Original Article

Quadriceps strength in patients with chronic obstructive pulmonary disease

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ABSTRACT

Background: Skeletal muscle dysfunction is well known in chronic obstructive pulmonary disease (COPD). The muscle strength is altered in various muscles variedly. Lower-limb muscle strength is very important for walking distance. Reduced lower-limb strength can affect the physical quality of life. **Objectives:** The aim of the study was to assess and compare the quadriceps strength in COPD patients and age-matched healthy controls and to study the correlation between lung function parameters and the quadriceps strength in patients with COPD. **Methodology:** Thirty nonsmoker male patients; thirty nonsmoker female patients with COPD; and sixty age-, BMI-, and gender-matched healthy controls were studied. Quadriceps muscle strength was measured using a quadriceps dynamometer. Forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), FEF 25–75, and peak expiratory flow rate were measured using Helios 702 Spirometer. The quadriceps muscle strength between the two groups was compared using the unpaired Student's *t*-test. Correlations between FVC and FEV_1 with muscle strength were analyzed using the Pearson's coefficient. **Results:** The mean unilateral and bilateral quadriceps strength in both male and female COPD patients was significantly lesser than the healthy controls ($P < 0.05$). There was a significant positive correlation between muscle strength and FVC and muscle strength and FEV_1 in patients with COPD. **Conclusion:** The study shows that there is quadriceps weakness in COPD patients, and pulmonary functions have a direct impact on skeletal muscle strength. Identifying those patients who have reduced strength will allow early interventions targeted at improving the quality of life of the patient.

KEY WORDS: Chronic obstructive pulmonary disease, forced vital capacity, muscle strength, quadriceps

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is characterized by a persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. COPD is characterized by two distinct and frequently coexisting aspects: small airway abnormalities and parenchymal destruction. These changes do not always occur simultaneously. The chronic inflammation causes structural changes and narrowing of small airways resulting in lung parenchymal destruction.[1]

The available information from State Health Systems Resource Centre suggests that COPD is the leading cause of death in Maharashtra.[2] Patients with COPD have an impaired quality of life. Especially physical health is affected more compared with psychological and social health because of frequent symptoms and limitations on

Access this article online

Quick Response Code:

Website: www.lungindia.com

DOI: 10.4103/lungindia.lungindia_27_19

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How to cite this article: Shah S, Darekar B, Salvi S, Kowale A. Quadriceps strength in patients with chronic obstructive pulmonary disease. Lung India 2019;36:417-21.

physical activities. Some proposed mechanisms of skeletal muscle dysfunction in COPD include (i) systemic hypoxia which causes a change in the muscle metabolic phenotype from oxidative metabolism to anaerobic metabolism as an adaptive process[3] and (ii) increased circulating levels of inflammatory mediators such as interleukin-6, tumor necrosis factor-α, and C-reactive protein.[4]

Skeletal muscle dysfunction is frequently reported as fatigue in patients with COPD. In most of the individuals, it is the main limiting symptom, particularly during cycle-based exercise.[5] Studies have shown controversial results of reduced muscle strength in upper and lower limbs in patients with COPD. Moreover, In India, there are very few studies on quadriceps strength in COPD patients. With this background, this study was undertaken to assess and compare quadriceps strength in patients with COPD and age- and gender-matched healthy controls.

METHODOLOGY

The study was conducted in the Department of Physiology, B. J. G. Medical College, Pune, and the Respiratory Medicine Outpatient Department, Sassoon General Hospital. This was a case–control study. The sample size was calculated assuming 80% power and 5% level of significance. Thirty nonsmoker male and thirty nonsmoker female patients with COPD between the ages of 40 and 60 years attending the Respiratory Medicine Outpatient Department, Sassoon General Hospital, were randomly selected and invited to participate in the study. They were all diagnosed COPD patients by the treating chest physicians based on history and a postbronchodilator forced expiratory volume in 1 s/forced vital capacity (FEV_1/FVC) ratio of <70% on spirometry.[6] All the patients were nonsmoker to avoid the complications due to smoking in COPD. COPD in nonsmokers is also common in developing countries like India.[7] Patients with serious concomitant illnesses were excluded from the study. Thirty male and thirty female sedentary healthy volunteers of the same age group with normal lung function were selected randomly from the staff members of Sassoon General Hospital. Those patients with cardiorespiratory, musculoskeletal, or endocrine diseases were excluded from the study. Control population had similar socioeconomic status as the study population.

The study was approved by the institutional ethics committee. After obtaining written informed consent, all study participants were administered a questionnaire which captured demographic details, detailed medical history, personal history, and diagnosis as per the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines and duration of COPD with current symptoms.[8]

Spirometry was performed using the turbine flow sensor-based Helios 702 Spirometer by trained personnel in a quiet room as per the guidelines of the American Thoracic Society and European Respiratory Society.[8] All spirometries were performed between 12.30 p.m. and 1.30 p.m. to avoid diurnal variations. The parameters measured were FVC in liters, FEV_1, forced expiratory flow during 25%–75% of FVC (FEF 25%–75%), and peak expiratory flow rate (PEFR).

Quadriceps strength was measured by a specially designed dynamometer. It was constructed with the help of a chair, a load cell, and an integrated circuit. The chair was fixed on a wooden plank. At the base of the chair, a load cell was fixed to which an inextensible strap was attached. The load cell was attached to an integrated circuit. The load cell was calibrated and validated by applying various weights. The participant was made to sit on the chair. The thighs were strapped to the chair to stabilize the thighs, keeping the knee flexed at 90° over the end of the chair. The inextensible strap was placed around the right ankle and connected to the load cell. The participant was asked to extend his/her knee maximally with the strap around the ankle. Consecutive efforts were made at 30 s intervals, with visual feedback and verbal encouragement from the investigator, until no further increase in maximal voluntary contraction occurred.[9] The reading on the dial on IC was recorded as the torque of quadriceps muscle. The maximum value was recorded for the analysis. The length of the leg was measured in meters from the midpoint of the patella to lower border of medial malleolus. The following formula gave the muscle strength:

Torque = Force × radius.

Force = Muscle strength, Radius = Length of leg.

Similarly, left quadriceps strength was also measured in kilograms. For both quadricepses, a separate attachment was fixed with the load cell with the help of inextensible strap. This attachment consisted of two parallel rods to which a pair of floaters were fixed. The participant sat on the chair with the thighs strapped to the chair. He/she had to wear the floaters, and he/she was asked to extend both the knees maximally. Consecutive efforts were made at 30 s intervals, with visual feedback and verbal encouragement from the investigator, until no further increase in maximal voluntary contraction occurred. The maximum value was recorded for the analysis. The length of the leg was measured in meters. The above-mentioned formula gave the muscle strength.

The data were collected in data collection forms. Discrepant values were corrected by checking the data collection form. Final clean data were then analyzed statistically.

Statistical analysis

All the variables were expressed as mean ± standard deviation. Quadriceps strength was compared between COPD patients and healthy controls using the unpaired

Student's *t*-test for males and females separately. The correlations between FVC and FEV_1 with muscle strength were analyzed using the Pearson's coefficient correlation. All statistical analyses were performed using GraphPad Prism software version 6.0 (Graph pad software, San Diego, California, US).

RESULTS

The study population included 60 healthy controls and 60 COPD patients. There were no significant differences between the mean ages, heights, and weights of the controls and COPD patients [Table 1]. The respiratory parameters (FVC, FEV_1, FEF 25–75, and PEFR) were significantly lower in patients with COPD when compared with normal control population ($P < 0.005$) [Table 2].

The mean right quadriceps strength in male COPD patients was 28.76 ± 8.67 kg and was significantly lesser than the normal males (41.16 ± 10.28 kg, $P < 0.001$). In females, the mean right quadriceps strength in COPD patients was 21.67 ± 6.87 kg and was significantly lesser than the normal controls (35.75 ± 10.54 kg, $P < 0.001$). While on comparing left quadriceps strength, we found that, in both male and female COPD patients (27.1 ± 7.34 kg and 19.32 ± 8.65 kg, respectively), it was statistically significantly reduced than the control group (19.32 ± 8.65 kg and 34.43 ± 6.90 kg, respectively) ($P < 0.001$). Similarly, both quadricepses' strength was also reduced in both male and female patients with COPD (30.76 ± 3.77 kg and 21.66 ± 7.49 kg, respectively) compared to normal controls (45.39 ± 9.81 kg and 38.31 ± 5.12 kg, respectively, $P < 0.001$) [Table 3]. When the data were pooled, FVC showed a positive correlation with bilateral quadriceps muscle strength in patients with COPD ($r^2 = 0.33$, $P < 0.05$), while FEV_1 was also positively correlated with bilateral quadriceps muscle strength ($r^2 = 0.37$, $P < 0.05$) [Table 4].

DISCUSSION

Our study has shown that there is a significant reduction in quadriceps strength in patients with COPD compared to normal healthy controls. Very few studies have assessed both unilateral and bilateral quadricepses' strength. In our study, we have assessed individual as well as both quadricepses together. It was found that both unilateral and bilateral as well as combined quadricepses' strengths were reduced in patients with COPD as compared to age- and gender-matched healthy controls.

Quadriceps strength is a noninvasive test, which is simple to perform and gives a functional assessment of muscle

Table 1: Comparison between study group and control group

Parameter	COPD (30 males)	Control (30 males)	*P*	COPD (30 females)	Control (30 females)	*P*
Age	55.18±4.45	54.88±4.28	>0.05	53.24±5.13	52.51±6.71	>0.05
Height	160.23±8.86	162.18±7.33	>0.05	148.26±7.66	150.83±6.66	>0.05
Weight	60.57±8.38	61.42±7.76	>0.05	50.17±4.19	51.97±2.17	>0.05

COPD: Chronic obstructive pulmonary disease

Table 2: Comparison of respiratory parameters (percentage predicted) in patients with chronic obstructive pulmonary disease and control population

Parameter	Control		*P*	COPD		*P*
	30 males	30 females		30 males	30 females	
FVC	94.32±5.66	87.6±5.54	<0.05	55.3±11.81	52±8.67	<0.05
FEV_1	88.58±6.33	84.8±4.13	<0.05	35.61±1.25	34.92±7.46	<0.05
FEF25–75	75.28±11.48	71.16±7.69	<0.05	25.66±5.20	20.41±4.31	<0.05
PEFR	79.6±12.87	72.2±11.14	<0.05	35.92±10.4	22.15±5.27	<0.05

FVC: Forced vital capacity, FEV1: Forced expiratory volume in 1 s, FEF25–75: Forced expiratory flow during 25–75, PEFR: Peak expiratory flow rate, COPD: Chronic obstructive pulmonary disease

Table 3: Comparison of right, left, and both quadricepses' muscle strength in patients with chronic obstructive pulmonary disease and control population

Gender	Mean±SD		*P*
	Right quadriceps strength (kg) in Control population (*n*=30)	Right quadriceps strength (kg) in COPD population (*n*=30)	
Males	41.16±10.28	28.76±8.67	<0.001
Females	35.75±10.54	21.67±6.87	<0.001
Gender	**Left quadriceps strength (kg) in control population (*n*=30)**	**Left quadriceps strength (kg) in COPD population (*n*=30)**	***P***
Males	39.16±6.08	27.1±7.34	<0.001
Females	34.43±6.90	19.32±8.65	<0.001
Gender	**Both quadricepses' strength (kg) in control population (*n*=30)**	**Both quadricepses' strength (kg) in COPD population (*n*=30)**	***P***
Males	45.39±9.81	30.76±3.77	<0.001
Females	38.31±5.12	21.66±7.49	<0.001

COPD: Chronic obstructive pulmonary disease, SD: Standard deviation

Table 4: Correlation of Pulmonary function tests (PFTs) and quadriceps strength

FVC Mean±S.D. *n*=60	Muscle Strength Mean±S.D. *n*=60	Pearson's Coefficient (r^2)	Significance
53.15±10.24	26.21±5.03	0.337	$p<0.05$
FEV1 Mean±S.D. *n*=60	**Muscle Strength Mean±S.D. *n*=60**	**Pearson's Coefficient**	**Significance**
35.21±4.35	26.21±5.03	0.375	$p<0.05$

bulk. Measurement of quadriceps strength could be used to identify high-risk patients with COPD having peripheral skeletal muscle weakness. These patients can get greater benefits from pulmonary rehabilitation or nutritional supplementation.

There are various studies showing conflicting results in COPD. Moreover, Allaire *et al*. showed reduced quadriceps strength and endurance in quadriceps muscle compared to normal healthy controls. In this study, patients with COPD had quadriceps muscle atrophy, as shown by a CT scan of the thigh. The authors found that, in the patients with COPD, quadriceps muscle strength was reduced by 17 kg on average, and the endurance test showed that the time to fatigue was 38 s shorter in the patients with COPD than in healthy individuals.[10] In our study, the individual quadriceps strength reduced is 13.5 kg on an average, while the strength of both quadriceps together also reduced by 16 kg in patients with COPD as compared to age- and gender-matched healthy controls. Swallow *et al*. found that quadriceps maximal voluntary contraction (QMVC)-Quadriceps strength predicts mortality in patients with moderate to severe COPD.[11]

The study by Man *et al*. showed reduced quadriceps strength in one-third of patients.[9] Kharbanda *et al*. studied quadriceps strength with the help of a hand-held dynamometer and found that 92% of participants were suffering from quadriceps muscle weakness. Significant quadriceps weakness was present in significantly high proportions even in those who had mild COPD.[12]

There are various systemic factors such as inflammation, hypoxia, acidosis, malnutrition, and local muscle factors such as deconditioning causing extrapulmonary complications in patients with COPD. One of the important findings in patients with COPD is disuse atrophy. As the disease progresses and symptoms intensify, patients because of breathlessness become inactive and this leads to muscle deconditioning. The greatest effect is on the muscles that are least used, that is, the quadriceps muscle resulting in reduced muscle strength.[9] Structural changes in the lower-limb muscles result in reduced overall exercise capacity, progressing to deconditioning caused by a reduction in the physical daily activities to avoid dyspnea.[13] The reduction in strength could be attributed to a decrease in the proportion of Type I fibers and an increase in the proportion of Type II fibers, as well as to reduced oxidative metabolism and quadriceps muscle deconditioning.[9]

Maltais *et al*. studied the oxidative capacity of the vastus lateralis muscle. They found that citrate synthase and 3-hydroxyacyl-CoA dehydrogenase were reduced in patients with moderate-to-severe COPD compared with normal controls of similar age.[14] Studies have shown decreased muscle mass and increased glycolytic enzymes.[15,16] There is a shift in muscle fiber composition, with preservation of Type IIb fibers and loss of Type I and IIa fibers in COPD. This change in composition could be an adaptive response to hypoxia because Type IIb fibers are glycolytic, while Type I and IIa fibers depend mainly on oxidative metabolism.[17]

Ultrasound rectus femoris cross-sectional area and quadriceps strength QMVC were reduced in all GOLD stages in a study by Shrikrishna *et al*.[18]

However, the literature about the relationship between muscle function and severity of COPD is highly controversial. Some of the studies indicate the presence of muscle dysfunction even in the early stages of COPD.[12] There is an increase in the prevalence of quadriceps weakness with increasing GOLD stage of the COPD disease.[12]

In our study, we found that there was a significant positive correlation between percentage predicted values of FEV1 and bilateral quadriceps strength ($P < 0.05$). In a study by Seymour *et al*., it was found that a significant proportion of patients with COPD in GOLD Stages 1 and 2 had quadriceps weakness (28% and 26%, respectively). These values increased to 38% in GOLD Stage 4 and 43% in patients with an MRC score of 4 or 5.[19] This shows that quadriceps weakness worsens with severity of the disease, which is in accordance with our study.

Limitation and scope of the study

Our study was a unique study, wherein a standardized instrument was devised to measure quadriceps strength. It was possible to measure individual as well as both quadricepses together. Furthermore, in India, there is very limited number of studies on quadriceps strength in COPD. In our study, in the same patients with COPD, assessing upper-limb muscle strength and electrophysiological parameters would have given better findings. This is the limitation of our study.

CONCLUSION

Our study showed a significant decrease in unilateral as well as bilateral quadriceps strength in patients with COPD as compared to age- and gender-matched healthy controls. There was a significant correlation between quadriceps strength and FVC and FEV_1 in COPD patients. Further studies will be required to evaluate the influence

of improving the pulmonary function parameters on the quadriceps muscle strength in patients with COPD.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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