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Personalized exercise training in chronic lung diseases

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ABSTRACT

Chronic respiratory diseases (CRD) are characterized by exertional dyspnoea, exercise limitation and reduced health-related quality of life (QoL). Exercise training is essential for improving symptoms, physical function and QoL. Current research available supports the effectiveness of exercise training in patients with chronic obstructive pulmonary disease (COPD), cystic fibrosis and interstitial lung disease (ILD). However, recent studies have also shown safety and effectiveness of exercise training in patients with pulmonary arterial hypertension (PAH) and asthma. Despite the lack of clinical guidelines for exercise training in PAH, a recent Cochrane review has reported improvements in functional capacity and effective reductions in mean pulmonary arterial pressure. In the other CRD, a number of Cochrane reviews, supported by numerous randomized controlled trials, have been published outlining the benefits of different types of exercise training. The aim of this review is to establish the principles and modalities of personalized exercise training and the effects of exercise training across a number of CRD. In addition, this review provides information on personalized exercise prescription for CRD patients with co-morbidities.

Key words: asthma, chronic obstructive pulmonary disease, exercise, interstitial lung disease, pulmonary arterial hypertension.

INTRODUCTION

Chronic respiratory diseases (CRD) are associated with abnormalities in the airways and other structures of the lung. The most common CRD are chronic obstructive pulmonary disease (COPD), asthma, cystic fibrosis (CF), interstitial lung disease (ILD) and pulmonary arterial hypertension (PAH).[1,2] Major risk factors include tobacco smoke, air pollution, occupational exposure to chemicals and dusts and frequent lower respiratory tract infections. CRD are not curable; however, treatment can benefit symptoms and increase the quality of life (QoL) for people with these diseases.[3]

In patients with CRD, exercise intolerance is common and refers to the inability of individuals to conduct physical activity at the same rate that would be expected of an age-matched individual with a relatively stable physical condition.[4] Regardless of the condition, this inability is commonly caused by impairment of several physiological systems, associated with the intensification of the perceptions of breathlessness. Equally important are the added effects of peripheral muscle discomfort.

The physiological mechanisms of exercise intolerance in patients with CRD include ventilatory constraints, gas exchange inadequacy, central and peripheral haemodynamic limitations and skeletal muscle abnormalities.[4]

Ventilatory constraints are caused by a disparity between reduced ventilatory capacity and increased ventilatory requirement secondary to increased metabolic demand of exercise. This leads to a reduced maximal and sustainable voluntary capacity progressively causing the inability to sufficiently increase minute ventilation relative to metabolic demands. The reduced capacity of ventilation during exercise is due to altered mechanics of breathing that affect respiratory muscle function. High inspiratory and expiratory airways resistance and/or abnormal lung compliance (increased in COPD and decreased in ILD) can significantly increase the work of breathing.[5]

Gas exchange is commonly impaired in patients with CRD. Gas exchange inadequacies comprise the pulmonary vasculature and the ability of oxygen/carbon dioxide transport between the alveolar–capillary interfaces. Abnormal alveolar–capillary inequalities and impairment of diffusion lead to hypoxaemia during exercise. It is therefore no surprise that many patients with CRD experience arterial oxygen desaturation during exercise.[6]

Central haemodynamic variables that involve the transport of oxygen are often impaired in patients with CRD, due to the coexisting right or left ventricular dysfunction, thereby adversely affecting cardiac output, reducing oxygen delivery and accelerating the onset of metabolic acidosis. In CRD that are characterized by pulmonary vascular abnormalities, pulmonary hypertension and right ventricular dysfunction have marked

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effects on cardiovascular function. These manifestations can be further impaired by the presence of hypoxaemia, elevating pulmonary vascular resistance, causing PAH.[7] A reduction in cardiac output, together with low oxygen content, reduces systemic oxygen delivery to both locomotor and respiratory muscles during exercise.[8]

Both structural and metabolic abnormalities of the limb muscles can be associated with early lactic acidosis and task failure during exercise. Due to a lack of regular physical activity in these patients, the peripheral muscles manifest significant muscle weakness as well as altered fibre type distribution, with specific reference to loss of high oxidative type-I fibres. A reduction in oxidative muscle fibre distribution reduces the oxidative potential of the muscles, making them prone to fatigue during exercise of moderate–high intensity.[9]

Considering that different pathophysiological factors limit exercise tolerance across the different CRD, a brief account of these pathophysiological factors is reported in this review article for a number of disease entities, namely COPD, CF, PAH, ILD and asthma. To partially mitigate the aforementioned cardiovascular and cellular metabolic abnormalities, regular physical exercise training is recommended by the joint American Thoracic Society (ATS) and European Respiratory Society (ERS) statement of pulmonary rehabilitation.[10]

However, because chronic lung conditions present various different co-morbidities, the ‘one size fits all’ approach does not benefit every patient with CRD.[2] In fact, there is evidence suggesting that an important proportion of patients do not sufficiently respond to a given training programme (non-responders).[11] In addition, individual patient’s response to training is highly variable, even though published guidelines suggest that any patient with stable respiratory disease and disabling symptoms would benefit from pulmonary rehabilitation.[11] The present review article introduces the principles and different modalities of exercise training, and also summarizes the effects of various types of exercise training in COPD, CF, PAH, ILD and asthma.

PRINCIPLES OF EXERCISE TRAINING

For patients suffering from CRD, the general principles of exercise training are the same as for healthy individuals.[12] To be beneficial, training volume must be based upon an individual’s specific requirements and capacities, exceeding in effort activities of daily living and progressing as physiological adaptations occur. Suitable training methods, tailored to the cardiovascular, pulmonary and peripheral muscle metabolic limitations of the individual patient, will be required to inform the programme of exercise conditioning.[10,12] For such programmes to be effective, the implementation of the fundamental principles of exercise training into clinical practice should be followed.[13] Table 1 provides details on the principles of exercise training and how they are best implemented in different CRD.

TYPES OF PERSONALIZED EXERCISE TRAINING

Endurance training modalities

Endurance training aims to improve cardiorespiratory fitness and condition the muscles of ambulation in order to increase exercise tolerance and reduce breathlessness and leg discomfort. To see improvements in exercise capacity, moderately intense continuous exercise is recommended.[10] However, patients with profound ventilatory limitation are unable to sustain such intensities for sufficiently long periods.[17] This is primarily due to the progressively increasing high levels of breathlessness, thereby compromising exercise tolerance. In these patients, high-intensity interval exercise training, consisting of repeated bouts of maximal/high-intensity exercise, alternating with short intervals of rest or low-intensity exercise levels, constitutes a suitable alternative to continuous exercise.[15] In patients with advanced COPD, high-intensity interval training has been associated with relatively lower ventilation and less dynamic hyperinflation compared to continuous exercise training. With interval exercise, there is a reduction in symptoms of dyspnoea and leg discomfort, thus allowing a significantly greater amount of work to be performed compared to that of continuous exercise.[18]

Optimal exercise modalities for endurance training include cycling on a cycle ergometer and/or walking on a treadmill or on a flat surface.[10] The prescription of such modalities should be individualized for each patient’s chronic lung condition. Stationary cycling is commonly implemented as it provides precise implementation of training intensity and a greater load on the locomotor muscles and results in less oxygen desaturation than walking.[19] However, for certain individuals, walking training (treadmill or flat ground) may have more beneficial effects as it is an activity easily translated into improvements in walking capacity.[20] Alternative forms of exercise are stair climbing, stepping, Nordic walking and water-based exercise training.

One-legged cycling

One-legged cycling constitutes an alternative modality providing an aerobic stimulus to the leg muscles without placing a high ventilatory load on the respiratory system. The ability to separate the work of leg muscles during exercise, with sufficient metabolic stimulus has resulted in a lower minute ventilation and dyspnoea sensations.[21] Studies report that one-legged cycling as a method of exercise training enhances peak oxygen consumption and decreases submaximal heart rate and minute ventilation to a larger extent than commonly implemented endurance cycling.[21] These findings indicate a greater cardiovascular and/or muscular training effect which does not substantially prolong the duration of the training session, as it appears sufficient to train each leg for half of the bi-legged cycling time. However, the practicality of this modality requires modification of a typical cycle ergometer, which may complicate the process of organizing exercise sessions.[22,23]

Table 1 Principles of training

Principles	Description	Implementation
Overloading	To achieve a training effect, it is necessary to expose the physiological systems to an overload, which presents a stress greater than regularly encountered in daily life[12]	Programme length: The general consensus for CRD is that longer programmes (7–12 weeks) rather than shorter programmes (4–6 weeks) produce greater training effects[10] Duration: 30–40 min Frequency: 3–5 training sessions per week Intensity: Endurance training programmes should be set at moderate levels (50–70% peak load). High-intensity endurance training produces greater physiological benefits (>80% peak load); however, severe symptoms may restrict this intensity.[14] An alternative to overcome increasing symptom limitation is high-intensity interval training (80–120% peak load)[15]
Progressive overloading	Producing a training effect becomes greater as the course of training progresses, due to an increase in exercise tolerance. Therefore, training intensity has to be progressively and continuously increased to achieve further physiological improvements[12]	For the majority of CRD, training overload should be progressed using the modified Borg score (ranged 0–10 points), with appropriate training intensities met when dyspnoea and leg discomfort are rated between 4 and 5[10] The appropriate progression of training overload for patients with PAH should be guided by patients' physiological targets of vital signs; HR < 120 bpm, O_2 SATS > 85% and Borg score < 5/10[16]
Specificity of loading	Physiological adaptations are specific to the exercise type (endurance or resistance training), muscle groups (upper or lower extremities) and the mode of exercise (continuous or interval exercise)[12]	For the majority of chronic lung diseases, exercise programmes involve lower body aerobic (treadmill walking or ergometer cycling), which improve the capacity of the lower limbs. Upper body aerobic is less frequently incorporated in exercise programmes, but can be performed using arm cycle ergometers[10]
Reversibility (de-conditioning)	When exercise training stops, established physiological adaptations will be reversed[12]	There are studies following up patients post-rehabilitation and report that the effects are maintained up to 6 months and most of them are lost within 12 months. Find these references from papers investigating maintenance strategies post-training compared to usual care post-training[10]

bpm, beats per minute; CRD, chronic respiratory disease; HR, Heart Rate; PAH, pulmonary arterial hypertension; SATS, Saturation.

Resistance/strength training

Resistance training involves the training of local muscle groups by the repetitive lifting or pushing of moderately heavy weights. This training modality is considered important for both healthy individuals and patients with CRD.[10,12] Peripheral muscle dysfunction and muscle weakness are extra-pulmonary features commonly associated with a number of CRD, to which resistance training, in part, is reported to partially reverse these features and thereby reduce the impairment in chronic disease.[24] The characteristics of the prescription of resistance training vary significantly, with a different number of repetitions, intensities and/or the method of strength training reported across the literature.[25] The ATS/ERS guidelines for pulmonary rehabilitation suggest performing two to four sets of 6–12 repetitions, with intensities ranging from 50% to 85% of one repetition maximum two to three times per week.[10]

Upper limb training

Patients with CRD often have difficulty undertaking activities of daily living involving the upper extremities. Therefore, upper limb training is commonly integrated into exercise sessions, including aerobic regimens (arm cycle ergometer) and resistance (free weights and elastic bands) regimens. When implementing these exercise modalities, targeted muscles include biceps, triceps, deltoids, latissimus dorsi and the pectorals. A recently published Cochrane review gathering the previous literature available on upper limb training has found benefits of this training modality on symptoms of dyspnoea and health-related QoL.[26]

Flexibility and stretching exercises

Flexibility exercises are a common element of many programmes, performed through both upper and lower body exercises.[2] This includes stretching of major muscle groups such as the calves, hamstrings, quadriceps and biceps, as well as motion exercises for the neck, shoulders and trunk.[2] In patients with CRD, postural impairment can cause a decline in pulmonary function leading to an increased work of breathing. It can also cause abnormalities associated with body mechanics (i.e. back pain), which alters breathing mechanics. To date, clinical trials demonstrating the effectiveness of flexibility training are scarce. It is suggested that improved thoracic mobility and posture in CRD patients may increase vital capacity.[2]

Water-based rehabilitation

Implementation of water-based exercise as an option for rehabilitation has been void for many years due to thoughts that immersion in water will increase cardiac and respiratory work due to increased chest wall pressures.[27] However, emerging evidence suggests that water-based training sessions can be performed safely even in those patients with a severe disease.[28–30]

Water-based exercise engages the lower extremities with minimal impact on the body.[31] Water-based exercises allow patients to gain the benefits of land-based training, without the overt stress or strain on arthritic joints, due to the buoyancy of water facilitating balance and gait.[32] Evidence is available surrounding water-based exercise training as a potential means of therapeutic training in patients with COPD, including a recently published Cochrane review.[29,30,33–35] Improvements in exercise capacity and QoL within these patients have been reported, with the benefits comparable to those of land-based exercise.[35] In patients with COPD, water-based exercise training can provide additional beneficial physiological effects caused by hydrostatic pressure. The hydrostatic pressure exerted during immersion in water can facilitate expiration and thereby reduce the degree of air trapping during exercise.[36] Partial immersion in water has been shown to decrease functional residual capacity by about 54% and expiratory reserve volume by 75% in people with COPD.[35]

Tai Chi

Tai Chi, originating from China, is a systematic callisthenic exercise, involving a series of slow, rhythmic, circular motions, highlighting the use of 'mind' or concentration to aid the control of breathing and circular body movement.[37,38] Studies have found that Tai Chi achieved improved pulmonary function and exercise capacity in patients with COPD compared to usual care.[39,40] Oxygen consumption during Tai Chi was measured to be 63% of peak maximal oxygen consumption and 52% of oxygen uptake (VO_2) reserve, providing evidence as an exercise of moderate intensity in chronic disease.[40] Specifically, Leung *et al.* found a short form sun-style Tai Chi more effective than usual medical care in improving aspects of exercise tolerance, balance, physical performance and QoL.[40] Different forms of Tai Chi are available and studies within chronic disease have adopted different approaches, meaning many styles or forms of this exercise modality could be implemented for patients with CRD.[40]

Yoga

Yoga is a low-impact complementary therapy that can be used in patients with chronic diseases. Mainly consisting of movement-coordinated breathing, it is known to improve exercise capacity and QoL. Many healthcare professionals see it as a useful adjunct to rehabilitation programmes for patients with chronic diseases including heart disease, stroke and COPD.[41] A systematic review is available assessing the effects of yoga training on the management of patients with COPD. Five included studies reported significant improvements in forced expiratory volume in 1 s (FEV_1) (mean difference: 123.57 mL) and 6-min walk test (6MWT) distance (mean difference: 38.84 m).[42]

Whole-body vibration training

Whole-body vibration training involves an individual standing on a vibrating platform that produces sinusoidal oscillations. These vibrations at a high intensity induce muscle contractions from the leg through to the trunk. Individuals have no direct influence on muscle activity, removing the voluntary muscle contractions which make up common resistance activities. Instead, muscle contractions are caused by stretch reflexes of the muscle fibres. The majority of previous research has concentrated on studies within patients with COPD, with a systematic review available.[43] This review article consisted of six studies focusing on very different aspects of whole-body vibration training. All studies reported superior benefits on exercise capacity (measured by the 6MWT), thereby providing evidence that whole-body vibration training is effective in improving functional capacity in patients with COPD.[43]

PERSONALIZED EXERCISE TRAINING IN SPECIFIC CRD

Exercise training as an intervention to promote functional independence in CRD, especially in COPD, has been extensively researched to date. Several studies of supervised aerobic exercise training have confirmed that patients with a wide range of severity of CRD can improve exercise capacity, with improved cardiovascular physiology and skeletal muscle strength and endurance.[44] A number of Cochrane reviews have provided evidence of the effects of exercise training on CRD, including COPD,[45] CF,[46] PAH,[16] ILD[47] and asthma.[48]

Chronic obstructive pulmonary disease

Due to a large pathophysiological heterogeneity of COPD (i.e. emphysema and/or chronic bronchitis) and the added co-morbidities associated with this CRD, the fundamental elements of impaired exercise capacity in these patients may vary.[49,50] Intolerable exertional symptoms, including, increased breathlessness and/or leg discomfort limit exercise tolerance. The physiological limitations are multifactorial, involving ventilatory, pulmonary gas exchange, haemodynamic and peripheral muscle abnormalities, all of which prevent adequate oxygen transfer from the atmosphere to its utilization within the mitochondria.[51–53]

The standard recommendations for exercise training include moderate-/high-intensity aerobic endurance exercise in the form of cycling or walking and upper and lower extremity resistance training.[10] For patients with a greater disease severity, high-intensity interval training is an alternative due to the ability to perform high intensities of exercise for short periods of time followed by sufficient rest periods.[10] The benefits of exercise training in patients with COPD have been documented in a number of systematic review meta-analyses and in two Cochrane reviews.[45,54] Data available from those reviews have accepted that exercise training is an essential strategy in the ongoing management of COPD. Specifically, 38 studies within the most recent Cochrane review reported an improvement in 6MWT distance of 44 m, above the minimum clinically important difference of 30 m.[45] A further 16 studies used an incremental cycle ergometer test to measure maximal exercise capacity, reporting an increase in mean peak work rate of 6.8 W among those patients allocated to pulmonary rehabilitation.[45] These marked improvements in exercise tolerance and functional capacity have been associated with reductions in dynamic hyperinflation and dyspnoea sensations during exercise. Exercise also increases muscle function, delaying the onset of peripheral muscle fatigue and resulting in increased exercise tolerance (Table 2).

Cystic fibrosis

Three major factors limit exercise in CF patients, namely pulmonary, metabolic and cardiovascular. Impaired lung function and obstructive lung disease alter the ventilatory responses to exercise, with the majority of patients presenting an FEV_1 <50% of predicted values.[56] Significant digestive system impairment leads to low body mass and, in particular, less skeletal muscle mass. Given the relationship between muscle size and force output, a lack of lean muscle mass and impaired metabolic function has major associations with impaired exercise response.[57] In addition, it is common to see elevated heart rates at rest in CF patients. Higher resting heart rates limit the reserve of cardiac output to increase during exercise, leading to premature cessation of higher intensity activities.[58]

Exercise training has an established role in general disease management.[59] A Cochrane review (total number of 15 studies with 487 participants) has examined the effects of different types of training in CF (aerobic, anaerobic and a combination of both types).[46] The implementation of aerobic and/or anaerobic physical exercise training was found to have positive effects on exercise capacity (peak oxygen uptake), pulmonary function and health-related QoL[46] (Table 2). Exercise training in this patient population requires a programme length of at least 6 weeks for an initially tolerable duration, but progressing to at least 20–30 min at an intensity of 55–65% maximum heart rate, for 3–5 days per week[10,46] (Table 2).

The beneficial effects of exercise are associated with an increase in sputum clearance through a combination of hyperventilation, mechanical vibration, coughing and changes in sputum rheology leading to facilitated and increased sputum expectoration.[60] This indicates that exercise may play a potential role in maintaining bronchial hygiene, a crucial aspect of CF care.[60]

Pulmonary arterial hypertension

The major limitations to exercise in PAH are breathlessness and leg discomfort. In these patients, cardiac output is lower than healthy age-matched individuals and the relationship between cardiac output and oxygen uptake is reduced. This abnormality has been attributed to increased right ventricular afterload reducing stroke volume and hence cardiac output.[61] Consequently, oxygen delivery to the peripheral muscles is reduced, accelerating the onset of muscle fatigue and leg discomfort, alongside increased ventilatory requirement and dyspnoea sensation.[62]

The mechanisms by which exercise training improves exercise capacity in patients with PAH are less clear than for other CRD. This is due to exercise training being actively discouraged in people with PAH because it would worsen symptoms and negatively affect cardiac function.[16] A Cochrane review has recently been published considering the effects of exercise-based rehabilitation for PAH patients.[16] The review examined five studies, all reporting a large clinically significant improvement in exercise capacity, measured using both the 6MWT and incremental cardiopulmonary exercise testing. The mean increase in the 6MWT distance of 60.1 m was well in excess of the minimal important difference of 30 m. Similarly, increases in peak power of 16.4 W were reported. To date, there is no minimal important difference for cardiopulmonary exercise testing-derived measures of exercise capacity in PAH; however, the improvements in peak power reported are in excess of the minimal important difference reported for COPD of 5–10 W.[63]

Limited knowledge is available of the possible mechanisms of improved exercise capacity following exercise training (Table 2). A potential mechanism involved an improvement in pulmonary haemodynamic with a lower mean pulmonary artery pressure and an improvement in submaximal and maximal cardiac output. The authors hypothesized that exercise training may improve right ventricular function.[64] Combined with these central changes, there is evidence that exercise training improves skeletal muscle oxidative capacity and capillary density, similar to the improvements found in other CRD populations.[10]

Interstitial lung diseases

Patients with ILD during exercise exhibit a rapid, shallow breathing pattern. This causes a small tidal volume and increased respiratory rate, which increases the work of breathing. In addition to the inefficient respiratory mechanics, impairment of gas exchange and circulatory limitation play an important role in exercise limitation.[6] Peak VO_2 measured during cardiopulmonary exercise

Table 2 Training modalities for patients with different chronic respiratory disease entities

	COPD	Cystic fibrosis	Pulmonary hypertension	ILD	Asthma
Modality	Aerobic (continuous or interval) and resistance[10,45]	Aerobic or anaerobic or a combination of both[46]	Aerobic (interval) and peripheral muscle training[16]	Aerobic and resistance training[47]	Aerobic conditioning using treadmill/bicycle ergometer or swimming[48]
Intensity	60–80% of Peak work capacity for continuous exercise and 100–120% of peak work capacity for interval exercise[10,45]	55–65% Maximum heart rate[10,46]	<120 bpm, $SpO_2 > 85\%$ and Borg score < 5/10[16]	60–80% of Peak work capacity for continuous exercise[10]	50–75% VO_2 max aerobic exercise[55]
Length	8–12 weeks[10,45]	Minimum of 6 weeks[10,46]	6–8 weeks[16]	8–12 weeks[2]	8–12 weeks[55]
Duration	20–60 min[10,45]	20–30 min[10,46]	30–60 min[10,45]	20–60 min[10,45]	30–40 min[55]
Frequency	3–5 days per week[10,45]	3–5 days per week[10,46]	2–3 Supervised exercise[10,45]	3–5 days per week[10]	2–3 Sessions per week[55]
Outcomes	Improvements in exercise capacity, strength and QoL[10,45]	Improvements in exercise capacity, strength and QoL; slower rate of decline in lung function[46]	Improved exercise endurance, QoL, peak VO_2, increased peak workload and increased peripheral muscle function[16]	Improved 6MWD, dyspnoea and QoL[47]	Improved physical fitness, asthma symptoms, anxiety, depression and QoL[48]

Indicative content of training modalities commonly implemented in patients with lung disease as part of pulmonary rehabilitation.
6MWD, 6-min walk distance; bpm, beats per minute; COPD, chronic obstructive pulmonary disease; ILD, interstitial lung disease; QoL, quality of life; SpO_2, peripheral capillary oxygen saturation; VO_2, oxygen uptake.

tests correlated better with measures of central haemodynamic impairment (measures of heart rate, stroke volume and cardiac output), than with other limitations, providing an understanding that circulatory impairment was the primary limitation to exercise. Circulatory limitations are a result of pulmonary capillary destruction and hypoxic pulmonary vasoconstriction, leading to cardiac dysfunction and potential pulmonary hypertension. Destruction of pulmonary capillary beds and/or thickening of the alveolar–capillary membrane are the main causes of impaired gas exchange in ILD causing a mismatch between ventilation and perfusion.[4]

The implementation of exercise training was associated with short-term benefits in patients with ILD[10] (Table 2). Training strategies have used aerobic exercise alone or a combination of aerobic and resistance training; however, the most effective exercise training strategy for patients has yet to be confirmed. Both exercise durations and frequencies have been documented, with longer programmes and more frequent sessions appearing to provide greater benefits[10] (Table 2).

The most recent Cochrane review identified nine studies reporting improvement in both measures of the 6MWT and incremental cycle ergometer test.[47] QoL and sensation of breathlessness were also significantly improved immediately following pulmonary rehabilitation. Mean improvement in the 6MWT following pulmonary rehabilitation was 44.3 m, which exceeds the minimal important difference for the 6MWT distance among patients with ILD, ranging from 30 to 33 m.[65] Furthermore, a recent randomized control trial, not included in the Cochrane review, concluded that exercise training can be effective across the range of ILD, in terms of improving the 6MWT distance (>25 m) and health-related QoL.[66] Larger improvements were reported in 6MWT, Chronic Respiratory Disease Questionnaire (CRDQ), St George's Respiratory Questionnaire (SGRQ) and dyspnoea in asbestosis and interstitial pulmonary fibrosis.

Asthma

Asthma is a common long-term inflammatory disease of the airways of the lungs. It is characterized by variable and recurring symptoms, reversible airflow obstruction and easily triggered bronchospasms. Symptoms include episodes of wheezing, coughing, chest tightness and shortness of breath.

During exercise, these symptoms can be provoked or worsened, a contributing factor towards reduced participation in exercise, leading to deconditioning and lower exercise tolerance.[67]

The overall impact of exercise training on functional capacity and symptoms of asthma is scarce. The current global strategy for asthma management and prevention has given brief guidelines around physical activity, suggesting that regular physical activity improves cardiopulmonary fitness; however, no evidence towards specific exercise training has been documented.[67] A single Cochrane review is available examining exercise training in these patients.[48] Included studies have suggested that exercise improved asthma-related symptoms and cardiopulmonary fitness. Studies have reported that an increase in physical activity through exercise training may lower ventilatory requirement of mild and moderate exercise thereby reducing the likelihood of provoking exercise-induced asthma. In addition, a 12-week aerobic training programme demonstrated reductions in bronchial hyperresponsiveness and serum pro-inflammatory cytokines associated with improvements in QoL and asthma exacerbations in adults with moderate to severe persistent asthma.[68]

EXERCISE TRAINING IN PATIENTS WITH CO-MORBIDITIES

People with COPD often have co-morbidities that markedly affect functional capacity.[69] These include chronic heart disease, metabolic syndrome, musculoskeletal or neurological co-morbidities and many types of cancer. Regular exercise and physical activity are commonly recommended to benefit patients with many chronic morbidities, with aerobic and resistance training modalities suggested as evidence-based treatment in patients with heart failure and/or type 2 diabetes.[3] Patients with cardiovascular disease should begin supervised exercise training with continuous ECG monitoring and decrease to intermittent or no ECG monitoring after 6–12 sessions. For patients with certain musculoskeletal co-morbidities, commonly implemented land-based exercise training may cause adverse events. These patients may benefit from water-based exercise training described earlier.

Over the last two decades, an increased prevalence of obesity as a major co-morbidity in patients with asthma has become apparent. A recent study by Freitas *et al.* examined the effect of an exercise training programme alongside a structured weight loss programme.[70] They reported improvements in aerobic capacity and strength, associated with improved symptoms of asthma and weight loss. These results suggest that combining exercise with weight loss programmes allow patients to achieve better asthma control in a shorter period of time.[70]

In patients with CF, 20% of adolescents and 40–50% of adults develop CF-related diabetes (CFRD).[71] For patients with CFRD, exercise training is still recommended even though it is likely to make activities more difficult. When conducting exercise training in these patients, additional precautions should be used to monitor blood glucose, specifically after exercise has ceased.[72]

CONCLUSION

Available literature demonstrates that in the majority of CRD, whole-body exercises, consisting of aerobic and resistance training, decrease respiratory symptoms, improve cardiovascular and muscle function leading to significant improvements in functional capacity. The benefits of personalized exercise training in COPD and ILD are available in abundance, with both moderate-intensity continuous and high-intensity interval exercise alongside whole-body resistance training frequently incorporated into personalized pulmonary rehabilitation. However, in higher risk diseases such as PAH, the previous notion that exercise would worsen symptoms and negatively affect cardiac function has slowed down the progress of exercise as a beneficial therapy and only recent research has begun to report beneficial effects. The availability of alternative exercise modalities, such as water-based exercise training, Tai Chi and single leg exercises, provides many patients with CRD who suffer co-morbidities a personalized approach to incorporating exercise training into their disease management.

Future randomized controlled trials are needed to continue to evaluate personalized exercise training in patients with more severe CRD or with multiple co-morbidities, due to the known benefits exercise has on aerobic capacity and muscle strength. Additional studies are needed to determine the optimal exercise training strategy for patients with PAH and asthma, including the modality and intensity of training, length of programme and degree of supervision.

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Abbreviations: 6MWT, 6-min walk test; ATS, American Thoracic Society; CF, cystic fibrosis; CFRD, CF-related diabetes; CRD, chronic respiratory disease; ECG, electrocardiogram; ERS, European Respiratory Society; FEV_1, forced expiratory volume in 1 s; ILD, interstitial lung disease; PAH, pulmonary arterial hypertension; QoL, quality of life; VO_2, oxygen uptake.

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