

Exercise assessments and trainings of pulmonary rehabilitation in COPD: a literature review

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Abstract: Skeletal muscle dysfunction leads to reduction in activity in patients with COPD. As an essential part of the management of COPD, pulmonary rehabilitation (PR) alleviates dyspnea and fatigue, improves exercise tolerance and health-related quality of life, and reduces hospital admissions and mortality for COPD patients. Exercise is the key component of PR, which is composed of exercise assessment and training therapy. To evaluate PR's application in clinical practice, this article summarizes the common methods of exercise measurement and exercise training for patients with COPD. Exercise assessments should calculate patients' symptoms, endurance, strength, and health-related quality of life. After calculation, detailed exercise therapies should be developed, which may involve endurance, strength, and respiratory training. The detailed exercise training of each modality is mentioned in this review. Although various methods and therapies of PR have been used in COPD patients, developing an individualized exercise training prescription is the target. More studies are warranted to support the evidence and examine the effects of long-term benefits of exercise training for patients with COPD in each stage.

Keywords: COPD, pulmonary rehabilitation, exercise assessment, exercise training

Introduction

COPD is a common pulmonary disease worldwide and is characterized by progressively persistent airflow limitation.¹ The economic and social burden of COPD is substantial and increasing. COPD will be the seventh leading cause of disability-adjusted life years and the fourth leading cause of death in 2030.² Daily symptoms such as chronic and progressive dyspnea, cough, and sputum production deserve the blame for the burden and lead to activity limitation and ultimately COPD patients' inability to work and take care of themselves.³ Patients with COPD are trapped in a vicious circle of inactivity, which begins with breathlessness.⁴ The exertional dyspnea of COPD patients is usually multifactorial, partly reflecting peripheral muscle dysfunction,⁵ dynamic hyperinflation,⁶ and higher fat mass.⁷ Some of these factors are amenable to exercise training incorporated as a major component of a pulmonary rehabilitation (PR) program.

PR is defined as a "comprehensive intervention based on a thorough patient assessment followed by patient-tailored therapies that include, but are not limited to, exercise training, education and behavior change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors".⁸ PR is an essential part of the management of COPD, alleviating dyspnea and fatigue, improving exercise tolerance and health-related quality of life, and reducing hospital admissions

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and mortality in COPD patients.^{9,10} Exercise training is the cornerstone of PR and includes many types of training, such as ground walking exercise training, cycling training, resistance training, water-based exercise training, Tai Chi, and so on. The type of training most suitable for COPD patients depends on their physiologic requirements and individual demands. This review focuses on the physical pathology of COPD, exercise assessment methods, and trainings for COPD patients.

Physical pathology

Skeletal muscle dysfunction

Skeletal muscle dysfunction, which is affected by skeletal muscle performance (strength and endurance) and structure (fiber size, fiber type distribution, capillary density, and metabolic capacity), due to deconditioning leads to less activity in patients with COPD.¹¹ Skeletal muscle function is largely dependent on the physiologic structural components of a muscle, especially the fibers.

Fiber type shift

The speed of fiber contraction and predominant type of metabolism inversely determine their resistance to fatigue and are the most relevant physiologic features. Type I fibers, which are slow-twitch fibers and very resistant to fatigue, are composed of myosin heavy-chain (MyHC) type I. Type IIx are fast-twitch fibers and have low resistance to fatigue, and they are made up of MyHC type IIx. A previous study reported that a fiber type I proportion <27% can be considered as abnormally low. Likewise, a fiber type IIx proportion >29% can be regarded as abnormally high.¹² In COPD patients, the proportion of type I fiber is smaller than in healthy persons and is accompanied by an increase in type IIb fiber, which might be an important factor in increased leg muscle fatigability and reduced endurance.¹³

Muscle fiber atrophy

Muscle fiber atrophy is a major systemic impairment in COPD. Respiratory and limb muscles are usually affected in these patients, thus contributing to impaired muscle function, poor exercise capacity, and reduced health status. The reduction in muscle fiber cross-sectional area (CSA) is a generally accepted marker of muscle atrophy and can be a predictor of mortality in COPD.¹⁴ Midthigh muscle CSA has been found to predict survival in patients with moderate-to-severe COPD,¹⁵ and the mid-arm muscle area can also predict mortality in COPD patients.¹⁶ An imbalance between protein degradation and synthesis, which is

enhanced by reduced regenerative repair leads to muscle wasting. The recruitment of key components of ubiquitin-mediated proteolytic systems, such as Atrogin-1 and Nedd4, can regulate protein degradation and myostatin, a negative regulator of muscle growth.¹⁷ Insulin-like growth factor-1 is sufficient to induce skeletal muscle hypertrophy, and in patients with COPD, it is decreased during an acute exacerbation.¹⁸

Hyperinflation

One critical characteristic of COPD patients is hyperinflation, occurring either at rest (static hyperinflation) or during exercise (dynamic hyperinflation), which can be expressed by functional residual capacity (FRC) or end-expiratory lung volume (EELV).¹⁹ Static hyperinflation is a decrease in the inward elastic recoil of the lungs without changes of the elastic properties in the chest wall due to pulmonary emphysema. In COPD patients with emphysema, the lung recoil pressure is further reduced by a reduced elastic load, resulting in a larger FRC or EELV.²⁰ Dynamic hyperinflation is defined as an increase in FRC or EELV above the resting value during periods of dynamic forces such as exercise.²¹ During exercise, to accommodate additional respiratory demands, respiratory rate and tidal volume are increased.²² A faster respiratory rate allows less time for exhalation. In COPD patients, decreased lung elastic recoil pressure and increased airways resistance lead to an increase in the mechanical time for lung emptying. Thus, insufficient exhalation causes an increase in operational lung volumes and progressive air retention called “air trapping”, resulting in dyspnea.²³

Exercise assessment methods

The assessment of patients and program outcomes is a crucial element of a PR program.²⁴ Before training, rehabilitation therapists should measure the condition of patients, including symptoms, endurance and strength, health-related quality of life, and so on. As well as during and after a certain time of training, we should reassess patient performance and program effectiveness.

Symptom evaluation

For COPD patients, dyspnea is the most common symptom. Before, during, and after PR, it is important to identify and evaluate the symptom as a guide for training. Some of the common methods to calculate breathlessness are listed in Table 1. The modified Medical Research Council (mMRC) dyspnea scale is a five-grade scale that ranges from 0 to 4 based on various physical activities.²⁵ It allows either self- or interviewer administration. An mMRC of ≥ 2 is considered

Table 1 Assessment of symptom evaluation in patients with COPD

Items	Assessment methods	Function	Advantage	Disadvantage	MCID
Dyspnea	mMRC ²⁵	Rates dyspnea and measures disability levels	Short completion time (30 seconds)	Only cover breathlessness	2 units
	Borg ²⁶	Measures intensity of the sensation of breathlessness and leg fatigue	Quick and easy, can be used over the phone	–	1 unit
	VAS ²⁹	Measures breathlessness	Within-subject repeated measurement	Not suitable to compare in different patients	10–20 units
	NRS ³¹	Measures dyspnea	A valid measure of present dyspnea, and more repeatable than the VAS	Need smaller sample sizes to detect a change	–
	BDI/TDI ³²	Measures dyspnea and the change with time	Valid, responsive measures of acute changes	Only cover breathlessness	1 unit
OCD	A variation of the VAS ³³	Calculates oxygen cost at different activity levels	Simple and easy to administer	Responsiveness and validity are unproved	–

Abbreviations: MCID, minimal clinically important difference; mMRC, modified Medical Research Council; VAS, Visual Analogue Scale; NRS, Numeric Rating Scale; BDI, Baseline Dyspnea Index; TDI, Transition Dyspnea Index; OCD, oxygen-cost diagram.

as the cut point for distinguishing “less breathlessness” from “more breathlessness”.¹ The Borg CR-10 scale[®] is a category score that ranges from “Nothing at all” to “Maximal” based on breathlessness and leg fatigue.^{26,27} One unit is regarded as the minimum important difference for the scale.²⁸ Generally, the Borg scale has been used before and after the 6-minute walking test (6-MWT) to calculate breathlessness and leg fatigue. The Visual Analogue Scale (VAS) is one method that has been used to measure dyspnea.²⁹ It is a 100 mm horizontal or vertical line, changing approximately every 10–20 units as the recommended minimal clinically important difference (MCID).³⁰ Other than the VAS, the numeric rating scale (NRS) is a 0–10 (“no breathlessness at all” to “the worst breathlessness imaginable”) scale that measures presence of dyspnea. It can be used over the phone and is more repeatable than the VAS.³¹ The Baseline Dyspnea Index (BDI), as its name indicates, calculates the initial baseline assessment of breathlessness. To explore any changes in dyspnea with respect to the baseline condition, the Transitional Dyspnea Index (TDI) has been used after therapy or PR. A variation of 1 unit in the TDI score is considered as the MCID.³² The oxygen-cost diagram is a 100 mm vertical line-oriented VAS that calculates oxygen cost at different activity levels during activities of daily living.³³

Exercise capacity assessment

Exercise capacity is measured by endurance and strength.

Endurance assessment

Generally, the most common method used to calculate endurance is the field test, such as the 6-minute walk test (6MWT),³⁴ the incremental shuttle walking test (ISWT), and the endurance shuttle walking test (ESWT) (Table 2).³⁵ The 6MWT

is a self-paced test with an MCID of 30 meters (m). The shuttle walking tests are externally paced and controlled by a series of pre-recorded signals. The MCID of the ISWT for COPD patients is 48 m.³⁶ The ESWT is a derivative of the ISWT using the same 10 m shuttle course and an audio signal to control pace, with an MCID of 65 seconds or 95 m.^{37,38} The 4 m gait speed is a simple functional assessment tool used in community-dwelling older adults³⁹ and has been verified reliable in COPD, with an MCID of 0.11 m/s.⁴⁰ In addition, a new field test, the 6-minute stepper test, has been identified as a reproducible, sensitive, secure, well-tolerated, and feasible test for patients with COPD.⁴¹ It records the largest number of steps on a stepper for 6 minutes with an MCID of ~20 steps.⁴² In recent years, the sit-to-stand test (STST), an easy-to-use field test, has been applied to evaluate exercise tolerance in patients with COPD.⁴³ Among different versions and lengths, the 1-minute STST is the most widely used version with an MCID of 3 repetitions.⁴⁴

The cardiopulmonary exercise test (CPET) has long been the gold standard method for assessment of exercise capacity in COPD, using a cycle ergometer to measure the indexes of cardiac and pulmonary performance, such as maximum oxygen consumption (VO_{2max}).⁴⁵ The rate of decline in VO_{2max} in the USA is ~10% per decade for normal people.⁴⁶ The common exercise types used in the CPET are the incremental (or ramp) exercise test, maximal incremental treadmill test, and the constant work-rate exercise test. Compared with the 6MWT, the CPET is more expensive and requires additional measurements.⁴⁷

Strength assessment

Strength has marked decrements in COPD patients, especially in severe patients (Table 3). It is necessary to identify peripheral muscle weakness (including limb and respiratory

Table 2 Assessment of exercise endurance in patients with COPD

Assessment methods	Function	Advantage	Disadvantage	MCID
Field test				
6MWT ³⁴	Evaluates functional capacity	Easy, cheap, better tolerated, and more reflective of activities of daily living	Very sensitive to variations in methodology and environment	30 m
ISWT ³⁶	Measures cardiopulmonary exercise capacity	Provokes a similar physiological response to CPET	Needs a prerecorded signal	48 m
ESWT ³⁷	Calculates endurance capacity	More sensitive to change than 6MWT	Must enforced after ISWT	65 seconds or 95 m
4MGS ³⁹	A marker of exercise capacity and a consistent risk factor for disability	Reliable and quick to perform	Usually used in older adults or frail individuals	0.11 m/s
6MST ^{41,42}	An evaluation of exercise tolerance and used to individualize aerobic training	Avert the environmental constraints of the 6MWT	Safety concerns on the stepper	20 steps
STST ^{43,44} (1-minute)	An easy-to-use field test to evaluate exercise tolerance	A reliable, valid, and responsive test and comparable to 6MWT	Need to be more widespread	3 repetitions
CPET ⁴⁵	Identifies the reasons of exercise limitation, assesses maximal exercise capacity, and the prognosis	Standard aerobic exercise testing assessment	Carries an additional cost and competency requirements	–

Abbreviations: MCID, minimal clinically important difference; 6MWT, 6-minute walk test; ISWT, incremental shuttle walking test; ESWT, endurance shuttle walking test; 4MGS, 4-metre gait speed; 6MST, 6-minute stepper test; STST, sit-to-stand test; CPET, cardiopulmonary exercise testing.

strength) before and after PR to prescribe appropriate resistance training loads.

In clinical and research settings, volitional or nonvolitional techniques are used to measure strength. The former includes manual muscle testing (MMT), which is a rough assessment tool used for COPD patients, especially in the critical care setting.⁴⁸ Handheld dynamometry can provide more quantitative information than MMT. It is suitable to assess changes in muscle strength for groups of people with COPD, but it is not suitable for one person.⁴⁹ Handgrip dynamometry is used to evaluate handgrip strength, especially in aging adults as a predictor of mortality and physical function.⁵⁰ Computerized dynamometry, such as the Cybex, Biodex, and Kin-Com, is used to measure isokinetic and isometric strength of various muscle groups at different joint angles and contraction velocities.⁵¹ Strain gauge is a simple and portable tool to measure maximal voluntary contraction of quadriceps and isometric knee extension tension in COPD patients, which is equipped with a semi-recumbent chair.^{52,53} Furthermore, the one-repetition maximum (1RM) test is defined as the maximal weight that can be lifted once using a proper lifting technique. It is regarded as the gold standard for assessing muscle strength in nonlaboratory situations.⁵⁴ The 1RM is a reliable and well-tolerated method used in PR programs for individuals with COPD.⁵⁵ All of the above testing

methods may be affected by the patient's ability, testers, and other external factors. Therefore, the nonvolitional technique has been used to calculate muscle force, most commonly in quadriceps. Supramaximal electrical nerve stimulation was used to measure the maximal voluntary contraction force but is not popular because of its discomfort and technical difficulty. Subsequently, the relatively painless magnetic nerve stimulation has emerged to assess skeletal muscle strength in patients with COPD.⁵⁶

Impairment of (inspiratory and expiratory) respiratory muscles is a common clinical finding in patients with COPD.⁵⁷ Early detection of respiratory muscle weakness is necessary to prevent and intervene with respiratory failure. Some measures including volitional or nonvolitional techniques are shown in Table 3. Maximal inspiratory pressure (MIP) and maximal expiratory pressure are easy, portable, well-tolerated, and noninvasive indices of respiratory muscle strength at the mouth.⁵⁸ In different populations, the reference values of the lower limit of normal are diverse.⁵⁹ Sniff tests, such as sniff esophageal pressure (Sniff Pes), sniff nasal inspiratory pressure (SNIP), and sniff transdiaphragmatic pressure (Sniff Pdi), are performed with catheters through one or both unobstructed nostrils to calculate respiratory muscle strength.⁶⁰ Sniff Pes, performed with a balloon catheter, is a useful test of inspiratory muscle strength and an alternative

Table 3 Assessments of muscle strength in patients with COPD

Regions	Assessment methods	Function	Advantage	Disadvantage	LNN/mean
Limb strength	MMT ⁴⁸	A rough assessment tool to calculate muscle strength	Easy and simple, without any equipment	Semiquantitative and imprecision	–
	Handheld dynamometry ⁴⁹	Evaluates knee and peak hip extension strength	Reliable, valid, portable, and inexpensive	Only in one angle. Not suitable to detect changes for one person	–
	Handgrip dynamometry ⁵⁰	Measures handgrip strength	Easy, simple, reliable, and valid	Measure only handgrip strength	–
	Computer dynamometry ⁵¹	Measures isometric and isokinetic torque	Reliable, reproducible, and standardized. Measures various muscle groups at different joint angles and contraction velocities	Need cost and technique requirements	–
	Strain gauge ^{52,53}	Measures maximal voluntary contraction of quadriceps and isometric knee extension tension	Easy, simple, portable, and inexpensive	Generally equipped with a purpose-built chair	–
	IRM ⁵⁴	Assesses muscle strength	Quick and easy	Requires trained personnel and equipment	–
	Electrical or magnetic stimulation ⁵⁶	Non-volitional assessment to measure quadriceps and diaphragm muscle strength	Valid and reliable	Discomfort and technical difficulty	–
Respiratory muscle	MIP/MEP ^{58,59}	Measures respiratory muscle strength	Not complicated to perform and well tolerated by patients	Not objective. Depends on patient cooperation	MIP LLN: male = 62 – (0.15 × age) female = 62 – (0.50 × age), MEP LLN: male = 117 – (0.83 × age) female = 95 – (0.57 × age)
	Sniff Tests ⁶¹	Measure respiratory muscle strength, especially the inspiratory muscle and diaphragm	Easy, rapid, and portable to perform	Need at least one unobstructed nostril and upper airway	Different sniff tests with various reference values
	ES ⁵⁸	Measures strength and fatigue of diaphragm through transcutaneous electrical stimulation	Noninvasive	Difficult to master	Mean: 10–26 cmH ₂ O for COPD patients
	CMS ⁵⁸	Measures the strength and fatigue of diaphragm through magnetic stimulation	Easily performed and more reproducible	Uncomfortable for patients	Mean: 18.5 cmH ₂ O for COPD patients
			Need little practice	May interfered by the upper rib cage and neck	
			An original method for generating an isolated contraction of the diaphragm		
			Easier and faster to apply and more accurate		

Abbreviations: LNN, lower limit of normal; MMT, Manual Muscle Testing; IRM, one-repetition maximum; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure; ES, transcutaneous electrical stimulation; CMS, cervical magnetic stimulation.

method in patients who are unable to cooperate with the MIP maneuver.⁶¹ SNIP is recommended as a complement to MIP for assessing inspiratory muscle strength in patients with COPD. Unlike the Sniff Pes, SNIP is performed with a polyethylene catheter in an occluded nostril during a maximal sniff through the contralateral nostril.⁶² Sniff Pdi is measured with various kinds of catheters, such as balloon or fluid-filled catheters. It is used to assess the strength of the diaphragm, which is the main inspiratory muscle.⁶³ Nonvolitional techniques include transcutaneous electrical phrenic nerve (ES) stimulation and cervical magnetic stimulation (CMS).⁵⁸ The mean value of CNS in COPD patients is 18.5 cmH₂O, and for the ES is 10–26 cmH₂O.^{64,65}

Assessment of life quality

There are many methods to calculate life quality of COPD patients, such as the St George's Respiratory Questionnaire (SGRQ),⁶⁶ the Clinical COPD Questionnaire (CCQ),⁶⁷ the COPD Assessment Test (CAT),⁶⁸ and the Chronic Respiratory Questionnaire (CRQ) (Table 4).⁶⁹ The MCID of the SGRQ, CCQ, CAT and CRQ is 4 units, 0.4 points, 2 points and 0.5 points for each domain, respectively, as an improvement for COPD treatment in clinical trials.^{70–73} In addition, the 36-item short-form (SF-36) is a valid instrument to measure life quality

in patients with COPD.^{74,75} Changes greater than 8.3 points are regarded as clinically important differences of the SF-36.⁷⁶ Body mass index, airflow obstruction, dyspnea, and exercise capacity index (BODE) is a new multidimensional grading system to predict the mortality and stage and monitor progression in COPD patients. Patients with a BODE of 7–10 were shown to survive ~3 years.^{77,78} BODE is also used to calculate the health-related quality of life in COPD patients.⁷⁹

Exercise training

Exercise training is beneficial for patients with COPD independent of age, gender, level of dyspnea, or disease severity. All COPD patients with decreased physical capacity or physical activity level should be recommended and offered exercise training.⁸⁰ Various training types exist, and prescription should be individualized based on the patient's condition.

Endurance exercise training

Endurance exercise training improves exercise-induced hyperinflation and exertional dyspnea, heart rate recovery, and counteracting muscle dysfunction in COPD.^{81–83} Walking (either on a treadmill or the ground) or cycling (on a cycle

Table 4 Assessment of life quality in patients with COPD

Assessment methods	Function	Advantage	Disadvantage	MCID/CID
SGRQ ^{66,70}	A gold standardized self-completed questionnaire for measuring quality of life	Well validated and frequently used in COPD trials	Complicated and time consuming, especially for older patients Need special spreadsheets to calculate the scores Restricted in daily clinical practice	4 units
CCQ ^{67,71}	A self-administered questionnaire specially developed to measure clinical control	Short and easy to complete, usually tested in mild-to-moderate COPD	Skewed distributions in functional and mental state domains	0.4
CAT ^{68,72}	A patient-completed questionnaire for assessing and monitoring COPD	Easier and faster to complete, especially for patients with low education level	Need to testify in different patient population characteristics, such as females, patients with mild disease	2 points
CRQ ^{69,73}	An established measure of health status including self-reported and interviewer-led versions	Demonstrates changes in disability in older patients	Lack of sensitivity in patients with minor symptoms Unable to make comparisons between populations	0.5 for each domain
SF-36, version 2.0 ^{75,76}	A self-administration 36-item short-form health survey	Has good construct validity and correlates well with objective assessments of health status. Completed in person or by telephone	Weak correlation with lung function tests Used less in clinical trials and practice	8.3 points
BODE ^{77,79}	A simple multidimensional grading system to predict the risk of death and calculate the life quality	A better tool to predict mortality and a significant predictor of life quality in patients with severe COPD	Has not been widespread applied now	–

Abbreviations: SGRQ, St George's Respiratory Questionnaire; CCQ, Clinical COPD Questionnaire; CAT, COPD Assessment Test; CRQ, Chronic Respiratory Questionnaire; BODE, body-mass index, airflow obstruction, dyspnea, and exercise capacity.

ergometer) is commonly recommended as endurance training. Ground walking mainly increased endurance walking capacity compared with cycling.⁸⁴ Upper limb training is also important in COPD patients, such as aerobic regimens that include arm cycle ergometer training. The biceps, triceps, deltoids, latissimus dorsi, and the pectorals are the typical muscles to be trained.

Breathlessness is the main important symptom after walking, while leg effort or fatigue of the quadriceps is an infrequent symptom in COPD.⁸⁵ If the patient needs to improve walking capacity, ground walking can be the better choice. Bike training usually leads to quadriceps fatigability. Using one-legged cycle training reduces the total metabolic demand and improves aerobic capacity compared with conventional two-legged training in stable COPD patients.⁸⁶ One-legged cycling is recommended as an option for exercise training in future professional PR guidelines.

The endurance training prescription recommended by the American Thoracic Society/European Respiratory Society is 20–60 minutes per session at >60% maximal work rate, 3–5 times per week.⁸ The Borg scale can be used to monitor the intensity of exercise training, an exercise level with a score of 4–8 is closer to the target training intensity.⁸⁷

Resistance/strength training

Muscle atrophy and weakness are common in patients with COPD, and endurance training has little effect on the two problems. Many studies found that strength training can improve not only muscle strength and quality of life but also exercise capacity in patients with COPD.^{88,89} Free weights (eg, weight lifting, dumbbell, lead ball, etc.) or training with machines for arms and legs are common methods used in strength training.⁹⁰ Paoli et al suggested that resistance training with multi-joint exercises (eg, bench press, deadlift, abdominal crunches, etc.) was more efficient for improving muscle strength.⁹¹ In daily activities, we should encourage patients to perform multi-joint exercises. Besides, single-joint exercise may be necessary to strengthen lumbar extensors and to correct muscular imbalances.⁹²

O'Shea et al discovered that short-term progressive resistance exercise significantly enhanced muscle strength, which could be applied in daily activities.⁹³ With regard to progressive resistance exercise, the American College of Sports Medicine recommends that, for novice training (untrained individuals), loads corresponding to a repetition range of 8–12 RM are appropriate. When the current workload can be performed for one to two repetitions over the desired target, a 2–10% increase in load is recommended. The training frequency should be 2–3 days each week for novice training.⁹⁴

Moreover, strength training combined with endurance training produces more improvements in muscle power and endurance performance and prevents cognitive decline and associated comorbidities, which is considered as an adequate training strategy for COPD patients.^{83,95}

Respiratory muscle training

Respiratory muscle training, especially inspiratory muscle training (IMT), in patients with COPD induces an improvement in inspiratory muscle force and endurance, functional exercise capacity, dyspnea, and quality of life.⁹⁶ In patients with inspiratory muscle weakness, IMT can be used as part of the treatment during PR. The most common approach to training the respiratory muscles uses resistive or threshold breathing devices, such as Threshold™ Inspiratory Muscle Trainer, PowerBreathe.^{97,98} Inspiratory resistive breathing and threshold loading are considered a mixture of strength and endurance training. Training intensity was usually set at an inspiratory load of $\geq 30\%$ MIP ($P_{i, \max}$).⁹⁶ Other studies showed that high-intensity IMT is feasible in patients with moderate-to-severe COPD, significantly improving the respiratory muscle strength and endurance.⁹⁹ Persistence with IMT is recommended because the benefits of training will decline gradually over time once IMT is stopped.⁹⁷

In addition, IMT combined with specific expiratory muscle training improve respiratory muscle strength more than IMT only.¹⁰⁰ However, whether combined training improves functional capacity and/or reduces dyspnea has not been demonstrated. More studies with larger sample sizes are needed to on this issue.

Neuromuscular electrical stimulation (NMES)

NMES is an alternative method of enhancing quadriceps strength and exercise capacity in moderate-to-severe COPD patients.¹⁰¹ NMES uses various devices, such as low-frequency current, medium-frequency current, monopolar pulses, bipolar pulses, and so forth.¹⁰² Previous studies have shown low-frequency (15 Hz) or high-frequency (75 Hz) NMES to be a suitable rehabilitative modality in severely dyspneic COPD patients.¹⁰³ This finding is the same as a study implemented in patients with acute exacerbation of COPD at a frequency of 35 or 50 Hz NMES intensity.¹⁰⁴ The exact frequency for patients with different stages of COPD needs to be determined by more additional studies with larger sample sizes and randomized trials. We may explore the benefits of NMES combined with other muscle trainings in the future.

Other training methods

Tai Chi, derived from China as a systematic callisthenic exercise, is recognized as an exercise of moderate intensity in patients with COPD. It not only is safe but also obtains better functional capacity and pulmonary function as compared with usual care in people with COPD.¹⁰⁵ At present, Tai Chi has various styles, with Chen, Yang, Wu, and Sun styles the most commonly practiced.¹⁰⁶ The training recommendation is that the exercise intensity of Tai Chi reaches a moderate level in people with COPD. A short-form Sun style is also applied in COPD, which achieves a moderate exercise intensity.¹⁰⁷ Although different styles and forms of Tai Chi have been adopted in different studies, there is no accordant, simple, and effective style or form for COPD patients. Future studies should take this into consideration.

Yoga is an appropriate complementary therapy in patients with COPD because it consists of movement-coordinated breathing and low-impact fitness.¹⁰⁸ Yoga programs improve exercise capacity and life quality, which have the same components and designs. It may be a useful adjunct to formal rehabilitation programs.¹⁰⁹

There are many other training modalities, such as pursed lip breathing,¹¹⁰ water-based training,¹¹¹ and so on. Various methods of training have emerged, and we should explore the best, most effective, and synthetic training system for patients with COPD.

Conclusion

Patients with COPD have varying degrees of activity limitation because of skeletal muscle dysfunction. Nonmedical staff, societies, and families should also pay attention to inactivity. There are many methods of exercise assessments for patients with COPD, choosing the most suitable method to calculate the situation of patients is crucial. In future, we may formulate a systemic and standardized measurement to assess COPD patients before starting PR. Moreover, developing an individualized exercise training prescription for COPD patients is our target. More studies are warranted to support the evidence and examine the effects of long-term benefits of exercise training for patients with COPD in each stage.

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