluations of exercise intolerance, including muscle pain, shortness of breath, or headaches, were carried out, and the exercise sessions were stopped if needed. The evaluation was made by the physiotherapist. These upper and lower limb body exercises were performed twice a week for 2 months (16 training sessions).

Upper limb endurance training, incorporating simple gymnastics exercises, targets the neck, shoulders, and arms. Along with these procedures, pursed-lip breathing is performed to facilitate breathing training. Upper limb endurance training in our setting consists of 10 moves [6]:

1. Pursed-lip breathing with exhalation while tilting your head towards your shoulder;
2. Bird-like pattern with inhalation while body straightening, exhaling while bending forward to the bottom;
3. No-way pattern with pursed-lip breathing, seeing movement to left and right alternately;
4. Shoulder shrugs with pursed-lip breathing;
5. Fan-like movement with pursed-lip breathing, hands are bent together, then turn right and left;
6. Chicken cuckoo-like movements by rotating the shoulder with hands bent at the shoulder;
7. Vampire-like movement, hands straight forward while inhaling, then rotating the body to the right, left, and forwards while exhaling;
8. Calling movement, the hand is lifted, then touched downwards, in the opposite direction;
9. In a butterfly-like pattern, hands are stretched straight forward, then stretch the hands;
10. Cooling down.

The lower body exercise procedure consists of three procedures:

1. Warming up and muscle stretching for 5 to 10 minutes to prevent muscle injury;
2. Cycling using a stationary bike by Ketler bike with the duration gradually increasing from 5 to 30 minutes;
3. Cooling down.

VO_2 max is calculated using the Formula Nury® specially developed for the Indonesian population. VO_2 max = (0.053 x distance) + (0.022 x age) + (0.032 x height) – (0.164 x weight kilogram) – (2.228 x gender) – 2.287.

Note: Age (years), height (centimeters), weight (kilogram), and gender (0 male; 1 female). The distance was assessed with a 6-minute walk distance test. VO_2 max was assessed at baseline, after one month, and after two months of upper and lower body exercises. Muscle mass was measured using Omron Karada Scan scales, which employ the Bioelectrical Impedance Analysis (BIA) method. The normal value of muscle mass in men is 32.9-35.7%. All subjects were examined for the value of muscle mass before exercise as the baseline, after one month, and after two months of exercise.

Statistical Analysis

The data were collected and processed using the Statistical Package for the Social Sciences (SPSS) software application. Univariate analysis was used to determine the value of Mean and Standard Deviation before and after the intervention. The analysis continued with a bivariate analysis to compare the results before and after the intervention. The resulting data comparing VO_2 max values before and after testing were analyzed using a paired sample t-test statistical test, followed by further analysis with a repeated ANOVA test and a post-hoc ANOVA test. The relationship between combination training and VO_2 max is stated to be significant if $p < 0.05$.

RESULTS

The baseline of muscle mass was 28.8 ± 2.43%. After one month of exercise, there was an increase in muscle mass to 29.1 ± 2.34%. Meanwhile, after two months of exercise, the muscle mass increased to 29.5 ± 3.01%. However, the statistical analysis shows no significance with $p > 0.05$ (Table 2).

Table 2. Effect of Exercise on Muscle Mass

	Mean	SD	Median	Min-Max	p-value
Pre-exercise	28.8	2.43	29.3	24.1 - 35.8	
One-month exercise	29.1	2.34	29.3	24.1 - 35.9	0.484
Two-month exercise	29.5	3.01	29.6	23.2 - 37.3	

*Repeated ANOVA

After being calculated using Nury's formula, the baseline VO_2 max was 21.0. Both post-1 month and 2 months of training showed a significant increase in VO_2 max (21.3 and 23.0) (Table 3).

Table 3. Effect of Exercises on VO_2 Max

	Mean	SD	p-value
Pre-exercise	21.0	3.08	
			0,001
After one-month exercise	21.3	3.22	
After two-month exercise	23.0	3.6	

*significant with repeated ANOVA test

Further analysis with ANOVA post-hoc analysis showed no significant change in VO_2 max after one-month exercise compared with baseline. However, the effect of longer exercises showed both significances compared with baseline and one-month exercise ($P < 0.001$) (Table 4).

Table 4. Advanced analysis of the effect of one-month and two-month exercises on VO_2 max

	p-value
Pre-exercise vs one-month exercise	0.41
Pre-exercise vs two-month exercise	< 0.001*
one-month exercise vs two-month exercise	< 0.001*

*significant by using post-hoc with ANOVA test

DISCUSSION

The demographic characteristics in this study showed no differences from those in recent studies. Males predominant with severe smokers and older age showed predominant in this study. Another study also showed that all participants enrolled in their study were male patients with COPD [7]. This is related to the fact that most of the smokers were men. In addition, due to their role as breadwinners in developing countries, men have more activities outside, increasing the risk of biomass and pollution. Age is associated with changes in lung structure and function that may increase the pathogenesis of COPD, which can increase the incidence of COPD in old age [8].

Deconditioning syndrome, followed by limb muscle dysfunction, is a complication following the disease course of COPD that is strongly related to decreasing exercise tolerance, quality of life, and even life expectancy. As a consequence of systemic inflammation, muscle dysfunctions are a significantly poor predictor of disease mortality, better than lung function [9]. The significant reductions of muscle mass in the thigh are relatively greater than the overall body part, so the objective measure of thigh muscle mass is the best predictor for skeletal muscle loss [9].

According to GOLD 2023 and various systematic reviews, pulmonary rehabilitation is strongly recommended in COPD group B-E due to its impact on improving breathlessness, exercise capacity, health status, and decreased hospital admissions [10]. Physical exercises, including cardiovascular exercise and muscle training, are the main pillars of pulmonary rehabilitation and are considered the best strategies for improving exercise tolerance and muscle function in COPD patients [3]. Another study divided exercise into various types, including endurance training, strength training, and inspiratory muscle training. Each training has its main aims and targets for pulmonary rehabilitation [6].

The goal of endurance exercise as part of muscle exercise is to coordinate the peripheral muscle and improve the cardiorespiratory capacity. This will improve physical activity and exercise tolerance in COPD patients, which can be evaluated by decreasing shortness of breath and fatigue [11]. Various studies have assessed the benefits of endurance exercise in COPD. A study by Tarigan et al. described the improvement in lung function after eight weeks of lower limb exercise using a stationary bicycle in patients with stable COPD for all degrees of obstruction [12].

Another study with upper limb exercise using the shoulder muscles and upper arm accompanied by pursed-lip breathing exercises found improvements in lung function, exercise capacity, and quality of life in patients with stable COPD with moderate to severe degrees of obstruction [13].

Apart from endurance exercises, the main goal is to improve exercise capacity. The American College of Sports Medicine (ACSM) recommends two to three times a week of limb strengthening exercises consisting of 8-10 exercises involving the major muscles with 8-15 repetitions (60-80% of the maximum repetition) for muscle restoration. Increased muscle strength can be achieved through strengthening exercises alone or in combination with aerobic or endurance training [14].

In this study, a decrease in muscle mass was observed at the baseline examination, with an average of 28.8 ± 2.43%. Many factors contribute to these structural abnormalities, including genetics, smoking, inflammatory response to COPD, history of exacerbations, hypoxia, malnutrition, obesity, decreased physical activity, and comorbidities [5]. After training, there is a slight increase in muscle mass, although it is not statistically significant. Contrary to this study, Farias et al. showed a significant increase in muscle mass, estimated as 8.3%, after lower limb aerobic exercise by walking 40-60 minutes five times a week for eight weeks [15]. Another study also showed a significant increase in muscle mass after 60 minutes of resistance training [16]. Another study reported an increase of 7% in the cross-sectional area (CSA) of the quadriceps after combining aerobic and resistance exercises for eight weeks (16 sessions twice a week) [17]. However, both studies measured muscle mass using magnetic resonance imaging (MRI) [16, 17].

Although physical exercises cannot morphologically reverse the muscle fiber type, a study showed the increased CSA of muscle fibers by at least 20% [18]. Combining resistance and aerobic exercise showed a greater increase in skeletal muscle mass compared with endurance or aerobic exercise alone, indicating that peripheral muscles can adapt to the provision of appropriate exercise despite severely impaired ventilation [19]. Providing additional protein intake as muscle nutrition, combined with endurance and strength training for muscles, can be considered a future research direction to assess the improvement of muscle mass in COPD patients.

Functional capacity can be represented by Nury's formula that measured VO_2 max. This study showed improvement in VO_2 max after one month and two months of exercise. However, the significant difference was only observed after two months of exercise. Along with this study, Leite et al. showed an increase of 16.2 ml/kg/minute VO_2 max after cycling exercise for 12 weeks [20]. Another study explained that exercise with moderate to high intensity for a longer duration (> 8 weeks) showed more improvement in VO_2 max [21]. Several factors also influence the VO_2 max value, including gender, age, body composition, exercise, cardiorespiratory function, and hemoglobin level [20, 21].

CONCLUSION

Combining endurance of upper and lower limb exercise showed a slight increase in muscle mass, although it is not statistically significant. Longer exercise durations provide better improvement in VO_2 max for COPD patients.

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Ethics approval: *The study procedure was approved by the Health Research Ethics Committee, Faculty of Medicine Universitas Sumatera Utara (No:700/TGL/KEPK FK USU-RSUP HAM/2018).*

Informed consent from participants: *Informed consent was obtained from all participants included in the study.*

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