European Geriatric Medicine (2018) 9:863–870
https://doi.org/10.1007/s41999-018-0111-x

RESEARCH PAPER

Determinants of the 6-minute pegboard and ring test as an unsupported upper-extremity exercise capacity measure in older adults with chronic obstructive pulmonary disease

Ismail Ozsoy[1] · Buse Ozcan Kahraman[2] · Gulsah Ozsoy[3] · Nursen Ilcin[2] · Turhan Kahraman[4] · Serap Acar[2] · Nil Tekin[5] · Sema Savci[2]

Received: 29 July 2018 / Accepted: 15 September 2018 / Published online: 25 September 2018

Abstract

Purpose Upper extremities play an important role in performing of many activities of daily living. Physical and pathological changes limit upper extremity functions in older adults with chronic obstructive pulmonary disease (COPD). Although the 6-minute pegboard and ring test (6PBRT) is a reliable and commonly used method for the assessment of unsupported upper-extremity exercise capacity in patients with COPD, there is lack of evidence about the possible determinants of the 6PBRT score. The study aimed to investigate the possible determinants of the 6PBRT in older adults with COPD.
Methods Fifty-two older adults (age $\geq$ 65 years) with stable COPD and 23 age-matched healthy older adults participated in this study. Demographic characteristics, unsupported upper-extremity exercise capacity, pulmonary function, functional exercise capacity, disease related symptoms, peripheral and respiratory muscle strength were evaluated. Stepwise multiple linear regression analysis was used to investigate the possible determinants of the 6PBRT score.
Results The 6PBRT score was significantly higher in healthy participants compared with those with COPD ($p = 0.024$). In participants with COPD, shoulder flexor muscle strength, age and functional exercise capacity were significant and independent predictors of the unsupported upper-extremity exercise capacity with explaining 55.4% of the variance.
Conclusions This study suggests that shoulder flexor muscle strength, age and functional exercise capacity are independent determinants of the unsupported upper-extremity exercise capacity assessed by the 6PBRT in older adults with COPD.

Keywords Older adults · Unsupported upper-extremity exercise capacity · Chronic obstructive pulmonary disease · 6-minute pegboard and ring test

Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by respiratory symptoms and airflow limitation that is a leading cause of mortality and morbidity worldwide [1]. The prevalence of COPD increases with advancing age and becomes an important health care problem in older adults [2]. Age-related changes in structural and physiological changes including respiratory system cause high mortality rates in older adults with COPD [3]. Both ageing and COPD increase physical impairments that result in functional disability [4]. For example, activities of daily living performance is reduced in older adults with COPD compared with younger individuals with same disease severity, dyspnea levels and comorbidities [5].

Upper extremities play an important role in performing of many activities of daily living such as eating, personal

✉ Ismail Ozsoy
ozsoy.ismail@yahoo.com

1 School of Physical Therapy and Rehabilitation, Kırsehir Ahi Evran University, Kırsehir, Turkey

2 School of Physical Therapy and Rehabilitation, Dokuz Eylül University, Izmir, Turkey

3 Institute of Health Sciences, Dokuz Eylül University, Izmir, Turkey

4 Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Izmir Katip Celebi University, Izmir, Turkey

5 Family Medicine, Narlıdere Nursing Home Elderly Care and Rehabilitation Center, Izmir, Turkey

hygiene, and work-related tasks [6]. Moreover, upper extremity muscles sustain the upper girdle and act as accessory respiratory muscles. These muscles are usually inactive in healthy people in rest and active during a physical effort [7]. However, it is known that upper extremity muscles are active even at rest in persons with COPD [8]. Therefore, during the most common activities of daily living involving activation of upper extremity muscles, respiration becomes ineffective in persons with COPD due to the accessory respiratory muscles work for sustaining the shoulder girdle, thus the diaphragm becomes overloaded [8]. This functional overload of diaphragm may increase the sensation of dyspnea and fatigue in persons with COPD [8].

The importance of upper extremities support the rationale of the inclusion of upper exercise training in pulmonary rehabilitation programs for persons with COPD as recommended by the most up-to-date Official American Thoracic Society/European Respiratory Society Statement [9]. The previous studies suggested that the resistance training for muscles of the upper extremities could increase their strength and improve the performance in related tasks, such as the 6-minute pegboard and ring test (6PBRT) [8, 10]. However, since the training tasks and the tested tasks are similar such in the 6PBRT, it cannot be concluded that the upper extremity training led to additional benefits [8, 10, 11]. Although the 6PBRT is a reliable and commonly used method for the assessment of unsupported upper-extremity exercise capacity (UUEEC) in persons with COPD, there is lack of evidence about the possible determinants of the 6PBRT performance [8, 10, 11]. Knowing the possible determinants of the 6PBRT performance will contribute to the development of both the upper extremity exercise capacity and activities of daily living. Furthermore, it will guide the planned rehabilitation programs for individuals with COPD. If the wider range of outcome measures besides upper extremity muscle strength such as respiratory functions, dyspnea, disease severity, and functional exercise capacity would be found as possible determinants of the 6PBRT, the improvements in this test can be interpreted as the improvements in these domains. Therefore, to the best of our knowledge, this is the first study which aimed to investigate the possible determinants of the 6PBRT in older adults with COPD.

Materials and methods

Study design and participants

Fifty-two older adults (age $\geq$ 65 years) with COPD and 23 age-matched healthy older adults participated in this cross-sectional study. The diagnosis of COPD was made according to global initiative for chronic obstructive pulmonary disease (GOLD) guidelines (medical history, current symptoms, and pulmonary function testing) by a specialist. The demographics and clinical characteristics were recorded. The inclusion criteria for the person with COPD were a diagnosis of COPD [forced expiratory volume in 1 s (FEV_1) < 80% of predicted]. All participants with COPD were in stable clinical condition at the study time and they had been on the same medication routine in the previous 3 weeks and not taking antibiotics. There were no participants with COPD using oxygen therapy during the tests. The inclusion criteria for healthy older adults were normal spirometry values. Persons with orthopedic problems, cardiovascular disease or dementia were excluded from the study. The study protocol was approved by the Ethics Committee of Dokuz Eylül University and all participants provided written consent to participate in the study according to the Helsinki Declaration.

Data collection

Pulmonary function was assessed with a computer-based spirometer (Minispir; Medical International Research, Rome, Italy). The highest value from at least three technically acceptable maneuvers was recorded as the score. Values of FEV_1, forced vital capacity (FVC), FEV_1/FVC, peak expiratory flow rate (PEF), and forced expiratory flow between 25% and 75% of FVC ($FEF_{25-75\%}$) were evaluated [12].

The Modified Medical Research Council (mMRC) Dyspnea Scale which is largely used in the assessment of dyspnea in COPD, was used to assess dyspnea [1]. The mMRC Dyspnea Scale has five levels from score 0 (only get breathless with strenuous exercise) to score 4 (too breathless to leave the house or breathless when dressing) [13].

The COPD Assessment Test (CAT) is well known test which provides a reliable measure of the impact of COPD on a patient's health status. It has eight items and the score ranges from 0 to 40. As the score increases, the presence of symptoms increases [1].

A hand-held mouth pressure device (Micro RMP; Micro Medical, Rochester, UK) was used to measure inspiratory muscle strength (MIP) and expiratory muscle strength (MEP). The participants performed three to five acceptable and reproducible maximal maneuvers (i.e., differences of 10% or less between values). The recorded value was the highest unless this was obtained from the last effort [14].

Isometric shoulder flexor muscle strength was measured with a hand-held dynamometer (Lafayette Manual Muscle Testing System; Lafayette Instrument Company, Lafayette, Indiana, USA) [15]. The Jamar® hand dynamometer (Patterson Medical, Warrenville, Illinois, USA) was used to assess the handgrip strength. The Jamar® hand dynamometer is recommended by the American Hand Therapist Association for the measurement of handgrip strength and considered to be the gold standard because of its high validity and reliability [16]. Measurements were repeated three times from the dominant limbs and average values were recorded.

The 6-minute walk test (6MWT) was performed to assess functional exercise capacity. The test performed in accordance with guidelines of American Thoracic Society [17]. Blood pressure (Erka Manual Sphygmomanometer, Germany), heart rate (Beurer pulse oximeter, Germany), oxygen saturation (Beurer pulse oximeter, Germany), dyspnea and fatigue by the modified Borg Scale were recorded before and after the 6MWT.

The 6PBRT was performed to assess UUEEC. The test performed in accordance with the method of described Zhan et al. [11]. Blood pressure, heart rate, oxygen saturation, dyspnea and fatigue were also recorded before and after the 6PBRT.

Data analysis

Since the data were normally distributed (checked by the Shapiro–Wilk test and histograms), parametric analyses were conducted. Mean and standard deviation (SD) values were reported for the continuous variables, and number and percent values were reported for the categorical variables. The Chi-squared test and independent samples *t* test were used to compare the groups. The Pearson correlation coefficient was calculated to examine the correlation between the 6PBRT and other study variables. Stepwise multiple linear regression analysis was used to identify variables that could best determine the 6PBRT score. Significantly correlated variables (age, mMRC, CAT, MIP, MEP, 6MWT, handgrip strength, and shoulder flexor muscle strength) with the 6PBRT score included in the regression model for the participants with COPD. In addition, significantly correlated variables (age, mMRC and 6MWT) with the 6PBRT score included in the regression model for the healthy participants. The correlation coefficients, > 0.5 were interpreted as strong, 0.3–0.5 as moderate, and 0.2–0.3 as weak [18]. The level of significance was set at $p < 0.05$. The data were analyzed using the IBM® SPSS® Statistics for Windows software (Version 20.0. Armonk, NY: IBM Corp.).

There is no study which has investigated the determinants of UUEEC in older adults with COPD. However, a previous study has revealed that age was a significant predictor of the 6MWT distance in the persons with COPD ($R^2 = 0.173$, $p < 0.001$) [19]. Based on the results of that study, the minimum required sample size for a multiple regression analysis was calculated as 42 participants for the probability level as 0.05, nine predictors in the model, the anticipated effect size as 0.20, and the statistical power level as 80% using G*Power Software (Version 3.1.9.2, Düsseldorf University, Düsseldorf, Germany).

Results

Since all participants completed all the tests, the data obtained from 52 persons with COPD (38 men and 14 women) and 23 healthy older adults (16 men and 7 women) were analyzed. The characteristics of the participants are presented in Table 1.

There was no significant difference in demographic characteristics (age, gender, BMI) and handgrip strength between the two groups ($p > 0.05$). The spirometry values, 6MWT distance, 6PBRT score, respiratory and shoulder muscle strength were significantly higher in healthy group compare with the COPD group ($p < 0.05$). The mMRC score and smoking history were higher in COPD group than healthy group ($p < 0.05$) (Table 1).

The comorbidities observed in the participants with COPD were hypertension (53.8%), heart failure (36.5%), diabetes mellitus (19.2%), other respiratory disease (asthma, obstructive sleep apnea syndrome) (9.6%), and other comorbidities (liver disease, gastroesophageal reflux disease, anxiety disorder) (11.5%) (Table 1).

The 6PBRT score had moderate to strong correlations with age ($r = -0.488$, $p < 0.001$), mMRC score ($r = -0.423$, $p = 0.002$), CAT score ($r = -0.370$, $p = 0.007$), MIP ($r = 0.510$, $p < 0.001$), MEP ($r = 0.400$, $p = 0.003$), 6MWT distance ($r = 0.580$, $p < 0.001$), handgrip strength ($r = 0.578$, $p < 0.001$), shoulder flexor muscle strength ($r = 0.599$, $p < 0.001$) in participants with COPD. The 6PBRT score had strong correlations with age ($r = -0.685$, $p < 0.001$), mMRC score ($r = -0.716$, $p < 0.001$) and 6MWT distance ($r = 0.727$, $p < 0.001$) in healthy participants. Table 2 presents the correlation coefficients between the 6PBRT score and other study variables.

The stepwise multiple regression analysis revealed that shoulder flexor muscle strength, age and the 6MWT distance were significant and independent predictors of the 6PBRT in older adults with COPD with explaining 55.4% of the variance in 6PBRT score. The regression model was accepted as adequate since *F* value was significant ($F = 22.113$, $p < 0.001$), the variance inflation factors (VIF) values were less than 10, residual distribution was random, and there was only one outliner (Table 3, Fig. 1a). The regression equation formula for prediction of the 6PBRT score was calculated using explanatory variables (shoulder flexor muscle strength, age and the 6MWT distance) and coefficients in older adults with COPD (Table 3). The regression equation formula is "6PBRT score = 160.535 + (2.802 × shoulder flexion strength (kg)) + (− 1.479 × age (year) + (0.086 × 6MWT distance (m))" in older adults with COPD.

The stepwise multiple regression analysis revealed that and the 6MWT distance and mMRC score were

Table 1 Demographic and clinical characteristics of the participants

	COPD group	Healthy group	*p*
Age (years)	74.3 ± 6.5	73.6 ± 8.0	0.700
Sex (men/women)	38/14	16/7	0.755
Body mass index (kg/m^2)	27.0 ± 4.3	26.9 ± 4.3	0.955
GOLD stage (I/II/III/IV)	3/29/19/1	N/A	N/A
Comorbidities		N/A	N/A
Hypertension	28 (53.8)		
Heart failure	19 (36.5)		
Diabetes mellitus	10 (19.2)		
Other respiratory disease (asthma, obstructive sleep apnoea syndrome)	5 (9.6)		
Other comorbidities (liver disease, gastroesophageal reflux disease, anxiety disorder)	6 (11.5)		
Smoking (pack-year)	40.8 ± 28.8	17.6 ± 19.2	**0.002**
FEV_1 predicted (%)	55.6 ± 15.7	98.1 ± 22.9	**< 0.001**
FVC predicted (%)	71.6 ± 15.6	85.4 ± 11.0	**< 0.001**
FEV_1/FVC	59.1 ± 8.5	91.9 ± 18.7	**< 0.001**
PEF predicted (%)	56.7 ± 19.4	95.0 ± 31.4	**< 0.001**
$FEF_{25–75\%}$ predicted (%)	30.5 ± 17.0	112.2 ± 59.6	**< 0.001**
mMRC score (0–4)	1.8 ± 0.7	0.6 ± 0.6	**< 0.001**
CAT score (0–40)	12.5 ± 4.9		
MIP (cmH_2O)	57.4 ± 25.2	72.7 ± 30.9	**0.027**
MEP (cmH_2O)	76.1 ± 26.2	110.5 ± 46.2	**< 0.001**
6MWT distance (m)	376.6 ± 77.7	434.1 ± 81.5	**0.005**
6PBRT score (*n*)	128.4 ± 26.6	143.5 ± 25.3	**0.024**
Handgrip strength (kg)	27.1 ± 8.6	26.1 ± 5.3	0.591
Shoulder flexor muscle strength (kg)	16.2 ± 4.08	18.9 ± 5.1	**0.014**

Values are expressed as mean (standard deviation) for continuous variables and number was reported for categorical variables

Significant *p* values are present in bold

GOLD global initiative for chronic obstructive pulmonary disease, *FVC* forced vital capacity, FEV_1 forced expiratory volume in 1 s, *PEF* peak expiratory flow rate, $FEF_{25–75\%}$ forced expiratory flow between 25% and 75% of FVC, *mMRC* modified medical research council, *CAT* COPD assessment test, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *6PBRT* 6-minute pegboard and ring test, *6MWT* 6-minute walk test

significant and independent predictors of the 6PBRT in healthy older adults with explaining 63.9% of the variance in 6PBRT score (Table 4, Fig. 1b). The regression equation formula of prediction of the 6PBRT score was calculated using explanatory variables (the 6MWT distance and mMRC score) and coefficients in healthy older adults (Table 4). The regression equation formula is "6PBRT score = 89.955 + (0.149 × 6MWT distance (m)) + (− 19.462 × mMRC score) in healthy older adults.

Discussion

This study was the first which determined the predictors of UUEEC and formulated regression equations to predict the 6PBRT score in older adults with COPD. The main finding of the study demonstrated that shoulder flexor muscle strength, age and functional exercise capacity were found as independent determinants of the UUEEC assessed by the 6PBRT with explaining 55.4% of the variance in older adults with COPD. This study also showed that the 6PBRT was correlated with disease related symptoms, respiratory muscle and handgrip strength. Additionally, the study showed that there is an impairment of upper extremity exercise capacity in older adults with COPD compared to healthy older adults. Furthermore, the study showed that functional exercise capacity and dyspnea were found as independent determinants of the UUEEC with explaining 63.9% of the variance in the healthy older adults.

Impairment in the peripheral muscle function is one of the well-known systemic consequences of COPD [19]. Systemic hypoxia, oxidative stress and systemic inflammation cause muscle dysfunction in persons with COPD [20, 21]. Peripheral muscle dysfunction is one of the reasons of exercise intolerance [22]. Previously, most of the studies have focused on the influence of lower extremity on the exercise

Table 2 Correlation between 6PBRT score and other assessments

	COPD group		Healthy group	
	r	*p*	*r*	*p*
Age (years)	– 0.488	**< 0.001**	– 0.685	**< 0.001**
FEV_1 predicted (%)	0.170	0.237	0.398	0.060
mMRC score (0–4)	– 0.423	**0.002**	– 0.716	**< 0.001**
CAT score (0–40)	– 0.370	**0.007**	N/A	N/A
MIP (cmH_2O)	0.510	**< 0.001**	0.232	0.286
MEP (cmH_2O)	0.400	**0.003**	0.211	0.333
6MWT distance (m)	0.580	**< 0.001**	0.727	**< 0.001**
Handgrip strength (kg)	0.578	**< 0.001**	0.348	0.103
Shoulder flexor muscle strength (kg)	0.599	**< 0.001**	0.238	0.273

Significant *p* values are present in bold

FEV_1 forced expiratory volume in 1 s, *mMRC* modified medical research council, *CAT* COPD assessment test, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *6MWT* 6-minute walk test

intolerance. However, recent studies have suggested that since the upper extremities are very important due to their roles in the activities of daily living, they should be evaluated in the persons with a respiratory disease [23, 24]. In this study, we found that shoulder flexor muscle strength was a predictor of the 6PBRT. This finding shows that weakness of shoulder flexor muscle strength can cause a limitation in the upper extremity function. Additionally, this study demonstrated that a decreased handgrip strength had significantly correlated with a reduced decreased UUEEC in older adults with COPD.

There are many age-related changes in the structural and physiological parameters of the respiratory system. Reduction of lung volumes, alternation in respiratory muscles and changes in thoracic cavity occur with aging [25]. These changes cause a reduction of exercise capacity throughout the normal aging process [26]. Additionally, the presence of COPD with aging makes the decline in exercise capacity even more apparent [27]. We found that age was an independent determinant of the 6PBRT. Therefore, age appears

Table 3 Stepwise multiple linear regression model of the 6PBRT in older adults with COPD

Variable	*B*	SE	Beta	VIF	*t*	*p*
Constant	160.535	35.600	–	–	4.509	**< 0.001**
Shoulder flexion strength (kg)	2.802	0.712	0.430	1.362	3.935	**< 0.001**
Age (year)	– 1.479	0.398	– 0.398	1.100	– 3.716	**0.001**
6MWT distance (m)	0.086	0.039	0.250	1.477	2.202	**0.033**

$R = 0.762$, $R^2 = 0.580$, adjusted $R^2 = 0.554$ ($F = 22.113$, $p < 0.001$)

Significant *p* values are present in bold

B unstandardized regression coefficient, *SE* standard error, *VIF* variance inflation factors, *6MWT* 6-minute walk test

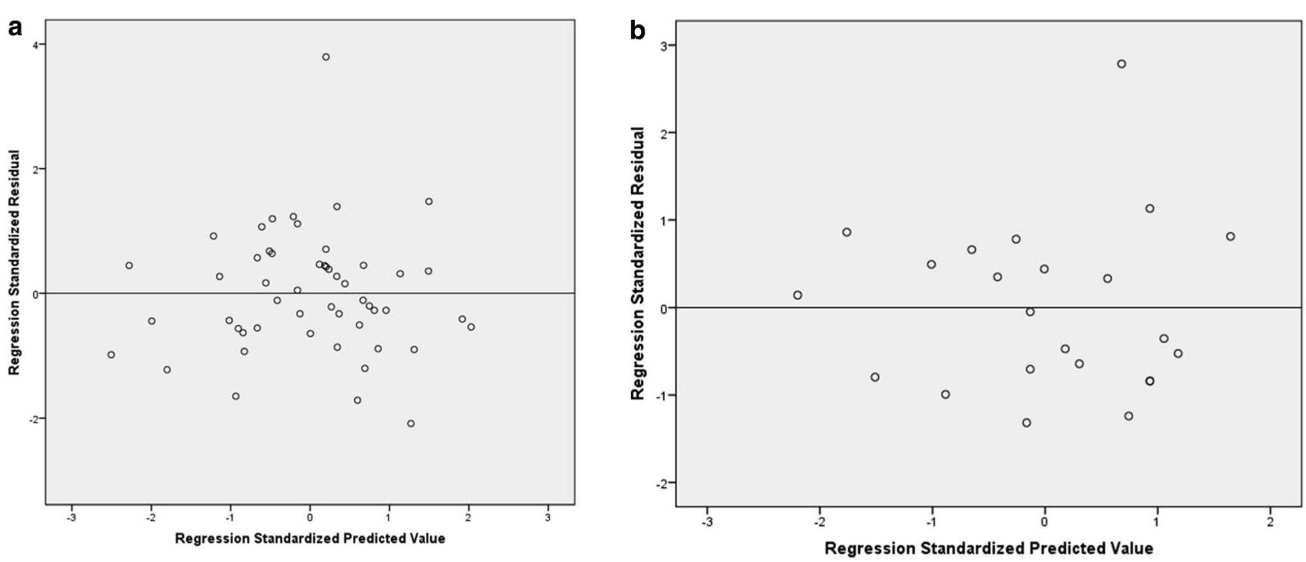

Fig. 1 Regression model in COPD (**a**) and healthy participants (**b**)

Table 4 Stepwise multiple linear regression model of the 6PBRT in healthy participants

Variable	*B*	SE	Beta	VIF	*t*	*p*
Constant	89.955	23.162	–	–	3.884	**0.001**
6MWT distance (m)	0.149	0.048	0.478	1.431	3.119	**0.005**
mMRC score (0–4)	− 19.462	6.585	− 0.453	1.431	− 2.955	**0.008**

$R=0.820$, $R^2=0.672$, adjusted $R^2=0.639$ ($F=20.458$, $p<0.001$)

Significant *p* values are present in bold

B unstandardized regression coefficient, *SE* standard error, *VIF* variance inflation factors, *6MWT* 6-minute walk test, *mMRC* Modified Medical Research Council

as an unchangeable risk factor for the UUEEC limitation in older adults with COPD.

The 6MWT is a method that commonly used in determining functional status of persons with COPD since it is a simple and inexpensive method that reflects integrated cardiopulmonary and musculoskeletal function [19]. The 6MWT is used to assess prognosis and treatment response of chronic respiratory diseases including COPD [28]. We found that functional status made an individual contribution to the 6PBRT. It is demonstrated that the UUEEC would be increased with a better functional status in older adults with COPD. Furthermore, the 6MWT was found as independent predictor of the 6PBRT in healthy older adults. These findings show that functional status, whether with or without COPD, affects upper extremity exercise capacity in all older adults.

Reduction compliance of thoracic wall, lung hyperinflation and decline elastic recoil caused respiratory weakness in older adults with COPD [29–31]. Weakness in respiratory muscles is frequently seen in persons with COPD, thus contributing to exercise intolerance and reduced quality of life [30]. We found that the 6PBRT had positive and moderate to strong correlations between MIP and MEP. Respiratory muscle dysfunction affects the upper extremity function and limits the UUEEC.

Additionally, the study showed that 6PBRT is correlated between shoulder flexor, handgrip, inspiratory and expiratory muscle strength in patients with COPD contrast to the healthy individual. These findings demonstrate that the 6PBRT reflects respiratory and upper limb muscle strength in older adults with COPD.

The mMRC Dyspnea Scale and CAT were recommended by the GOLD guideline for the symptom assessment [1]. While the mMRC is used to assess dyspnea, the CAT assesses the comprehensive symptoms [1]. Although the mMRC and CAT scores were not an independent predictor of the 6PBRT in older adults with COPD, they were negatively and moderately correlated with the 6PBRT. This finding demonstrated that the presence of symptoms may limit the upper extremity function. Dyspnea causes worse health status and quality of life in older adults [32]. The mMRC dyspnea scale is used to assess dyspnea in patients with COPD as well as in older adults [33]. We found that mMRC score was an independent determinant of the 6PBRT in healthy older adults. Dyspnea also seems a factor affecting upper extremity exercise intolerance in healthy older adults.

The FEV_1% is used to demonstrate the degree of airway obstruction and disease severity in persons with COPD [1]. Additionally, studies demonstrated that the FEV_1% affect exercise capacity [34, 35]. We found that there were no significant correlation between the 6PBRT and the FEV_1%, which agrees with a previous report [36]. This result may be due to the low number of GOLD I and IV group persons with COPD in both studies.

This study has some limitations. Although more participants are involved than the minimum required sample size, percentage of participants from GOLD I and IV group was low. In this respect, findings cannot be generalized to all persons with COPD having different disease severity. Additionally, the small sample sizes of the female persons with COPD included in the study reduce the generalizability.

Conclusion

This study was the first study, which determined predictors of UUEEC and formulated regression equations to predict the 6PBRT score in older adults with COPD. This study suggests that shoulder flexor muscle strength, age, and functional exercise capacity are independent determinants of the UUEEC assessed by the 6PBRT in older persons with COPD. In addition, functional exercise capacity and dyspnea are independent determinants of the UUEEC in healthy older adults. The level of independence in the activities of daily living can be increased by improving the upper extremity functions in older adults with COPD. These determinants should be taking into consideration while planning pulmonary rehabilitation programs for persons with COPD.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the Ethics Committee of Dokuz Eylül University and all procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent All participants gave their informed consent.

References

1. GOLD. Global Initiative for Chronic Obstructive Lung Disease (2018) Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. https://goldcopd.org. Accessed 20 Jul 2018
2. Incalzi RA, Scarlata S, Pennazza G, Santonico M, Pedone C (2014) Chronic obstructive pulmonary disease in the elderly. Eur J Intern Med 25(4):320–328. https://doi.org/10.1016/j.ejim.2013.10.001
3. Kobayashi S, Yanai M, Hanagama M, Yamanda S (2014) Burden of chronic obstructive pulmonary disease in the elderly population. Respir Investig 52(5):296–301. https://doi.org/10.1016/j.resinv.2014.04.005
4. Fried TR, Vaz Fragoso CA, Rabow MW (2012) Caring for the older person with chronic obstructive pulmonary disease. JAMA 308(12):1254–1263. https://doi.org/10.1001/jama.2012.12422
5. Kutukcu EÇ, Arikan H, Sağlam M, Yagli NY, Oksüz Ç, Ince Dİ et al (2015) A comparison of activities of daily living in geriatric and non-geriatric patients with chronic obstructive pulmonary disease. Turk J Geriatr 18(1):68–74
6. Pendleton HM, Schultz-Krohn W (2012) Pedretti's occupational therapy: practice skills for physical dysfunction, 7th edn. Mosby, pp 157–162
7. Saboisky JP, Gorman RB, De Troyer A, Gandevia SC, Butler JE (2007) Differential activation among five human inspiratory motoneuron pools during tidal breathing. J Appl Physiol (1985) 102(2):772–780. https://doi.org/10.1152/japplphysiol.00683.2006
8. Costi S, Crisafulli E, Degli Antoni F, Beneventi C, Fabbri LM, Clini EM (2009) Effects of unsupported upper extremity exercise training in patients with COPD: a randomized clinical trial. Chest 136(2):387–395
9. Spruit MA, Singh SJ, Garvey C, ZuWallack R, Nici L, Rochester C et al (2013) An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. Am J Respir Crit Care Med 188(8):e13–e64
10. Janaudis-Ferreira T, Hill K, Goldstein RS, Robles-Ribeiro P, Beauchamp MK, Dolmage TE et al (2011) Resistance arm training in patients with COPD: a randomized controlled trial. Chest 139(1):151–158
11. Zhan S, Cerny FJ, Gibbons WJ, Mador MJ, Wu YW (2006) Development of an unsupported arm exercise test in patients with chronic obstructive pulmonary disease. J Cardiopulm Rehabil 26(3):180–187 **(discussion 8–90)**
12. Ranu H, Wilde M, Madden B (2011) Pulmonary function tests. Ulster Med J 80(2):84–90
13. Perez T, Burgel PR, Paillasseur JL, Caillaud D, Deslee G, Chanez P et al (2015) Modified Medical Research Council scale vs Baseline Dyspnea Index to evaluate dyspnea in chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis 10:1663–1672. https://doi.org/10.2147/copd.s82408
14. Neder JA, Andreoni S, Lerario MC, Nery LE (1999) Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res 32(6):719–727
15. Leggin BG, Neuman RM, Iannotti JP, Williams GR, Thompson EC (1996) Intrarater and interrater reliability of three isometric dynamometers in assessing shoulder strength. J Shoulder Elbow Surg 5(1):18–24
16. Shechtman O, Gestewitz L, Kimble C (2005) Reliability and validity of the DynEx dynamometer. J Hand Ther 18(3):339–347. https://doi.org/10.1197/j.jht.2005.04.002
17. American Thoracic Society (2002) ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 166(1):111–117. https://doi.org/10.1164/ajrccm.166.1.at1102
18. Cohen J (1988) Statistical power analysis for the behavioural sciences, 2nd edn. Routledge, pp 109–116
19. Criner G (2011) 6-minute walk testing in COPD: is it reproducible? Eur Respir J 38(2):244–245. https://doi.org/10.1183/09031936.00023011
20. Skeletal muscle dysfunction in chronic obstructive pulmonary disease (1999) A statement of the American Thoracic Society and European Respiratory Society. Am J Respir Crit Care Med 159(4 Pt 2):S1–S40. https://doi.org/10.1164/ajrccm.159.supplement_1.99titlepage
21. van Eeden SF, Yeung A, Quinlam K, Hogg JC (2005) Systemic response to ambient particulate matter: relevance to chronic obstructive pulmonary disease. Proc Am Thorac Soc 2(1):61–67. https://doi.org/10.1513/pats.200406-035MS
22. Pepin V, Saey D, Laviolette L, Maltais F (2007) Exercise capacity in chronic obstructive pulmonary disease: mechanisms of limitation. Copd 4(3):195–204. https://doi.org/10.1080/15412550701480489
23. Shah S, Nahar P, Vaidya S, Salvi S (2013) Upper limb muscle strength & endurance in chronic obstructive pulmonary disease. Indian J Med Res 138(4):492–496
24. McKeough ZJ, Velloso M, Lima VP, Alison JA (2016) Upper limb exercise training for COPD. Cochrane Database Syst Rev 11:CD011434. https://doi.org/10.1002/14651858.cd011434.pub2
25. Lowery EM, Brubaker AL, Kuhlmann E, Kovacs EJ (2013) The aging lung. Clin Interv Aging 8:1489–1496. https://doi.org/10.2147/cia.s51152
26. Akerman JP, Heckman GA, McKelvie RS (2015) Exercise capacity and aging. Am J Lifestyle Med 9(4):252–265
27. Ozsoy I, Savci S, Ozsoy G, Acar S, Ozalevli S, Akkoclu A (2015) Exercise capacity and muscle strength influences in geriatric individuals with COPD. Eur Respir J 46:PA974. https://doi.org/10.1183/13993003.congress-2015.pa974
28. Holland AE, Spruit MA, Troosters T, Puhan MA, Pepin V, Saey D et al (2014) An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. Eur Respir J 44(6):1428–1446. https://doi.org/10.1183/09031936.00150314
29. McKenzie DK, Butler JE, Gandevia SC (2009) Respiratory muscle function and activation in chronic obstructive pulmonary disease. J Appl Physiol (1985) 107(2):621–629. https://doi.org/10.1152/japplphysiol.00163.2009
30. Barreiro E, Gea J (2015) Respiratory and limb muscle dysfunction in COPD. COPD 12(4):413–426
31. Miller MR (2010) Structural and physiological age-associated changes in aging lungs. Semin Respir Crit Care Med 31(5):521–527. https://doi.org/10.1055/s-0030-1265893
32. Miner B, Tinetti ME, Van Ness PH, Han L, Leo-Summers L, Newman AB et al (2016) Dyspnea in community-dwelling older persons: a multifactorial geriatric health condition. J Am Geriatr Soc 64(10):2042–2050. https://doi.org/10.1111/jgs.14290
33. Ho SF, O'Mahony MS, Steward JA, Breay P, Buchalter M, Burr ML (2001) Dyspnoea and quality of life in older people at home. Age Ageing 30(2):155–159

34. Celli BR, Cote CG, Marin JM, Casanova C, Montes de Oca M, Mendez RA et al (2004) The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. N Engl J Med 350(10):1005–1012. https://doi.org/10.1056/NEJMoa021322
35. Babb TG, Viggiano R, Hurley B, Staats B, Rodarte JR (1991) Effect of mild-to-moderate airflow limitation on exercise capacity. J Appl Physiol (1985) 70(1):223–230
36. Takeda K, Kawasaki Y, Yoshida K, Nishida Y, Harada T, Yamaguchi K et al (2013) The 6-minute pegboard and ring test is correlated with upper extremity activity of daily living in chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis 8:347–351. https://doi.org/10.2147/copd.s45081