Upper Extremity Strength Training Effectiveness on COPD Patients' Muscle Mass Using Home - Based Pulmonary Rehabilitation

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Abstract: ***Background**: COPD patients often report physical activity reduction. Malnutrition subsequently follows due to the extra workload on respiratory muscles. Therefore, proper nutrition is necessary. Telerehabilitation, part of Home Based Pulmonary Rehabilitation (HBPR), helps to train upper body strength. However, the efficacy is undetermined. **Aims**: To measure the effectivity of upper extremity strength training on COPD patients' muscle mass with additional egg whites during the Covid - 19 pandemic. **Methods**: The design was a quasi - experimental test conducted from September to October 2020. We used a consecutive sampling technique. Participants who met the inclusion criteria must complete an informed consent and questionnaire, undergo a physical examination and consume seven egg whites daily. The exercise guide was given through online video and leaflet. Post - test performed after completing the study. The data were examined using the pair - t test or Wilcoxon test on SPSS. **Results**: 15 patients participated in the experiment. A statistically significant relationship and increased body weight (p - value=0.047) and muscle mass (p - value=0.048) before and after home - based upper body training. **Conclusions**: Upper extremity strength training is beneficial for rehabilitation in restricted conditions. With the addition of egg whites, the training could increase muscle mass and prevent deconditioning syndrome and muscle dysfunction.*

Key words: Chronic Obstructive Pulmonary Disease (COPD), telerehabilitation, upper extremity strength training, nutrition, muscle mass

1. Introduction

One common complaints COPD patients have is limitations in physical activities. [1]Other than lung abnormality which leads to obstructed breathing, COPD patients also face deteriorating functions of skeletal muscle because of lack of routine activity or muscle dysfunction. A smoker usually loses appetite caused by the anorexic effect of tobacco in the cigarettes. [2]Malnutrition materializes more frequently in the elderly and it is correlated with decreasing functional status, muscle function, bone mass, immunology function, anemia, cognitive function, wound healing, and post - surgery recovery. [3] Malnutrition occurs in COPD patients due to increased energy expenditure led by increased respiratory muscle effort which results in a hypermetabolic condition. [4] The lungs' structure, flexibility and function, the strength and endurance of the respiratory muscle, the lungs' immune system and breathing control will be affected by malnutrition. Patients with COPD have a higher energy expenditure which may cause lower food consumption. [5]Thus, nutrition intake is crucial for the elderly population's health, especially for those with COPD.

Pulmonary rehabilitation has been recommended by the International Guidelines to treat COPD patients of I, II and III degree who experience loss of muscle mass and weight loss. [6]Telerehabilitation can be another option to enable COPD patients' lung rehabilitation to continue during Covid - 19 pandemic. This treatment can be conducted without COPD patients' leaving their home. It will improve patient's compliance with the training program. [7]Home base pulmonary rehabilitation (HBPR) is a type of telerehabilitation. When an individual strictly follows the HBPR, his or her will improve his symptoms and quality of life. [8]

Still, supervision is required in the planning of HBPR in order to ensure COPD patients' consistency in following the rehabilitation instructions. [9]For that reason, the goal of this experiment was to evaluate the change in the muscle mass of COPD patients who received extra nutrition of egg whites during the upper - body strength training so that the HBPR efficacy could be measured.

2. Literature Survey

Small airway dysfunction and loss of parenchyma are the combined pathogenesis which cause the obstruction in chronic obstructive pulmonary disease (COPD). [10] The observed interaction between environment and gene contributes to the risk factors of COPD. Cigarette smoke, air pollution, frequent infection of lower respiratory passage, socioeconomic factors, lung growth and development record, genetics, and sex are some of COPD risk factors. However, smoking is the most significant among all of the risk factors. The age when smoking start, number of cigarettes smoked per year, and the length of time they have been smoking are COPD risk factors in smokers, which can be inferred from Brinkman Index. [4]

Simple daily tasks such as walking, lifting small objects, and cycling can make COPD patients experience fatigue and breathing exertion. The ability to be involved in certain activities are limited for COPD patients due to several reasons. Generally, this condition is caused by three mechanisms: the imbalance between the lung capacity and the respiratory needs, the discrepancy between the amount of oxygen distributed in the respiratory and in the peripheral muscle, and the imbalance between the two mechanisms. [1]

COPD patients with dysfunctional extremity muscle also have weak muscle strength, low muscle endurance, and significant level of exertion. Depending on the severity of the disease, muscle weakness affects averagely 20 - 40% people, while 30 - 80% of COPD patients have stamina problem and upper extremity fatigue. [11]Issues related to structures and functions of a muscle can lead to a dysfunction. Systemic inflammation, reactive oxygen species (ROS), deconditioning, diet, effect of smoking and medicine are several reasons for muscle dysfunction in COPD patients. Skeletal muscle intracellular protein will trigger degradation in COPD patients due to systemic inflammation. Atrogene producing transcription factor triggers the process of protein ubiquitination and causes excessive protein degradation in COPD patient's skeletal muscle, especially in the lower extremity. [2]

Increase in neutrophils, macrophages and CD8+ T lymphocytes, higher concentration of proinflammatory cytokines, and oxidative stress due to cigarette's smoke inhalation or the inflammatory cells themselves are the characteristics of lung inflammation in response to smoke exposure. Patients with COPD who consume systemic corticosteroids undergo structural and functional muscle loss, leading to chronic myopathy. Deconditioning occurs as a result of decreased physical activity. This will cause COPD patients to stop moving their muscle, shrink muscle fibers, and increase the proportion of muscle fiber type 2. [2]

Patient's socialization, peripheral muscle strength, increased oxygen usage inside the muscle, improved training capacity and reduced exertion are some of the advantages of a pulmonary. [6] The three elements that serve as a base of a rehabilitation program are: physical activity psychosocial support, and breathing technique. The foundation of pulmonary rehabilitation is physical exercise, including aerobic and muscle training. Physical exercise is considered most effective to increase training capacity and muscle strength of COPD patients. The general physical exercises for COPD patients are in the form of muscle strength, physical endurance, interval, and respiratory muscle workouts. [11]

Constrained physical condition (pain, mobility problem, and physical illness) may hinder patients from completing the pulmonary rehabilitation therapy program. Lack of motivation, attention and support, patient's own perception of the disease, time limitation, transportation and financial problems, and smoking habit are some of the reasons for patient's non - compliance. [12]Medical professionals utilize electronic communication and information technology to provide treatment for patients outside the health - care facilities (telerehabilitation), which is a part of telemedicine. Many technologies are used in telemedicine, namely: video conference, internet access, mobile applications, and wireless communication. [7]

Moreover, prior to Covid - 19 pandemic, telerehabilitation has been widely used for COPD patients. Most studies showed positive effects from complying with the program i. e. lowering the use of health - care facilities (due to lower COPD exacerbation, emergency visits, and rate of hospitalization), and improving quality of life and tolerance to physical activities (6 minute walking test/6MWT). [7]

3. Methods

The design used in this study was quasi - experimental clinical study with one pre - test and post - test. The research wanted to measure the increase in muscle mass of stable COPD patients by giving upper arm weight - lifting exercise and eggwhite diet for a month. The experiment was conducted from September to October 2020. The sampling technique was non - probability sampling, namely consecutive sampling. The size of the required minimum sample was calculated based on the formula of hypothesis test for paired numerical data.

The inclusion criteria in this experiment are as follows: COPD patients from the outpatient polyclinic of USU Department of Pulmonology and Respiratory Medicine/H. Adam Malik Hospital Medan and Physiotherapy Unit of Siti Hajar Hospital Medan; aged 40 - 70 years; stable degree of COPD (FEV1/FVC <70%) with mMRC score 1 - 3 (mild - severe). Those who fulfilled the inclusion criteria and agreed to comply with all of the research procedures, were asked to sign the form of informed consent. On the other hand, the exclusion criteria of this research were: existing malignant comorbidity, having severe neuromuscular and musculoskeletal disorder such as stroke and severe osteoarthritis, not going through with the treatment until the end, having severe infection and sepsis, being prescribed long - term oxygen therapy (O2 saturation 88%), and being involved in other lung rehabilitation or trainings.

The Medical Research Ethics Committee of the Faculty of Medicine of USU Medan gave their ethical consent in the form of ethical clearance No.1110/KEP/USU/2021. Based on history taking, physical check - up, and other supporting examinations, COPD patients with inclusion criteria were identified. If subjects consented, they would answer a questionnaire and undergo several tests. The demographic information gathered in the questionnaire included name, age, sex, weight, height and disease history. The physical examination involved general physical and vital signs checkup, spirometry, pre - intervention lung function, pre - intervention mMRC and muscle mass measurement.

The calculation of base muscle mass was done by using Omron Karada Scan to estimate the value of muscle mass. First, input the patient's height, sex and age. Then the patient stepped onto the scale to determine his or her muscle mass. Based on height, age and sex, the muscle mass was calculated in unit of percentage. For every upcoming upper extremity strength training, the study subjects were notified and instructed to consume 7 eggwhites. For 8 training sessions with a frequency of two sessions per week, the boiled eggwhites were divided into 3 portions: morning, noon and evening. Subjects received 1 - 2 pumps of SABA inhaler prior to the exercise. The exercise instructions were given in the form of an online video and a leaflet. Vital signs were checked after each session. When study subjects had completed all the steps/procedures in the experiment, the final test was performed i. e. post - intervention test (at the end of the 8th workout).

SPSS was the chosen statistics software to process the information gained from the research. Univariate analysis was performed to calculate the mean and median value of the muscle mass before and after the intervention. Then, bivariate analysis was used to contrast the value of muscle mass before and after the intervention as part of the analysis (pre - test and post - test sample data). Shapiro - Wilk test used to determine if the data were normally distributed. The results were then analyzed further using the paired - t test or the Wilcoxon test, provided the data were normally distributed or not.

4. Results

Basic *characteristics of participants*

Fifteen patients met the inclusion criteria and successfully added into the experiment. The characteristics of the participants were described in Table 1. Based on sex, 14 subjects were male (93%) and 1 female (7%). The study involved patients between 40 - 70 years old. Of 15 subjects, 12 were 60 - 69 (80%), 2 were over 69 (13%) and 1 between 50 - 59 years of age (7%). Every test subject's height was measured, and it was found that 8 (53.3%) were <160cm tall.

14 participants (93%) were active smokers, while 1 (7%) was not. Of all participants, 5 people (33%) smoked >30 cigarettes per day, 5 (33%) smoked 20 - 30 per day, 4 people (27%) smoked <20 per day, and 1 (7%) did not smoke (Table 1).9 subjects were categorized as heavy smokers in Brinkman Index. All test subjects were evaluated using Modified British Medical Research Council (mMRC), and the results being 6 people (40%) received >=2.

Table 1: Characteristics of Participants

Characteristics	N=15	%
Sex		
Male	14	93
Female	1	7
Age		
50 - 59 years	1	7
60 - 69 years	12	80
> 69 years	2	13
Body Height		
<160 cm	8	53.5
>160 cm	7	47.7
Smokers		
Yes	14	93
No	1	7
Cigarettes consumption daily		
>30	5	33
20 - 30	5	33
<20	4	27
None	1	7
mMRC Dyspnea Scale		
≥2	6	40
0 - 1	9	60

Body Weight and Muscle Mass Before and After Strength Training

The value of mean and standard deviation of body weight calculated before the exercise was 64, 09 ± 11, 89. The mean and standard deviation after the training session was 65, 72 ± 10, 65. Because the data were distributed normally, a correlation test was performed and the correlation was found to be significant with p<0.05 (p - value=0.047). Upon examination, patients' muscle mass before exercising was on average 29, 60 ± 4, 27 and 31, 75 ± 3, 38 after. With p=0.048, the correlation analysis was deemed significant. Table 2 contains the results of the research.

Table 2: p - value of Body Weight and Muscle Mass Before and After Strength Training

	Mean ± Standard Deviation	Median (Minimum - Maximum)	*p* value
Body Weight			
Before training	64, 09 ± 11, 89	66, 30 (46, 60 – 86, 00)	0, 047^{+}
After training	65, 72 ± 10, 65	67, 00 (48, 40 – 86, 10)	
Muscle Mass			
Before training	29, 60 ± 4, 27	30, 30 (22, 70 – 38, 80)	0, 048^{+}
After training	31, 75 ± 3, 38	31, 90 (23, 30 – 37, 70)	

$^{+}$ = Paired sample T Test. * = Wilcoxon Test

5. Discussion

In this study, there was a significant statistical improvement (p=0.047) in body weight before and after the upper arm strength training and adding egg whites nutrition for a month. Additionally, muscle mass (lean mass) also showed a significant increase (p - value=0.048) between the two HBPR and additional egg whites. Nevertheless, an opposing result was found in the latest study by Rinaldo, et al. They observed an increase in fat mass and reduced muscle mass during follow - up period, without any extra nutrition from egg whites. The experiment also lasted for a longer period (28 weeks) whereas our research lasted for 4 weeks. They used Dual - energy X - ray Absorptiometry (DXA), while we used BIA analysis. [13]

Alcazar et al., who recently did a research on the effect of exercising on systemic oxidative stress and muscle dysfunction in older patients with COPD, supported our hypothesis. They discovered a negative correlation between the variation of systemic oxidative stress and the size and strength of muscle, cardio respiratory wellness, and physical capability. Moreover, oxidative stress directly damages muscle contractility by reducing the activity of sarcoplasmic reticulum, interfering the excitation - contraction coupling, or causing dysfunctional metabolic capability and muscle enzyme. Thus, strength training will significantly change muscle function and aerobic capacity. [14]

When one or two characteristics of the primary muscle (strength and endurance) show a sign of weakening, it is said that the muscle has a dysfunction. Muscle endurance is defined as the ability to withstand longer submaximal weight training, whereas muscle strength means the ability to create short bursts in an effort to reach maximal contractile. Muscle mass (that can be measured by size and density of muscle fiber), resting length, shortening velocity, and pattern of motor unit recruitment are the main factors that influence strength. [15, 16]

Muscle dysfunction is an important systemic sign of COPD which can cause loss of muscle mass. The total or volume of skeletal muscle is known as muscle mass. [17]In COPD patients, loss of muscle mass (muscle atrophy) especially in the lower limbs is usually related to the reduced function of those muscles. For example, patients with upper extremity muscle dysfunction will have difficulties doing work that require coordinated movement, such as grabbing and other similar actions. In addition, other comorbidities like lack of physical activities, insufficient nutrition, chronic heart failure., and pulmonary hypertension can affect the functions and muscle mass in COPD patients that will lead to loss of muscle mass and function. [18]

A system which identifies body compartment, such as Matiegka method, and calculates body weight as the summation of four aspects, can be used to calculate muscle mass. However, operators are not involved in the bioelectrical impedance analysis (BIA), a non - invasive test to determine body composition. [18]Muscle mass is the largest body of tissue and the richest in electrolytes. Muscle functions as the main conductor of human body. Based on the idea that human tissue is an ionic cylindrical conductor in which extracellular and intracellular loose fat acts as a resistor and capacitor, the calculating method is by tracking the change in the electric current of the body tissue. [19]

Cross – sectional area (CSA) studies reported a significant decrease in muscle mass is the most common clinical manifestation in COPD patients. This happens because hypoxia can trigger oxydative stress, systemic inflammation, protein imbalance, and high level apoptosis in multicells like the muscle. Eventually this will lead to muscle atrophy. For example, there is 30% decrease of CSA in COPD patients' thigh muscle. Other than that, there is a strong correlation between VEP - 1 and quadriceps muscle strength which means as the COPD gets more severe, the quadriceps muscle gets weaker. [2]Inaddition, changes in the growth factor and the relationship with IGF - I could result in decreased muscle mass. [20]

Pulmonary disease is the most general condition that recommends physical exercise as a treatment. Patients with a chronic disease usually experience deconditioning syndrome i. e. diminishing their ability to work and affecting their social and economic status. [2]Increasing medical bills, draining patients' fund for other necessities and will lead to problems with their psychology, social and even sex life.

Strength training is a form of exercise where specific group of muscles constantly work by lifting weight. Strength training is recommended for adults in order to reach healthy aging and also for those with chronic pulmonary disorder like COPD. In general, patients with COPD have weaker muscle, especially in the periphery area, compared to healthy people. [2]

There are some physiological mechanisms involved in strength training. First, the adaptation of the nerveous system. Strength training has to begin by increasing muscle capacity by incorporating all motoric unit. At the beginning stage of the training, neural adaptation can increase muscle strength before muscle growth. Strength training also reduces inhibitions from the central nervous system to obstruct over contraction. [21]

Patients with chronic lung disease who exercise regularly show lower level of stress, anxiety, and depression; also, better sleep quality and higher confidence level. Exercising boosts immunity, effective breathing, and ability to tolerate exertion pain in COPD patients, particularly those with more severe damage to their lungs. Nonetheless, workouts cannot repair physiological and structural discrepancy in these patients. [2]

The important component in caring for COPD patients is to provide sufficient nutrition for them. It is crucial for the patients to consume enough protein and energy to maintain body weight, fat - free mass, and healthy nutrition. Protein intake 1.2 - 1.5g/kg of body weight (mean 1.2g/kg) and energy input 125 - 156 percent (mean 140 percent) above the original energy expenditure is enough to prevent protein loss. [3, 5]

One of poultry products is eggs which are widely known as high protein source. Eggs are food that have many benefits for our body e. g. high nutrition value and their relatively cheap price compared to other sources of protein. [22]The eggs used in this study came from broiler chicken that are ubiquitous and widely consumed in Indonesia, they are also sold adequately and cheap. One egg, according to its volume, contains more egg whites than yolk. Of a 53 grams egg, 65.64% is the eggwhite while the shell and the yolk take 23.61% of the total volume. [23]It is known that ovalbumin, the type of albumin contained in eggs, is mostly found in the eggwhite instead of the yolk. Every 100grams of egg contains 10.5 grams protein of which 95% is albumin. [22]

After finishing the upper - body workout, study subjects ate the egg whites given by the researchers. For 4 weeks, the nutrition was given simultaneously with the upper body training i. e. twice a week (8 times during the experiment). The nutrition administration of 7 egg whites to the participants equals with a total protein intake of + - 25.55 grams.

6. Conclusion

Upper extremity strength training is beneficial for rehabilitation in restricted conditions. With the addition of egg whites, the training could increase muscle mass and prevent deconditioning syndrome and muscle dysfunction.

7. Future Scope

The limitations of the main methodology in this research are the absence of control group and the relatively small sample size. Furthermore, the HBPR strength training session was monotonous and boring for the patients. This issue can be remedied by implementing a combined exercise and instructions of physical activities. Also, the research can be further expanded in the future with longer duration of experiment and better design methodology i. e. employing a control group.

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