Systematic Review

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Effects of one-leg exercises in rehabilitation of chronic obstructive pulmonary disease: A systematic review

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Abstract:

BACKGROUND AND AIM: Many patients with chronic obstructive pulmonary disease (COPD) experience little or no increase in VO_{2peak} levels with pulmonary rehabilitation because their exercise capabilities are too respiratory-limited to reach an intensity high enough for physiological training. This study aims to investigate the effects of one-leg exercises on the cardiopulmonary system and whether they can find a place in pulmonary rehabilitation for individuals with COPD.

METHODS: Six major databases were searched up to December 2021 without imposing restrictions on publication date, gender, or age. Citations were accepted if they discussed one-leg strengthening or aerobic exercises in patients with chronic obstructive pulmonary disease. After reading the full texts, nine papers met the inclusion criteria and were included. Eight of these studies were randomized controlled studies, and one was a prospective cohort study.

RESULTS: In total, 169 subjects including healthy participants were observed. There is insufficient evidence to state that one-leg exercises have the potential to increase VO_{2peak} levels in patients with COPD more than traditional pulmonary rehabilitation options. Perceived dyspnea severity is lower, and leg fatigue is higher in one-leg exercises compared to two-leg exercises. The total work done by individuals with COPD during one-leg exercises was found to be close to that of healthy individuals.

CONCLUSIONS: We think that the possible potential of one-leg exercises focusing on a smaller muscle group can eliminate exercise-induced respiratory and cardiac stress and, therefore, may be included in pulmonary rehabilitation for patients with COPD.

Keywords:
Chronic obstructive pulmonary disease, COPD, exercise physiology, pulmonary rehabilitation

Introduction

Chronic obstructive pulmonary disease (COPD) is a global health problem characterized by physical activity-induced dyspnea, impaired muscle function, decreased cardiorespiratory fitness, and multi-organ involvement.[1,2] Dysfunction in extremity muscles is one of the most important problems causing exercise intolerance, a decrease in quality of life and physical activity, and increased

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mortality in individuals with COPD.[3] Cardiorespiratory fitness, which can be defined as peak oxygen uptake (VO_{2peak}), is recognized as a well-defined predictor of health status and the risk of mortality.[4] Pulmonary rehabilitation is recommended for COPD patients within one month following an acute exacerbation due to its benefits in improving shortness of breath, exercise tolerance, cardiorespiratory fitness, and health-related quality of life.[5,6] However, many patients with COPD experience little or no increase in VO_{2peak} because their exercise capabilities are so respiratory-limited that they cannot reach an intensity high enough for physiological training.[7,8] VO_{2peak} is affected by pulmonary diffusing capacity, maximal cardiac output, the oxygen carrying capacity of the blood, and skeletal muscle characteristics.[9] Peripheral airway limitation, a feature of COPD, progressively traps air during expiration, causing hyperinflation.[10] This hyperinflation may cause pulmonary hypertension due to the loss of vasculature resulting from hypoxic vasoconstriction of the small pulmonary arteries. Hyperinflation and pulmonary hypertension both affect lung diffusion capacity, causing it to decrease.[11] Due to the characteristic features of COPD, VO_{2peak} exposure can be considered one of the important problems in patients in terms of both endurance and quality of life.[12] The cardiorespiratory system is the primary determinant of VO_{2peak},[9] and improving cardiorespiratory fitness may have positive effects on VO_{2peak}. Exercises performed with one leg have been shown to increase cardiorespiratory fitness,[13] increase insulin sensitivity locally,[14] potentially increase blood flow velocity,[15] and gene expression[16] in both the contralateral and ipsilateral extremities, and decrease sympathetic system activity[17] in healthy individuals.

It is believed that one-leg exercises focusing on a smaller muscle group can eliminate exercise-induced respiratory and cardiac stress and, therefore, have a place in pulmonary rehabilitation for COPD patients.[3,18,19] The aim of this study is to answer the following question: Are one-leg exercises effective in the rehabilitation of COPD patients?

Materials and Methods

Six databases, including PubMed, PEDro, Cochrane Library, YOKTEZ, TrDizin, and Dergipark, were searched using the combinations of the keywords "one legged, one leg exercise, single leg" and "COPD, chronic obstructive pulmonary disease" up to December 2021. We did not impose restrictions on publication date, gender, or age. Studies in English and Turkish were reviewed. In the search, the title, abstract, and keyword fields were examined. Articles in the references of the included studies were also subsequently reviewed.

After selecting the relevant literature, members of the study group rated the studies for levels of evidence and quality according to Table 1.

Eligibility criteria

Since the number of studies on this subject is very limited, we examined studies investigating one-leg strengthening exercises or one-leg aerobic exercises without being selective among study types. Inclusion criteria: Studies on individuals over 20 years of age with a spirometry-confirmed diagnosis of COPD;[20–22] studies examining one-leg strengthening or one-leg aerobic exercises. Exclusion criteria: Studies that included a population diagnosed with COPD with a history of pulmonary surgery or with another respiratory disease such as asthma were excluded. Studies that performed one-leg balance exercises were also excluded. In addition, letters to the editor, conference summaries, duplicate studies, studies with a design that did not fit the purpose of this review, and studies that did not clarify the interventions used were excluded.

Results

A total of 317 studies were found in the searches, and after eliminating repetititve studies and those that did not contain keywords, 74 studies were analyzed. After reading the full texts, eight studies met the inclusion criteria. From the references of the included studies, one additional study was included, and a total of nine studies met the inclusion criteria [Fig. 1]. These studies examined 169 participants, including healthy controls. The main results of the nine studies reviewed are shown in "Table 2".

Studies Implementing Rehabilitation with One-Leg Exercises

In a prospective study published by Dolmage et al.[23] in 2008, patients with COPD were included in a pulmonary rehabilitation program for 21 sessions (30 minutes, 3 days/7 weeks), which was divided into two groups of two-leg and one-leg cycling exercise. It was shown that those who performed one-leg cycling had better results

Table 1. Methodological quality rating of included studies

Level of evidence	Interventional studies	Diagnostic accuracy studies
A1	Systematic reviews Meta-analysis	
A2	Randomized, double blind trial with good study quality	Index test compared to reference test (reference standard); cut-offs were defined a priori; independent interpretation of test results; all patients received both tests
B	Clinical trial but without randomization or poor study quality	Index test compared to reference test, but without all the features mentioned for level A2
C	Non-comparative studies	Case-control studies
D	Expert opinion	

in terms of VO_{2peak}, peak ventilations per minute, lower heart rate, and the number of ventilations than those who performed two-leg cycling.

In the study published by Bjørgen et al. in 2009,[24] patients with COPD undergoing pulmonary rehabilitation with hyperoxic oxygen support (65% O_2, 35% N_2) in one group and without oxygen support (normoxic) in the other group were compared with 24 sessions (3 days/8 weeks) of one-leg exercises. They showed that high-intensity interval training with one-leg cycling exercise increased VO_{2peak} independently of oxygen supplementation.

In another study conducted by Brønstad et al.,[2] in which patients with COPD were compared to healthy individuals, patients with COPD underwent 18 sessions (3 days/6 weeks) of one-leg knee extensor exercise and high-intensity intermittent exercise training. Compared to pretreatment, patients experienced a significant increase in aerobic endurance, peak quadriceps muscle oxygen uptake (VO_{2peak}), and maximal mitochondrial respiration. They found no difference in maximal respiration after treatment and compared with controls, indicating normally functioning mitochondrial complexes.

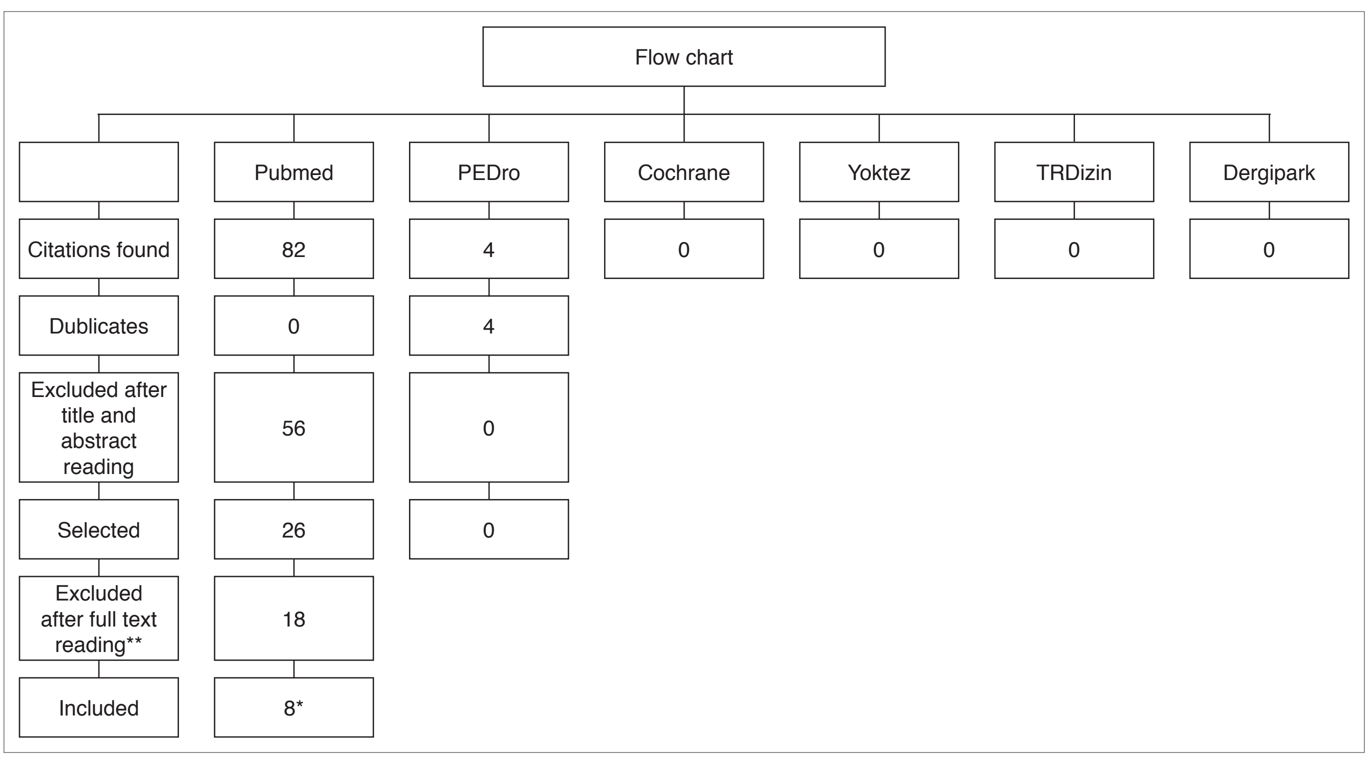

Figure 1: Flow chart

*: The ninth study included was obtained from the references of the studies in which the full text was read, **: The articles were excluded based on the inclusion and exclusion criteria described in the methods section.

Table 2. Included studies

Authors, study	Participants/intervention	Outcomes measures	Results	Key points
Richardson et al., 2004 [18] Case-control study (evidence level: C)	• 12 participants (6 people with COPD, 6 healthy controls) • All participants completed both the two-leg and one-leg cycling exercise test in a different order (8-12 minutes).	• Blood analysis (pO_2, pCO_2, pH, O_2 saturation, hemoglobin concentration) • Muscle biopsy (vastus lateralis) • Leg length, circumference, and skinfold fat measurement	• Type 1 muscle fiber area was less in participants with COPD than in the control group. • On the other hand, type 2, especially type 2 mixed muscle fiber was increased 2.5 times in COPD patients compared to healthy individuals. • Participants with COPD performed less work in the two-leg cycling exercise compared to the control group in terms of total workload. However, the workload during one-leg exercises was similar to the control group. • In addition, VO_{2peak} levels in one-leg exercises were similar to the control group. • Participants subjectively felt less dyspnea during the one-leg exercise.	• There was no long-term rehabilitation program, only a trial application of the test was made one week beforehand. • Two- and one-leg exercise tests were applied on the same day for each participant in a different order. • A mechanical inefficiency was demonstrated when examining skeletal muscle in patients with COPD without central limitations. • The increase in the amount of type 2 muscle fibers may be the possible cause of this inefficiency. • It has been concluded that although there are dysfunctions and structural changes in skeletal muscles in individuals with COPD, these changes do not completely affect muscle function and structure.
Dolmage et al., 2006 [25] Case-control study (evidence level: C)	• 27 participants • 9 healthy control, 9 COPD incremental exercise test, 9 COPD constant power exercise test • Healthy individuals were subjected to both exercise tests. • All tests were performed with two legs and one leg for 30 minutes.	• Ventilation rate, tidal volume, power, VO_{2peak}, VCO_{2peak}, gas exchange rate, heart rate, dyspnea (Borg scale), leg fatigue (Borg scale), • O_2 saturation, dynamic hyperinflation	Incremental exercise test-COPD • All individuals with COPD described dyspnea in two-leg exercise tests. • There was no difference in VO2peak scores between two-leg and one-leg exercises. • One-leg exercise test created less workload in individuals. Constant power exercise test-COPD • Endurance time was almost 4 times longer in one-leg exercises than in two-leg exercises. • Total workload was 2 times higher in one-leg exercises. • The peak values of ventilation number and heart rate were found to be lower in one leg exercises.	• There was no long-term rehabilitation program. • The groups were not statistically compared with each other. • The VO_{2peak}-power relationship refers to metabolic efficiency and was within the normal range in the control group. • COPD patients did not reach the maximum ventilation rate and heart rate during constant power one-leg exercises. • The reason for terminating the exercise test was leg fatigue.
Dolmage et al., 2008 [23] Randomized controlled study (evidence level: A2)	• 18 participants (9 people with one-leg exercise, 9 people with two-leg exercise) • 7 weeks/3 days • 30 minutes of continuous cycling exercise, excluding warm-up and cool-down periods • The one-leg cycling exercise group continued exercise with the other leg after 15 minutes.	• VO_{2peak}, power, heart rate, O_2 saturation, dyspnea, fatigue (Borg scale), ventilation rate, tidal volume, dynamic hyperinflation	• Exercise endurance and workload were better in one-leg exercises. • In post-treatment VO2peak measurements, the one-leg exercise group had a better outcome by 0.186 L/min. • There was no difference between groups in peak heart rate. • There was no difference between the groups in the perception of dyspnea. • Leg fatigue was 2.1 levels higher in the one-leg exercise group.	• It was observed that one-leg exercise training in COPD patients resulted in significant improvement in VO_{2peak} compared to two-leg training. • Although the one-leg exercise group performed muscle-specific higher-intensity exercise, their overall exercise intensities were lower than those in the two-leg exercise group. • The total workload by the one-leg exercise group approached that of the two-leg exercise group. • In the one-leg exercise training group, peak power increased beyond the upper confidence limit more than twice that reported in conventional exercise rehabilitation.
Bjørgen et al., 2009 [24] Randomized controlled study (evidence level: B)	• 12 participants with COPD (GOLD, COPD stage III) • 7 participants continued exercise training with hyperoxia support (65% O_2, 35% N_2). • 5 participants continued their normoxic (without oxygen support) exercise training. • 8 weeks/3 days of exercise training.	• VO_{2peak}, power, ventilations rate, gas exchange rate, O_2 saturation, heart rate, lactate, fatigue (Borg scale) • Both one-leg and two-leg cycling exercise tests were evaluated.	• In the one leg exercise test, VO_{2peak} increased by 24% and 15% in the hyperoxia and normoxia training groups, respectively. • In the two-leg exercise test, VO_{2peak} increased by 14% in both the hyperoxia and normoxia groups.	• High-intensity interval training with one leg significantly increases VO2peak in individuals with COPD, but supplemental oxygen support does not change these results.

Table 2. Cont.

Authors, study	Participants/intervention	Outcomes measures	Results	Key points
Mercken et al., 2009 [19] Case-control study (evidence level: C)	• 15 participants with COPD, 10 healthy controls • First, the incremental one-leg exercise test was performed, followed by the maximal one leg exercise test after one week, and, finally, the submaximal one-leg exercise test was conducted 3 days later.	• Power, endurance, O_2 uptake, CO_2 efficiency, heart rate, O_2 saturation, respiratory gas exchange rate, lactate, dyspnea and fatigue (Borg scale). Effects on erythrocyte.	• Muscle endurance duration was lower in COPD patients than in the control group. • No evidence of exercise-induced systemic inflammation was found. • Increased urinary malondialdehyde and uric acid levels were observed in COPD patients. • Erythrocyte oxidized glutathione and low glutathione levels tended to increase in COPD patients compared to the control group after exercise.	• Despite the reduced cardiopulmonary response from one-leg exercise, hydrogen peroxide levels in breath intensity were significantly increased in COPD patients. • Oxidative stress and pulmonary responses were higher in COPD participants than in the control group, without increasing systemic inflammation levels. • Urine uric acid significantly increased immediately after exercise in COPD patients compared to healthy controls. • It has been suggested that oxidative stress may play a role in peripheral muscle dysfunction in patients with COPD.
Brønstad et al., 2012 [2] Case-control study (evidence level: C)	• 12 participants • 5 healthy controls (did not receive exercise training), 7 participants with COPD. • 6 weeks/3 days	• VO_{2peak}, ventilation rate, power, quadriceps muscle mass, femoral blood flow, muscle VO_2, lactate.	• Peak strength in the vastus lateralis muscle and maximal mitochondrial respiration in COPD patients matched the level of control subjects. • Muscle VO_2 increased during peak workload compared to pretreatment. • Lactate level increased compared to before exercise training.	• The six-week training program resulted in a significant increase in aerobic power, peak quadriceps muscle oxygen uptake (VO_2) and maximal mitochondrial respiration. • When citrate synthase activity normalized, no difference in maximal respiration was found after intervention or compared with controls, suggesting normally functioning mitochondrial complexes. • Training of the regional muscle group has been shown to be highly effective in restoring skeletal muscle function in COPD patients.
Evans et al., 2015 [4] Pre-post study (evidence level: B)	• 22 participants with COPD (GOLD, Stage II and III) • 6 weeks/3 days • Daily walking, strengthening exercises for lower and upper extremities 3 times a week	• VO_{2peak}, • ECG and O_2 saturation, mMRC dyspnea scale, 6-minute walking test distance, self-walking endurance time, chronic respiratory questionnaire	• VO_{2peak} uptake increased by 1.1 ml/min (8%). • The 6-minute walking test distance increased by an average of 72 meters. • Chronic respiratory survey results increased by 1.6 points, showing improvement in four clinically significant areas. • 75% of the participants said that they would recommend this exercise method to other patients.	• Patients with COPD have sufficient muscle volume used during one-leg cycling exercise to achieve a central response to match the effort expended with conventional two-leg cycling exercise. • Dyspnea levels of the patients were similar to traditional two-leg cycling exercise. • Results may not be generalizable to patients with moderate COPD.
Iepsen et al., 2018 [1] Case-control study (evidence level: C)	• 18 participants. 10 with COPD (GOLD, Stage II and III) and 8 healthy participants. • The one-leg exercise test was performed before, during, and after the "Tyramine" injection.	• Lower extremity hemodynamics • Blood sample (blood gas).	• Lower leg blood flow and leg vascular conductivity during exercise were found to be lower in COPD patients. • Tyramine decreased leg vein conductivity in both groups at 10W and 20% workload exercise. • Incremental infusions of ATP caused dose-dependent vasodilation with no difference between groups, and the vasoconstrictor response to Tyramine co-infused with ATP was not different between groups.	• Compared with healthy control subjects of the same age, COPD patients showed intact vasodilator response to ATP, and their ability to blunt sympathetic vasoconstriction as assessed by intra-arterial Tyramine during exercise or ATP infusion was preserved.
Ribeiro et al., 2018 [3] Case-control study (evidence level: C)	• 28 participants. 14 with COPD (GOLD, Stage II, III and IV), 14 healthy. • 2 assessment sessions • In the first session, exercise capacity was measured with CPET. • In the second session, 30 maximal isokinetic quadriceps exercise tests were performed.	• Physical activity questionnaire, spirometry, anthropometric measurements, exercise capacity. • Power, knee extension peak torque, peak heart rate, VO_{2peak}, VCO_{2peak}, peak ventilation, O2 saturation, fatigue, and dyspnea (Borg scale).	• Total muscle work during quadriceps isokinetic endurance exercise was 2.25 kJ in COPD and 3.12 kJ in controls. • At the end of the quadriceps isokinetic endurance exercise, no difference was found between groups in VO_{2peak}, number of ventilations, cardiac output, and heart rate. • Quadriceps deoxyhemoglobin increased by 47% in individuals with COPD versus 33% in controls, with a significant difference between groups. • Fatigue index was higher in individuals with COPD than in the control group.	• The CPET assessment and the isokinetic quadriceps endurance test were not compared with each other. • - One-leg quadriceps isokinetic endurance exercise induced significant central cardiorespiratory responses in COPD; however, muscle deoxygenation and a higher muscle fatigue index were associated with muscle overload in COPD compared to controls.

COPD: Chronic obstructive pulmonary disease, pO_2: Partial oxygen pressure, pCO_2: Partial carbon dioxide pressure, kJ: Kilojoule, VO_{2peak}: peak oxxygen uptake, W: Watt, ATP: Adenosine triphosphate, mMRC: Modified medical research council, GOLD: Global Initiative for Chronic Obstructive Lung Disease, ECG: Electrocardiogram, CPET: Cardiopulmonary exercise test

In the study conducted by Evans et al.[4] in 2015, which investigated the effects of one-leg cycling exercise in patients with COPD, participants underwent 18-24 sessions (30 minutes, 3 days/6-8 weeks) of one-leg cycling exercise, daily walking, lower and upper extremity strengthening exercises (3 days/week), breathing exercises for half an hour daily, and a 1-hour daily self-management program. It was shown that the participants' VO_{2peak} values increased by an average of 8%, their 6-minute walking distance was 72 meters on average, and their quality of life scores increased by 1.6 points compared to pre-treatment.

Studies Investigating the Effects of One-Leg Exercises

In the study published by Richardson et al.[18] in 2004, individuals with COPD and healthy controls were compared. They performed cardiorespiratory testing on both groups during both one-leg extensor exercise and two-leg cycling exercise. They found that VO_{2peak} (control: 0.63±0.1, COPD: 0.37±0.1) and total work done during two-leg exercises were 128% greater in healthy controls. The difference in VO_{2peak} levels between groups disappeared during one-leg extensor exercise. They found Type one muscle fiber area to be less in COPD participants compared to the control group, whereas type two (especially type two mixed) muscle fiber was found to be 2.5 times higher in COPD patients compared to healthy individuals. They also stated that the participants felt less dyspnea during one-leg exercises.

In the study published by Dolmage et al.[25] in 2006, which compared individuals with COPD and healthy individuals, they divided the participants into three groups. They applied both one-leg and two-leg incremental cycling exercise tests to the first group, cycling exercise test for both one leg and two legs at constant power to the second group, and one-leg and two-leg cycling exercise tests at both incremental and constant power to the third group (healthy individuals). They found that VO_{2peak} values (difference: 0.03L/min), ventilation rate, and dyspnea scores were similar when the incremental one-leg and two-leg exercise tests were compared in individuals with COPD. They showed that patients with COPD who were subjected to the constant power one-leg exercise test showed "16.97 minutes" more endurance than the two-leg exercise test.

In another study, Mercken et al.[19] compared COPD patients and healthy individuals in 2009 in terms of systemic and pulmonary oxidative stress after a submaximal one-leg cycling exercise test. They found that total exercise time was shorter in individuals with COPD. Since an increase in interleukin-6 (IL-6) and tumor necrosis factor alpha (TNF-a) levels was not observed in both groups, they thought that systemic inflammation was not induced. They showed that urinary malondialdehyde and uric acid levels increased in COPD patients, while erythrocyte oxidized glutathione and low glutathione levels also tended to increase after exercise compared to the control group. Therefore, they thought that it indicated that pulmonary and systemic oxidative stress increased during one-leg exercises in patients with COPD.

In the study published by Iepsen et al.[1] in 2018, they compared the muscle adrenergic response and adenosine triphosphate (ATP) induced vasodilation during the one-leg exercise test of COPD patients with healthy individuals. They found that leg blood flow and leg vascular conductance (leg blood flow/femoral artery pressure) decreased in patients with COPD. They found that tyramine injection decreased leg vascular conductance in both groups. They showed that ATP infusions provided dose-dependent vasodilation and there was no difference between the groups.

In the study published by Ribeiro et al.[3] in 2019, they evaluated cardiorespiratory responses, quadriceps oxygenation, and muscle fatigue by comparing individuals with COPD and the control group during one-leg isokinetic endurance exercise. They found the mean total work done to be "0.87 kJ" less in COPD patients. They found no difference between the groups in terms of VO_{2peak}, peak ventilations per minute, cardiac output, and heart rate. They found that quadriceps deoxyhemoglobin increased by 47% during exercise in individuals with COPD, and this increased rate was 33% in healthy individuals. The fatigue index was also found to be higher in individuals with COPD than in the control group.

Discussion

One-leg exercises may have the potential to increase VO_{2peak} levels in patients with COPD more than pulmonary rehabilitation, which includes widely used two-leg cycling exercises.[23,26] Perceived dyspnea severity is lower, and leg fatigue is higher in one-leg exercises compared to two-leg exercises.[3,18,23] The total work done by individuals with COPD during one-leg exercises was found to be close to that of healthy individuals.[23]

According to our findings, one-leg exercises may decrease the number of ventilations, perception of dyspnea, and cardiac load in individuals with COPD. This enables them to maintain their localized muscle functions more without reaching the exercise limits as cardiorespiratory. Conventional whole-body exercise uses relatively large muscle mass and therefore puts stress on the central ventilation system in patients with COPD.[4] In one-leg exercises, patients can use their muscular endurance at higher limits and exercise with a higher workload without being restricted by the respiratory system.

In the study published by Dolmage et al. in 2008,[23] they compared two-leg cycling exercise with one-leg cycling exercise in COPD patients, and there is evidence that one-leg cycling enhances the adaptive response of peripheral muscles. The one-leg cycling treatment group has an increase in VO_{2peak}, peak power, peak ventilation, and a decrease in submaximal heart rate compared to the two-leg cycling group.[23] They provide evidence that one-leg cycling improves the adaptive response of peripheral muscle and produces an increase in VO_{2peak}, peak power values, and peak ventilation, and a decrease in submaximal heart rate compared to two-leg cycling.

The fact that the submaximal heart rate is lower than that in two-leg exercises suggests that it is possible to increase VO_{2peak} levels more effectively by exercising before reaching the limits of the cardiorespiratory system. However, the COPD stages of the individuals participating in the study were not specified, making it difficult to determine which groups can benefit from one-leg exercises, although there was no difference between the groups. It may be appropriate to include one-leg exercises in the rehabilitation program, especially in patients with more cardiorespiratory limitations in the clinic, because one-leg cycling exercise results in less dyspnea,[18] a lower submaximal heart rate,[23] and workload that can be achieved close to that of the traditional method.[23]

During dynamic exercises involving large muscle mass, maximum oxygen uptake (VO_{2peak}) is primarily limited to the O_2 delivered to the working muscles. However, only "~2.5-6.0 kg" active skeletal muscle mass works during dynamic exercises involving small muscle mass such as one-leg extension exercise or arm cycling.[27] Maximum cardiac output cannot be reached, and O_2 delivery cannot limit muscle volume of oxygen uptake (VO_2). Therefore, more than twice the O_2 delivery per unit muscle mass is observed during one-leg exercises compared to conventional cycling. However, muscle mass-specific VO_2 increases by 70%.[28] The primary mechanism by which one-leg endurance training increases O_2 consumption is thought to be an increase in muscle oxidative capacity, which enables more efficient O_2 diffusion from capillaries to mitochondria. It is thought that one-leg exercise can efficiently improve exercise capacity and O_2 consumption by improving mitochondrial proteins.[29] According to the mechanism described above, the use of one-leg exercises that can be performed before reaching maximum cardiac output in patients with COPD can provide more efficient O_2 diffusion in local small muscle groups, prevent possible muscle fiber type changes[18] and muscle dysfunctions, and increase the functional capacity and quality of life of the person in daily life.

VO_{2peak} is primarily limited by the cardiovascular system, but skeletal muscle oxidative capacity can also affect VO_{2peak}.[9] Increasing cardiac output and skeletal muscle oxidative capacity play a decisive role in increasing VO_{2peak} with aerobic exercise. However, it is difficult to fully reveal the effect of the oxidative capacity of skeletal muscle on VO_{2peak}, as cardiac output often limits exercise capacity.[13] This limitation can be demonstrated with one-leg exercises because they can be performed without being limited by the cardiovascular system.

One-leg exercise increases quadriceps muscle mass and oxidative muscle phenotype, which means it increases the number of slow and fast-twitch fibers and decreases the number of hybrid fibers.[13] It has been shown that while the number of slow and fast-twitch fibers decreases in COPD patients, the number of hybrid fibers increases 2.5 times compared to healthy individuals.[18] One-leg quadriceps isokinetic endurance exercise has been shown to lead to greater muscle load with muscle deoxygenation and a higher muscle fatigue index in COPD compared to healthy controls.[3] Therefore, more muscle loading in one-leg exercises can increase the proliferative effects on muscle fibers and positively affect peripheral muscle strength in COPD. However, no comparison was made between two groups with COPD in any of the studies reviewed in the literature, so it is not possible to compare two-leg cycling exercise and one-leg cycling exercise in terms of their effects on the muscular system. By reducing the number of hybrid fibers and increasing the oxidative capacity of the muscle and changing muscle fiber types with one-leg exercises, it may be possible to treat or prevent peripheral muscle dysfunction, which is common in patients with COPD.

The current research shows that in some of the studies examined, the stages of COPD (Global Initiative for Chronic Obstructive Lung Disease-GOLD) were not provided. In studies that described the stages of COPD, mostly stage 2 and stage 3 COPD patients were included. In the study conducted by Ribeiro et al.,[3] patients with stage 2, 3, and 4 COPD were included. However, considering the intervention method, one-leg exercises may provide better results as the increased amount of dyspnea and cardiorespiratory limitation may make it difficult to perform bipedal cycling exercises in more advanced stages of COPD. In future studies, the results of separating the stages of COPD should be examined.

Another common cause of peripheral muscle dysfunction in patients with COPD may be chronic inflammation and oxidative stress.[19] In their study published by Mercken et al.,[19] they showed that plasma inflammatory cytokine levels did not change during the one-leg exercise test and did not induce systemic inflammation. However, COPD patients showed an increased systemic oxidative stress response after one-leg exercise compared to control subjects, indicating that one-leg exercises did not induce systemic inflammation to the same extent while increasing oxidative stress.[19] It is thought that systemic inflammation may be induced in COPD patients because the antioxidant system cannot respond to increased free radicals and oxidative stress. Therefore, patients with COPD may produce an adequate antioxidant response in the rehabilitation program applied with one-leg exercises.

Age, blood pressure, and thoracic aortic calcification are associated with increased arterial stiffness in patients with COPD.[30] In healthy individuals, it has been shown that one-leg stretching exercises reduce the arterial diameter in the stretched leg, while they do not change the blood flow velocity and shear force. During relaxation, it was observed that while the arterial diameter returned to its original state, blood flow velocity and shear stress increased. One-leg exercises also increase blood flow velocity and amount in the contralateral extremity.[15] One-leg exercise improves insulin sensitivity for glucose uptake in the exercised muscle. One-leg exercise to local fatigue reduces the rate of whole-body glucose infusion compared to rest. This is because glucose uptake is decreased on the non-exercise side.[14] For these reasons, one-leg exercises or exercises performed with small muscle groups until fatigue increases regional blood flow and glucose uptake to the tissue. Thus, focusing on a single area or muscle can allow for more effective restoration of function.

Limitations

The use of one-leg exercises in patients with COPD, which is the subject of this study, has gained attention in recent years, and the number of studies conducted on this subject is very limited. In addition, the small sample size in the studies may affect the accuracy of the results. The application form of one-leg exercises varies, such as cycling, isokinetic, and extension exercises. Although bicycle ergometry was used in studies with a pulmonary rehabilitation program, the use of different exercise types in our other findings may affect the accuracy of the results.

Conclusion

Despite being a localized exercise, one-leg exercises impose high demands on the cardiovascular and respiratory systems and elicit high muscle deoxygenation responses and a high degree of muscle fatigue in COPD. However, since the methodology and sample sizes of the studies were not sufficient and COPD stages were not examined in detail, the results cannot be applied to the general population. This should be considered when designing the best exercise training strategy for patients with COPD. As a result, there is a need for new studies with larger sample groups and long-term results in this type of exercise, which has the potential to provide positive results in COPD patients.

Conflicts of interest

There are no conflicts of interest.

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Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept – Ö.H., E.P.; Design – Ö.H., E.P.; Supervision – Ö.H., E.P.; Funding – Ö.H.; Materials – Ö.H., E.P.; Data collection &/or processing – Ö.H., E.P.; Analysis and/or interpretation – Ö.H., E.P.; Literature search – Ö.H.; Writing – Ö.H.; Critical review – Ö.H., E.P.

References

1. Iepsen UW, Munch GW, Ryrsø CK, Secher NH, Lange P, Thaning P, et al. Muscle α-adrenergic responsiveness during exercise and ATP-induced vasodilation in chronic obstructive pulmonary disease patients. Am J Physiol Heart Circ Physiol 2017;314(2):H180–7. [CrossRef]
2. Brønstad E, Øivind Rognmo, Arnt Erik Tjonna, Hans Henrich Dedichen, Idar Kirkeby-Garstad, Asta K. Håberg, et al. High-intensity knee extensor training restores skeletal muscle function in COPD patients. Eur Respir J 2012;40(5):1130–6. [CrossRef]
3. Ribeiro F, Oueslati F, Saey D, Lépine PA, Chambah S, Coats V, et al. Cardiorespiratory and Muscle Oxygenation Responses to Isokinetic Exercise in Chronic Obstructive Pulmonary Disease. Med Sci Sports Exerc 2019;51(5):841–9. [CrossRef]
4. Evans RA, Dolmage TE, Mangovski-Alzamora S, Romano J, O'Brien L, Brooks D, et al. One-Legged Cycle Training for Chronic Obstructive Pulmonary Disease. A Pragmatic Study of Implementation to Pulmonary Rehabilitation. Ann Am Thorac Soc 2015;12(10):1490–7.
5. Marciniuk DD, Brooks D, Butcher S, Debigare R, Dechman G, Ford G, et al; Canadian Thoracic Society COPD Committee Expert Working Group. Optimizing pulmonary rehabilitation in chronic obstructive pulmonary disease--practical issues: a Canadian Thoracic Society Clinical Practice Guideline. Can Respir J 2010;17(4):159–68.
6. Burge AT, Cox NS, Abramson MJ, Holland AE. Interventions for promoting physical activity in people with COPD. Cochrane Database Syst Rev 2017;2017(4):CD012626. [CrossRef]
7. Marillier M, Bernard AC, Vergès S, Neder JA. Locomotor Muscles in COPD: The Rationale for Rehabilitative Exercise Training. Front Physiol 2020;10:1590. [CrossRef]
8. Plankeel JF, McMullen B, MacIntyre NR. Exercise outcomes after pulmonary rehabilitation depend on the initial mechanism of exercise limitation among non-oxygen-dependent COPD patients. Chest 2005;127(1):110–6. [CrossRef]
9. Bassett DR Jr, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc 2000;32(1):70–84. [CrossRef]
10. Hogg JC, Timens W. The pathology of chronic obstructive pulmonary disease. Annual Review of Pathology: Mechanisms of Disease 2009;4:435–59. [CrossRef]
11. Ni Y, Yu Y, Dai R, Shi G. Diffusing capacity in chronic obstructive pulmonary disease assessment: A meta-analysis. Chron Respir Dis 2021;18:14799731211056340. [CrossRef]
12. Zhao L, Peng L, Wu B, Bu X, Wang C. Effects of dynamic hyperinflation on exercise capacity and quality of life in stable COPD patients. Clin Respir J 2016;10(5):579–88. [CrossRef]
13. Wolff CA, Konopka AR, Suer MK, Trappe TA, Kaminsky LA, Harber MP. Increased cardiorespiratory fitness and skeletal muscle size following single-leg knee extension exercise training. J Sports Med Phys Fitness 2019;59(6):934–40. [CrossRef]
14. Steenberg D. E., Hingst JR, Birk JB, Throup A, Kristensen JM, Sjoberg KA, et al. A single bout of one-legged exercise to local exhaustion decreases insulin action in nonexercised muscle leading to decreased whole-body insulin action. Diabetes 2020;69(4):578–90. [CrossRef]
15. Yamato Y, Hasegawa N, Fujie S, Ogoh S, Iemitsu M. Acute effect of stretching one leg on regional arterial stiffness in young men. Eur J Appl Physiol 2017;117(6):1227–32. [CrossRef]
16. Popov DV, Makhnovskii PA, Shagimardanova EI, Gazizova GR, Lysenko EA, Gusev OA, et al. Contractile activity-specific transcriptome response to acute endurance exercise and training in human skeletal muscle. Am J Physiol Endocrinol Metab 2019;316(4):E605–14. [CrossRef]
17. Ray CA. Muscle sympathetic nerve responses to prolonged one-legged exercise. J Appl Physiol 1993;74(4):1719–22. [CrossRef]
18. Richardson RS, Leek BT, Gavin TP, Haseler LJ, Mudaliar SR, Henry R, et al. Reduced mechanical efficiency in chronic obstructive pulmonary disease but normal peak VO_2 with small muscle mass exercise. Am J Respir Crit Care Med 2004;169(1):89–96. [CrossRef]
19. Mercken EM, Gosker HR, Rutten EP, Wouters EF, Bast A, Hageman GJ, et al. Systemic and pulmonary oxidative stress after single-leg exercise in COPD. Chest 2009;136(5):1291–1300. [CrossRef]
20. Siafakas NM, Vermeire P, Pride NB, Paoletti P, Gibson J, Howard P, et al. Optimal assessment and management of chronic obstructive pulmonary disease (COPD). The European Respiratory Society Task Force. Eur Respir J 1995;8(8):1398–420. [CrossRef]
21. Vogelmeier CF, Román-Rodríguez M, Singh D, Han MK, Rodríguez-Roisin R, Ferguson GT. Goals of COPD treatment: Focus on symptoms and exacerbations. Respir Med 2020;166:105938. [CrossRef]
22. Celli BR, MacNee W; ATS/ERS Task Force. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J 2004;23(6):932–46. Erratum in: Eur Respir J 2006;27(1):242. [CrossRef]
23. Dolmage TE, Goldstein RS. Effects of one-legged exercise training of patients with COPD. Chest 2008;133(2):370–6. [CrossRef]
24. Bjørgen S, Helgerud J, Husby V, Steinshamn S, Richadson RR, Hoff J. Aerobic high intensity one-legged interval cycling improves peak oxygen uptake in chronic obstructive pulmonary disease patients; no additional effect from hyperoxia. Int J Sports Med 2009;30(12):872–8. [CrossRef]
25. Dolmage TE, Goldstein RS. Response to one-legged cycling in patients with COPD. Chest 2006;129(2):325–32. [CrossRef]
26. Bjørgen S, Hoff J, Husby VS, Høydal MA, Tjønna AE, Steinshamn S, et al. Aerobic high intensity one and two legs interval cycling in chronic obstructive pulmonary disease: the sum of the parts is greater than the whole. Eur J Appl Physiol 2009;106(4):501–7. [CrossRef]
27. Calbet JA, González-Alonso J, Helge JW, Søndergaard H, Munch-Andersen T, Saltin B, et al. Central and peripheral hemodynamics in exercising humans: leg vs arm exercise. Scand J Med Sci Sports 2015;25:144–57. [CrossRef]
28. Calbet JA, Rådegran G, Boushel R, Saltin B. On the mechanisms that limit oxygen uptake during exercise in acute and chronic hypoxia: role of muscle mass. J Physiol 2009;587(2):477–90. [CrossRef]
29. Skattebo Ø, Capelli C, Rud B, Auensen M, Calbet JAL, Hallén J. Increased oxygen extraction and mitochondrial protein expression after small muscle mass endurance training. Scand J Med Sci Sports 2020;30(9):1615–31. [CrossRef]
30. Bhatt SP, Cole AG, Wells JM, Nath H, Watts JR, Cockroft JR, et al. Determinants of arterial stiffness in COPD. BMC Pulm Med 2014;14(1):1–7. [CrossRef]