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# Types of Physical Exercise Training for COPD Patients

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## 1. Introduction

Pulmonary diseases are increasingly important causes of morbidity and mortality in the modern world (Ries et al., 2007). Chronic obstructive pulmonary disease (COPD) is the most common chronic lung disease, and a major cause of lung-related death and disability (Fishman, 2008). COPD is characterized by chronic airflow limitation, progressive and largely irreversible, associated with an abnormal inflammatory reaction (Ancochea Bermúdez et al., 2009). COPD is very disabling and features extra-pulmonary manifestations, but it can be prevented and treated.

The disease is diagnosed by a clinical history based on the combination of history, physical examination and confirmation of the presence of airflow obstruction with the use of spirometry (Figure 1 Spirometry). Spirometric assessment is performed according to the guidelines of the American Thoracic Society (ATS) (Laszlo, 2006). The technician asks the subjects three exhaling exercises and the best is used for the analysis (Miller et al., 2005). If the Tiffenau rate (value of  $FEV_1/FVC$ ) is less than seventy percent, COPD exists (Global initiative for chronic obstructive lung disease [GOLD], 2010). Smoking is the major risk factor for the disease (Hilberink et al. 2011).



Fig. 1. Spirometry

The most common symptoms of COPD are breathlessness, chronic cough, wheezing, sputum production, recurrent respiratory infection may be associated with some of the following systematic effects such as undernourishment, weight loss, exercise limitation and muscle weakness (GOLD, 2010). Knowledge regarding the disturbance of muscle function that occurs in patients with COPD is continuously increasing. Initially muscular dysfunction was considered to be a self-limiting disease resulting from inactivity and lack of exercise. However, recent studies have shown that in addition to this factor, peripheral muscles such as the quadriceps seem to have some type of myopathy (Couillard & Prefaut, 2005). Although the presence of myopathy is still being debated, there is some evidence pointing to myopathy associated with oxidative stress (Rabinovich et al., 2001). Recent studies in COPD have highlighted the role of the ubiquitine proteasome system in the breakdown of skeletal muscle protein in COPD patients. Malfunction of the mitochondria has also recently been identified in these patients (Rabinovich & Vilaro, 2010).

COPD is a major cause of disability and mortality worldwide and the prevalence increases with age. COPD will increase by more than thirty percent in the next ten years, if the population does not cut down smoking (Ancochea Bermúdez et al., 2009). Actually, due to high prevalence, associated to high morbidity, economic and social cost COPD is a major health problem (Ramsey & Sullivan, 2003; Sullivan, Ramsey, & Lee, 2000). COPD is not curable, but treatments can help to control symptoms and improve quality of life of patients. It is necessary to reduce risk factors such as smoking and physical inactivity (GOLD, 2010).

Many people suffer from COPD for years and die prematurely of it or its complications. The goals of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) (Rabe et al., 2007) are to improve prevention and management of COPD through a concerted worldwide effort of people involved in all facets of health care and health care policy, and to encourage an expanded level of research interest in this highly prevalent disease. The GOLD report separates COPD patients into the four different stages (figure 2) (GOLD, 2010).

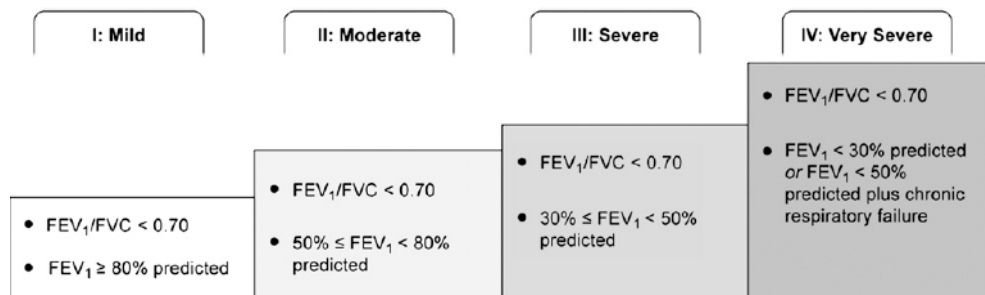


Fig. 2. Stages for Chronic Obstructive Pulmonary Disease

Pulmonary rehabilitation has emerged as a recommended standard of care for patients with chronic lung disease based on a growing body of scientific evidence. The American Thoracic Society and European Respiratory Society (ATS /ERS) published a document in 2006 defining respiratory rehabilitation as "a multidisciplinary and comprehensive intervention has proved effective from the perspective of evidence-based medicine for patients with chronic respiratory diseases who are symptomatic and often have decreased daily life activities. Integrated into individualized treatment of the patient, pulmonary rehabilitation is designed to reduce

symptoms, optimize functional status, increase participation, and reduce health-care costs by stabilizing or reversing systemic manifestations of the disease" (Nici et al., 2006). This definition focuses on three aspects of successful rehabilitation: a multidisciplinary approach; an individualized program; tailored to the patient's needs; and attention to physical psychological and social functioning (Ries, 2008). Not forgetting a primary goal of rehabilitation interventions for people with COPD is to optimize function (Nici et al., 2006).

The components of multidisciplinary respiratory rehabilitation programs include education of patients and their families, chest physiotherapy, muscle training, the emotional support, nutritional support, occupational therapy (Ries et al., 2007). Physiotherapy consists of various phases of treatment (exercise training, peripheral and respiratory muscle training, and breathing exercises) that are considered cornerstones of the physiotherapeutic intervention (Langer et al., 2009). Also consider patients that are incorporated into a respiratory rehabilitation program must have an optimal pharmacological treatment, although not analyzed in this chapter.

There is no consensus of opinion regarding the optimal duration of the pulmonary rehabilitation intervention (Ries et al., 2007). The duration depends on changes in the patient's lifestyle. A number of external factors also influence program duration including health-care systems and reimbursement policies, access to programs, level of functional disability, health-care provider referral patterns, and the ability of individual patients to make progress toward treatment goals.

Few clinical trials have focused on the impact of program duration on rehabilitation outcomes, but existing data suggest that gains in exercise tolerance may be greater following longer programs (Berry et al., 2003; Foy, Rejeski, Berry, Zaccaro, & Woodard, 2001; Green, Singh, Williams, & Morgan, 2001; Troosters, Gosselink, & Decramer, 2000). Besides Verrill et al. (2005) demonstrated that patients achieved significant gains in exercise tolerance in the six minute walk distance, after twelve weeks of pulmonary rehabilitation. However, in an older trial Wijkstra et al. (1995) showed that there was no difference noted between groups in the magnitude of gains in the six minute walk distance for patients who underwent 18 months and three months of home-based rehabilitation.

Moreover, although some studies suggest that the duration of the pulmonary rehabilitation program has an impact on exercise tolerance improvement, it is not clear that other outcomes such as health status or dyspnea are similarly affected by program duration (Ries et al., 2007). Thus, given the variations found in types of rehabilitation programs and content as on duration (Clini et al., 2001). Besides the differences found in clinical study design, patient populations, health systems in different countries, program location, and program content.

The purpose of this literature review is to compare the effectiveness of various exercises training programmes in the rehabilitation of COPD patients. This study analyzes the different types of aerobic exercises that are carried out with different intensities, doses and frequencies.

## 2. Exploratory testing

The chronic symptoms of COPD (cough, expectoration, wheezing, dyspnea and exercise tolerance) are the major factors responsible for altering the relationship between health and

quality of life. Studies of health-related quality of life (HRQoL) in patients with COPD with varying degrees of severity have consistently shown that patients have significant decrements in HRQoL (Okubadejo, Jones, & Wedzicha, 1996; Schrier, Dekker, Kaptein, & Dijkman, 1990). Therefore, HRQoL is an important clinical outcome in COPD. The Chronic Respiratory Disease Questionnaire (CRQ) (Guyatt, Berman, Townsend, Pugsley, & Chambers, 1987) and St George's Respiratory Questionnaire (SGRQ) (Jones, Quirk, Baveystock, & Littlejohns, 1992; Jones, 2001) are the main questionnaires used to measure the quality of life in COPD patients.

The evidence-based clinical practice guidelines document concluded that there was a strong level of type A evidence, that Pulmonary Rehabilitation Programmes (PRP) improve the symptom of dyspnea in patients with COPD with a strong level of type A evidence (Jones, 2002). Dyspnea is a sensation of respiratory discomfort and the evaluation of the degree of dyspnea provides an independent dimension that is not provided by pulmonary function tests or by measuring dyspnea in an exercise laboratory. So, dyspnea is a main symptom associated with exercise performance and, therefore, quality of life. One of the major goals of COPD treatment is a reduction in dyspnea. The severity of the disease can be determined by the intensity of dyspnea (Camargo & Pereira, 2010). The severity of COPD is habitually classified by forced expiratory volume in the first second (FEV<sub>1</sub>) after bronchodilator use (Rabe et al., 2007). Various instruments are available to measure the degree of dyspnea during exercise; the modified Medical Research Council (mMRC) dyspnea scale is the most used (Barbera et al., 2001). The mMRC has five levels that increase with the level of activity in which dyspnea appears. It assesses common tasks the patient can develop without displaying dyspnea. Levels of Dyspnea are graded as follows. Grade 0: "I only get breathless with strenuous exercise"; grade 1: "I get short of breath when hurrying or walking up a slight hill"; grade 2: "I walk slower than people of the same age because of breathlessness or have to stop for breath when walking at my own pace"; grade 3: "I stop for breath after walking 100 yards or after a few minutes"; grade 4: "I am too breathless to leave the house".

The mMRC was unidimensional, to overcome this limitation; Mahler (Mahler, Mejia-Alfaro, Ward, & Baird, 2001) designed the index known as the Baseline Dyspnea Index (BDI), which was later supplemented with the Transitional Dyspnea Index (TDI). BDI analyzes dyspnea from a triple perspective; the difficulty of the task, magnitude of effort and functional impairment, each of the sections will be assessed from 0 (severe) to 4 (none), so total amount can range between 0 and 12 (Mahler, 2006). TDI assessed changes over time compared to baseline (BDI), the changes in each of the three sections are measured between -3 and +3. Therefore, the total score can be between +9 and -9. A score of 0 indicates no changes have occurred, while -9 is very negative result (Sobradillo et al., 1999). Both multidimensional scales, BDI and TDI, are clinical instruments that can be used during cardiopulmonary exercise testing for clinical and research purposes. Besides, Borg et al., (Borg, Borg, Larsson, Letzter, & Sundblad, 2010) described the matching of the increase in dyspnea related to ventilation and oxygen consumption in exercise.

In a review of application of dyspnea and quality of life scales in COPD, it was concluded that a unidimensional scale can be used if applied in conjunction with specific quality of life scales. Alternatively, a multidimensional scale, which correlates better with quality of life, can be used (Bausewein, Farquhar, Booth, Gysels, & Higginson, 2007). Consequently, multidimensional clinical instruments were developed in order to provide a more

comprehensive assessment of the severity of dyspnea, combined with the Chronic Respiratory Disease Questionnaire (CRQ) incorporates five physical activities that are specific for individual patients (Guyatt et al., 1987). These instruments have been shown to be valid, reliable, and responsive (Reda, Kotz, Kocks, Wesseling, & van Schayck, 2010).

In 2004, Celli et al. created a mortality prediction index, known as the BODE index. It encompassed the body mass index (B), the degree of airflow obstruction as expressed by the FEV<sub>1</sub> (O), dyspnea with the modified medical research council (D), and exercise (E) measured with six-minute walk distance (Table 1 Variables and point value used for the computation of BODE index) data adapted from Celli et al. (2004). The cut-off values for the assignment of points are shown for each variable. \*The FEV<sub>1</sub> categories were identified by the American Thoracic Society (1995). † Scored on the modified Medical Research Council (mMRC) dyspnea scale can range from 0 to 4, with a score of 4 indicating that the patient is too breathless to leave the house or becomes breathless when dressing or undressing.

Variables	BODE index			
	Points on BODE index			
	0	1	2	3
FEV <sub>1</sub> % of predicted*	≥ 65	50–64	36–49	≤ 35
Six-minute walk distance (m)	≥ 350	250–349	150–249	≤ 149
MRC dyspnea score†	0–1	2	3	4
Body mass index (kg/m <sup>2</sup> )	>21	≤ 21		

Table 1. Variables and point value used for the computation of BODE index, adapted from Celli et al. (2004)

The BODE index is a multidimensional classification system that systemically determines the degree of mortality in individuals with COPD, that provides useful prognostic information in patients with COPD and might be able to measure health status. However, it is unknown whether the BODE index is a sensitive tool for predicting the impact of quality of life in such patients. Araujo (Araujo & Holanda, 2010) found correlations between the BODE index scores and all of the CRQ domains in COPD patients. Moreover, there are studies where patients who moved from moderate to high physical activity improved their SGRQ scores by 18.4 and their CRQ scores by 14.8 (Esteban et al., 2010).

Over recent decades, several organizations have championed pulmonary rehabilitation and developed comprehensive statements, practice guidelines, and evidence-based guidelines (Ries, 2008), however there are differences about how assessment of severity of disease. The 2010 NICE Guidelines defended that multidimensional assessment tool (BODE index) is a better predictor of mortality and exacerbation rate than FEV<sub>1</sub> alone (Gruffydd-Jones & Loveridge, 2011).

Exercise testing is frequently used in the clinical evaluation of patients with COPD to evaluate the functional impact of a treatment (American Thoracic Society & American College of Chest Physicians, 2003). Exercise testing is a useful evaluative tool, allowing standardized measurement of exertional dyspnea and exercise tolerance (*GOLD*, 2010). There is, however, no consensus regarding which exercise testing protocol should be used for this application (Pepin, Saey, Whitton, LeBlanc, & Maltais, 2005). A research indicated that walking, as performed in the endurance shuttle walk, is sensitive to detect changes in exercise performance after bronchodilation (Pepin et al., 2005). Besides Pepin et al. (2007)

indicate that the response of the 6MWT test is not sensitive to change and may not be appropriate for an assessment tool. Another research also suggests that the endurance shuttle walk is more responsive to the effects of pulmonary rehabilitation than the 6MWT for detecting changes in exercise performance following bronchodilations (Eaton, Young, Nicol, & Kolbe, 2006). Together, these findings provide growing support for the use of the endurance shuttle walk as an evaluative tool to monitor response to treatment to COPD.

The six minute walk test (6MWT) is used in order to determine the six-minute walk distance (6MWD), which correlates with the performance of activities of daily living in patients with COPD (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, 2002; Brooks, Solway, & Gibbons, 2003). The 6MWT measures the global and integrated responses of all organ systems involved during exercise, has been shown to be an important parameter related to morbidity and mortality in COPD (Casanova et al., 2007), and is also part of the BODE index (Celli et al., 2004). Although rehabilitation improves both exercise tolerance and quality of life in COPD, it is not known whether these improvements are related to each other. Several trials show the weak correlation between quality of life and the six minute walking distance in patients with COPD suggests that these parameters measure different aspects of health (Wijkstra et al., 1995).

Recently, the use of accelerometer has been incorporated as an objective measure to assess physical activity level of the patient performs daily (Troosters et al., 2010). It is necessary to analyze physical activity in daily life in patients across different disease stages according to GOLD. Other studies have shown that grip strength in the wrist is a strong independent predictor of mortality in COPD (Cortopassi, Divo, Pinto-Plata, & Celli, 2011). A significant relationship was found between hand grip strength and peripheral muscle strength (flexion of elbow and knee) and strong relationship ( $r = -0.75$ ,  $p < 0.0001$ ) with the force respiratory muscles (maximum inspiratory muscles, inspiratory capacity, forced vital capacity and maximum volume ventilation).

There is no clinical trial review that has found a connection between rehabilitation respiratory programs and an increase in exercise tolerance. It is necessary to clarify the change in quality of life was related with a change in exercise tolerance in COPD patients. The difference between current studies and previous controlled studies (Sinclair, 1980; Vale, Reardon, & ZuWallack, 1993) are the use of the 12 minute walking distance which is probably more sensitive to change than the six minute walking distance (Wijkstra et al., 1995).

COPD is often associated with exacerbation of symptoms. An exacerbation of COPD is defined as "an event in the natural course for the disease characterized by a change in the patient's baseline dyspnea, cough, and/or sputum that is beyond normal day-to-day variations, is acute in onset, and may warrant a change in regular medication in a patient with underlying COPD" (Burge & Wedzicha, 2003). The most common causes of an exacerbation are infection of the tracheobronchial tree and air pollution (White, Gompertz, & Stockley, 2003). Studies investigating effects on pulmonary function and oxygenation did not show benefits in either acute exacerbations of COPD (Newton & Bevans, 1978) or in chronic COPD (May & Munt, 1979). Assessment of the severity of an exacerbation is based on the patient's medical history before the exacerbation, pre-existing comorbidities, symptoms, physical examination, arterial blood gas measurements, and other laboratory

test. Physicians should obtain the results of previous evaluations, where possible, to compare with the current clinical data. Specific information is required on the frequency and severity of attacks of breathlessness and cough, sputum volume and color, and limitation of daily activities (Vilaró et al., 2007).

Other targets of rehabilitation are anxiety control, dyspnea reduction and improvement of the health-related quality of life (Lacasse et al., 2006). The illness evolution can be associated with extra-pulmonary components, such as muscle loss is related with reduction of physical activity. After exacerbation, symptoms of depression have been identified as an independent factor of mortality risk (Yohannes, Baldwin, & Connolly, 2005), as well as risk a factor for rehabilitation program drop-outs (Garrod, Marshall, Barley, & Jones, 2006). The skeletal muscle dysfunction and depressive symptoms are potentially amenable to rehabilitation with exercise training (Rodrigues, 2010). We have made the following figure 3 in order to collect intra-pulmonary components (airways obstruction and dyspnea) with extra-pulmonary factors (muscle wasting, reduce mobility, exercise limitation, depression and sedentary lifestyle).

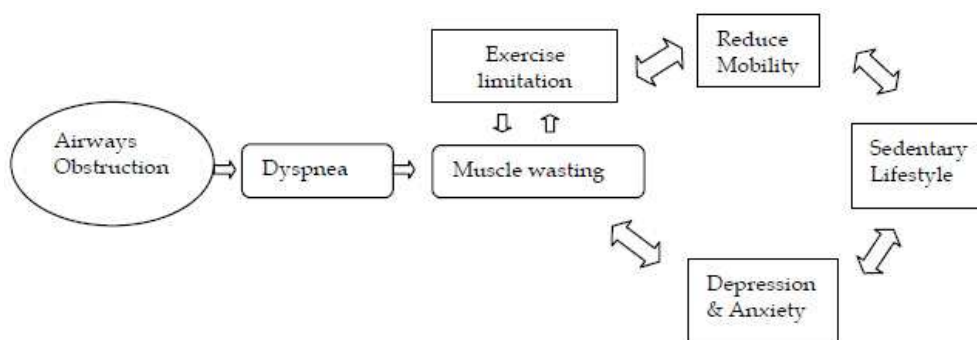


Fig. 3. Relation between intra-pulmonary components with extra-pulmonary factors.

### 3. Types of exercises

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure beyond resting energy expenditure (Thompson et al., 2003). Information on the importance of physical activity in COPD has grown, especially in the last few years, although major questions remain to be answered. The present chapter aims to provide an update on the most important studies of physical activity in COPD (Esteban, 2009).

Findings from meta-analysis of pulmonary rehabilitation strongly supports that exercise training as part of treatment of patients with COPD should last at least four weeks (Lacasse, Goldstein, Lasserson, & Martin, 2006). Exercise training should be available to people with COPD, because it improves breathlessness, quality of life, exercise tolerance and functional ability (Lacasse et al., 2006). Physical therapists are crucial to the delivery of rehabilitation because of their training in exercise and movement therapies (Garrod & Lasserson, 2007).

The primary goal of the rehabilitation programs is to restore the patient to the highest possible level of independent function (Ries et al., 2007). This goal is accomplished by



helping patients become more physically active, and to learn more about their disease, treatment options, and how to cope. Within the program of rehabilitation, the physiotherapeutic intervention is responsible for various treatment phases (specifically physical exercise training, peripheral and respiratory muscle training, and breathing exercises) (Langer et al., 2009).

Aerobic exercise is the main non-pharmacological treatment better tolerated by patients with COPD (Martín-Valero, Cuesta-Vargas, & Labajos-Manzanares, 2010). Exercise training is one of the key components of pulmonary rehabilitation. The exercise prescription for the training program is guided by the following three parameters: intensity; frequency; and duration.

The standardized criterions on intervention period, dose, intensity of physical exercises in COPD patients is needed. Seven (Coppoolse et al., 1999; Kurabayashi et al., 2000; O'Shea, Taylor, & Paratz, 2004; Puente-Maestu, Sanz, Sanz, Cubillo et al., 2000; Puente-Maestu, Sanz, Sanz, Ruiz de Ona et al., 2000; Wadell, Sundelin, Henriksson-Larsen, & Lundgren, 2004; Wijkstra et al., 1995) agreed with the criteria of the American College of Sports Medicine (ACSM) (Garber et al., 2011) for the intervention period and number of sessions varied from eight weeks in the majority on trials to twelve weeks in two trials and from two to four sessions a weeks. Therefore, the number sessions a week were at least between two or four sessions a week. Only one trial (Wijkstra et al., 1995) took into account, that patients had to practise twice a day for an individualised protocol, for 0 to 5 hours the first three months and then once a day only for 0-5. The time of sessions is variable in these seven articles with a minimum of 20 minutes up to 60 minutes because two articles do not talk about the time of sessions.

According to the recommendations of the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR), *high-intensity training targets* have been operationally defined to be at least 60 to 80% of the peak work rate achieved in an incremental maximum exercise test. The intensity of the training sessions in five articles (Coppoolse et al., 1999; Puente-Maestu, Sanz, Sanz, Cubillo et al., 2000; Puente-Maestu, Sanz, Sanz, Ruiz de Ona et al., 2000; Wadell, Sundelin, Henriksson-Larsen, & Lundgren, 2004; Wijkstra et al., 1995) showed that the goal is 60-90% of heart rate maximum ( $HR_{max}$ ) set by the ACSM for improving aerobic fitness ("American college of sports medicine position stand. exercise and physical activity for older adults,"1998a; "American college of sports medicine position stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults,"1998b)

Exercise training intervention can be adapted to the individual exercise limitations of the patient (Troosters, Gosselink, Langer, & Decramer, 2007). Troosters et al. review focused on different training types (endurance, interval and resistance training) (Troosters et al., 2007). In this chapter regarding types of exercise training intervention, it has been divided into aerobic and resistance training types. Aerobic exercise training for older people should have a target intensity of 50-85% of the oxygen uptake reserve - a range that includes both moderate exercise (minimum of 30 minute five days a week) or vigorous exercise (20 minutes three days each week)(Garber et al., 2011).

Resistance training is an ideal intervention for patients with peripheral muscle weakness and pronounced symptoms of dyspnea during exercise (O'Shea, Taylor, & Paratz, 2004).

There is not consensus on the optimal method of resistance training (callisthenics, resistance weight training, isometrics or isokinetic-type training) in patients with COPD. Each type produces strength gains highly specific to the type of training. There are no studies that compared different intensities of resistance training in patients with COPD. It is recommended to use (lower limb) resistance training according to ACSM (two or three times a week) ("ACSM", 1998a; "ACSM", 1998b; Garber et al., 2011). Exercises should be performed at 60-80% of the first repetition maximum (RM), resistance exercises should train 8-10 exercises involving the major muscle groups in bouts of 8-15 repetitions at least 30 minutes a day of moderate-intensity activity on two or three non-consecutive days each week (Nelson et al., 2007). Multiple sets of repetitions (2-5 sets) provide greater benefit (Langer et al., 2009). Resistance activities include a progressive-weight training program, done with therabands (wrist or ankle weights) or progressive weight.

Given that muscle weakness is a common problem in this population, progressive resistance exercise represents a beneficial treatment for improvements in muscle strength (O'Shea, Taylor, & Paratz, 2009). Moreover, improvements in muscle strength can be obtained when progressive resistance exercise is conducted alone or in combination with aerobic training, indicating that it can be successfully performed in conjunction with other training types during pulmonary rehabilitation (O'Shea, Taylor, & Paratz, 2009).

Careful consideration is also required when prescribing progressive resistance exercise programs for people with COPD who have comorbid health conditions (O'Shea, Taylor, & Paratz, 2004). Therefore, progressive resistance exercise may not be appropriate for all people with COPD attending pulmonary rehabilitation, and it is recommended that prescription be targeted to the individual (Storer, 2001).

It is essential to educate the patient about the importance of the training program beginning with an initial phase: warming up and stretching (Table 2 Session outline). The central part consists in aerobic training (endurance or interval exercise), resistance training and breathing retraining. Finally, the sessions finish with stretching and relaxation exercises.

Initial phase	Central phase	Final phase
*Stretching *Warming up	*Aerobic training (Endurance or Interval) *Resistance training *Breathing retraining	*Stretching *Relaxation exercises

Table 2. Session outline

It is recommended to apply training strategies that enable patients to resume participation in a rehabilitation programme after an acute exacerbation as soon as possible (Puhan, Scharplatz, Troosters, Walters, & Steurer, 2009). Resistance training and interval training are best suited for early reactivation of patients. Moreover, arm exercises in patients with COPD were shown to increase arm muscle force (Epstein et al., 1997) and reduce symptoms of dyspnea and fatigue during arm activities (Bauldoff, Hoffman, Sciruba, & Zullo, 1996).

Patient education is included as an important recommendation in current clinical practice guidelines for COPD (GOLD, 2010; Celli, MacNee, & ATS/ERS Task Force, 2004) Education should be an integral component of pulmonary rehabilitation (Ries et al., 2007). Moreover,

education should include information on collaborative self-management and prevention and treatment of exacerbation. So, patient education interventions are necessary to ensure long-term maintenance of treatment effects. Studies with successful results in chronically ill adults both used physical activity self-monitoring (pedometers or diaries) and applied behavioural strategies to increase patient's self efficacy and self-regulatory skills (Conn, Hafdahl, Brown, & Brown, 2008). It is necessary to initiate and maintain physical activity behaviour change during and after supervised physical exercise training programs. Rose et al., (Baraniak & Sheffield, 2011; Rose et al., 2002) evaluated psychosocial interventions to treat anxiety and panic in patients with COPD; however the data indicated that there were no changes in cognitive function. Overall, the educational intervention may have facilitated aspects of program adherence.

### **3.1 Continuous or incremental aerobic exercise**

In this section different types of physical exercise training that can be applied to improve exercise performance in patients with COPD are presented. The authors have compared programmes with constant load training and incremental load training in COPD patients. There is high level evidence that aerobic training is effective for aerobic capacity and there is moderate evidence that interval training is effective for strength, endurance, functionality and psychosocial parameters (Normandin et al., 2002).

#### *Endurance or continuous training*

Supervised continuous training is recommended for patients in all stages of the disease who are able to perform continuous training of at least moderate intensity. Training frequency should be three times weekly in the first weeks of the exercise programme (Langer et al., 2009). Patients with severe symptoms of dyspnea during exercise are frequently not capable of performing high-intensity (70 to 80% of the peak work rate) continuous type training (Casaburi et al., 1997; Maltais et al., 1997). It seems that moderate intensity continuous training (50 to 60% of the peak work rate or 5-6 out of 10 according to the modified Borg Scale) is minimally required to achieve changes in physical fitness. Improvements in health-related quality of life after training at moderate intensities were comparable with those observed after high intensity training (Puente-Maestu, Sanz, Sanz, Cubillo et al., 2000).

Lower extremity exercise training at higher exercise intensity produces greater physiologic benefits than lower intensity training in patients with COPD. Moreover, both low-intensity and high-intensity exercise training produce clinical benefits for patients with COPD (Ries, 2008).

Two categories of tasks can be found during everyday activities, endurance and strength tasks. Endurance tasks require repetitive actions over an extended period of time (walking, cycling and swimming) as shown in figure 4. While strength tasks require explosive performance over short time periods (jumping, lifting weights, sprinting)(Ries et al., 2007). The addition of a strength-training component to a program of pulmonary rehabilitation increases muscle strength and muscle mass (Ries, 2008).

#### *Interval training*

Interval training is recommended as an alternative to continuous training in patients with severe symptoms of dyspnea due to the fact that they are unable to sustain continuous

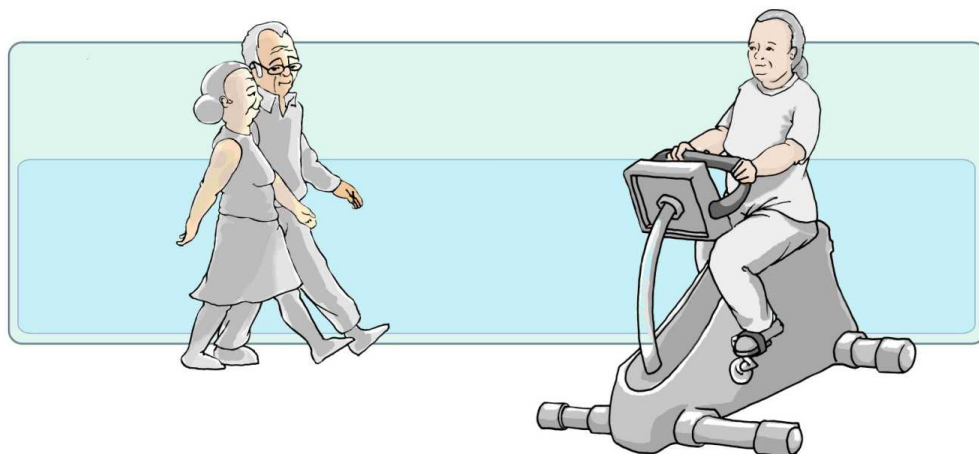


Fig. 4. Endurance tasks taken from “Manual de Rehabilitación Respiratoria para personas con EPOC”.

training at the recommended intensities. Short high intensity (at least 70-80% of peak work rate) exercise bouts of 30-180 seconds are necessary during interval training. Recommended frequency of training is the same as with continuous training (Langer et al., 2009).

Only one article (Puente-Maestu, Sanz, Sanz, Cubillo et al., 2000) showed that patients responded to supervised training with incremented loads also changed their ventilatory pattern to deeper, slower breathing. Therefore, improved ventilation this type of incremental training also tended to be more efficient with an average decrease in dead space. Perhaps, the quality of life questionnaires are not sensitive tools to detect changes in the functional variables of disease progression. The changes produced by aerobic physical training in COPD do not have clinical relevance, but they are a success because it slows down disease progression.

Most patients with severe COPD are not able to sustain a continuous exercise protocol. For these patients, interval exercise represents an alternative because it offers the same benefit as high-intensity exercise. Besides, incremental exercise is better tolerated, as expressed by fewer breaks during the rehabilitation program and better adherence to exercise protocols (Puhan MA et al., 2006). Therapeutic intervention can be done in or out of water; the next section explains the therapeutic aquatic exercise intervention.

### 3.2 Therapeutic aquatic exercise intervention

This intervention is known for its power of prevention and treatment in different conditions, although not considered part of standard pulmonary rehabilitation. Therapeutic aquatic exercise intervention is a discipline that includes hydrotherapy, spa therapy, balneotherapy and physiotherapy, and is used for the prevention and treatment of diseases through water (Geytenbeek, 2008). Hydrotherapy is defined as a complementary therapy that uses the temperature and pressure of water as a therapeutic agent at a given temperature (Geytenbeek, 2002).

There is controversy in the scientific literature regarding the beneficial and harmful effects of water exercise for the respiratory system in people with respiratory problems. Different types of exercises can be carried out: walking, cycling, lifting weights in a swimming pool (figure 5), and so on. Previous studies show that hydrostatic pressure exerts on inspiratory muscle strength and limited chest expansion; this effect is enhanced as the temperature of the pool water decreases (Frontera, Herring, Micheli, & Silver, 2008). In addition, the diaphragm moves during diving due to compression by the abdomen, thus decreasing respiratory vital capacity (Greenleaf, 1984). Patients with chronic obstructive pulmonary disease benefit from the hydrostatic pressure exerted during immersion, which facilitates expiration and reduces the residual volume, decreasing the air trapped in this pathology (Asanuma, 1999; Dahlback, 1975; Schoenhofer, Koehler, & Polkey, 2004). Previous studies show that water exerts hydrostatic pressure on inspiratory muscle strength and limited chest expansion, this effect is enhanced with decreasing the temperature of the pool water (Agostoni, Gurtner, Torri, & Rahn, 1966). Therapeutic aquatic exercise intervention is known for its ability to prevent and treat different conditions. This intervention is a specialized field of physical training and therapy, used to achieve certain physical and functional goals using the properties of water (Geytenbeek, 2008).

The reviewed articles covered incremental therapeutic aquatic exercise with an intensity ranging from 50% to 90% of maximal oxygen consumption ( $VO_{2max}$ ) with sessions of 30 to 50 minutes 2 to 5 days a week, for a total of 8 to 24 weeks at a temperature of 29 °C to 38 °C (Kurabayashi et al., 2000; Wadell, Sundelin, Henriksson-Larsen, Lundgren, 2004). COPD patients walked in water to the level of their shoulders, and they breathed out slowly through their mouth into water after sinking their nose 3-5 cm below the water level. The patients' eyes were not under the water. After exercise, patients dressed and rested on a chair in a comfortable room (25°C) for 30 minutes. Two studies showed clinical changes in the questionnaire of quality of life for respiratory patients. People who performed incremental exercise in the water showed functional changes in the distance walked in the walking test, in forced vital capacity and forced expiratory volume (Kurabayashi et al., 2000; Wadell, Sundelin, Henriksson-Larsen, & Lundgren, 2004). The aquatic intervention group that performed incremental exercise had improved health-related quality of life, compared to a control group without intervention (Wadell, Sundelin, Henriksson-Larsen, & Lundgren, 2004).



Fig. 5. Cycling and lifting weights

Physical therapy for COPD requires a certain duration and frequency in order to improve clinical parameters. Wadell et al. (2005a) indicated that training once a week (high intensity/low frequency) was not sufficient to sustain the improvements in physical capacity and quality of life achieved after a period of 3 months of high frequency aquatic exercise training with three sessions of 45 minutes each a week (high intensity/high frequency). However, high intensity physical training once a week for 6 months seemed to be enough to avoid deterioration compared to baseline. According to Kurabayashi's study, 6 consecutive days of exercise a week would be preferable to 3 alternative days of exercise a week, even if the cumulative exercise period was the same (Kurabayashi et al., 1998). The studies reviewed showed much heterogeneity with respect to the duration of treatment, ranging from 6 to 24 weeks. However, the typical duration of treatment was 8 to 12 weeks. Further studies should direct more attention to the specific duration, frequency and accuracy of aerobic intensity thresholds. Other authors found that exercise in water tends to provide even greater benefits than similar exercise training on land (Wadell, Sundelin, Henriksson-Larsen, & Lundgren, 2004).

Breathing exercises during immersion in water at 38 °C could be recommended as physical therapy after diagnosis of COPD. Elevation of the sub-peritoneal diaphragmatic pressure by the hydraulic pressure could help raise the diaphragm and assist in the evacuation of air during exhalation, resulting in a decrease in dead space. In addition, hydraulic pressure was reported to increase cardiac output, resulting in an improvement in blood gas exchange in lung capillaries. Besides these effects, inhalation of gas containing thermal hydrogen sulfate lowers the viscosity of sputum (Asanuma, Fujita, Ide, & Agishi, 1971). Only three studies (Kurabayashi et al., 2000; Kurabayashi et al., 1998; Perk, Perk, & Bodén, 1996) included breathing exercises during therapeutic aquatic exercise intervention.

### 3.3 Respiratory muscle training

In general, patients with COPD have weak inspiratory muscles (Polkey et al., 1996). This weakness may contribute to dyspnea and exercise limitation in patients with significant COPD. When evaluating the strength of respiratory muscles we should be aware that we are focusing primarily on the ability of these muscles to generate tension during a forced inspiratory or expiratory maneuver. The result of the maneuver can be measured with the mouth (Figure 6 Equipment to maneuver), and it is measured in centimeters H<sub>2</sub>O. This primarily reflects a set of variables such as muscle mass (ability to generate force) and length-tension relationship.

The role of inspiratory muscle training (IMT) for individuals with stable COPD is unclear (Geddes, O'Brien, Reid, Brooks, & Crowe, 2008). The first systematic review on IMT found little evidence to support the use of IMT (Shoemaker, Donker, & Lapoe, 2009). The American Thoracic Society/European Respiratory Society standards (Celli, MacNee et al., 2004) nor the Canadian Thoracic Society Recommendations for the Management of COPD (O'Donnell et al., 2008) recommend the incorporation of IMT into management plan. The Global Initiative for Chronic Obstructive Lung Disease (*GOLD*, 2010) states that "respiratory muscle training is beneficial, especially when combined with general exercise training" based on non-randomized trials and observational studies.



Fig. 6. Equipment to maneuver

In an attempt to reduce the severity of breathlessness and to improve exercise tolerance, IMT has been applied in many COPD patients (Weiner, Magadle, Beckerman, Weiner, & Berar-Yanay, 2003). Several different respiratory muscle training devices are available, ranging from sophisticated computerized systems to simple hand-held resistive devices. In addition, the relative benefits of strength versus endurance training, inspiratory versus expiratory training and effect in patients of differing severity are unknown (Garrod & Lasserson, 2007)

*Types of intervention: Sham, low- and high-intensity IMT*

There are studies comparing the effect of different types of intervention (Geddes, Reid, Crowe, O'Brien, & Brooks, 2005). In order to standardize studies that showed sham IMT and low intensity IMT at similar percentages of maximum inspiratory pressure (P<sub>I</sub>max). Bégin et al., (Begin & Grassino, 1991) measured these loads using the tidal inspiratory pressure (PI) of individuals with COPD. Sham IMT was defined as that using the same type of device as the intervention group at an intensity less than or equal to the mean plus one standard deviation (SD). Since PI is directly proportional to the partial pressure of carbon dioxide in the arterial blood (PCO<sub>2</sub>) of patients with COPD (Begin & Grassino, 1991), sham IMT for normocapnic individuals was defined as intensity p8.3 cm H<sub>2</sub>O (mean PI +1 SD) and for individuals with moderate hypercapnia, as intensity p11.5 cm H<sub>2</sub>O (Geddes et al., 2005).

Using IMT in combination with other interventions and using flow-dependent resistive training is important in the pulmonary rehabilitation program (Geddes et al., 2008). However, there are no established thresholds for what constitutes a clinically meaningful change in inspiratory muscle strength or endurance, other methods must be utilized to infer clinical benefit (Shoemaker et al., 2009). Geddes et al. (2005) recommended using IMT at least a total of 30 minutes daily but can be spread over more than one session a day. Training should occur at least 5 days a week. While gains may be measurable after as short

as 5 weeks, IMT should become part of the individual's exercise program. The minimal training intensity necessary could start as low as 22% P<sub>I</sub>max and be progressed to as high as 60% P<sub>I</sub>max using a targeted inspiratory resistive or threshold trainer (Geddes et al., 2005). Therefore, IMT significantly increased inspiratory muscle strength and inspiratory muscle endurance (Lotters, van Tol, Kwakkel, & Gosselink, 2002). In addition, research review found a clinically significant decrease in dyspnea sensation at rest and during exercise is observed after IMT (Lotters et al., 2002).

In conclusion, IMT improves inspiratory muscle strength and endurance, functional exercise capacity, dyspnea and quality of life. Inspiratory muscle endurance training was shown to be less effective than respiratory muscle strength training. In patients with inspiratory muscle weakness, the addition of IMT to a general exercise training program improved P<sub>I</sub>max and tended to improve exercise performance (Gosselink et al., 2011).

Furthermore, maximal inspiratory pressure is a volitional test and therefore open to criticism (Polkey & Moxham, 2004). Further research is needed to explore the impact that different training protocols (frequency, intensity and duration of IMT, supervision) may have on outcomes and to determine the extent to which changes in outcomes associated with IMT translate into clinically important improvement for adults with COPD (Geddes et al., 2008).

#### 4. Implications

In the research reviewed, there are strong arguments that pulmonary rehabilitation is beneficial for improving the quality of life related to health at the beginning of the program. Furthermore pulmonary rehabilitation reduces symptoms and increases participation in everyday activities. However, it is necessary to do more randomized controlled trials to clarify which components of the lung rehabilitation are essential. Future studies to discover the ideal length of treatment, the necessary degree of supervision, training intensity and how long the treatment effect persists.

Without no doubt, it is necessary to individualize programs for this population taking into account their different levels of severity. The prescription should begin at low intensity and short duration, for both parameters gradually increasing to the threshold of fatigue.

In summary, incremental aerobic resistance physical exercises are better than constant load physical exercises at an intensity range from 90% to 50 % of VO<sub>2</sub>max, with a frequency of two or four days a week, the session is from 30 to 60 minutes during a period of treatment from eight to twelve weeks. Exercise training induces several symptomatic and functional adaptations resulting in an increased aerobic capacity, although clinical relevance is not collected in the study population. Maybe, for further studies we should take intrinsic patient factor (severity of COPD) into account over a longer period of time and how extrinsic factors of the exercises affect disease progression. Moreover, it is important to determine whether these physiological benefits of COPD patients who have performed an incremental aerobic resistance physical exercises program supervised justify the increased costs. Therefore, a cost/effectiveness analysis is necessary to determining whether the type of intervention program is supervised or not.

It is essential to investigate physical activity in daily life in patients with COPD in accordance to the GOLD stages. Pulmonary rehabilitation programs should incorporate the



use of an accelerometer, the values of respiratory muscle strength and peripheral muscle strength (hand grip, knee- extension); also more sensitive tools for detecting changes in exercise tolerance should be included.

## 5. References

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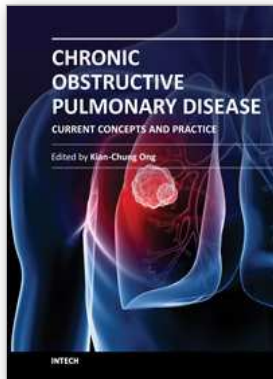
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## **Chronic Obstructive Pulmonary Disease - Current Concepts and Practice**

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A decade or so ago, many clinicians were described as having an unnecessarily 'nihilistic' view of COPD. This has certainly changed over the years... This open access book on COPD provides a platform for scientists and clinicians from around the world to present their knowledge of the disease and up-to-date scientific findings, and avails the reader to a multitude of topics: from recent discoveries in the basic sciences to state-of-the-art interventions on COPD. Management of patients with COPD challenges the whole gamut of Respiratory Medicine - necessarily pushing frontiers in pulmonary function (and exercise) testing, radiologic imaging, pharmaceuticals, chest physiotherapy, intensive care with respiratory therapy, bronchology and thoracic surgery. In addition, multi-disciplinary inputs from other specialty fields such as cardiology, neuro-psychiatry, geriatric medicine and palliative care are often necessary for the comprehensive management of COPD. The recent progress and a multi-disciplinary approach in dealing with COPD certainly bode well for the future. Nonetheless, the final goal and ultimate outcome is in improving the health status and survival of patients with COPD.

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