Functional capacity, physical activity, and quality of life in hypoxemic patients with chronic obstructive pulmonary disease

Background: The risk of hypoxemia increases with the progression of chronic obstructive pulmonary disease (COPD) and the deterioration of pulmonary function. The aim of this study was to compare functional capacity, physical activity, and quality of life in hypoxicemic and non-hypoxicemic patients with COPD.

Methods: Thirty-nine COPD patients (mean age: 62.0±7.03 years) were included in this study. Arterial blood gas tensions were measured, and patients were divided into two groups according to oxygen partial pressure (Pao2); the hypoxic COPD (Pao2 <60 mmHg) (n=18), and the control (Pao2 ≥60 mmHg) (n=21) groups. Functional exercise capacity was evaluated using the 6-minute walk test (6MWT). Oxygen saturation, dyspnea, and fatigue perception were measured before and after the 6MWT. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) and an accelerometer. Quality of life was assessed using the St George’s Respiratory Questionnaire (SGRQ).

Results: The number of emergency visits and hospitalizations were higher in hypoxicemic patients (P<0.05). Lung function parameters, 6MWT distance, exercise oxygen saturation, IPAQ total score, and energy expenditure during daily life were significantly lower, but percentage of maximum heart rate reached during the 6MWT was significantly higher, in hypoxicemic COPD patients than in controls (P<0.05).

Conclusion: Hypoxemia has a profound effect on functional capacity and physical activity in patients with COPD.

Keywords: COPD, hypoxemia, 6-minute walk test

Introduction
Chronic obstructive pulmonary disease (COPD) is one of the leading diseases causing mortality and morbidity.1 The progression of disease and deterioration in pulmonary function increases alveolar hypoxia and ultimately the risk of hypoxemia.2 The greatest contributing factor to hypoxemia is ventilation/perfusion mismatch resulting from progressive airway limitation and emphysematous destruction of the pulmonary capillary bed. Dynamic hyperinflation, total lung capacity, cardiovascular factors such as oxygen consumption and cardiac output, nutritional status, and female sex also contribute to the risk of hypoxemia.3–6

Hypoxemia and tissue hypoxia cause systemic imbalance and inflammation. Protein synthesis is reduced and muscle cell structure is altered in hypoxemia. Complications and extrapulmonary comorbidities including cardiovascular disorders, pulmonary hypertension, polycythemia, neurocognitive dysfunction, impairment of life quality, lower exercise tolerance, and skeletal muscle weakness are common, and the risk of death is increased with the presence of hypoxemia in COPD.7–9
Hypoxemia leads to the conversion of aerobic metabolism to anaerobic metabolism in low levels of physical activity in COPD. Physical inactivity is considered an important marker of advanced COPD. Reduced skeletal muscle oxidative capacity can have a negative effect on exercise capacity and physical activity in COPD patients. Few studies have examined hypoxemia and related factors including exercise capacity, muscle function, and quality of life. To our knowledge, no published study has examined whether quality of life, functional capacity, and physical activity change between hypoxic and non-hypoxic COPD patients. Identifying these factors can guide clinicians in the follow-up of COPD patients. The aim of this study was to compare functional capacity, physical activity, and quality of life in hypoxic and non-hypoxic patients with COPD.

Methods
This cross-sectional, observational study included 39 clinically stable COPD (34 male and five female) patients between the ages of 41 and 78 years with a mean forced expiratory volume in 1 second (FEV<sub>1</sub>) of 50.64%±23.17%. Diagnosis of disease and classification of disease severity were established in line with the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria. Patients who were not able to walk or perform the 6-minute walk test (6MWT), patients who were not able to cooperate in pulmonary function testing, patients with oral corticosteroid use for at least 6 weeks, and patients with heart disease and acute exacerbation were not included in the study. According to arterial blood gas analysis, patients with oxygen partial pressure (PaO<sub>2</sub>) of <60 mmHg were assigned to the hypoxic COPD group and patients with PaO<sub>2</sub> ≥60 mmHg were assigned to the non-hypoxic control group. The hypoxic group consisted of 18 patients and the non-hypoxic control group consisted of 21 patients. The study was approved by the Ethics Committee of Hacettepe University, Ankara, Turkey, and signed informed consent forms were obtained from each patient before the study.

Physical, physiological, and sociodemographic data of the patients were recorded. Body mass index was calculated by the following formula: body weight/height<sup>2</sup> (kg/m<sup>2</sup>). The patients’ smoking history was recorded as pack-years.

The lung function test was performed in a seated position using a Spirolab III spirometer (Medical International Research, Rome, Italy) consistent with American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines. Forced vital capacity (FVC), FEV<sub>1</sub>, FEV<sub>1</sub>/FVC rate, peak expiratory flow, and forced expiratory flow between 25% and 75% of FVC (FEF<sub>25%-75%</sub>) were recorded. Lung function test parameters were expressed as percentage of the predicted values for age, height, body weight, and sex.

Resting arterial blood gas analysis was performed in environmental air, with radial arterial blood collected to analyze the concentration of hydrogen ions (pH), PaO<sub>2</sub>, partial carbon dioxide pressure, and oxygen saturation. We used the AVL Compact I (AVL Medical Instruments A.G., Schaffhausen, Switzerland) blood gas analyzer to adjust these variables. The alveolar–arterial oxygen gradient (P[A-a]O<sub>2</sub>) was calculated using the measured PaO<sub>2</sub> and partial carbon dioxide pressure assuming a standard respiratory exchange ratio of 0.8.

The 6MWT was performed according to ATS guidelines. Patients were asked to walk quickly along a 30 m level corridor for 6 minutes, and the total distance walked was recorded as meters. The test was carried out twice with a 30-minute interval. The best value of the two tests was used for statistical analysis. Heart rate and oxygen saturation were recorded during the 6MWT using a pulse oximeter (KPTS-01, Seoul, South Korea). Fatigue and dyspnea perception were assessed using the modified Borg rating of perceived exertion scale scores before and after the test.

Physical activity was determined using the self-administered short form of the International Physical Activity Questionnaire (IPAQ). The IPAQ requires respondents to estimate time spent in various levels of physical activity during the previous week. Scores for walking and moderate and vigorous activities are calculated as durations and frequencies multiplied by known metabolic equivalents per activity. The results for all activity-based items are summed for the total physical activity score. An item regarding time spent sitting is not included in the total physical activity score and is a separate score expressed as minutes.

Daily energy expenditure was measured for 4 consecutive days (2 weekdays and 2 weekend days) using the Caltrac accelerometer (Muscle Dynamics Fitness Network, Torrance, CA, USA). Patients were asked to continue their typical daily physical activities. For data analysis, the average energy expenditure during the 4 days was used.

The St George’s Respiratory Questionnaire (SGRQ) was used to assess quality of life. The SGRQ has 76 items that are divided into three sections including symptoms, activity, and impacts. Scores for each section and the total score range from 0–100, with high scores indicating poor health status.

Statistical analysis
Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 18.0 software.
Results

Thirty-nine patients entered the study (21 non-hypoxemic, 18 hypoxemic), and none of them were excluded during the measurements. Five patients in the hypoxemic COPD group were prescribed supplementary oxygen therapy. Patients’ characteristics are shown in Table 1. There were no significant differences in age, sex, height, weight, body mass index, disease duration, and smoking history between the two groups (P > 0.05).

According to GOLD phenotypes, seven (33%) patients were in group A, ten (47.6%) patients were in group B, three (14.3%) patients were in group C, and one (4.8%) patient was in group D classification level among the non-hypoxemic patients. In the hypoxemic patient group, one (5.6%) patient was in group A, five (27.8%) patients were in group B, and 12 (66.7%) patients were in group D classification level. There was a significant difference between the groups when classified by GOLD ABCD index, and patients in the hypoxemic group were more likely to be in higher-risk GOLD classes (P < 0.05). Higher GOLD severity classification was significantly correlated with hypoxemia (r = −0.645, P < 0.001). GOLD ABCD classification was correlated with 6MWT distance (r = −0.625, P < 0.001), IPAQ total score (r = −0.355, P = 0.03), IPAQ walking score (r = −0.373, P = 0.02), daily energy expenditure (r = −0.468, P = 0.003), SGRQ total score (r = −0.565, P < 0.001), SGRQ symptom subdomain (r = −0.560, P < 0.001), SGRQ activity subdomain (r = 0.495, P = 0.002), and SGRQ impact subdomain (r = 0.527, P < 0.001).

The numbers of emergency visits and hospitalizations were higher in the hypoxemic patients (P < 0.05). Lung function test findings were significantly lower in the hypoxemic patients (P < 0.05) (Table 1).

Functional capacity, physical activity, and quality of life variables are shown in Table 2. The 6MWT distance and exercise oxygen saturation were significantly lower and

**Table 1** Physical and demographic variables in hypoxemic and non-hypoxemic patients with COPD

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hypoxemic COPD</th>
<th>Non-hypoxemic COPD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62.83±7.37</td>
<td>59.95±6.83</td>
<td>0.335</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>16/2</td>
<td>18/3</td>
<td>0.768</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.59±6.40</td>
<td>167±5.59</td>
<td>0.839</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.00±13.41</td>
<td>75.44±12.91</td>
<td>0.322</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>25.88±3.60</td>
<td>27.31±5.24</td>
<td>0.338</td>
</tr>
<tr>
<td>Time from diagnosis (years)</td>
<td>6.89±4.70</td>
<td>8.61±7.56</td>
<td>0.791</td>
</tr>
<tr>
<td>Smoking (pack-years)</td>
<td>48.14±23.88</td>
<td>42.63±29.51</td>
<td>0.553</td>
</tr>
<tr>
<td>Number of doctor visits (n/year)</td>
<td>3.56±1.26</td>
<td>2.67±1.53</td>
<td>0.460</td>
</tr>
<tr>
<td>Number of emergency visits (n/year)</td>
<td>1.06±1.83</td>
<td>0.48±2.18</td>
<td>0.04*</td>
</tr>
<tr>
<td>Number of hospitalizations (n/year)</td>
<td>0.67±0.91</td>
<td>0.05±0.21</td>
<td>0.03*</td>
</tr>
<tr>
<td>pH</td>
<td>7.41±0.04</td>
<td>7.43±0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>PaO₂ (mmHg)</td>
<td>55.36±4.01</td>
<td>77.80±5.93</td>
<td>–</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>43.26±7.90</td>
<td>35.68±3.02</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>SaO₂ (%)</td>
<td>87.5±5.56</td>
<td>95.9±1.19</td>
<td>–</td>
</tr>
<tr>
<td>P(A-a)O₂ (mmHg)</td>
<td>22.04±8.66</td>
<td>9.06±5.78</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>HCO₃⁻ (mEq/L)</td>
<td>26.70±4.21</td>
<td>23.20±2.61</td>
<td>0.001***</td>
</tr>
<tr>
<td>FEV₁ (%)</td>
<td>36.67±12.91</td>
<td>62.62±23.50</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>FVC (%)</td>
<td>54.39±15.27</td>
<td>78.38±19.00</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>FEV₁/FVC (%)</td>
<td>52.00±13.49</td>
<td>80.1±18.80</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>PEF (%)</td>
<td>65.93±28.87</td>
<td>64.1±13.75</td>
<td>0.06</td>
</tr>
<tr>
<td>PEF₂₅-₇₅ (%)</td>
<td>45.06±15.24</td>
<td>38.10±21.32</td>
<td>&lt;0.001***</td>
</tr>
</tbody>
</table>

Notes: Values are expressed as mean ± standard deviation. *P < 0.05; **P < 0.001.

Abbreviations: COPD, chronic obstructive pulmonary disease; PaO₂, oxygen partial pressure; PaCO₂, carbon dioxide partial pressure; SaO₂, oxygen saturation; P(A-a)O₂, alveolar–arterial oxygen gradient; HCO₃⁻, hydrogen bicarbonate; FEV₁, forced expiratory volume in 1 second; FVC, forced vital capacity; FEV₁/FVC, forced expiratory volume in 6 seconds; PEF, peak expiratory flow; PEF₂₅-₇₅, forced expiratory flow between 25% and 75% of FVC.
The current study has two main findings: 1) more frequent

discussion compared to the non-hypoxemic group (P<0.05) (Table 2).

The IPAQ total score and energy expenditure during daily

life were significantly lower in hypoxemic patients (P<0.05) (Table 2).

There were no significant differences in SGRQ total and

subscale scores between the hypoxic and the non-

hypoxic patients with COPD (P>0.05) (Table 2).

According to P(A-a)O2 gradient, eleven (61.1%) patients

had a higher gradient level assuming low ventilation/

perfusion ratio and seven (38.9%) patients had a normal

P(A-a)O2 level due to hypoventilation in the hypoxic

COPD group. All patients had a normal gradient in the non-

hypoxic group. Post hoc analysis revealed no differences

when the normal and higher gradient hypoxic groups were

compared to the non-hypoxic group (P>0.05).

Discussion

The current study has two main findings: 1) more frequent

emergency visits and hospitalization and 2) reduced lung

function, functional exercise capacity, and physical activity

level in daily life in hypoxic patients with COPD. Higher

GOLD severity classification was significantly correlated

with hypoxemia in patients with COPD.

Emergency department visits and hospitalizations are

an important risk of disease progression and are the

predictors of acute exacerbations in COPD. They are related

with morbidity, mortality, worsened health status, and impaired

lung function.23,24 In this study, we showed that the presence

of hypoxemia may have an effect on number of emergency

visits and hospitalizations. Implementation of a comprehen-

sive self-management strategy, especially including oxygen

therapy, may result in a lower hospitalization rate and fewer

emergency department visits. COPD patients who experi-

enced exacerbations and a higher hospitalization rate have

shown markedly lower skeletal muscle strength, 6-minute

walk distance, physical activity, and quality of life.25

The decline of PaO2 was in line with a decrease in FEV1,

FVC, peak expiratory flow, and FEF25%–75% in COPD patients

in our study. Airway obstruction reduces ventilation and

causes ventilation/perfusion mismatch. One study showed

that airflow limitation increased progressively with arte-

rial blood gas disturbances.26 A multicenter 3-year follow-

up study also demonstrated that lower levels of PaO2 were

associated with a higher functional residual capacity and total

lung capacity that reflects the degree of hyperinflation.27

Functional exercise capacity measured using the 6MWT

was markedly reduced in our hypoxic patients. Romer

et al showed that the reduction in PaO2 negatively impacted

Table 2 Functional capacity, physical activity, and quality of life in hypoxic and non-hypoxic patients with COPD

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hypoxic COPD</th>
<th>Non-hypoxic COPD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>6MWT distance (m)</td>
<td>445.29±92.96</td>
<td>547.58±87.24</td>
<td>0.002*</td>
</tr>
<tr>
<td>%HRmax</td>
<td>78.84±7.49</td>
<td>68.79±11.66</td>
<td>0.007*</td>
</tr>
<tr>
<td>Borg-dyspnea (0–10)</td>
<td>3.72±3.06</td>
<td>2.19±2.79</td>
<td>0.073</td>
</tr>
<tr>
<td>Borg-fatigue (0–10)</td>
<td>2.64±2.54</td>
<td>2.64±2.33</td>
<td>0.989</td>
</tr>
<tr>
<td>SpO2 (%)</td>
<td>85.61±8.54</td>
<td>95.76±3.02</td>
<td>–</td>
</tr>
<tr>
<td>IPAQ total score (MET-min/week)</td>
<td>1,012.4±890.93</td>
<td>2,844.0±1,164.01</td>
<td>0.023*</td>
</tr>
<tr>
<td>IPAQ walking score (MET-min/week)</td>
<td>828.9±671.58</td>
<td>1,512.5±2,101.16</td>
<td>0.581</td>
</tr>
<tr>
<td>IPAQ moderate score (MET-min/week)</td>
<td>178.8±395.82</td>
<td>552.3±1,018.18</td>
<td>0.128</td>
</tr>
<tr>
<td>IPAQ vigorous score (MET-min/week)</td>
<td>4.7±19.40</td>
<td>779.0±2,400.65</td>
<td>0.467</td>
</tr>
<tr>
<td>IPAQ sitting score (min)</td>
<td>608.2±240.21</td>
<td>532.8±202.56</td>
<td>0.243</td>
</tr>
<tr>
<td>Energy expenditure (cals/day)</td>
<td>412.3±277.62</td>
<td>599.6±221.66</td>
<td>0.04*</td>
</tr>
<tr>
<td>SGRQ symptom score (0–100)</td>
<td>63.5±29.98</td>
<td>52.7±23.56</td>
<td>0.196</td>
</tr>
<tr>
<td>SGRQ activity score (0–100)</td>
<td>62.8±26.30</td>
<td>52.4±23.77</td>
<td>0.186</td>
</tr>
<tr>
<td>SGRQ impact score (0–100)</td>
<td>45.7±21.75</td>
<td>37.5±19.33</td>
<td>0.167</td>
</tr>
<tr>
<td>SGRQ total score (0–100)</td>
<td>53.9±22.55</td>
<td>44.7±19.64</td>
<td>0.158</td>
</tr>
</tbody>
</table>

Notes: Values are expressed as mean ± standard deviation. *P<0.05.

Abbreviations: COPD, chronic obstructive pulmonary disease; 6MWT, 6-minute walk test; %HRmax, percentage of maximal heart rate; SpO2, oxygen saturation with pulse oximeter; MET, metabolic equivalent; IPAQ, International Physical Activity Questionnaire; sgrQ, st george’s Respiratory Questionnaire.
functional capacity and fatigability in healthy individuals with skeletal muscle dysfunction. Exercise performance depends on aerobic metabolism and oxidative capacity. Hypoxemia has been linked to a more glycolytic muscle profile and ultimately with the decline in 6MWT. Our hypoxemic patients also experienced more severe oxygen desaturation during the 6MWT. Oxygen desaturation during the 6MWT occurs due to the imbalance between oxygen supply and demand during exercise associated with skeletal muscle dysfunction and hemodynamic and respiratory problems in COPD patients. Arterial hypoxemia is associated with poor oxygen transport to the muscles, increasing oxygen desaturation during exercise. This desaturation during exercise increases the risk of poor prognosis.

We found that patients with hypoxemic COPD were less physically active during their daily life measured using both subjective and objective methods. To our knowledge, this was the first study that reported the physical activity level in hypoxemic patients with COPD. Like exercise performance, physical activity also predominantly depends on the aerobic capacity. It appears that hypoxemia has a significant impact on physical activity in COPD. Endurance training is known to promote more aerobic muscle performance in COPD, with increases in number of type 1 muscle fibers, mitochondrial density, oxidative enzyme activity, and capillarization. Exercise may facilitate gas exchange in patients with COPD by improving the ventilation/perfusion ratio. Supplemental use of noninvasive ventilation, oxygen therapy, and heliox during exercise to enhance the physiological benefits of exercise is not well established and is not routine in clinical practice.

Hypoxemia and acidosis affect sympathetic activation and chemoreflex control of heart rate responses. Studies showed a relationship between higher resting heart rate and low levels of PaO₂. The presence of hypoxemia increased resting heart rate 49% per ten beats per minute. In accordance with the literature, the hypoxemic patients in our study also exhibited elevated heart rate responses during exercise testing.

Most related studies have demonstrated a significant impairment of quality of life in hypoxemic COPD patients compared to a control group. As was the case in our study, however, a few studies showed no relationship between PaO₂ and quality of life scores. A possible explanation for these findings is that few patients used supplementary oxygen in our hypoxemic group; therefore, there was no improvement in health status resulting from long-term oxygen therapy.

We did not find any differences between hypoxemic patients with normal and higher P(A-a)O₂ gradient levels compared to the non-hypoxemic group. However, there were very few patients in each group. Further research with larger patient numbers is needed to investigate the effect different causes of hypoxemia have on functional parameters.

Our study had limitations which must be taken into consideration. The small sample size may not allow for the determination of the relationship between hypoxemia and quality of life in COPD. Measurement of static lung volume and diffusing capacity of the lungs for carbon monoxide can yield more information about the relationship between hypoxemia and lung function. However, we showed for the first time in the literature that functional capacity, physical activity, and exercise heart rate change between hypoxemic and non-hypoxemic COPD patients.

Conclusion
We can conclude that hypoxemia is an important variable to detect reductions in lung function, functional exercise capacity, and physical activity level in patients with COPD. Arterial hypoxemia and lung function deterioration have a main negative impact of limitation of exercise capacity in COPD. Further study is needed to investigate the effects of long-term oxygen therapy on functional capacity and physical activity in patients with hypoxemic COPD.

Disclosure
The authors report no conflicts of interest in this work.

References


