

Functional capacity in severe chronic obstructive pulmonary disease

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ABSTRACT

Objective: To investigate the functional capacity in patients with severe chronic obstructive pulmonary disease (COPD) and healthy subjects.

Methods: The present study was conducted in the School of Physical Therapy and Rehabilitation, Department of Chest Medicine, Medical School, Hacettepe University, Ankara, Turkey, from June 2002 to July 2003. Forty-five male patients with severe (23 moderately severe, 22 very severe) COPD and 45 healthy controls participated in the study. Pulmonary function tests and 6-minute walk test (6MWT) were performed. The Borg score and heart rate were measured before and after the test. External work of walking was calculated as the product of body weight and walked distance. Functional dyspnea was measured using the modified Medical Research Council (MRC) dyspnea scale.

Results: Both distance and external work of 6MWT were significantly lower in severe COPD patients than healthy subjects ($p<0.05$). No significant differences in

distance, external work, and exertional dyspnea were found between moderately severe and very severe COPD patients ($p>0.05$). Patients with very severe impairment had a significantly lower percentage of predicted 6MWT distance ($p<0.05$). In these patients, 6MWT distance was correlated significantly with forced expiratory flow in one second (FEV_1), MRC score, and Borg score whereas external work of walking correlated with age, FEV_1 , forced expiratory flow from 25-75%, MRC, and resting Borg score ($p<0.05$).

Conclusion: Severe COPD patients had a significantly impaired functional capacity as compared to their healthy counterparts. Patients with $FEV_1 <35\%$ have a lower percentage of functional capacity. Both distance and external work of 6MWT are influenced by large and small airway function, level of breathlessness reported during daily activity or scored during an exercise test in patients with $FEV_1 <35\%$.

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Chronic obstructive pulmonary disease (COPD) is a common disease among adults and elderly. Functional capacity, which reflects the individual's capacity to meet the needs of daily living, has been recognized as one of the important outcomes in clinical evaluation of COPD patients.^{1,2} As many elderly and severely limited patients cannot be tested with standard evaluations of maximal exercise capacity, field tests including the 6-minute walk test (6MWT) have been developed as an effective alternative method to measure disability.^{1,3}

The 6MWT is a simple self-paced test. It includes a familiar activity that can be performed even most severely disabled patients. In this test, the distance that an individual can walk on a horizontal surface for 6 minutes is used as the outcome measure of functional capacity.^{1,2} Recent studies have shown that external work of walking, or energy expenditure exerted during the test, is a more precise measure of functional capacity for walking than the distance.^{4,5} The COPD is a slowly

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progressive disease with widely differing degrees of severity. Patients with severe COPD suffer from significant impairment in their quality of life compared to mild to moderate COPD patients.^{6,7} The portion of patients with severe disease increases with the advancing age,⁸ and life-threatening acute exacerbations are especially seen in these patients.⁹ Pulmonary rehabilitation of these patients is more difficult,¹⁰ and requires a longer program than other forms.¹¹ Although, 6MWT has been extensively used in COPD patients, few studies included patients with severe pulmonary impairment.^{4,5,12} In 2 studies, patients with moderate and severe airflow obstruction were analyzed together, and information related to severe patients were not presented separately.^{4,5} Wegner et al¹² used a 6MWT performed on a treadmill rather than a flat surface. Use of treadmill for 6MWT is not recommended as it can interfere with the self-pace nature of the test.² Determination of functional capacity using a simple and familiar activity might improve evaluation and quality of care of patients with severe COPD. Therefore, the purpose of this study was to investigate the distance and external work of 6MWT in patients with severe COPD as compared to healthy subjects, and to compare the functional capacity of patients with moderately severe and very severe pulmonary impairment. We also evaluated correlations between their functional capacity and other clinical variables.

Methods. Forty-five males aged 39-77 years with stable COPD participated in this study. All COPD patients were recruited from the outpatient clinic, Department of Chest Medicine, Medical School, Hacettepe University, Ankara, Turkey, from June 2002 to July 2003. Twenty-three patients had moderately severe (forced expiratory volume in one second [FEV₁] 35-49%), and 22 patients had very severe (FEV₁ <35%) COPD.¹³ Control subjects were a group of 45 healthy sedentary hospital employees or their healthy sedentary relatives. All measurements were parts of routine clinical evaluation of COPD patients. Informed consent was obtained from all subjects prior to enrollment. Chronic obstructive pulmonary disease patients were included if they had a post-bronchodilator FEV₁ <50% predicted.¹³ All COPD patients were clinically stable and were receiving a stable drug regimen in a period of 4 weeks before the study. Exclusion criteria included a 12% or higher increase in FEV₁ after routine reversibility test, and the presence of active heart disease, musculoskeletal, neurological, peripheral vascular or other disabling disorders that would interfere with exercise tolerance.

Pulmonary function test was performed by using Vitalograph Compact spirometer (Vitalograph Limited, Buckingham, England). The highest value

from at least 3 technically acceptable maneuvers was expressed as the percentage of predicted values.¹⁴ The forced vital capacity (FVC), FEV₁, peak expiratory flow rate (PEF), and forced expiratory flow from 25-75% (FEF_{25-75%}) were recorded. Arterial oxygen saturation (SpO₂) was measured using a pulse oximeter (Vitalmax 500, Pace Tech Inc, USA). Functional dyspnea was evaluated using the modified Medical Research Council (MRC) dyspnea scale.¹⁵ This includes 5 grades of physical activities that precipitate breathlessness. The ratings of the MRC scale ranged from 0 (non-exertional dyspnea at all) to 4 (breathlessness on dressing or undressing). The higher score indicates the worse severity of dyspnea.

After resting measurements, functional exercise capacity was evaluated using 6MWT.² The subjects were instructed to walk as far as possible in 6 minutes in an enclosed hospital corridor 55-m long. Standardized phrases of encouragement were given in every one-minute.² The distance covered in 6 minutes was recorded as nearest meter at the end of the test. Breathlessness during the 6MWT was determined using a 10-point modified Borg scale, with 10 as the maximum score.¹⁶ Heart rate was measured using Polar heart rate monitor (PF 3000 Polat Electro, Finland). Predicted maximum heart rate was calculated as 220 minus the patient's age to determine the percentage of maximum heart rate reached at the end of the test.¹⁷ Percentage of predicted 6MWT distance was calculated according to the reference equation by Troosters et al¹⁸ using patient's age, height, weight, and gender. External work of walking was calculated as the product of body weight and distance.^{4,5} Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 10.¹⁹ Data were presented as means and related standard deviations (mean ± SD). Between-group comparison was performed using Student's t-test or Mann-Whitney u test, as appropriate. Values at rest and at the end of the 6MWT were compared using paired t-test or Wilcoxon signed rank test, where applicable. The relationship among the continuous variables was examined using Pearson's correlation coefficient analysis. Spearman rank correlations were used to analyze the relationship of categorical variables. Statistical significance was defined as a value of $p < 0.05$.

Results. Patients with severe COPD and healthy controls were similar with regard to age and height ($p > 0.05$, Table 1). Weight and body mass index were significantly lower, and smoking history was significantly higher in COPD patients as compared to healthy controls ($p < 0.05$, Table 1). Similarly, there was a significant difference in MRC

Table 1 - Subject characteristics of severe COPD patients and healthy subjects.

Characteristics	COPD	Healthy	p-value
Age (years)	62.8 ± 7.5	61.7 ± 5.3	0.46
Height (cm)	168.6 ± 6.9	170.8 ± 7.2	0.18
Weight (kg)	67.0 ± 11.7	76.5 ± 12.0	0.001
Body mass index (kg/m ²)	23.6 ± 3.8	26.1 ± 3.6	0.003
Smoking (pack/years)	48.0 ± 30.8	20.6 ± 20.5	<0.001
MRC dyspnea score	1.98 ± 1.12	0.03 ± 0.18	<0.001
FEV ₁ (% predicted)	35.3 ± 10.2	100.5 ± 15.7	<0.001
FVC (% predicted)	59.0 ± 15.0	106.9 ± 16.8	<0.001
PEF (% predicted)	41.8 ± 11.3	107.8 ± 22.6	<0.001
FEF _{25-75%} (% predicted)	17.0 ± 7.7	90.8 ± 32.1	<0.001
SpO ₂ (%)	91.3 ± 4.4	96.7 ± 1.5	<0.001
Distance (m)	438.4 ± 64.0	555.9 ± 77.9	<0.001
% Predicted distance	69.5 ± 11.9	88.0 ± 14.2	<0.001
ΔBorg score	1.8 ± 2.1	0.2 ± 0.6	<0.001
External work (kgm)	29560.6 ± 76.33.4	42434.1 ± 8810.5	<0.001

COPD - chronic obstructive pulmonary disease, MRC - modified Medical Research Council dyspnea scale, FEV₁ - forced expiratory volume in one second, FVC - forced vital capacity, PEF - peak expiratory flow rate, FEF_{25-75%} - forced expiratory volume from 25-75%, SpO₂ - oxygen saturation, ΔBorg score - change in Borg score

dyspnea score, pulmonary function tests and SpO₂ between the patients and healthy controls ($p < 0.05$, **Table 1**). In addition, patients with severe COPD walked a shorter distance, exert lower external work of walking, and experience more breathlessness during 6MWT than healthy counterparts ($p < 0.05$, **Table 1**).

When moderately severe and very severe COPD patients were compared, no significant differences were found in age, body weight, height, body mass index, smoking status, and SpO₂ ($p > 0.05$, **Table 2**). The FEV₁, FVC, PEF, and FEF_{25-75%} were significantly lower in very severe patients than the patients with moderately severe airflow obstruction ($p < 0.05$, **Table 2**). A significant difference was not found in the MRC scores between the 2 stages of disease severity ($p = 0.36$, **Table 2**). The MRC dyspnea scale was significantly related to FEV₁ ($r = -0.53$, $p = 0.01$) in patients with moderately severe pulmonary impairment. Such a relationship was not found for very severe patients. In 6MWT, there was a significant increase in heart rate ($p < 0.001$) and breathlessness ($p = 0.001$) at the end of the 6MWT in

patients with both moderate and very severe COPD. No significant differences were found in distance ($p = 0.18$) and external work of 6-minute walking ($p = 0.84$) between the groups (**Table 3**). However, percentage of predicted 6MWT distance for patients with very severe impairment was significantly lower than patients with moderately severe pulmonary impairment ($p = 0.04$, **Table 3**). In patients with very severe pulmonary impairment, distance covered during the 6MWT was significantly related with body mass index ($r = 0.43$, $p = 0.04$), FEV₁ ($r = 0.45$, $p = 0.03$), MRC score ($r = -0.52$, $p = 0.01$), and change in Borg score ($r = -0.48$, $p = 0.02$). Similarly, external work of walking was significantly correlated with age ($r = -0.45$, $p = 0.03$), MRC score ($r = -0.57$, $p = 0.006$), baseline Borg score ($r = -0.49$, $p = 0.02$), FEV₁ ($r = 0.44$, $p = 0.04$), and FEF_{25-75%} ($r = 0.43$, $p = 0.04$) in these patients.

Discussion. In this study, we showed that functional capacity of patients with severe COPD

Table 2 - Comparison of demographic and clinical characteristics of patients with moderately severe and very severe chronic obstructive pulmonary disease.

Characteristics	Moderately severe COPD	Very severe COPD	p-value
Age (years)	64.4 ± 7.2	61.2 ± 7.6	0.15
Height (cm)	166.6 ± 7.3	170.6 ± 5.8	0.05
Weight (kg)	64.6 ± 10.8	69.5 ± 12.3	0.17
Body mass index (kg/m ²)	23.3 ± 3.6	23.9 ± 4.1	0.59
Smoking (pack/years)	45.1 ± 19.6	51.1 ± 39.6	0.53
MRC dyspnea score	1.8 ± 1.0	2.2 ± 1.2	0.36
FEV ₁ (% predicted)	43.7 ± 5.3	26.6 ± 5.7	<0.001
FVC (% predicted)	67.9 ± 10.8	49.6 ± 13.0	<0.001
PEF (% predicted)	37.2 ± 11.4	46.2 ± 9.6	0.007
FEF _{25-75%} (% predicted)	21.6 ± 7.9	12.2 ± 3.6	<0.001
SpO ₂ (%)	92.2 ± 4.7	90.4 ± 3.9	0.16

COPD - chronic obstructive pulmonary disease, MRC - modified Medical Research Council dyspnea scale, FEV₁ - forced expiratory volume in one second, FVC - forced vital capacity, PEF - peak expiratory flow rate, FEF_{25-75%} - forced expiratory volume from 25-75%, SpO₂ - arterial oxygen saturation

(FEV₁ <50%) was lower than their healthy counterparts. The distance and external work of 6MWT were similar in patients with moderately severe and very severe airflow obstruction. However, percentage of predicted 6MWT distance was lower in very severe than moderately severe patients. The distance and external work of 6-minute walking were limited by the lung function, functional and exertional dyspnea ratings only in patients with a FEV₁ of <35%.

The 6MWT provides simple evaluation of disability caused by respiratory impairment.^{1,2} The test imposes a sustainable work to exercising body in patients with severe COPD.²⁰ Although determination of work load is difficult due to its self-paced nature of the test, it can be roughly estimated from the body weight and velocity (or walking distance in 6 minutes),²⁰ which are the main factors determining the energy requirements during the test.^{4,20} In an attempt to quantify the work rate during the 6MWT, Chuang et al⁸ showed that the product of body weight and walking distance is superior to the distance alone when related with aerobic capacity. Their study also revealed that external work of walking was significantly related to functional and exertional dyspnea in patients with moderate to severe COPD.⁸ Our study revealed that both distance and external work of walking were similar in patients with moderately severe and very severe COPD patients. These findings suggest that

functional capacity and energy requirements of 6MWT did not differ in terms of severity of airflow obstruction in patients with moderately severe and very severe COPD.

Previous studies have shown that age, gender, height, and weight are statistically significant predictors of distance both in patients with chronic lung disease and healthy subjects.^{20,22} The variability in walking distance is substantially increased when the results were corrected for age, height, gender and weight.¹⁸ This finding suggests that these factors should be considered when comparing the distance covered by an individual patient to another to improve the interpretation of the data obtained from the 6MWT. Therefore, we calculated the percentage of predicted 6MWT distance for all subjects, and found that it was significantly lower in patients with a FEV₁ of <35% than patients with a FEV₁ of 35-49% despite the similar walked distance, external work of walking, and exertional heart rate during the test. We thought that this finding is due to the improved interpretation of the 6MWT results since it relates the walking distance to the performance of healthy subjects. The percentage of predicted 6MWT distance should be included in future studies especially those aiming to compare different study groups.

Our results revealed a significant correlation between breathlessness, whether reported during daily activity (MRC) or scored during an exercise

Table 3 - Comparison of 6-minute walk test results in patients with moderately severe and very severe chronic obstructive pulmonary disease.

Variables	Moderately severe COPD	Very severe COPD	p-value
% Maximum heart rate	64.6 ± 8.3	66.1 ± 10.2	0.61
ΔHeart rate (beats/min)	18.8 ± 7.8	22.8 ± 16.1	0.30
ΔBorg score	1.7 ± 1.7	2.1 ± 2.5	0.78
Distance (m)	451.0 ± 58.1	425.3 ± 68.5	0.18
% Predicted distance	73.0 ± 10.6	65.9 ± 12.3	0.04
External work (kgm)	29326.2 ± 7264.6	29805.7 ± 8165.6	0.84
COPD - chronic obstructive pulmonary disease.			

test (Borg score at 6MWT), and lower functional capacity in patients with a FEV₁ of <35%. This contrasts with the previously reported relationship of MRC to exercise capacity,^{12,32,34} and change in Borg score²³ in patients with moderate to severe COPD. Our results proved that such a relationship was relevant only for patients with very severe airflow obstruction. In addition to dyspnea, patient's age and FEF_{25-75%} are the other factors influencing the external work of walking in these patients. Age is a well-known factor influencing the exercise capacity.^{20,22} Forced expiratory flow from 25-75% shows the level of small airway obstruction. Our results revealed that degree of small airway obstruction contributed to work of walking rather than the distance. This finding was in accordance with the finding of Pineda et al²⁵ showing that FEF_{25-75%} is a strong indicator of total external work of walking during maximal treadmill exercise (r²=0.56, p=0.01) in patients with COPD.

In conclusion, functional exercise capacity of severe COPD patients was significantly lower than healthy counterparts. In addition, distance and external work of 6 minute walking were similar in patients with moderately severe and very severe COPD. The main difference between these disease stages is the percentage of the predicted distance walked during the test. Those patients with a FEV₁ of <35% has a lower functional capacity than the patients with less airflow obstruction, and both lung function and dyspnea perception are the factors that influence the capacity to undertake the daily life activities.

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