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Relation between upper-limb muscle strength with exercise capacity, quality of life and dyspnea in patients with severe chronic obstructive pulmonary disease

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Abstract

Introduction: In chronic obstructive pulmonary disease (COPD), skeletal muscle weakness is characterized by reduced muscle strength, reduced muscle endurance and the presence of muscle fatigue especially in lower limbs. There has been little research into the upper limb skeletal muscles.

Objectives: In this study, we aimed to investigate the relation of upper limb muscle strength with pulmonary function, exercise capacity, quality of life (QoL) and dyspnea sensation.

Methods: Eigthy-eight patients (89.8% male; age: 64.2 ± 8.7 years) with COPD ($FEV1 = 34.2\% \pm 15.2\%$) were evaluated. Tests included hand grip strength and actual 1-repetition maximum (1RM) test for upper limb strength. Dyspnea sensation was assessed with medical research council (MRC) scale. St. George Respiratory Questionary (SGRQ) was used to evaluate patients health related QoL. Exercise capacity was evaluated with incremental shuttle walk test and endurance shuttle walk test.

Results: Upper limb muscle strength correlated with exercise capacity but no correlations were found with pulmonary functions.There were negative correlations with all the domains of SGRQ both actual 1RM and handgrip strength. MRC scores revealed a negative correlation with upper limb muscle strength.

Conclusion: In our study, we showed that upper limb muscle strength correlated with exercise capacity, QoL, dyspnea sensation. Identifying patients who have greater reductions in strength will allow early interventions with a multidisciplinary manner.

KEYWORDS
COPD, dyspnea, pulmonary rehabilitation, quality of life, upper limb strength

1 | INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is characterized by airway obstruction, systemic inflammation and skeletal muscle dysfunction.[1] The estimated overall prevalence of skeletal muscle weakness in patients with COPD was shown to be 32%.[2] In addition, a trend towards higher prevalence of skeletal muscle weakness with disease severity (Global Initiative for Chronic Obstructive Lung Disease stages) has been reported independently of lung function.[2,3] Dyspnea on exertion, muscle fatigue and exercise limitation are associated with a gradual decline in functional status. Muscle weakness is mainly observed in the lower limb muscle of patients with COPD, whereas the structure and function of the upper limb muscles are found relatively preserved.[4,5] Against this background, physical performance is affected during walking or stair climbing and during simple activities of daily living (ADL) that involve the upper extremities.[1] Numerous problematic activities of daily living involve the upper extremities, including dressing, bathing, shopping and many household tasks.[6] Accordingly, upper limb training is typically integrated into an exercise regimen.[1] It has been shown that daily arm activities that need elevation above the shoulders may interfere with regular breathing and are associated with dynamic hyperinflation in patient with COPD.[7] Dynamic hyperinflation is one of the most important limiting factors for exercise capacity in patients with COPD, it is also related with increased dyspnea sensation. Muscle strength in the lower limbs has previously been shown to be an important factor in determining exercise tolerance,[1] though, the influence of upper-limb muscle strength on exercise capacity, quality of life (QoL) and dyspnea sensation has not been investigated in detail.

The aim of this study was to evaluate the relationship between upper limb muscle strength,which was evaluted using the actual 1-repetition maximum (1RM) test and handgrip strength with pulmonary function, exercise capacity, health-related QoL and dyspnea sensation in patients with COPD.

2 | MATERIALS AND METHODS

2.1 | Subjects

The present retrospective, nonrandomized study included patients with COPD who were admitted to Ataturk Chest Diseases and Chest Surgery Education and Research Hospital, Pulmonary Rehabilitation (PR) Center. Eighty-eight patients with diagnosed of COPD based on history and a postbronchodilator FEV1/FVC ratio of <70% on spirometry.[8] The exclusion criteria were presence of heart disease such as unstable angina, congestive heart failure, uncontrolled arrhythmias, sinus tachycardia at rest (HR >120 rpm), hypertension at rest and/or stress if not adequately controlled by therapy, presence of orthopedic diseases and neuromuscular disorders that could influence outcomes. All patients provided written informed consent to participate in PR.

2.2 | Pulmonary function

Lung function testing was performed (Vmax 229 series, Sensormedics, Yorba Linda, CA) by trained personnel in a quiet room as per the guidelines of the American Thoracic Society and European Respiratory Society.[9] All spirometries were performed between 12:30 PM and 13:30 PM to avoid diurnal variations. The parameters measured were post bronchodilator 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, which are expressed as percentages of predicted values.

2.3 | Quality of life and dyspnea

A version of the St. George's Respiratory Questionnaire (SGRQ) that is divided into three components (symptom, activity, impact) was used to evaluate patient health-related QoL. SGRQ scores range from zero (the best level of health) to 100 points (the poorest level of health).[10] We used the Medical Research Council (MRC) scale to measure the intensity of dyspnea during activities of daily living.[11]

2.4 | Handgrip, and actual 1-RM tests

In this study, we used both hand grip and actual 1-RM tests because it is unclear as to which test represents a useful measure to evaluate upper limb muscle strength in patients with COPD. Handgrip measures muscle strength of the hands and distal upper limb muscles. Actual 1RM measures proximal upper limb muscle and shoulder muscle strength. Skeletal muscle strength of the hand was estimated based on hand grip strength of the dominant hand measured using a dynamometer (Jamar Hydraulic Hand Dynamometer, Mississauga, Canada). In a seated position, each subject kept his or her arm at the side, with the shoulder adducted and neutrally rotated, the elbow flexed at 90° and the forearm in a neutral position between supination and pronation. The examiner stabilized the elbow, and the subject was asked to squeeze the dynamometer, exerting maximum grip.[12] Three trials were performed of each hand in alternating fashion. For this analysis, the maximum of three trials on the dominant side was selected. Upper limb isotonic muscle strength was assessed through the determination of the actual 1RM test. The patient stood with feet shoulder-width apart, and after a warm up, chose a weight that was achievable, gripped a dumbell and raised one arm until her/his arm was parallel to the floor. Then, after a rest of at least several minutes, the weight was increased and they tried again. The load was increased until the subject could only perform-one-repetition. The load was recorded that the patient raised only one time.

2.5 | Exercise capacity

We evaluated execise capacity using the incremental shuttle walk test (ISWT) and endurance shuttle walk test (ESWT) according to methods described by Singh and coworkers, respectively.[13] Patients walked between two cones 10 m a part at an incrementally increasing pace. Each increment was signalled by a fully calibrated audio cassette. To assist, the operator accompanied the patient throughout the test. The endpoint was reached when the patient could no longer maintain the required speed or became too breathless to proceed further.[14] Heart rate, blood pressure, oxygen saturation and dyspnea perception according to the modified Borg scale[15] were recorded before and immediately after finishing the field exercise tests. The ESWT was performed at 85% of peak oxygen consumption, as predicted by the ISWT. Peripheral oxygen saturation (SpO2) was monitored throughout the test using a pulse oximeter. The tests were performed with oxygen supplementation in patients who were hypoxic at rest and who were using long-term oxygen therapy.

2.6 | Statistical analysis

Data were analyzed using IBM SPSS Statistics 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) and the R package 'polycor' was used for calculating polyserial correlation coefficients. Statistical significance was accepted as $P < .05$

The Shapiro-Wilk test was used for the normality test. Mean ± standard deviation is given for the variable of age. Descriptive statistics for variables that did not have normal distribution are shown as median (minimum, maximum). The mean ± standard deviation was calculated as in additional information in Table 1. Frequency (n) and percentage (%) are reported for sex and MRC variables.

The Spearman's correlation coefficient was calculated to evaluate the correlation between variables. The correlation between MRC and actual 1RM, handgrip variables were examined using the polyserial correlation coefficient.

The strength of correlation was described by using the guide that Alpar suggested, the absolute value of correlation coefficients. When the correlation coefficient was in the range of 0.0–0.19; 0.20–0.39; 0.40–0.69; 0.70–0.89 and 0.9–1.00 it was determined there was no correlation or very weak, weak, moderate, strong and very strong correlation, respectively.

3 | RESULTS

3.1 | Baseline characteristics of the study population

Previous PR program, baseline characteristics of the 88 patients with COPD are shown in Table 1. Of the 88 patients, 79 (89.8%) were men, and all were aged >36 years. The patients mostly had severe to very severe airflow obstruction with a post bronchodilator FEV1 of 34.2% ± 15.2% predicted. Fifty-eight patients were receiving domiciliary oxygen therapy for at least 15 hours per day (Table 2).

Health-related QoL was assessed using the SGRQ (Table 1). The mean values of SGRQ scores were 49.9 ± 22.4, 63.9 ± 17.7, 74.8 ± 18.8 and 59.93 ± 18.12 in impact, symptom, activity and total score, respectively.

The mean value for dyspnea sensation was 3.31 ± 1.03 when evaluated using the MRC scale (Table 2).

TABLE 1 Baseline characteristics of the study population

Variables	Median	Min; max	Mean ± Standard deviation[a]
Age (years)	65.0	36.0; 85.0	64.2 ± 8.7
Smoking (pack/year)	40.0	2.0; 200.0	49.6 ± 31.8
ISWT (m)	190.0	0.0; 650.0	194.6 ± 119.8
ESWT (min)	3.3	0.0; 20.0	5.9 ± 5.9
FEV1	30.0	12.0; 74.0	34.2 ± 15.2
FVC	49.5	19.0; 112.0	53.2 ± 16.9
FEV1/FVC	51.5	7.0; 84.0	53.2 ± 13.8
SGRQ (Impact)	48.6	10.1; 92.4	49.9 ± 22.4
SGRQ (Activity)	80.7	35.8; 100.0	74.8 ± 18.8
SGRQ (Symptom)	65.5	16.5; 97.6	63.9 ± 17.7
SGRQ (Total)	63.8	24.5; 91.1	59.9 ± 18.1
Actual 1RM in kg	5.5	1.0; 14.0	5.8 ± 2.1
Handgrip (kg)	30.0	12.0; 61.0	30.8 ± 7.9

[a]Mean ± SD: Mean ± standard deviation/min; max: minimum; maximum. ISWT, incremental shuttle walk test; ESWT, endurance shuttle walk test; FEV1, forced expiratory volume in the first second (predicted%); FVC, forced vital capacity (predicted%); SGRQ, St. George's respiratory questionnaire; actual 1RM, 1-repetition maximum.

3.2 | Upper limb muscle strength and exercise capacity

Four of the patients were immobile. The mean ISWT and ESWT results were 194.6 ± 119.8 min and 5.9 ± 5.9 min,

TABLE 2 Other parameters

	n (%)
Male/female	79 (89.8)/9 (10.2)
MRC Grade 1	1 (1.1)
MRC Grade 2	26 (29.5)
MRC Grade 3	15 (17)
MRC Grade 4	37 (42.0)
MRC Grade 5	9 (10.2)
LTOT	58 (65.9%)

MRC, medical research council; LTOT, long-term oxygen therapy.

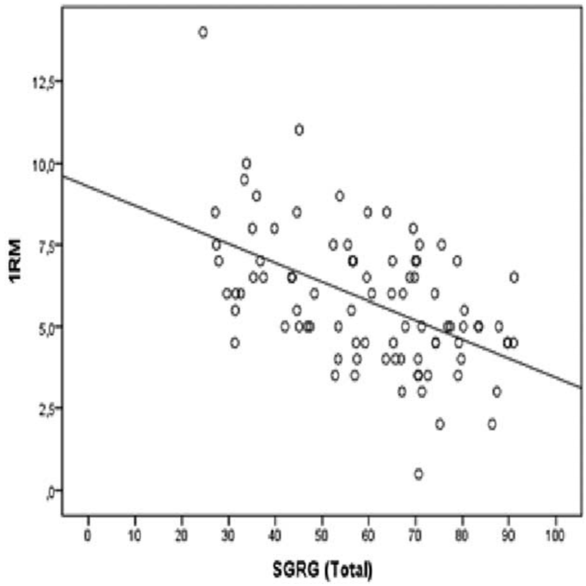

FIGURE 1 The correlation between 1-repetition maximum and St. George's respiratory questionnaire total

respectively, which showed impaired exercise capacity according to the reference values.[16] The mean 1RM exercise was 5.8 ± 2.1 kg and handgrip strengths were within very low values obtained for healthy individiuals in the various age groups.[16] A statistically significant correlation was found between handgrip and actual 1RM ($P < .001$, $r = 0.620$).

There was a negative correlation between the actual 1RM and all the domains of the SGRQ ($P < .001$, Figure 1), and handgrip was negatively correlated with the scores of SGRQ activity (rho = −0.329, $P = .002$) symptom domains (rho = −0.346, $P = .001$) and total (rho = −0.237, $P = .026$ Figure 2). The correlations between handgrip, actual 1RM and the variables are given in Table 3. Both handgrip and actual 1RM were statistically significantly positively correlated with ISWT (rho = 0.415, $P < .001$ and rho = 0.411, $P < .001$, respectively), ESWT (rho = 0.242, $P = .023$ and rho = 0.273, $P = .010$, respectively) and there was a negative corelation with the MRC score (rho = −0.432, $P < .001$, and rho = −0.606, $P < .001$, respectively) (Figures 3 and 4).

TABLE 3 Significant correlations between handgrip, actual 1RM and variables

	Handgrip (kg)		Actual 1RM (in kg)	
	Rho	*P*	Rho	*P*
ISWT (meter)	0.415	**<.001**	0.411	**<.001**
ESWT (min)	0.242	**.023**	0.273	**.010**
FEV1	0.092	.395	0.036	.737
FVC	0.170	.114	0.142	.186
FEV1/FVC	0.096	.375	0.036	.737
SGRQ (Impact)	−0.110	.308	−0.372	**<.001**
SGRQ (Activity)	−0.329	**.002**	−0.485	**<.001**
SGRQ (Symptom)	−0.346	**.001**	−0.534	**<.001**
SGRQ (Total)	−0.237	**.026**	−0.484	**<.001**
MRC score	−0.432	**<.001**	−0.606	**<.001**

ISWT, incremental shuttle walk test; ESWT, endurance shuttle walk test; FEV1, forced expiratory volume in the first second (predicted%); FVC, forced vital capacity (predicted%); SGRQ, St. George's respiratory questionnaire; MRC, medical research council; actual 1RM, 1-repetition maximum.

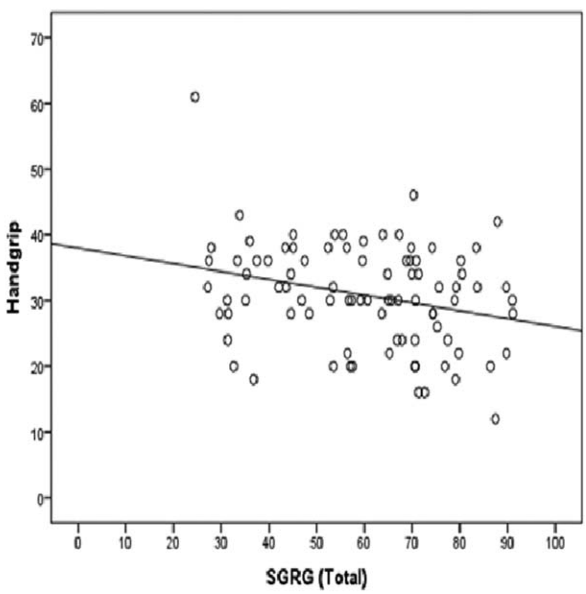

FIGURE 2 The correlation between handgrip and St. George's respiratory questionnaire total

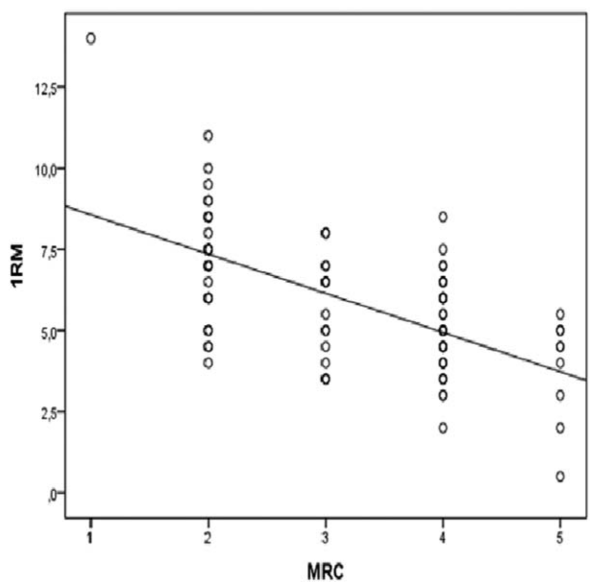

FIGURE 3 The correlation between 1-repetition maximum and medical research council

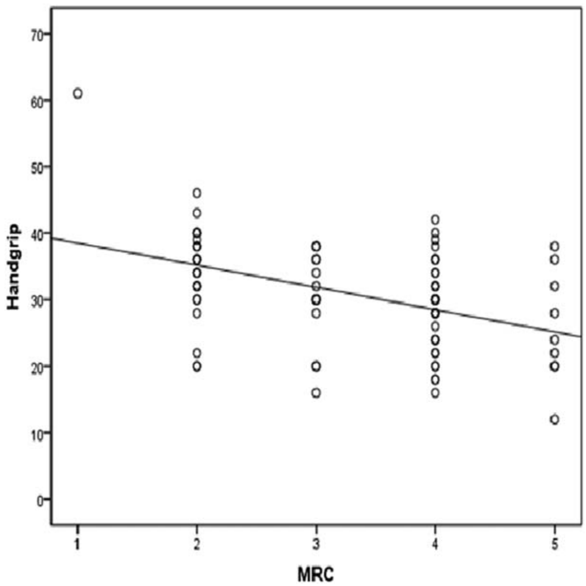

FIGURE 4 The correlation between handgrip and medical research council

4 | DISCUSSION

In this study, it has been shown that there is a moderate but significant association between upper extremity strength and incremental shuttle walking distance and endurance shuttle walking time in patients with COPD. In addition, negative correlations were found between actual 1RM and all domains of theSGRQ, as well as the MRC scale. Handgrip strength was negatively correlated with SGRQ activity, symptom domains and the MRC scale. There was no correlation between upper extremity strength and lung function parameters.

We hypothesized that handgrip strength reflected whole body strength; therefore, lower limb muscle strength was not measured. Gosselink et al showed no statistically significant differences between arm muscle strength and quadriceps muscle strength.[17] Various authors found that grip strength was significantly positively correlated with six-minute walking distance (6MWD) and ISWD, especially in patients with COPD.[18–21] The results of our study suggest a strong relationship between upper and lower limb muscle function. Therefore, measuring upper limb strength, which is a very easy and quick method, can also reflect exercise capacity. Both handgrip strength and actual 1RM were below the reference levels and moderately correlated with ISWT and ESWT results, which have also been shown as reduced. Several studies showed strong-to-very strong correlations between lower limb muscle strength and walking capacity, whereas we found low-to-moderate correlations for upper limb muscle strength and walking capacity. The reason why the correlations were moderate in our study might be related with measuring upper limb muscle strength instead of lower limb stregth. Conversely, assessment of grip strength has broad clinical applicability because it is a low-cost, simple, rapid and noninvasive method[22,23] that provides an indicator of general health and overall muscle function.[23]

Skeletal muscle dysfunction is one of the most important and frequent comorbidities related with exercise capacity that affects the performance of daily living activities in patients with COPD.[24] It occurs when performing lower body tasks and during arm activities. Approximately, 80% of ADL are performed using the upper limbs.[25] Patients with COPD experience a relatively high metabolic load and dyspnea during the performance of self-paced domestic arm ADL compared with healthy control subjects. There are two mechanisms to which that finding might be attributable: neuromechanical dysfunction (thoracoabdominal asynchrony) of respiratory muscles (diaphragm and accessory muscles), and changes in lung volume during activities involving the upper limbs.[5,26]

Couser et al showed that simple elevation of the arms of normal individuals resulted in a significant increase in Vo_2 (16%) and in pulmonary ventilation (24%), which was associated with an increase in the final gastric inspiratory and transdiaphragmatic pressure, suggesting that arm elevation disturbs the mechanics of the chest and abdominal compartments.[27] The underlying mechanism is probably multifactorial. In our study, moderate but significant correlations were found between upper limb strength and dyspnea sensation. The correlation with the MRC scale and actual 1RM was much more evident than hand grip strength. This finding may be explained by the use of proximal upper limb muscles in the shoulder girdle test, which in turn belongs to the group of accessory muscles used for respiration.[28]

Celli et al were the first to compare lower limb and upper limb activities in patients with COPD showing that unsupported upper limb activities in COPD ended before lower limb exercises did. The middle deltoid is directly involved in all ADL with upper limbs, especially those that require elevation of the shoulders. Unlike the quadriceps femoris, it seems that the middle deltoid has a multimode fiber distribution (ie, normal, atrophic and hypertrophic sizes), which could influence the development of muscle fatigue when performing ADL with upper limbs.[29] Thus, it can be postulated that muscle weakness in stable patients with COPD does not affect all muscles to a similar extent proximal upper limb muscle strength was impaired more than distal upper limb muscle strength.[17]

In our study, it was found that both handgrip strength and actual 1RM were significantly correlated with health-related QoL. There were weak-to-moderate negative correlations with all domains of the SGRQ in both actual 1RM and handgrip strength. Other studies found associations between handgrip strength and health-related QoL[30] and oxygen pulse reliable index of stroke volume.[31] These findings are important because poorer upper extremity muscle strength may result in reduced exercise performance, QoL and dyspnea.

Although it was not within the scope of this study, PR is an important tool for strengthening these muscles, possibly providing a positive impact on the degree of dyspnea during ADL and reflecting in QoL.

There is no clear relationship between muscle strength and disease severity in patients with COPD. Bernard et al reported a significant correlation between FEV1 and quadriceps strength.[4] In another study, correlations between maximum inspiratory and expiratory pressures with upper and lower limb muscle strengths were shown.[32] In that study, handgrip strength and actual 1RM showed no correlation with either postbronchodilator FEV1 or FVC % predicted values. Therefore, regardless of the spirometric values, upper limb muscle strength and endurance should be evaluated in patients with COPD. In a recent study, although no correlation was found between FEV1 and handgrip strength, there was a significant correlation between handgrip strength and inspiratory capacity/total lung capacity ratio.[33]

The most important limiting factors of our study were the absence of a control group, its retrospective design and the lack measurements of lower limb muscle function.

5 | CONCLUSION

In our study, we showed that upper limb muscle strength correlated with exercise capacity, QoL and dyspnea sensation. Identifying patients who have greater reductions in strength will allow early interventions with a multidisciplinary manner. There is increasing interest in the assessment of upper limb exercise capacity in patients with COPD enrolled in PR to better document the impact of upper extremity training. Additional research in the area of arm exercise capacity measurement is necessary in order to contribute to advancements in the field of upper extremity training.

CONFLICT OF INTERESTS

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

AUTHOR CONTRIBUTIONS

D.K. collected the data of the participants, designed and write the manuscript, İ.Ç.C. had a role in collecting the data and literature search, P.E. had a role in design, analysis and interpretation of data, critical revision and final version of the manuscript, N.D and F.T. are physiotherapists who applied the incremental shuttle walk test and endurance shuttle walk test to all patients. P.D. is a statistician.

ETHICS

Ethics Committee approved this study. All participants gave written informed consent before data collection began.

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