

# Progress in Research into the Effectiveness of Pulmonary Rehabilitation in Children with Asthma - A Narrative Review

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**Abstract:** Asthma is the most common chronic respiratory disease in children. It has a serious impact on children's physical and mental health. Pulmonary rehabilitation is a multidisciplinary and comprehensive intervention for patients with chronic respiratory disease, whose major components include breathing training, inspiratory muscle training and exercise training. Pulmonary rehabilitation is a multidisciplinary and comprehensive intervention for patients with chronic respiratory diseases, the main components of which are breathing training, inspiratory muscle training and exercise training. Pulmonary rehabilitation can improve the physical and mental condition of patients with chronic respiratory diseases and promote healthy behaviors. However, there is little research on pulmonary rehabilitation in children with asthma. This review comprehensively evaluated the effect of pulmonary rehabilitation in children with asthma at home and abroad, aiming to provide reference for clinical research on pulmonary rehabilitation in children with asthma.

**Keywords:** bronchial asthma, pulmonary rehabilitation, breathing training, inspiratory muscle training, exercise training

Bronchial asthma, namely asthma, is a respiratory disease characterized by chronic airway inflammation. Asthma has a long course and is prone to recurrent attacks that can cause irreversible damage to the airways.<sup>1</sup> Asthma usually begins in childhood and in the last decade the prevalence of asthma in children has increased from 11.1% to 13.2% worldwide, which is much higher than the prevalence of asthma in adults.<sup>2</sup> It is responsible for considerable global morbidity and health-care costs.<sup>3</sup> It is defined by the history of respiratory symptoms such as wheezing, shortness of breath, chest tightness and cough that vary over time and in intensity, together with variable expiratory airflow limitation.<sup>4</sup> Restricted expiratory airflow results in the lung expansion, which subsequently alters the shape and position of the diaphragm and impairs the functionality of the respiratory muscles.<sup>5</sup>

Rational and standardized medication is an important measure in the current management of asthma.<sup>6</sup> However, Asthma remains poorly controlled in some children even after receiving standardized treatment. At present, at least 20% of children with asthma cannot get good control of their symptoms.<sup>7</sup> Therefore, it is necessary to add complementary therapies to standardized treatment. Pulmonary rehabilitation, as a measure of adjuvant therapy, can develop comprehensive interventions for children based on a comprehensive assessment of the child patients. Specifically, Pulmonary rehabilitation includes exercise training, respiratory exercise, and health education, etc. Recently, Zampogna et al indicated pulmonary rehabilitation plays an important role in the treatment of asthma.<sup>8</sup> This review evaluated the effect of pulmonary rehabilitation in asthmatic children at home and abroad, aiming to help clinical practice of pulmonary rehabilitation in the later stage.

## Application of Pulmonary Rehabilitation

We used the following words to systematically retrieve relevant literature: pulmonary rehabilitation, asthma, Bronchial Asthma, children. There is the extensive scope of research on the rehabilitation of chronic respiratory diseases. The types of diseases suitable for pulmonary rehabilitation include various chronic respiratory diseases, such as COPD, pulmonary hypertension, interstitial lung disease, etc.<sup>9</sup> The corresponding rehabilitation models mainly consist of hospital-centered pulmonary rehabilitation training, home-centered pulmonary rehabilitation training, and telemedicine rehabilitation training. These primarily focus on the exercise training and physical activities of these patients.

## Pulmonary Rehabilitation in Childhood Asthma

The asthma process includes acute exacerbation, chronic persistence, and clinical remission.<sup>10</sup> The chronic persistent and clinical remission phases of asthma are relatively stable and thus children in these two stages have few or no respiratory symptoms. An expert consensus<sup>11</sup> indicates that the strengthening and standardisation of treatment and rehabilitation management of children with chronic airway inflammatory diseases in remission is important for reducing the risk of acute exacerbations, improving motor function, facilitating the restoration of a normal developmental trajectory of lung function, reducing irreversible airflow limitation, and improving the quality of life. It is also recommended that once childhood asthma has stabilised into remission, rehabilitation and management can be initiated for different diseases.<sup>12</sup>

## Impact of Pulmonary Rehabilitation on Children with Asthma

The study by Liu et al suggested that the pulmonary rehabilitation programme can effectively improve exercise tolerance and lung function in children with asthma improve their asthma control and quality of life, and reduce the number of acute exacerbations and hospitalisation in the later stages of asthma, which is of high value for promotion and application.<sup>13</sup> Currently, pulmonary rehabilitation programmes for children with asthma include respiratory training, exercise training, inspiratory muscle training, health education, psychological and nutritional guidance. [Table 1](#) summarized basic information of the relevant studies, including study design, sample characteristics follow-up time, etc.

## Breathing Training

Breathing training is one of the main training programmes in pulmonary rehabilitation, and studies have shown that children with asthma have expiratory difficulties and movement limitations. Restricted expiratory airflow causes the lungs to expand, thus changing the shape and position of the diaphragm and decreasing the function of the respiratory muscles.<sup>26</sup> Breathing training is the training of muscles with respiratory function by applying a certain load resistance during expiration and inhalation of the body, adjusting the respiratory rate, increasing muscle strength and endurance, and increasing the coherence of the mental, neural, immune, and cognitive systems, which can positively affect the patient's recovery. Breathing training mainly includes lip-contraction breathing, abdominal breathing and partial breathing.

Prem et al<sup>14</sup> studied the effect of Buteyko breathing training on children with asthma and the results showed that in children with asthma, the addition of Buteyko training to conventional treatment improved results in spirometry and parental emotional functioning, but there was no significant difference between the two groups in terms of changes in the dose of bronchodilator medication, which may be related to the shorter duration of the intervention and requires continued attention at a later stage.

A systematic review of diaphragmatic breathing exercises and quality of life in children with asthma showed that respiratory training using the diaphragm slowed down one's breathing, thus reducing excessive ventilation, and improving quality of life in asthmatics.<sup>15</sup> To study the effect of diaphragmatic breathing exercise applied in patients with cough variant asthma, the results showed that diaphragmatic breathing exercise can effectively improve patients' lung function, regulate serum immune indexes and improve diaphragm function.<sup>16</sup>

Current studies have shown that different respiratory training methods can improve lung function to different degrees, but there are no studies comparing which respiratory training methods can bring the best results for asthmatic children, and future studies can further explore this. There is a wide variation in the description of the duration of respiratory training between national and international studies, and no guidelines have been issued to recommend this.

**Table 1** Basic Characteristics of Relevant Studies

Literature	Study Design	Sample Characteristics		Intervention	Control	Frequency	Follow-Up Time	Outcome Indicators	Conclusion
		Sample Size T/C	Study population						
Prem 2013 <sup>14</sup>	Randomized controlled trial	Buteyko group 39/pranayama group36/control 40	18 to 60 years patients with asthma	Buteyko training and pranayama training	Followed routine physician care involving pharmacological management.	15 minutes twice daily, 3–5 days	Three months	Asthma quality of life questionnaire, asthma control questionnaire and pulmonary function n fev1 and FEV1/FVC	The Buteyko group showed better trends of improvement in quality of life and asthma control than the group performing the pranayama breathing exercise.
Prem 2013 <sup>15</sup>	Systematic review	Three RCTs were eligible for inclusion (254 subjects), ranged from 31 to 183 individuals	Mean age ranged from 45 to 48	Two studies compared diaphragmatic breathing exercise to asthma education; one compared with asthma medication		10 to 20 minutes each day, 2–3 times	6 months	Quality of life (QoL)	There is moderate evidence of improvement in QoL following diaphragmatic breathing both in short-term and long-term basis.
Li luoyao 2022 <sup>16</sup>	Randomized controlled trial	59/58	18 to 75 years patients with asthma	Diaphragm deep breathing training	Routine breathing training	3 to 5 minutes each time, 2 times each day	Three months	FVC, FEV1, PEF, IgE, IL-4, TNF- $\alpha$ , DTEI, DTF	Diaphragmatic deep breathing training applied to respiratory rehabilitation of cva patients can effectively improve patients' pulmonary function, regulate serum immunity indexes and improve diaphragm function.
Liu rui 2022 <sup>17</sup>	Randomized controlled trial, prospective study.	51/55	4 to 12 children with asthma	Imt	Asthma follow-up and education	20–30min each time, 1–2 times a week	Three months	FVC, FEV1, PEF, FEF25, FEF50, FEF75, pedsqI	Inspiratory muscle training is safe and effective for children with asthma, which can reduce symptoms, improve quality of life and improve pulmonary function in children with asthma
Elnaggar 2021 <sup>18</sup>	Randomized controlled trial	17/17	12 to 16 children with asthma	IMT at 40% of the maximal inspiratory pressure(IPmax)	Placebo IMT at 5% of IPmax	20min/ session	Three months	FVC, FEV1, PEF, FEF25, FEF50, FEF75, PedsQL	IMT can improve respiratory function, enhance respiratory muscle strength, and improve children's perception of asthma symptoms.
Elnagga 2023 <sup>19</sup>	Randomized controlled trial	In/Ex-SC group17/In-MT group17/placebo group17/	12 to 18 children with asthma	The In-MT group performed 6 sets of inspiratory muscle training succeeded by 6 sets of no-load training, totaling 12 sets. The In/Ex-SC group performed 12 sets of combined training of the inspiratory and expiratory muscles within the same cycle	Placebo training no-load respiratory muscle training	35min each time, 3 times a week	Three months	FVC, FEV1, FEV1/ FVC, MIP, MEP, ACT	Combined In/Ex-SC can considerably improve respiratory muscle strength, enhance pulmonary function, and promote control over asthma symptoms children and adolescents with bronchial asthma

(Continued)

Table I (Continued).

Literature	Study Design	Sample Characteristics		Intervention	Control	Frequency	Follow-Up Time	Outcome Indicators	Conclusion
		Sample Size T/C	Study population						
Yin MO 2021 <sup>20</sup>	A meta-analysis	A total of 10 publications including 456 patients were included	8 to 75 years patients with asthma	IMT	Placebo training or Routine breathing training	/	Ranged from 6W to 3 months	FVC, FEV1, PEF MIP, 6MWT, Dyspnea scale, quality of life.	Threshold pressure inspiratory muscle training can significantly improve patients' lung function indicators, enhance respiratory muscle strength, reduce dyspnea, and increase 6-min walking distance in asthmatic patients, but the effect in improving quality of life is not significant
Liu yiran 2012 <sup>21</sup>	A meta-analysis	A total of 22 RCTs involving 1346 patients were included ranged from 14 to 156 individuals	6 to 15 years children with asthma	Exercise was based on routine treatment, including aerobic training (swimming, ball games, rope skipping, jogging, and cycling), strength training, and balance and coordination training	Routine treatment includes medication, nutritional support, family breathing exercises, or routine activities without exercise.	/	Ranged from 2w to 4 months	FVC, FEV1, FEF25–75, PEF, 6MWT, RPE, PEAK POWER (PP). PAQLQ	Current evidence shows that exercise has a certain effect on improving pulmonary function recovery, exercise capacity, and quality of life in children with bronchial asthma.
Abdelbasset 2018 <sup>22</sup>	Randomized controlled trial	19/19	8 to 12 years children with asthma	Aerobic exercise	Conventional treatment	Three times each week	10 weeks	VO2max, 6MWT, and fatigue index, PQoL, FEV1, FVC	Ten weeks of physical exercise had beneficial effects on pulmonary functions, aerobic capacity, and pqol in school-aged children with asthma
Cox 2018 <sup>23</sup>	Randomized controlled trial, prospective study.	Swimming 9/ football 9/ basketball 11/ control 12	9 to 15 years children with asthma	Swimming training, football training and basketball training	Conventional treatment, did not take part in any regular exercise programme	Forty minutes once a week.	6 weeks	FVC, FEV1, FEV1/ FVC, PEF	Swimming training program is more beneficial in terms of peak flow measurements when compared with other exercise training programs.
Shen 2021 <sup>24</sup>	Randomized controlled trial	48/47	5 to 14 years children with asthma	Bird exercise in Wuqinxi	Routine pulmonary rehabilitation programme	Two times at a time, once a day	Three months	FEV1, FEV1/FVC, PEF, ACT, PedsQL	Bird exercise in Wuqinxi is effective in improving pulmonary function, symptom control and quality of life of asthmatic children
Lisag 2011 <sup>25</sup>	Randomized controlled trial	Nonobese37/ obese14/ Nonobese healthy21	Older than 18 years with stable asthma were recruited	A high-fat meal or low-fat meal	A high-fat meal	/	4 hours	FEV1, FEV1/FVC, sputum cell counts and Toll-like receptor 4 mRNA expression, ELISA quantification of plasma TNF- $\alpha$ , high-sensitivity C-reactive protein, and IL-6 concentrations	A high-fat meal augments neutrophilic airway inflammation, with the effect dependent on the type of fat consumed. A high-fat meal also suppresses bronchodilator recovery in asthma.

## Inspiratory Muscle Training

The increased work done by the inspiratory muscles may cause fatigue of the inspiratory muscles, which over time may result in a decrease in the child's maximal respiratory capacity and maximal exercise tolerance.<sup>27</sup> Inhalation muscle training (IMT) is an important form of exercise in pulmonary rehabilitation. Inspiratory muscle training (IMT) is an important form of exercise in pulmonary rehabilitation that improves the strength and tolerance of the thoracic and extrathoracic muscles, thereby relieving the symptoms of asthma.

Current studies have shown that inspiratory muscle training can improve the symptoms of asthma in children, but the effect on the quality of life is still controversial. In the study of Liu Rui et al,<sup>17</sup> 106 children with asthma aged 4 to 12 years were selected as the research objects and divided into 2 groups by the method of randomized control. 51 children in the experimental group received inspiratory muscle training and routine asthma health education and follow-up. 55 children in the control group received routine asthma health education and follow-up. After 3 months, the subjects were followed up for daytime symptoms, nighttime symptoms, quality of life scores, pulmonary function indexes and adverse reactions during training. The results showed that FVC (%pred), FEV1 (%pred), PEF (%pred), FEF25 (%pred), and the total score of quality of life in the inspiratory muscle training group were significantly higher than those in the control group ( $P < 0.05$ ). Compared with the control group, the scores of daytime and nighttime symptoms in the experimental group were lower. All were statistically significant ( $P < 0.05$ ). The results show that inspiratory muscle training can reduce the symptoms, improve the quality of life and improve lung function in children with asthma. This is consistent with the findings of Elnaggar<sup>18,19</sup> et al.

A total of 10 randomized intervention studies were included in the study of Imer,<sup>20</sup> including 456 patients with asthma aged 8 to 75 years. The effect of threshold pressure load inspiratory muscle training on pulmonary rehabilitation and quality of life of asthma patients was evaluated through meta-analysis. The results showed that: Threshold pressure loading inspiratory muscle training improved forced vital capacity [SMD=0.90, 95% CI (0.68, 1.11),  $P < 0.001$ ], forced expiratory volume in one second [SMD=0.62, 95% CI (0.41, 0.83),  $P < 0.001$ ], peak expiratory flow rate [WMD=0.32, 95% CI (0.01, 0.62),  $P = 0.040$ ], maximum voluntary ventilation [WMD=11.89, 95% CI (6.42, 17.37),  $P < 0.001$ ], enhanced maximum inspiratory pressure [SMD=29.76, 95% CI (18.15, 41.36),  $P < 0.001$ ], reduced the degree of dyspnea [SMD=-0.51, 95% CI (-0.95, -0.06),  $P < 0.001$ ], prolonged the 6-minute walking distance [WMD=77.13, 95% CI (24.58, 129.67),  $P = 0.004$ ], but there was no significant difference in improving the quality of life of patients [SMD=1.21, 95% CI (-2.11, 4.52),  $P = 0.480$ ].

More high quality clinical studies are needed to further validate the effectiveness of inspiratory muscle training in the management of childhood asthma.

## Sports Training

Some asthmatic children and their parents reduce exercise for fear that it will trigger an acute asthma attack. According to the Global Initiative for Asthma (GINA)<sup>21</sup> Regular exercise of moderate or higher intensity is more beneficial to children with asthma than to the general population, and promotes mental recovery and respiratory function in children with asthma. The study found that<sup>22,23</sup> Standardised treatment with exercise training can improve children's exercise tolerance, quality of life and lung function. Aerobic training in children with asthma promoted asthma control, quality of life, asthma symptoms, psychological distress, physical activity and airway inflammation.

Regarding the form of exercise, Cox<sup>24</sup> et al compared the effects of three sports such as swimming, football and basketball on children with asthma, and the results suggest that swimming is more advantageous in improving maximal expiratory flow compared to other sports. Other forms of exercise, eg, resistance exercise, have not attracted enough attention for asthma control, such as the five birds and the eight danjins.<sup>28</sup>

Short-term exercise is not conducive to the improvement of cardiorespiratory fitness, and long-time exercise can easily lead to fatigue accumulation, which not only affects the effect of exercise, but also may cause accidental injury. Therefore, exercise for children with asthma should start with a preliminary plan that is suitable for the individual characteristics of the child, and gradually reach the exercise goal, which includes the frequency of exercise, intensity of exercise, mode of exercise, time of exercise, total amount of exercise, and the process of

implementing the exercise prescription.<sup>29</sup> The following is an example of the process of implementing an exercise prescription. However, the descriptions of exercise time and frequency in children with asthma in the current study are inconsistent,<sup>30</sup> and a more reasonable exercise training programme for pulmonary rehabilitation needs to be developed at a later stage.

## Health Education

An Italian croup survey<sup>31</sup> found that about 40% of caregivers (mainly mothers) believe that asthma medication should be used only when the child has symptoms (cough, congestion or wheezing); a survey conducted in China for parents of 2960 asthmatic children showed that only 18.31% of parents answered more than 60% of the asthma-related questions correctly, and the lack of parental awareness of asthma and the lack of attention to asthma directly leads to a gap between the actual management of asthma and the expected level of control. Inadequate parental knowledge and attention to asthma will directly lead to a gap between actual management and expected control.<sup>25</sup> The lack of parental awareness and attention to asthma will directly lead to a gap between actual management and expected control.

Health education, as part of comprehensive rehabilitation for children with asthma, can change the medication behaviour of children and primary caregivers, help improve treatment adherence, enhance acute attack management ability and avoid triggers, thus facilitating asthma control. The content of health education includes the principles of asthma prevention and treatment, the methods and purposes of pulmonary rehabilitation, etc. The form of education is based on oral explanation by medical staff in the hospital, popular science magazines and books, and with the advent of the Internet era, there has been a gradual shift to the Internet of Things, artificial intelligence technology and social software (Jitterbugs, WeChat Groups), and so on.

## Nutritional Guidance

Food and nutrition play a role in the development, progression and control of asthma. Obesity is a risk factor for the development of asthma and increases dyspnoea and dyskinesia. High fat intake exacerbates respiratory inflammation, and studies have shown that sputum neutrophil counts increase in asthmatics 4 h after consumption of high-fat foods.<sup>32</sup> A diet rich in vitamins C and E, carotenoids, flavonoids and selenium provides antioxidants that reduce oxidative stress, assist in anti-inflammatory effects, and help to reduce asthma symptoms; vitamin D protects against respiratory infections and inflammatory diseases, and has an immunomodulatory and airway remodelling effect in children with asthma. Vitamin D can protect against respiratory infections and inflammation, and has an immunomodulatory and airway remodelling effect in children with asthma. The above studies suggest that establishing and providing a rational dietary and nutritional programme for children with asthma and evaluating the role of diet in asthma, as well as actively intervening in obesity, is necessary for children with asthma.

## Psychological Support

Asthma is a physical and mental disease, psychological factors in the occurrence and development of asthma plays an important role in the whole process. Overseas scholars of more than 7000 children and adolescents cross-sectional survey analysis found that the total prevalence of asthmatic adolescents with anxiety disorders as high as 22.7%, which is three times as high as the healthy population.<sup>33</sup> The prevalence of anxiety disorders among adolescents with asthma was 22.7%, three times that of the healthy population. The study shows that [34] among children with asthma, anxiety- and depression-related psychological disorders can lead to emergency room visits and a higher frequency of asthma attacks in children with asthma. Academics recommend that healthcare providers make appropriate referrals to mental health services as part of developing and monitoring asthma treatment plans for adolescent patients. Psychological interventions, which can be delivered in a variety of ways, including boot camps, phone calls, and the Internet, after assessment of psychological status with a specialist medical (nurse) practitioner, can increase the child's sense of security and improve treatment adherence. The psychological state of the child and his/her parents can facilitate or hinder the management of childhood asthma. For children with poorly controlled asthma, healthcare professionals should conduct psychological assessment of the child and his/her family for psychological support and intervention.

## Discussion and Summary

Above all, the implication of this study is as follows:

1. Several studies have shown that pulmonary rehabilitation is effective in controlling asthma symptoms, reducing asthma exacerbations, improving children's quality of life, and improving lung function.
2. It is noted that there are still some deficiencies and controversies in pulmonary rehabilitation research. At present, a unified pulmonary rehabilitation training method and effect assessment method have not been developed, and the results present a large variability.
3. More high-quality, large-sample randomised controlled trials are needed to confirm the therapeutic effect of pulmonary rehabilitation on children with asthma.
4. Pulmonary rehabilitation should be individualised and comprehensive, but how to develop individualised pulmonary rehabilitation programmes and training plans, and how to standardise the evaluation of the efficacy of pulmonary rehabilitation are problems that need to be solved in the treatment of children with asthma.

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