Upper limb muscle strength & endurance in chronic obstructive pulmonary disease

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Received June 3, 2013

Background & objectives: There are very few studies that have investigated the muscle strength and endurance of upper limbs (UL) in chronic obstructive pulmonary disease (COPD). We undertook this study to measure and compare the skeletal muscle strength and endurance of UL in COPD patients and age matched healthy controls and to study the association between lung function parameters and UL muscle strength and endurance.

Methods: Forty one COPD patients and 45 height and weight matched healthy subjects of the same age group were studied. UL skeletal muscle strength and endurance were measured using the hand grip dynamometer test. Forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV₁), forced expiratory flow during 25-75% FVC (FEF_{25-75%}) and peak expiratory flow rate (PEFR) were measured. The handgrip muscle strength and endurance between the two groups were compared and correlations between FVC and FEV₁ with muscle strength and endurance were analyzed.

Results: The mean handgrip strength and mean muscle endurance in COPD patients were significantly lesser than the normal subjects in both males and females (P<0.001). There was significant positive correlation between muscle strength and FVC in males (r^2 =0.32, P<0.05); and between muscle strength and FEV₁ in females (r^2 =0.20, P<0.05).

Interpretation & conclusion: The study showed that the handgrip muscle strength decreases as the FVC and FEV_1 decrease in patients with COPD. Identifying those patients who have reduced strength and endurance will allow early interventions targeted at improving the quality of life of the patient.

Key words Chronic obstructive pulmonary disease - hand grip spirometry - skeletal muscle dysfunction

Chronic obstructive pulmonary disease (COPD) is a chronic inflammatory disease of the airways and lung parenchyma associated with airway narrowing, alveolar wall destruction and systemic hypoxaemia. It is believed that the cellular mediators of inflammation present in the airways and alveolar walls spill over into the circulation and contribute to skeletal muscle dysfunction, cardiac failure, atherosclerosis and osteoporosis leading to poor quality of life and increased morbidity and mortality in COPD patients¹. It is, therefore, important to treat the systemic consequences also whenever possible to improve the quality of life and reduce mortality. Skeletal muscles are widely affected in COPD and several mechanisms have been postulated *viz*: (*i*) systemic hypoxia which causes a change in the muscle metabolic phenotype from oxidative metabolism to anaerobic metabolism as an adaptive process², and (*ii*) increased circulating levels of inflammatory mediators such as interleukin-6 (IL-6), tumour necrosis factor- α (TNF- α) and C-reactive protein (CRP)³.

Importance of dysfunction of peripheral skeletal muscles on exercise capacity in patients with COPD was first suggested by Killian and coworkers in 1992⁴. A few years later Hamilton and colleagues showed that approximately 70 per cent of patients with chronic lung disease had poorer quadriceps strength when compared to age matched healthy subjects⁵. Thereafter, there have been many studies showing reduced skeletal muscle strength and endurance, especially in the lower limbs of COPD patients⁶⁻⁹. However, there has been little research into the upper limb skeletal muscle dysfunction in COPD patients. If upper limb muscles show reduced strength and endurance, clinicians can plan out better pulmonary rehabilitation activities which could include upper limb muscle exercise training. We hypothesized that COPD patients would have poor hand grip strength and endurance as compared to age matched healthy subjects and that this would correlate with lung function parameters. The aim of this study was to compare the hand grip muscle strength and endurance of the distal skeletal muscles of the upper limb in patients with COPD with age and gender matched healthy controls. Further, their association with spirometric lung function parameters viz: forced vital capacity (FVC) and forced expiratory volume in one second (FEV₁) in COPD patients was also studied.

Material & Methods

This case control study was conducted in the department of Physiology at B. J. Medical College, and the Respiratory Medicine Outpatient Department at the Sassoon General Hospital, Pune, India, during March to August in 2009-2010.

A sample size of 41 for both COPD patient group as well as normal control group was calculated assuming power more than 80 and 5 per cent level of significance. Twenty one male and 20 female patients aged 40-70 yr attending the Respiratory Medicine outpatient department at Sassoon General Hospital were randomly selected for this study. They were all diagnosed COPD patients based on history and a post bronchodilator FEV_1/FVC ratio of <70 per cent on spirometry¹⁰. All were nonsmokers. Patients with serious concomitant illnesses such as major cardiovascular, neurological and musculoskeletal diseases were excluded from the study. Twenty five male and 20 female sedentary healthy volunteers of the same age group with normal lung function were selected randomly in control group. Since it was difficult to find normal controls with similar physical activity as that of the COPD patients, it was ensured that they had physical activity status almost similar to the patients *i.e.* having a sedentary life-style. We selected the normal controls from the workers of the Sassoon General Hospitals, so that they will have similar socio-economic status as that of the patients, which was also confirmed by verbal interview. Those with cardio-respiratory, musculoskeletal or endocrine diseases were excluded from the study.

The study was approved by the Institutional Ethics Committee. After obtaining a written informed consent, all study subjects were administered a questionnaire which captured demographic details, medical history, personal history and diagnosis as per the GOLD (Global Initiative for Obstructive lung disease) guidelines and duration of COPD with current symptoms¹⁰.

A handgrip dynamometer (INCO India Ltd., Ambala) was used to measure the muscle strength and endurance of the upper limbs according to the technique described and validated by Madanmohan et al¹¹. After explaining the procedure to the study subject and giving a demonstration, they were asked to hold the handgrip dynamometer in the dominant hand in sitting position. The forearm was extended over a table and elbow flexed at 90°. Subjects were asked to hold the dynamometer in such a way that the second phalanx was against the inner stirrup, and were then asked to grip the dynamometer handle with as much force as they possibly could apply. The handgrip muscle strength was recorded in kilograms as indicated by the pointer on the dynamometer. Three recordings were taken with a gap of two minutes between each effort and the maximum value was recorded for the analysis.

The handgrip endurance was measured by asking the subjects to maintain their grip on the handgrip dynamometer at $\frac{1}{3}$ rd of their maximum handgrip strength for as long as they could. The duration for which they could maintain the grip strength was noted in seconds. Two recordings were obtained with a gap of five minutes between each effort and the maximum value was recorded for the analysis. Spirometry was performed using the turbine flow-sensor based MIR Spirolab II (Italy) by trained personnel in a quiet room as per the guidelines of the American Thoracic Society and European Respiratory Society (ATS/ERS)¹². All spirometries were performed between 1230 to 1330 h to avoid diurnal variations. The parameters measured were forced vital capacity (FVC) in liters, forced expiratory volume in 1 sec (FEV₁), forced expiratory flow during 25-75% of FVC (FEF_{25-75%}) and peak expiratory flow rate (PEFR).

All data were collected in a Data Collection Form and then transferred to an Excel sheet by two independent data entry operators. Discrepant values were corrected by checking the data collection form. Clean data were then analyzed statistically.

Statistical analysis: All the variables were expressed as mean \pm standard deviation (SD). Handgrip muscle strength and handgrip muscle endurance were compared between COPD patients and normal subjects by using the unpaired Student's t test for males and females separately. The correlations between FVC and FEV₁ with muscle strength and muscle endurance were analyzed by using the Pearson's coefficient correlation. All statistical analyses were performed by using SPSS software version 11.0 (Chicago, USA) and Graphic Pad Prism software version 6.0.

Results

The study population included 45 healthy controls and 41 COPD patients. There were no significant differences between the mean ages, heights and weights of the control subjects and COPD patients (Table I). The respiratory parameters (FVC, FEV₁, FEF₂₅₋₇₅, PEFR) were significantly lower in COPD patients when compared with control population (P<0.001), (Table II).

Table I. Comparison of demographic characteristics between study and control groups						
Parameter	COPD patients (21 males, 20 females)	Control group (25 males, 20 females)				
Age (male) yr	56.9 ± 8.5	54.9 ± 8.3				
Age (female) yr	61.7 ± 6.9	59.4 ± 7.8				
Height (male) cm	159.2 ± 7.9	161.3 ± 7.3				
Height (female) cm	155.2 ± 6.8	154.9 ± 5.4				
Body mass (male) kg	61.6 ± 7.4	64.4 ± 8.7				
Body mass (female) kg	53.9 ± 7.1	55.8 ± 6.8				

The mean handgrip strength in male COPD patients was 21.8±4.7 kg and was significantly lesser than the normal males (31.2 \pm 4.3 kg, P<0.001). In females, the mean handgrip strength in COPD patients was 19.2±3.4 kg and was significantly lesser than the normal controls $(23.0\pm1.9 \text{ kg}, P < 0.001)$. The mean muscle endurance in male COPD patients was 48.9 ± 20.6 sec and was significantly lesser than the normal male subjects $(108.3\pm33.7 \text{ sec}, P < 0.001)$. The mean muscle endurance in female COPD patients was 37.4±11.2 sec and was significantly lesser than the normal subjects (99.1±9.1 sec, P < 0.001). On comparing the percentage reduction in COPD patients compared to controls, muscle endurance was more affected than muscle strength (muscle strength reduction-31% in males, 17% in females and muscle endurance reduction-56% in males and 63% in females). FVC showed a positive correlation with muscle strength in males ($r^2=0.32$, P<0.05), while in females FEV₁ was positively correlated with muscle strength (r²=0.20, P<0.05). Muscle endurance did not show any correlation with either FEV_1 or FVC both in males and females.

Table II. Comparison of respiratory parameters (% predicted) in patients with COPD and control population					
Parameter	Control (25 males)	Control (20 females)	COPD (21 males)	COPD (20 females)	
FVC	90.5 ± 9.7	83.2 ± 5.4	$54.3 \pm 10.9^{*}$	$53.2 \pm 9.7^{+}$	
FEV_1	88.5 ± 6.9	84.1 ± 4.4	$35.6\pm10.3^{\ast}$	$37.6 \pm 6.1^+$	
FEF _{25-75%}	74.3 ± 10.5	76.7 ± 7.1	$25.8\pm5.2^{\ast}$	$23.1\pm6.2^{\scriptscriptstyle +}$	
PEFR	78.6 ± 12.3	84.1 ± 10.1	$25.9 \pm 11.2^{*}$	$25.2\pm7.0^{\scriptscriptstyle +}$	

FVC, forced vital capacity; FEV₁, forced expiratory volume in 1 sec; FEF_{25-75%}, forced expiratory flow during 25-75% of FVC; PEFR, peak expiratory flow rate.

*P < 0.001 compared to controls (males); +P < 0.001 compared to controls (females)

Discussion

In this study, patients with COPD showed a significantly lower handgrip muscle strength and endurance compared to age matched controls. The reduced handgrip muscle strength correlated positively and with both FEV_1 and FVC% predicted values. Skeletal muscle dysfunction has been reported in COPD. Gosselink *et al*¹³ showed that in patients with COPD handgrip force decreased significantly. Clark and colleagues⁶ showed that in COPD patients upper limb muscle strength (biceps and triceps) was reduced but sustained performance was not reduced. Some studies have shown reduced strength of shoulder girdle and latissimus dorsi muscle⁸, and reduced endurance of the adductor pollicis muscle¹⁴. Another study showed that peak and average force of elbow flexor muscles was reduced in patients with COPD, but the difference was not statistically significant. Heijdra et al16 showed that there was no change in the handgrip strength in COPD patients compared to age matched healthy control group. This is in contrast to our study. They have taken the average of three measurements of right and left handgrip strength, while in the present study the best of three measurements of the dominant hand was taken.

There are many studies which have shown significant positive correlation between quadriceps strength/endurance and $\text{FEV}_1^{7,8,13}$. El-Din *et al*¹⁷ showed no correlation between the FVC, FEV_1 and the upper limb muscle strength, but they found significant positive correlation between FVC, FEV_1 and quantitative interference pattern EMG parameters. In our study, a significant positive correlation was found between percentage predicted FVC and handgrip strength and between percentage predicted FEV₁ and muscle strength. This indicates that pulmonary functions may have direct impact on skeletal muscle strength. Severity of the disease affects the extent to which the skeletal muscle functions are compromised.

Structural and biochemical abnormalities have been reported in the skeletal muscles of COPD patients such as lower fraction of type I fibers and higher fraction of type II fibers¹⁸. A high fraction of myosin heavy chain type 2B Isoforms have also been found¹⁹. Concentration of aerobic but not glycolytic enzymes is reduced in COPD patients²⁰. This indicates a switch over from aerobic to anaerobic metabolism. In our study the muscle endurance was more affected than the muscle strength. This finding suggests a shift from aerobic to anaerobic metabolism in COPD patients. The capillary density in the skeletal muscles is often reduced which results in increased diffusion distances for oxygen transport and thereby reduced oxygen utilization. Several studies have shown that lactic acidosis occurs at much lower work rates than in healthy subjects²¹.

Deconditioning is a major contributor to the skeletal muscle dysfunction seen in patients with COPD. These patients generally assume a sedentary lifestyle to avoid the dyspnoea that physical activity brings. Changes resembling the skeletal muscle alterations occurring with deconditioning have been described in patients with COPD. These include reduction in oxidative enzyme capacity and proportion of type I fibers; and atrophy of type I fibers². Hypophosphatemia associated with low intracellular ATP levels found in COPD may form the basis of observed muscle weakness².

Though most of the studies have been done in lower limb skeletal muscles in COPD, probably the similar factors are responsible for the reduced muscle strength and endurance in upper limb. Several studies have shown that upper limb muscle strength influences walking distance^{13,22,23}. It has been shown that for a 10 kg increment in grip strength, people could walk an average of 14 m farther²³. Hence measuring upper limb strength; which is a very easy and quick method compared to 6-minute walk test can give a clue about walking strength of the person. Probably by improving the pulmonary function parameters, upper limb muscle strength and the walking distance of the COPD patient can be improved.

Management of COPD should not be limited to symptomatic relief of respiratory symptoms. Pulmonary rehabilitation done in COPD patients should include effective exercise training for increasing the muscle strength and endurance; as studies have shown that strength training in patients with COPD can produce increase in muscle strength of upper and lower limbs²⁴. Identifying those patients who have greater reduction in strength and endurance will allow early interventions targeted at increasing strength such as diet, hormonal supplementation and strength training. Evidence based clinical practice guidelines²⁵ recommend the inclusion of exercise training targeted at the muscles of upper limbs in the physical therapy programs specific to COPD patients.

In conclusion, our study showed a significant association between handgrip muscle strength and FVC and FEV_1 in COPD patients. A study with larger sample

size along with varying severity of disease would be a better indicator of this relationship. Further studies will be required to evaluate the influence of improving the pulmonary function parameters on the skeletal muscle exercise capacity and indirectly the walking distance of the patient.

Acknowledgment

Authors acknowledge the Chest Research Foundation, Pune for technical support.

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