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Exercise and chronic pulmonary diseases in pediatrics

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ABSTRACT

Chronic respiratory diseases in pediatrics can significantly affect the quality of life of children and adolescents, impacting their ability to engage in daily activities, including sports. Physical exercise offers benefits for both physical and mental health and has become an integral part of managing chronic conditions. However, many pediatric patients with respiratory diseases are unable to participate in physical activities due to exercise intolerance. This review explores how different chronic respiratory conditions affect exercise response, examining the impact on lung function, physical capacity, and overall quality of life. It also highlights the effectiveness of various training programs that have demonstrated the most benefits. The literature suggests that physical exercise plays a crucial role in managing chronic respiratory diseases, offering both prognostic and therapeutic advantages. Incorporating exercise programs into treatment plans should become standard practice. Nonetheless, further research is necessary to determine the optimal training protocols for each specific condition.

Keywords: Physical exercise. Chronic respiratory diseases. Pediatrics. Training programs.

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INTRODUCTION

Physical exercise has been shown to significantly improve physical and mental health in healthy people, improving quality of life and well-being[1]. It decreases mortality from cardiovascular disease, the incidence of hypertension and type 2 diabetes, anxiety symptoms, and improves sleep quality[2]. In the pediatric age, it also promotes proper growth, improves physical condition (cardiorespiratory and muscular), improves cardiovascular health, and creates healthy habits for adult life[2,3]. The effects of exercise on emotional well-being have also been studied[4], and positive impacts on psychological and social health have been found. Among the modalities of physical activity, team sports have shown a more significant benefit in the psychosocial sphere[4]. In addition, physical exercise has also been shown to have an immunomodulatory role due to the release of anti-inflammatory cytokines from muscle[5] and stimulation of the immune system[6].

In the last three decades, knowledge about physical exercise in disease has increased significantly and it is now part of the first-line treatment in several chronic pathologies[7]. In 2007, the American Sports Medicine Association launched the "Exercise is Medicine" project to raise awareness and motivate physicians to use physical exercise to treat and prevent chronic diseases[8,9]. These initiatives were also applied to chronic respiratory diseases[10–13]. The next step has been to investigate what training may benefit these patients the most. For example, an article published in 2023 suggests that internalized moderate-intensity exercise may be an effective and safe way to improve fitness, muscle strength, body composition, and quality of life in patients with chronic obstructive pulmonary disease (COPD)[14].

On the other hand, it should be taken into account that respiratory symptoms with physical exercise are frequent in both healthy children and adolescents[15] and those with chronic respiratory pathologies. In these patients, dyspnea and limitation of physical exercise are persistent symptoms associated with worsening quality of life[16], so their improvement is one of the treatment objectives. Exercise intolerance, understood as the inability to perform physical activity at the same level as people of the same age with an adequate physical condition, is one of the treatment objectives[17] that often leads patients with chronic respiratory disease to perform less exercise, thus preventing them from experiencing its benefits. In addition, limitation to physical exercise in these patients is associated with a worse prognosis[12,18,19].

The reasons for this exercise intolerance in respiratory pathologies are multiple and may differ from one disease to another[17]. Ultimately, it is caused by an imbalance between the different physiological systems (decreased ventilatory capacity and increased ventilatory requirements due to increased metabolic demand from exercise). In addition, the increased perception of dyspnea is often added to the various pathophysiological processes[20]. Table 1 summarizes the physiological mechanisms involved in exercise intolerance in chronic respiratory diseases[13,20].

Pulmonary function tests or clinical history are not always sufficient to assess physical capacity in chronic respiratory diseases, partly

Table 1. Summary of pathophysiological mechanisms involved in limitation to physical exercise in patients with chronic respiratory diseases

Ventilation limitation: mismatch between ventilatory capacity and workload
Alteration of gas exchange. Reduction of oxygen supply to respiratory and locomotor muscles
Central and peripheral hemodynamic limitations: venous return and pulmonary capillary blood volume decrease, further altering the supply to working muscles
Musculoskeletal disorders: peripheral muscle dysfunction

Table 2. Main advantages and disadvantages of treadmill and cycle-ergometer cardiorespiratory ergometry

	Treadmill	Cycle-ergometer
Advantages	Easy calibration Suitable for all ages Regular physical activity Involves more muscle groups Higher VO_2 max is achieved	Greater patient stability Greater registry stability Load control Easier to apply ramp protocol
Disadvantages	Requires more space More expensive equipment Higher risk of falls Less stable registry	Not feasible for younger children More complex exercises to perform Involves fewer muscle groups

because when presenting symptoms with physical exertion, patients avoid performing it, thus underestimating clinical[21]. The best test to evaluate the response to physical exercise in these cases is the cardiorespiratory ergometry (CPET)[16], which identifies exercise limiting factors, those that can potentially be improved, and provides prognostic information[22]. The value that provides the most information in this test is the maximal oxygen consumption (VO_2 max), which is defined as the maximum amount of oxygen that a person can use in a given time, measured in milliliters of oxygen per minute per kg of body weight (ml/kg/min)[23]. Peak oxygen consumption refers to the amount of oxygen that the organism extracts per unit of time in a physical exertion performed up to the maximum tolerated intensity[24]. It is considered a good alternative to VO_2 max in evaluating physical condition, especially when it is possible to reach the maximum intensity, as occurs in pathologies that limit the ability to perform the physical exercise[25,26]. CPET can be performed both on a treadmill and on a cyclo-ergometer, with the treadmill offering advantages over the bicycle. This type of ergometry allows obtaining higher VO_2 peak values in healthy children and those with chronic pathologies[27]. This difference could be explained by greater muscle fatigue on the bicycle compared to the treadmill[27]. In addition, on the treadmill, there is a more rapid increase in ventilation[28], more muscle groups are activated, and it is a more common type of exercise. Table 2 details the advantages and disadvantages of both kinds of ergometry. CPET can be performed early (Fig. 1) in experienced centers, providing information on diagnosis, prognosis, and the effectiveness of training plans[29].

The 6-min walk test (6MW) is a submaximal test that also evaluates exercise response. It is a widely used field test, which is more economical and easier to perform[30]. The 6MW is essential in patients who cannot perform the CPET due to technical difficulties or in patients with more significant deterioration where ergometry may be a risk[31,32]. In pediatric chronic respiratory pathologies, the 6MW has an essential role in evaluating the efficacy of different treatments and prognostic value in pathologies such as pulmonary hypertension[33]

Figure 1. Six-year-old patient with cystic fibrosis performing cardiorespiratory ergometry *(this image belongs to the author).*

or lung transplantation[34]. It is also used in bronchopulmonary dysplasia (BPD)[35], cystic fibrosis (CF)[18], or post-infectious bronchiolitis obliterans (PIBO)[32,36].

This review aims to review the current literature on the role of physical exercise in managing chronic respiratory diseases, analyzing the underlying physiological mechanisms and specific recommendations on the types of training for each pathology.

ASTHMA

Asthma is the most common respiratory disease in the pediatric age group. The global initiative for asthma defines it as a heterogeneous disease characterized by chronic airway inflammation and bronchial hyperresponsiveness, resulting in variable airflow limitation that is generally reversible. Clinically, it is manifested by recurrent respiratory symptoms such as cough, dyspnea, and restriction of physical activity[37]. Symptoms with exercise are persistent, but on many occasions, they are not due to asthma but to lack of associated physical condition. It is thought that between 40 and 90% of patients with asthma have exercise-induced bronchospasm[25]. However, it is currently believed that this figure may be overestimated[38,39].

The limitation to physical exercise in asthma is associated with different factors[16,40]

- The degree of baseline airway obstruction and air trapping. Patients with more significant obstruction may present mechanical-ventilatory limitations and exertional dyspnea similar to COPD.

– Decreased ventilatory capacity. An excessive increase in ventilation (increased chemo-stimulation) and increased ineffective ventilation during exercise have been described. This could increase airway dehydration and favor bronchoconstriction.

– Increased perception of dyspnea.

– Bronchoconstriction by exertion. At present, the most accepted hypothesis is the osmotic stress in the airway mucosa. This initiates an inflammatory response that culminates in bronchoconstriction[28].

Physical exercise can provoke or worsen asthma symptoms, limiting sports practice in these patients. Less activity could lead to a deterioration of their physical capacity. However, there is controversy as to whether asthmatics are in worse physical condition than non-asthmatics. Some studies show that this difference does exist[41,42], and in others, a worse physical condition has not been objectified[43].

Exercise as part of the treatment of asthma has been studied for years. In 2013, a Cochrane review[44] concluded that physical training is well tolerated and significantly improves cardiorespiratory fitness in people with asthma. No differences were found in other lung function variables, such as 1st-s exhaled volume (FEV_1).

There have been numerous studies on asthma and exercise in the pediatric population. In 2014, a systematic review[45] included 29 studies conducted between 1972 and 2010, with 1,045 patients aged 6-18. The training programs evaluated were swimming in 7 studies, aerobic activities such as athletics, basketball, or soccer in 16, Tai Chi in 1, and respiratory exercises in another. Pulmonary function was evaluated in 24 studies; only three showed an improvement in FEV_1 after the training program. Peak expiratory flow was the parameter that showed a slight improvement after exercise in most studies. The authors conclude that it is impossible to relate the improvement in FEV_1 to training. Studies have continued to be published in which no differences have been found in lung function after different exercise programs[46,47]. However, there is also data in favor of improvements in lung function after training programs. The systematic review by Zhang et al.[48] found an improvement in forced vital capacity (FVC) after training programs, with no change in FEV_1. A study published in 2018[49] also observed an increase in FEV_1 and FVC after 10 weeks of training. In 2021, a new systematic review of adult patients[50] showed an improvement in lung function in almost half of the included studies.

In terms of quality of life, in the 2014 review[45], few studies evaluated quality of life, but most of them showed an improvement in this parameter[51,52], and the one that did not show an improvement in this parameter[53] related it to a good baseline quality of life with little possibility of improvement. The physical condition measured with VO_2max improved in the studies in which a training program with intensities fixed at the ventilatory threshold was used for at least 120 min/week[45]. No baseline medication changes were observerd after exercise in any study[34]. Publications on exercise in asthma have continued to increase in the last 10 years. The 2021 review[50] in adult patients provided data on the benefits of training in the control of asthma symptoms. Although outcome measures varied among studies, 7 of the 12 that looked at asthma control showed statistically significant improvement with exercise.

Different training strategies have been evaluated as a treatment for asthma, primarily based on aerobic exercise[54]. Much importance is given to muscle function in healthy and chronically ill individuals[55,56]. Therefore, combined programs have also begun to be published in children and adolescents with asthma. In 2020, Sanz-Santiago et al.[11] published the effects of an exercise program on lung function and asthma control quality of life in children with mild–moderate asthma who presented symptoms with exercise. They conducted a clinical trial with a control group. The intervention consisted of 12 weeks of training (3 days/week) with combined exercise (resistance and aerobic). A total of 60 patients were included, with no statistical differences in demographic or baseline clinical characteristics. At the beginning of the study, all patients underwent a bronchial provocation test to assess bronchial hyperresponsiveness, CPET strength measurement as the primary measurement. After the intervention, these measurements were repeated at the end of the study, showing an improvement in cardiorespiratory capacity muscle strength in the training group. The ergometry data also suggested improved ventilatory efficiency, which may improve dyspnea and exercise capacity perception. No significant differences in quality of life or lung function were found. More recently, in 2022, Jiang et al.[57] published a systematic review that aimed to measure the value of physical exercise in the treatment of asthma as well as to evaluate different training programs. Twenty-four randomized controlled clinical trials were analyzed. As a novelty, interval exercise is discussed. This improved quality of life with higher scores in the PAQLQ questionnaire and significantly improved the distance covered in the 6MW test. No significant differences were found in the FEV_1[45]. Table 3 summarizes the papers published in the last decade on different training programs in asthma[11,47,49,58–63].

Physical activity is recommended in children and adolescents with asthmaas an integral part of the treatment since it is safe and effective[36,37,45]. However, as the studies are very heterogeneous, it is still unclear what type of exercise and at what "dose" the most significant benefits are obtained. Aerobic training has been the most investigated so far, but both combined and interval exercise may offer more essential benefits, so studies comparing different training programs are needed.

CF

CF is the most common genetic disease in the caucasian race. It is caused by CFTR gene mutations that encode the protein of the same name. Alterations in this protein condition the transport of ions, causing thick secretions. This gene is expressed in different organs, so CF is a multisystemic disease, but the respiratory manifestations are the ones that cause the highest morbidity and mortality[64].

The life expectancy in CF has changed dramatically since it was first described in 1938[65]. Mucociliary clearance therapies, inhaled antibiotics, digestive treatment with pancreatic

Table 3. Summary of papers published in the last 10 years with different training programs

First author/year	Age (years)	Type of exercise	Frequency of training	Duration and intensity	Improvements
Yang et al. (2023)[58]	5–12	Combined: resistance exercise (aerobic) + respiratory muscle training	3-5 days/week. At least 30 min	12 weeks/moderate-high	Asthma control ($p < 0.05$) Quality of life ($p < 0.05$)
Elnaggar (2021)[59]	12–16	Inspiratory muscle training and respiratory training	Inspiratory muscles: 20 min/day. 3 days/week. Breathing training: 30 min 3 days/week	12 weeks/moderate	FEV_1 (p = 0.03) FVC (p:0.001) FEV_1/FVC (P:0.04)
Yadav et al. (2021)[60]	10–16	Aerobic (Yoga)	1 time/day for 45 min	12 weeks	FEV1 ($p < 0.01$) FVC (p = 0.01) PAQLQ (p:0.01)
Sanz-Santiago et al. (2020)[11]	7–17	Combined: Endurance + aerobic	3 times/week for 60 min	12 weeks/moderate-high	VO_2 peak (p = 0.016) Muscle strength in legs ($p < 0.01$)
Zhang and Yang (2019)[61]	4–12	Aerobic	3 times/week for 40 min	6 weeks	No change in FEV_1
Khodashenas et al. (2019)[62]	6–18	Aerobic + strength	3 times/week for 45 min	8 weeks	Quality of life ($p < 0.05$)
Abdelbasset et al. (2018)[49]	8–12	Aerobic (treadmill walking)	3 times/week for 40 min	10 weeks/moderate	FEV_1 (p = 0.47) VO2 max (p = 0.011)
Andrade et al. (2014)[47]	6–17	Aerobic	3 times/week for 60 min	6 weeks/moderate-high	Distance in 6MW Quality of life
Latorre-Román et al. (2014)[63]	10–12	Interval exercise	3 times/week for 60 min	12 weeks/high intensity	FEV_1 6MW Upper limb strength Quality of life

enzymes, nutritional support, the creation of multidisciplinary units, and neonatal screening increased survival into the third-fourth decade of life[66]. The advent of modulatory therapy in 2012 was a significant breakthrough in the survival and quality of life of people with CF. Studies based on mathematical simulations have estimated that those who initiate modulatory therapy from birth could reach the eighth decade of life, approaching the average life expectancy[67]. This change implies that the number of older adults with CF will increase, and they are likely to suffer from age-associated pathologies such as cardiovascular disease, so it is essential to create healthy habits for the future.

The mechanisms limiting physical exercise in CF appear to be related to alterations in exercise-induced ventilation, compromised gas exchange, peripheral muscle dysfunction, and poor nutritional status[68]. CFTR is also expressed in the skeletal musculature, and its dysfunction is another factor that may limit physical activity[69]. Figure 2 summarizes the pathophysiology of exercise in cystic fibrosis[13].

Despite the exercise limitation of people with CF, studies on the role of physical activity in treatment, primarily as a mucociliary clearance therapy, have been published since the 1960s[70,71]. One of the top 10 research questions in CF is whether physical exercise can replace

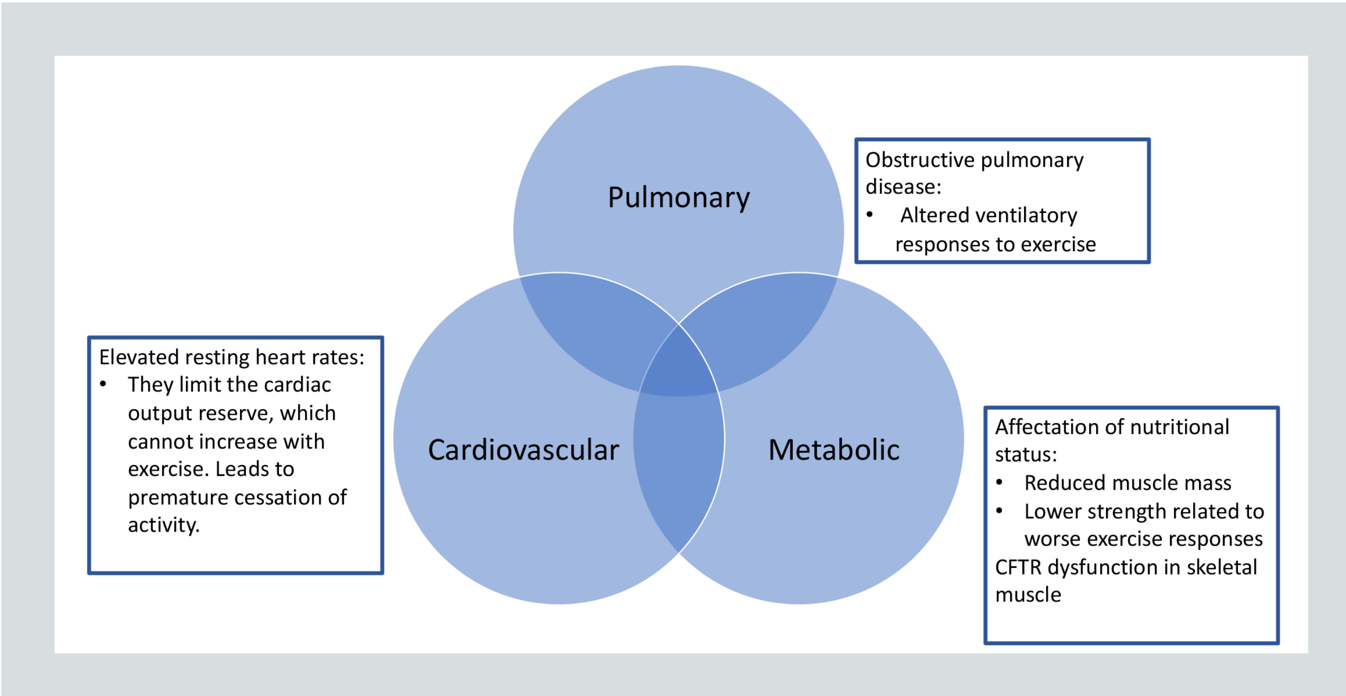

FIGURE 2. Factors involved in the response to exercise in people with cystic fibrosis.

respiratory physiotherapy. A survey of the CF community was published in 2020 and was answered by patients and health-care professionals in 488 of them. Fifty-four percent of patients already incorporated physical exercise into mucociliary clearance techniques, and 48% did not perform physical therapy when they had practiced physical activity. Only 8% of the health-care professionals (9/110) were willing to substitute physical therapy for exercise in selected cases, but 73% (80/110) agreed to conduct a trial by substituting physical therapy for exercise[72]. Exercise is considered one of the five most essential treatments for people with CF[73]. It contributes to improving dyspnea on exertion and exercise tolerance[74]. In addition, when performed regularly, it slows the decline in pulmonary function and facilitates the elimination of secretions[75,76]. Better physical condition has been associated with a lower risk of hospitalization[19]. In addition, it plays an essential role in the control of CF-related diabetes[77].

In 2022, a Cochrane review was published[78], to describe the long-term effects of physical activity on VO_2 peak, lung function (FEV_1), and quality of life. In addition, the authors aimed to identify the most optimal training guidelines for these patients, including the type of exercise, its duration, intensity, and the need for supervision. Twenty-four clinical trials (875 patients) were included, 13 of which included a pediatric population, with sample sizes ranging from 9 to 117 participants. The review showed that training programs lasting more than 6 months improved the physical condition (increase in VO_2 peak) of people with CF compared to those who did not undergo training (mean difference 1.60 mL/min per kg; CI: 0.16-3.05, $p < 0.005$). However, exercise had little or no effect on lung function or respiratory symptoms. The authors concluded that given that exercise's adverse effects are rare and its benefits on physical fitness are evident; its practice can be recommended in CF. The benefits of exercise are likely to depend on the type and duration of training. High-quality studies with larger sample sizes are needed to understand physical exercise's effect better.

In 2022, a team of Spanish researchers[12] published a systematic review with objectives similar to those of Cochrane[78]. The aim was to determine the effectiveness of exercise programs on physical fitness and lung function in people with CF to establish the most appropriate type and dose of exercise. Twelve studies were included, all controlled clinical trials, seven performed in pediatric ages. The interventions in children lasted between 2 and 12 months with training sessions of 60-210 min/week of light or moderate intensity. The types of exercise were resistance in four studies, resistance + neuromuscular stimulation in one, and respiratory muscle training in three. In adults, the interventions lasted 2-6 months; aerobic exercise was performed in three studies, and a combination of resistance + aerobic exercise was performed in two. There were no differences in the FEV_1 after the training programs. In children, there was no improvement in peak VO_2 (mean difference: 0.22; 95%CI: −0.25-0.68; $p = 0.73$), probably due to small sample sizes or the insufficient number of studies. Improvements in muscle strength were observed. In adults, there were statistically significant improvements in VO2peak. The most effective exercise programs use strength or cardiovascular training with high-intensity intervals.

The advent of CFTR modulating therapy has opened up the possibility of change in the response to exercise in people with CF receiving such treatment. As mentioned above, CPET would be the best tool to assess this response[16,22]. In addition, it has been shown that CPET parameters correlate with radiological deterioration[79] and lung clearance index values[80] in CF. Therefore, CPET parameters, especially peak VO_2, have begun to be used as a variable to evaluate the effect of new modulators[81]. However, the published data are limited and inconclusive as to the true impact of modulatory therapy on exercise response[82]. More studies with larger sample sizes will likely be published in the coming years.

INTERSTITIAL DISEASES

Interstitial lung diseases are a heterogeneous group of pathologies that share clinical (dyspnea, cough, and exercise intolerance) and functional characteristics such as decreased total lung capacity, diffusion impairment, or exercise-induced hypoxemia. In these entities, tidal volume cannot be increased when metabolic demand increases during exercise, preventing adequate exercise capacity. The respiratory dynamics during physical exertion are rapid and superficial, further expanding the work of breathing. In these patients, the alteration of gas exchange and circulatory alteration also play an essential role in limiting physical exertion[13]. In childhood, PIDs are infrequent; in Spain, a study published in 2022 calculated a prevalence of 46.53 cases/million children[83]. The studies on exercise in these pathologies are in adult patients, and pediatric data is not available.

One of the first symptoms of interstitial diseases in older children is dyspnea on exertion and desaturation with physical exercise, one of the first functional alterations[84]. Therefore, it would be advisable to evaluate the response to exercise in these patients as soon as possible, using CPET or with the 6MW. Suppose a drop in oxygen saturation ($SatO_2$) occurs during training; in that case, it may be necessary to take interval exercise, respiratory support with nasal cannula oxygen therapy, non-invasive ventilation, or other exercise alternatives such as Nordic walking or downhill training[7].

OTHER CHRONIC LUNG DISEASES

Bronchiolitis obliterans

Bronchiolitis obliterans is a rare and severe chronic obstructive small airway disease. It is produced as a consequence of pulmonary aggression that ends up causing a narrowing and obliteration of the smaller airway. The most frequent etiology in children is post-infectious (PIBO)[23], but it can also occur in the context of some systemic diseases or after lung or hematopoietic progenitor transplantation. The clinical presentation is characterized by persistent respiratory symptoms such as cough, labored breathing, dyspnea, or exercise limitation. In some patients, the symptoms may be silent, especially in the early stages of the disease, making diagnosis difficult. Pulmonary function will show a non-reversible obstructive pattern[85].

Symptoms of physical activity are frequent in patients with bronchiolitis obliterans; however, in the literature, few papers evaluate exercise capacity in this disease nor the role of sport as a treatment.

A systemic review of 2019 in PIBO[86] included four studies[36,87–89] with an adequate methodology that reviewed physical exercise capacity in patients with PIBO. The review included 135 patients (121 with PIBO and 14 healthy) aged between 8 and 23 years. Of the four studies, two used the 6-min test (6MW)[36,89], one used CPET[87], and another used both[88]. The pulmonary involvement of the patients included in the review was moderate–severe. Three of the included papers concluded that exercise capacity was decreased in patients with PIBO[87–89], and one of them found no decrease in distance traveled with the 6MW test[36]. Only one of the included studies had a control group[87]. Sixteen patients with PIBO were compared with a cohort of 14 healthy patients, and a statistically significant difference was found in the % predicted VO_2 max (PIBO: 101% ± 17 vs. healthy 84 ± 15; $p < 0.05$).

Given these results, it seems reasonable to conclude that physical exercise is limited in patients with PIBO. The reason why this occurs is extrapolated from other chronic respiratory diseases. As happens in CF, it appears that low respiratory reversal is also related to low performance[90].

Data still needs to be published on the role of physical exercise as a treatment and what type of exercise should be prescribed for these patients. Still, extrapolating from other chronic respiratory diseases, high-intensity interval exercise seems to be a promising therapeutic option[14].

Primary ciliary dyskinesia

Primary ciliary dyskinesia (PCD) is a rare genetic disease caused by alterations in the function of the cilia. These structures are responsible for secretion clearance, so their dysfunction causes secretions to accumulate in the upper and lower airways[91]. PCD is characterized by recurrent respiratory infections and persistent moist cough; most patients eventually develop bronchiectasis[92]. In addition, since cilia are also present in other organs, such as the reproductive tract, a symptom in adulthood may be infertility.

There are publications on exercise limitation in patients with SCD compared to healthy subjects[93–95]. One published in 2022[93] evaluated maximal inspiratory pressure (MIP), maximal expiratory pressure, muscle strength, and distance traveled in the 6MW in 27 patients with PCD between 6 and 18 years old and in 28 healthy controls. All these variables were lower in the PCD group compared to controls.

The effect of a training program was not found in this literature review.

Bronchopulmonary dysplasia

BPD is one of the main complications of preterm newborns. The improvements in neonatal intensive care have increased the survival of this pathology, but its incidence is stable[96,97]. It is defined as a chronic lung disease caused by intrauterine vascular and pulmonary developmental arrest and affects preterm newborns with low birth weight[98]. These children have increased respiratory morbidity and, at the functional level, an obstructive pattern[99].

Patients with BPD may have a lower respiratory reserve and require adaptations during physical exercise[100]. Several papers have evaluated the response to exercise in patients with BPD. In 2020, a study was published[101] in which the results of cycle ergometry and pulmonary function tests of children with BPD were compared with a control group. Forty-two school-aged children with BPD were included, with lower VO_2 peak, minute ventilation, and workload values compared to the control group. In addition, these children reported respiratory symptoms during exercise more frequently than healthy children. Other studies have obtained similar results, showing a lower physical condition in patients with BPD[102,103]. However, this lack of physical condition is unclear since some works have not found these differences[104,105]. Different reasons have been proposed as to why this limitation to exercise occurs in patients with BPD. Some studies suggest that in preterm infants, with or without dysplasia, there could be a limitation in ventilation[106,107] as well as an alteration of respiratory dynamics during exercise[107].

Few studies have evaluated the impact of exercise programs[108,109]. The only randomized clinical trial with exercise in children with BPD was carried out in Barcelona[109]. A total of 20 patients between 4 and 6 years of age were included. The intervention group underwent an intervallic and resistance training program for 4 weeks. After completing the program, an improvement in meters walked in the 6MW was observed (316.3 ± 31.4 m vs. 376.2 ± 39.5 m; $p = 0.002$).

Although the available data on the impact of exercise programs in patients with BPD are limited, the current results suggest that it could provide benefits.

Lung transplantation

Lung transplantation is a treatment option for children with severe chronic lung disease who do not respond to other treatments or who do not have therapeutic alternatives available to them[110]. The results of pediatric transplantation have improved in recent years. Although it is a complex procedure with short and long-term risks, it can significantly enhance pediatric patients' quality of life and survival[111].

Most studies have shown a reduction in VO_2 peak[112–114] in adults after lung transplantation. Studies in the pediatric population are more limited but present similar results, with a lower tolerance to physical exercise[115–117].

A 2020 systematic review[118] conducted in adults suggests that exercise has a beneficial effect before and after lung transplantation; however, insufficient clinical trials have demonstrated the impact of training programs in these patients. A prospective study was conducted on children, and it investigated the effect of an aerobic and resistance training program on children who had received a pulmonary or cardiac transplant[119]. Two groups were compared: one group of patients performing the training at home and the other at the hospital. The effect of the intervention was measured with the 6MW, with strength and flexibility measures. In both groups, an improvement in walking distance at 3 months and 1 year was targeted (baseline 425.7 ± 109.4 m; 3 months 500.6 ± 93.6 m, $p < 0.001$; 1 year 528.5 ± 66.6 m, $p = 0.001$). One case report involving inspiratory muscle training showed improvements in MIP, FVC, and dyspnea after lung transplantation[120]. This suggests that this type of training could be a line of future research.

Given these results, controlled physical exercise should be integrated into managing patients before and after lung transplantation. Still, more research is needed on the type of training.

DISCUSSION

This work has focused on reviewing the effect of physical exercise in those pathologies where training programs have more evidence, such as asthma or CF. Current data show that training programs improve most respiratory pathologies' physical condition, muscle function, respiratory symptoms, and quality of life[11,45,50,57,78,121]. The effect of exercise on pulmonary function is more controversial; there are insufficient data to show that it improves asthma[45,57] or CF[78]. Regarding quality of life in patients with asthma, the benefits of exercise are less conclusive. Some studies have shown no significant improvement[45], suggesting that this could be because baseline values were good and offered little capacity for improvement[53]. However, other studies[57,62] have observed improvements in the quality of life questionnaires. Despite some variables where the results are more controversial, the benefits and safety of physical exercise in the respiratory pathologies reviewed seem clear. In other chronic lung diseases, physical exercise also seems to play a role in their prognosis; however, with the current evidence available, more clinical trials are needed to confirm its efficacy.

To achieve the benefits of training programs, it is necessary to specify their duration, intensity, type, and dose. However, more data in the literature still needs to be on the best training program for each pathology in the

Table 4. Exercise recommendations for chronic respiratory pathologies

Pathology	Modality	Intensity	Frequency	Duration
Asthma	Aerobic running, bicycling, or swimming	50–75% of VO_2 max	2-3 days/week	30–40 min/session
Cystic fibrosis	Aerobic or anaerobic, or a combination of both	55–65% of maximum heart rate	3-5 days/week	20–30 min/session
Interstitial lung diseases	Aerobic + endurance	60–80% of VO_2 peak	3-5 days/week	20–60 min/session

VO_2 max: maximal oxygen consumption.

pediatric age group. Table 4 shows the type of exercise that has shown the most benefits in each pathology so far[13].

CONCLUSION

Physical exercise is vital in managing chronic respiratory pathologies in childhood, both as a prognostic factor and as a treatment. The response to exercise in patients with chronic lung disease should be evaluated periodically with the stress tests available (CPET and 6MW) in each center. CPET also allows us to plan the training program. Physical exercise benefits symptom control, physical condition, and quality of life. However, it is necessary to know the type of training, dosage, and pattern used to achieve these effects. Combined exercise or high-intensity interval training are good options. Still, more studies with a larger sample size are needed to determine the most appropriate and safe training program for each pathology.

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CONFLICTS OF INTEREST

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Confidentiality of data. The authors declare that no patient data appear in this article. In addition, the authors have acknowledged and followed the recommendations according to the SAGER guidelines, depending on the type and nature of the study.

Privacy rights and informed consent. The authors have followed their institution's confidentiality protocols, obtained informed consent from patients, and received approval from the Ethics Committee. The SAGER guidelines were followed according to the nature of the study.

Use of artificial intelligence to generate texts. The authors declare that they have not used any type of generative artificial intelligence in the writing of this manuscript or for the creation of figures, graphs, tables, or their corresponding captions or legends.

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