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Effects of chronic obstructive pulmonary disease stage on muscle oxygenation during exercise

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ABSTRACT

Aims: The aim of this study was to investigate peripheral muscle oxygenation in patients with chronic obstructive pulmonary disease (COPD) at rest, during submaximal exercise, and during recovery, and to determine the effects of disease stage on peripheral muscle oxygenation.

Methods: Of the 35 stable COPD patients (62.49±8.45 years), 18 patients in GOLD 1 and 2 were assigned to Group 1 and 17 patients in GOLD 3 and 4 were assigned to Group 2. Dyspnea perception of the patients was evaluated with the Modified Medical Research Council (mMRC) Dyspnea Scale, severity of the disease affecting daily life was evaluated with the COPD Assessment Test (CAT-COPD Assessment Test), respiratory function was evaluated with the Pulmonary Function Test, and quadriceps muscle strength was evaluated with a manual muscle testing device. Muscle oxygenation of the patients was measured with Near-infrared spectroscopy (NIRS) for 5 minutes at rest, 6 minutes during the 6-Minute Walk Test (6-MWT), and 5 minutes during recovery after the end of the test. The results of the two groups were compared.

Results: Intragroup comparisons of muscle oxygenation at rest, during 6-MWT and during recovery; in Group 1, there was a statistically significant decrease between resting SmO_2 mean and test SmO_2 mean ($p=0.001$), a increase between test SmO_2 mean and recovery SmO_2 mean ($p<0.001$), and a significant increase between resting SmO_2 mean and recovery SmO_2 mean ($p=0.022$). In Group 2, there was a statistically significant decrease between resting SmO_2 mean and SmO_2 mean during the test ($p=0.002$), increase between resting SmO_2 mean and recovery SmO_2 mean ($p<0.001$*), and resting SmO_2 mean and recovery SmO_2 mean ($p=0.024$). There was no significant difference between the groups in Δ Rest-Test SmO_2mean, Δ Recovery-Test SmO_2mean, and Δ Recovery-Rest SmO_2mean ($p>0.05$). In the SmO_2 comparison of Group 1 and Group 2 at rest, during 6-MWT, and during recovery, it was observed that the test SmO_2mean value was statistically higher in Group 2 ($p=0.023$).

Conclusion: When the disease stage increases in individuals with COPD, muscle oxygen utilization metabolism during submaximal exercise worsens, demanding more oxygen to the muscle to produce the same movement as in individuals with a lower disease stage. This may be explained by the fact that energy metabolism and endurance are affected due to the decrease in the oxygen level of the muscle and its capacity to utilize the available oxygen with increasing disease severity.

Keywords: COPD, near infrared spectrometry, severity, submaximal test

INTRODUCTION

According to the "Global Initiative for Chronic Obstructive Lung Disease (GOLD)-2023", Chronic Obstructive Pulmonary Disease (COPD) is defined as "a heterogeneous condition characterized by chronic respiratory symptoms (dyspnea, cough, and sputum), persistent and often progressive airway obstruction caused by airway (bronchitis/bronchiolitis) or alveolar (emphysema) abnormalities".[1] Historically, COPD has mainly been considered a lung disease and treatment has focused on the lung alone. Large cohort studies have shown that COPD is a complex, heterogeneous, and multicomponent disease with both pulmonary and extrapulmonary manifestations contributing to the burden of the disease.[2] Changes in body composition, such as muscle, fat, and bone wasting, are a cluster of extrapulmonary manifestations in COPD.[2,3] Muscle wasting is common in COPD patients and its frequency varies according to the patient's condition.[4] The prevalence of muscle wasting increases with airflow severity. One study showed that the prevalence of muscle weakness increased from 25% to 38% in patients with GOLD 1 to GOLD 4 COPD, respectively.[4]

Limited aerobic capacity is a characteristic feature of patients with chronic obstructive pulmonary disease (COPD). The magnitude of the limitation in

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aerobic capacity is determined by the interaction of three main factors: impaired pulmonary function, abnormal cardiopulmonary interactions, and skeletal muscle dysfunction.[5] Skeletal muscle dysfunction is associated with impaired peripheral muscle circulation, loss of muscle oxidative capacity, and mitochondrial dysfunction.[6,7] Despite these well-known systemic consequences of the disease, the association of skeletal muscle dysfunction with disease severity and severity of pulmonary impairment is unclear. This is due to the fact that measurements of skeletal muscle structure and function require complex methodological approaches.[8]

Patients with COPD breathe faster and more superficially at higher volumes than healthy individuals. This situation causes dyspnea, impaired pulmonary gas exchange, increased breathing, respiratory muscle fatigue, decreased exercise capacity and daily living activities, and loss of strength in peripheral muscles due to increased mechanical work and oxygen consumption on the respiratory muscles.[9,10] Decreased activity causes social isolation, causing this patient to become depressed. All of these create a vicious circle, decreasing exercise capacity and quality of life.[11,12] Dyspnea, exercise capacity, and peripheral muscle strength, which are of great importance in individuals with COPD, are frequently used parameters in studies where measurements are made, and the 6 MWT and mMRC Dyspnea scale used to evaluate these have minimal clinical significance values for COPD.[13] Although these evaluations provide important data regarding the patient's condition and the course of the disease, they are insufficient to elucidate the metabolic effects of the skeletal muscle and the oxygen metabolism of the muscle, and it is emphasized that further research is needed.[14,15]

Near-infrared spectroscopy (NIRS) has emerged as a non-invasive method to assess oxidative capacity and blood flow and metabolism in skeletal muscles in patients with COPD.[16] Studies have been conducted on the potential applicability of NIRS during exercise programs in COPD patients.[7,17] However, studies have resulted in limited information to analyze the role of muscle metabolism and muscle oxygenation given the multifactorial basis of muscle dysfunction in COPD.[7]

Assessment of skeletal muscle performance and metabolism by studying muscle oxygenation is an emerging field. Muscle oximetry based on NIRS of peripheral oxygen consumption in COPD patients can non-invasively provide information about these changes in oxygenation and hemodynamics in muscle tissues based on the oxygen-dependent properties of near-infrared light.[18] In the literature, studies with NIRS technology have been used to determine the blood flow and oxygenation level of muscle at rest and during exercise, and it has been one of the current methods used to assess blood flow and muscle oxygen availability in COPD patients, especially in recent years.[16] However, to date, in studies conducted with NIRS in COPD patients, muscle oxygenation has been evaluated by comparing individuals with healthy controls or by comparing different pulmonary rehabilitation programs, and the effect of disease severity on muscle oxygenation has remained an issue that has not yet been elucidated.

The aim of this study was to investigate peripheral muscle oxygenation in patients with COPD at rest, during submaximal exercise, and during recovery, and to determine the effects of disease stage on peripheral muscle oxygenation.

METHODS

The study was carried out with the permission of the Bandırma Onyedi Eylül University Health Sciences Non-Interventional Researches Ethics Committee (Date: 13.04.2023, Decision No: 2023-72), and registered at ClinicalTrials.gov (Identifier: NCT06041126). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Study Design and Participants

This prospective cross-sectional study was conducted between April 2023 and July 2023 in individuals who were followed up with a diagnosis of COPD in the Chest Diseases outpatient clinic of Balıkesir Bandırma Training and Research Hospital and whose conditions were stable. The study was conducted in the application unit of Bandırma Onyedi Eylül University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation.

Inclusion criteria were being diagnosed with COPD (according to GOLD Staging: GOLD 1, GOLD 2, GOLD 3, or GOLD 4), being between 40-80 years of age, having a Body Mass Index (BMI)<35, and having no history of an acute exacerbation in the last 3 months. Patients who did not want to participate in the study; patients with various conditions causing weakness in the lower extremities, such as arthritis, neurologic disease, deep vein thrombosis, peripheral arterial disease, muscle weakness, fracture; patients with extensive parenchymal damage such as malignancy, pulmonary embolism, vasculitis, collagen tissue diseases, interstitial fibrosis, and severe pneumonia; patients with diffuse parenchymal damage such as malignancy, pulmonary embolism, vasculitis, collagen tissue diseases, interstitial fibrosis, and severe pneumonia; patients on continuous oxygen therapy; patients with dyspnea and hemodynamic instability severe enough not to allow them to perform the 6 Minute Walk Test were excluded from the study. Patients with GOLD 1 and GOLD 2 were classified into Group 1, and those with GOLD 3 and GOLD 4 were classified into Group 2.

The patients who were diagnosed with COPD at Bandırma Training and Research Hospital Chest Diseases outpatient clinic and whose disease severity was determined by their physicians according to GOLD staging and who were referred to Bandırma Onyedi Eylül University Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation (GYG, CD) were first questioned about demographic information and disease history. Dyspnea perception of the patients who met the inclusion criteria and volunteered for the study was evaluated with the Modified Medical Research Council (mMRC) Dyspnea Scale, severity of the disease affecting daily life was evaluated with the COPD Assessment Test (CAT-COPD Assessment Test), respiratory function was evaluated with the Pulmonary Function Tests (PFTs), and quadriceps muscle strength was evaluated with a manual muscle testing device. Muscle oxygenation of the patients was measured with NIRS for 5 minutes at rest, 6 minutes during the 6-Minute Walk Test (6-MWT), and 5 minutes during recovery after the end of the test.

Measurements

Modified medical research council (mMRC) dyspnea scale: The Modified Medical Research Council (mMRC) Dyspnea Scale was used to assess the dyspnea levels of the patients. mMRC is a 0-4-point category scale in which patients select the statement that best describes their dyspnea levels from among 5 statements about shortness of breath.[19] mMRC increases, especially values of 2 and above, are considered as increased mortality risk.[20]

COPD assessment test (CAT): The CAT, which measures the effects of COPD and deterioration in health status and is easy to apply in clinical practice, consists of eight items questioning "cough, sputum, chest symptoms, fatigue, and confidence in leaving home". The validity and reliability study of the CAT scale was conducted by Yorgancıoğlu et al.[21] in 2012 in Turkey. In the study, Cronbach's alpha internal consistency coefficient was 0.91, item-total score correlation coefficients were between 0.62 and 0.79, and test-retest correlation coefficient was 0.96. In the same study, the construct validity of the scale was examined by exploratory factor analysis and it was reported that the scale showed a single-factor structure with factor loadings ranging between 0.71 and 0.85 and an eigenvalue of 4.95, explaining 61.9% of the variance. In addition, it has been reported that CAT total score has significant discriminative power according to different disease stages, severity, and levels and correlated significantly with pulmonary function tests.[21] A minimum score of 0 and a maximum score of 40 can be obtained from the scale. In the study, the Cronbach alpha coefficient of the CAT scale was found to be 0.86.

Pulmonary function tests (PFTs): PFTs were performed with a COSMED brand Pony FX model portable spirometer (COSMED, Italy). In PFTs performed according to the American Thoracic Society (ATS) and the European Respiratory Society (ERS) criteria, Force Vital Capacity (FVC), Forced expiratory volume in the first second (FEV1), FEV1/FVC, peak expiratory flow rate (PEFR), and forced expiratory volume 25%-75% (FEV25%-75%) flow rate values were recorded.[22] Individuals were informed about the test and values such as age, gender, height, and weight were entered into the device to compare them with standard values. The test was performed 3 times in a sitting position. It is a valid and reliable test for the assessment of respiratory function.[22]

Muscle oxygenation measurement with muscle oxygen monitor: The muscle oxygen monitor is a lightweight (42 g) and small (dimensions: 61 × 44 × 21 mm) device that measures regional blood flow and oxygenation using NIRS by non-invasively placing it on the skin. It has data acquisition and telemetric capabilities, enabling O_2 measurement in non-laboratory settings and field-based research. The muscle oxygen monitor has been shown to be a valid and reliable device to assess muscle oxygenation. Its validity in measuring muscle oxygenation (SROC: r=0.842-0.993, ICC: r=0.773-0.992, $p < .01$) was found to be strong or very good, and its reliability was moderate to high in low-intensity exercise.[23] Patients were first placed in a long sitting position on the stretcher and the NIRS device was connected to the vastus lateralis part of the quadriceps to measure muscle oxygenation. Measurements were taken for 5 minutes at rest. Then the 6-MWT was performed with the device connected to the leg. At the end of the test, the patient rested for 5 minutes and the NIRS device was removed. The 6-Minute Walk Test was performed in accordance with the guidelines. Muscle oxygen saturation (SmO_2) of the patients is shown with minimum, maximum, and mean values.

Quadriceps muscle strength measurement: Quadriceps muscle strength of the patients was evaluated using a manual muscle strength measuring device (Lafayette Instrument, USA) and recorded in kg/force. Maximal voluntary isometric contraction (a make test), which was reported to be more reliable and frequently used in the literature was used for muscle strength measurements.[24-26] In the muscle strength measurements, principles stated by Otman and Köse were taken into consideration, and the rest was performed three times 30 seconds apart in both lower extremities and the highest measurement was recorded.[27] For quadriceps muscle strength measurement, patients were seated on the treatment table with legs hanging down and a rolled towel was placed under the knee joint of the side to be evaluated and the thigh was fixed. The patient was asked to perform extension in this position until the knee was locked, and resistance was given slightly above the ankle joint.

6-minute walk test (6-MWT): It is a submaximal exercise capacity measurement test. The patient is asked to walk as briskly as possible on a 30-meter flat surface for 6 minutes.

During the test, the patient is reminded of the time every minute with standardized commands. Before and at the end of the test, oxygen saturation, heart rate, Borg fatigue scoring, and distance walked are recorded. It is a frequently used exercise test in the clinic because it requires little equipment and is easy to perform.[28] In our study, the test was performed in a 30-meter corridor in accordance with the guidelines. It was explained to the patients that they should walk as briskly as they could and that they could stop in case of shortness of breath or excessive fatigue, but that the test period would continue during this time. Resting saturation (SpO_2), heart rate, and modified Borg fatigue score were recorded before the test. Saturation and heart rate were continuously monitored with finger oximetry during the test. Measurements and scoring were taken again at the end of the test and 3 minutes after recovery. The distance traveled was recorded.

Statistical Power and Analysis

For the sample size in our study; similar to our study, the study of Barberan-Garcia et al.[5] which evaluated quadriceps muscle oxygenation with the NIRS device, was taken as an sample. According to this study, it was determined in G*Power 3.1.9.7 that a total of 32 people should be included, 16 people in each group, with a 95% confidence interval and 80% power. As a result of the power analysis performed at the end of our study, it was found that the power of our study was 85%.

Statistical analyses were performed using the IBM SPSS Statistics 26 (Version 26.0. Armonk, NY: IBM Corp). The Shapiro Wilk test was used to check whether the data fit the normal distribution. For descriptive statistics, numerical variables are given as mean and standard deviation if they met the parametric assumption, median and minimum-maximum values if they did not, and as frequency and percentage values for qualitative variables. Before the statistical evaluation, all continuous measurements were evaluated for conformity to normal distribution in the groups, and parametric tests were used when the normality assumption was met, and nonparametric tests were used when the normality assumption was not met. Independent groups t test was used for those that met the normality assumption and the Mann Whitney-U test for those that did not. The significance level was accepted as $p<0.05$ for all tests.

RESULTS

Of the 35 stable COPD patients (62.49±8.45 years), 2 were in GOLD 1 (5.7%), 16 in GOLD 2 (45.7%), 14 in GOLD 3 (40.0%), and 3 in GOLD 4 (8.6%). Eighteen patients in GOLD 1 and 2 were assigned to Group 1 and 17 patients in GOLD 3 and 4 were assigned to Group 2. Demographic and clinical characteristics of all patients and groups are given in **Table 1**. Age, body mass index (BMI), smoking status, CAT score, 6-MWT, right and left quadriceps muscle strength, and FEV1/FVC values of the groups were similar ($p>0.05$). The mMRC score was significantly higher in group 2 compared to group 1 ($p<0.001$); resting SpO_2 ($p=0.028$), SpO_2 at the end of the test ($p=0.010$), FEV1 ($p<0.001$), and FVC ($p<0.001$) values were significantly lower in Group 2.

Intragroup comparisons of muscle oxygenation at rest, during 6-MWT and during recovery are given in **Table 2**. In Group 1, there was a statistically significant decrease between resting SmO_2 mean and test SmO_2 mean ($p=0.001$), a statistically significant increase between test SmO_2 mean and recovery SmO_2 mean ($p<0.001$), and a statistically significant increase between resting SmO_2 mean and recovery SmO_2 mean ($p=0.022$). In Group 2, there was a statistically significant decrease between resting SmO_2 mean and SmO_2 mean during the test ($p=0.002$), a statistically significant increase between resting SmO_2 mean and recovery SmO_2 mean ($p<0.001$*), and a statistically significant increase between resting SmO_2 mean and recovery SmO_2 mean ($p=0.024$).

Table 1. Demographic and clinical characteristics of all patients and groups

	Total (n=35)	Group 1 (GOLD 1 and 2) (n=18)	Group 1 (GOLD 3 and 4) (n=17)	p
Age (year)	62.49 ±8.45	60.11±9.18	65.00±7.01	0.85
BMI (kg/m²)	26.99±4.78	26.29±5.41	27.73±4.02	0.377
Smoking (pack/year)	45.91±24.63	44.94±21.07	47.06±29.06	0.815
mMRC	1.68± 0.99	1.05±0.72	2.35±0.78	p<0.001
CAT	12.69±7.08	10.35±5.99	15.41±7.51	0.075
6-MWT (m), median (min-max)	472 (250-600)	478.50 (360-600)	450.00 (250.00-570.00)	0.305
SpO_2 rest	96.17±3.46	98 (82-100)	96 (91-98)	0.028
SpO_2 post-test	93.51±5.96	97 (71-99)	92(84-98)	0.010
Right Quadriceps Muscle Strength	19.00 (8.40-32.80)	19.00 (13.30-26.40)	18.30 (8.40-32.80)	0.815
Left Quadriceps muscle strength	19.97± 5.01	20.03±5.17	19.91±5.02	0.944
FEV1,%	51.39±16.02	63.00±10.70	37.11±7.95	p<0.001
FVC, %	69.84± 20.49	83.05±16.99	54.00±10.75	p<0.001
FEV1/FVC	62.46±12.48	64.72±12.80	59.75±11.93	0.258

BMI, body mass index; FEV1, volume expired in the 1st second of forced expiration; FVC, forced vital capacity; mMR,: Modified Medical Research Council Dyspnea scale; CAT, COPD Assessment Test; 6-MWT, six minute walking test; SpO_2, peripheral oxygen saturation; n, number of participants; X, mean value; SD, standard deviation.

Table 2. Intragroup comparison of muscle oxygenation at rest, during 6-MWT, and during recovery

Values	X ±SD	p
Group 1 (GOLD 1 and 2) (n=18)		
Rest SmO_2 Mean Test SmO_2 Mean	44.92±8.11 34.76 ±13.82	0.001*
Test SmO_2 Mean Recovery SmO_2 Mean	34.76±13.82 48.71±9.67	<0.001*
Rest SmO_2 Mean Recovery SmO_2 Mean	44.92±8.11 48.71±9.67	0.022*
Group 2 (GOLD 3 and 4) (n=17)		
Rest SmO_2 Mean Test SmO_2 Mean	50.51±11.049 44.63±10.23	0.002*
Test SmO_2 Mean Recovery SmO_2 Mean	44.63±10.23 55.51±12.72	<0.001*
Rest SmO_2 Mean Recovery SmO_2 Mean	50.51±11.049 55.51±12.72	0.024*

6-MWT, six minute walk test; n, number of participants; X, mean value; SD, standard Deviation; SmO_2, muscle oxygen saturation; p, level of significance; *, p<0.05

There was no significant difference between the groups in Δ Rest-Test SmO_2 mean, Δ Recovery-Test SmO_2 mean, and Δ Recovery-Rest SmO_2 mean (p>0.05) (**Table 3**). In the SmO_2 comparison of Group 1 and Group 2 at rest, during 6-MWT, and during recovery, it was observed that the test SmO_2 mean value was statistically higher in Group 2 (p=0.023), while there was no difference in resting and recovery SmO_2 mean values (p>0.05) (**Table 3**).

Table 3. Comparison of muscle oxygenation Δ values and muscle oxygenation at rest, during 6-MWT, and during recovery

	Group 1 (GOLD 1 and 2) (n=18)	Group 2 (GOLD 3 and 4) (n=17)	p
Δ Rest-Test SmO_2 mean	13.95±7.60	10.87±7.65	0.242
Δ Recovery-Test SmO_2 mean	10.16±11.09	5.87±6.49	0.175
Δ Recovery-Rest SmO_2 mean	3.78±6.37	5.01±8.31	0.628
Rest SmO_2 mean	44.92±8.11	50.50±11.04	0.101
Test SmO_2 mean	34.76±13.82	44.63±10.23	0.023*
Recovery SmO_2 mean	48.71±9.67	55.51±12.72	0.087

6-MWT, six minute walk test; n, number of participants; X, mean value; SD, standard Deviation; SmO_2, muscle oxygen saturation; p, level of significance; *, p<0.05; Δ, difference.

DISCUSSION

In the present study, 35 COPD patients were reached and the participants were divided into 2 groups according to GOLD Staging. The evaluation results showed that both groups were similar in terms of age, BMI, smoking, functional capacity, right-left quadriceps muscle strength, and CAT scores. The dyspnea level was higher and peripheral oxygen saturation was lower in the group with higher disease stage (GOLD 3 and 4). In both groups, muscle oxygenation decreased significantly during the 6-MWT compared to rest and increased during recovery. In addition, muscle oxygenation increased in recovery than at rest. When the differences (Δ) of the groups during these changes were compared, it was seen that there was no difference between the groups. However, when the muscle oxygenation mean values of the groups obtained during the test were compared, it was observed that the average muscle oxygenation of the group with high disease stage was significantly higher than the other group. In other words, the muscle oxygen utilization metabolism of people with high COPD stage was poorer during submaximal exercise; considering that the functional capacities of the groups were similar, it was thought that the muscle demanded more oxygen to produce the same movement.

Measurement of muscle oxygenation with near-infrared technology is a relatively new method for noninvasively obtaining physiological information on peripheral muscle metabolism and muscle oxygen utilization. Muscle oxygenation is expressed as SmO_2 and can take different values between 0 and 100 depending on the oxygen supply to the muscle via peripheral blood flow and the oxygen demand of the muscle, which varies depending on whether the muscle is at rest or during/after exercise. SmO_2 mean value shows the mean value during the measured time period. Muscle oxygenation decreases with exercise in healthy individuals compared to its value at rest, reaching the resting level in recovery after exercise.[29] In our study, normal physiological responses occurred and muscle oxygen saturation decreased with exercise in both groups and increased above the resting level during recovery.

In our study, there was no difference between the SmO_2 mean values of the groups at rest and during recovery, but there was a difference during exercise. Although there was no difference in the exercise capacity of the participants in both groups, the fact that the mean muscle oxygenation during exercise was lower in patients in GOLD stages 1 and 2 compared to those in stages 3 and 4 shows that they can provide the same level of exercise performance using less oxygen. This is an important clue that the peripheral muscles of patients in the early stages of COPD are able to balance the oxygen supply and demand status using oxygen more efficiently and effectively during exercise, which is how Szucs et al. explained the improvement in muscle oxygenation after pulmonary rehabilitation in patients with COPD.[30] These results obtained in muscle oxygen saturation are explained by the physical fitness status of healthy individuals, which varies according to whether they are sedentary or active, and by the fact that energy production-consumption systems have the potential to perform more work at the same oxygen levels.[31] In our study, although muscle oxygen saturation during exercise was higher in COPD patients with increasing disease severity, they performed functionally the same task as the group with less disease severity, which may be explained by the fact that energy metabolism and

endurance status were affected due to decreased oxygen level and oxygen utilization capacity of the muscle with increasing disease severity.

Oxygen saturation, which is an indicator of whole body oxygenation, is a parameter that provides important information about whether oxygen is sufficient in body tissues, and decreases of 4 percent or more indicate general deoxygenation in the body.[32] When the participants were analyzed in terms of SpO_2 levels in our study, deoxygenation was observed in the SpO_2 values of the group with high disease severity after the test in accordance with the clinical characteristics. According to the literature, this is an indication that metabolic adaptation to exercise decreases with increasing disease severity in COPD and the general oxygenation status of the body deteriorates.[33,34] The deoxygenated state of the patients during exercise may also have affected the oxygen utilization metabolism of the muscles during exercise. Since we worked with a select group of patients in terms of our exclusion criteria (such as patients receiving continuous oxygen therapy, patients with diffuse parenchymal damage, patients with dyspnea and hemodynamic instability so severe that they could not perform the 6-MWT, the SpO_2 and SmO_2 values of these patients were similar to those of the group with lower disease severity at rest and during recovery, even if the disease severity was high.

Tateishi et al.[35] compared muscle oxygenation at rest and during exercise in COPD patients with healthy controls and found that muscle oxygenation was impaired during exercise in COPD patients. They stated that this may be due to muscle fiber changes caused by the systemic effects of the disease and decreased oxidative capacity of the muscle, as well as increased oxygen consumption in respiratory muscles during exercise in COPD, and reported that future studies should focus on the causes of impaired muscle oxygenation. Evaluation of peripheral muscle oxygenation during exercise by spatially resolved spectroscopy in patients with chronic obstructive pulmonary disease.[36] Patients with COPD often develop skeletal muscle and vascular abnormalities as a complication of the disease, similar to patients with heart disease.[37,38] Studies have shown different parameters such as chronic immobilization, abnormal metabolic regulation, and decreased muscle oxidative capacity as the cause of impaired oxidative metabolism.[39] In our study, when we look at the CAT scores of our patients, which also reflect daily life, we see that they were moderately affected, and the 6-MWT result, which reflects the activities of daily living, was not too low. Therefore, the change in muscle oxygenation in both groups was similar. This result supports the above study and shows that when there is no condition such as chronic immobilization, that is, when the activities of daily living of COPD patients are not affected, there are no serious differences in muscle oxygenation changes between disease stages.

Our study has some limitations. First of all, the distribution of patients according to GOLD staging was not equal. In other words, a homogeneous number of patients with GOLD 1, 2, 3, and 4 would have allowed us to reach clearer results and the results of each stage could have been compared separately. Our study was conducted with a stable and select patient group. Separate evaluation of patients receiving continuous oxygen therapy could have revealed different perspectives. In addition, muscle oxygenation measurement was performed only on the lateral part of the quadriceps femoris due to insufficient number of devices. The results could have been strengthened by studying more than one muscle point. To the best of our knowledge, our study is the first study to evaluate muscle oxygenation in COPD patients according to staging. Although we have limitations, we think that our study is a pioneering study and the literature needs studies that offer different perspectives on this subject.

CONCLUSION

When the disease stage increases in individuals with COPD, muscle oxygen utilization metabolism during submaximal exercise worsens, demanding more oxygen to the muscle to produce the same movement as in individuals with a lower disease stage. This may be explained by the fact that energy metabolism and endurance are affected due to the decrease in the oxygen level of the muscle and its capacity to utilize the available oxygen with increasing disease severity. Our study is a pioneering study. Considering that COPD is a systemic disease and primarily affects the musculoskeletal system, studies with larger numbers of COPD patients with different clinical characteristics are needed to explain muscle metabolism.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of the Bandırma Onyedi Eylül University Health Sciences Non-Interventional Researches Ethics Committee (Date: 13.04.2023, Decision No: 2023-72).

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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