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CLINICAL TRIAL REPORT

The Effects of Combined Respiratory Muscle and Exercise Training in Children with Bronchial Asthma: A Randomised Controlled Study

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Objective: To investigate the effects of combined respiratory muscle and exercise training on inspiratory muscle strength, exercise capacity, spirometry measurements, asthma control the quality-of-life in children with asthma.

Methods: Fifty children with asthma, who were treated in children's hospital of Chongqing medical university in Chongqing between May and December 2021, were selected and randomly divided into a rehabilitation group and a control group by using a random number table. The control group was given routine drug treatment and health education while the rehabilitation group received a combination of respiratory muscle and exercise training on the basis of control group.

Results: After three months of treatment, the maximum inspiratory pressure, level of asthma control and quality-of-life in the rehabilitation group were significantly improved when compared with those in the control group ($P<0.05$); there were no significant differences in the 6-minute walking test and spirometry measurements ($P>0.05$). After three months of treatment, all outcome indicators in the rehabilitation group were significantly improved when compared to those before treatment ($P<0.05$). The mean value of maximum inspiratory pressure and some indices of spirometry measurements in the control group were significantly improved when compared to those before treatment ($P<0.05$).

Conclusion: Combining respiratory muscle and exercise training on the basis of the routine drug treatment and health education significantly improved inspiratory muscle strength, the level of asthma control and the quality-of-life in children with asthma. More research is needed to explore its role in asthma in the future.

Keywords: training, bronchial asthma, children, respiratory muscles, exercise capacity, spirometry measurements, asthma control level, quality of life

Background

Bronchial asthma is the most common chronic respiratory disease in childhood and the prevalence of this condition is increasing on an annual basis. The results of the 3rd National Pediatric Asthma Epidemiological Survey showed that the prevalence of asthma in children under the age of 14 was 3.02%, an increase of 53.3% when compared to data recorded 10 years previously.[1] The main goal of asthma treatment is to achieve good symptom control and reduce the risk of future attacks.[2] However, the level of asthma control in children in China is not satisfactory; approximately 20% of children with asthma are uncontrolled.[3] The Global Initiative for Asthma (GINA) reported that non-drug therapy should be considered in cases of unsatisfactory drug treatment.[4] Over recent years, respiratory rehabilitation has been widely used as a non-drug treatment for chronic respiratory diseases. Respiratory rehabilitation is an individualized comprehensive intervention that follows comprehensive evaluation of a patient, and includes exercise training, education, and behavioral changes. The aim of respiratory rehabilitation is to improve a patient's physical and emotional status and promote long-term adherence to health-enhancing behaviors.[5] Therefore, clinicians can guide children with asthma to apply respiratory rehabilitation on the basis of standardized treatment in order to achieve improved benefits.

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At present, respiratory rehabilitation is seldom used in children with asthma; most children received a combination of respiratory training (pursed lip breathing and Buteyko breathing) and exercise training to improve exercise ability, asthma control and quality-of-life in children.[6–8] However, previous research has shown that children experience difficulty in exhalation and limitations associated with exercise limitation; they are also limited by the fact that expiratory airflow can change the shape and position of the diaphragm and reduce the function of the respiratory muscles.[9] At present, there are no reports relating to the combination of respiratory muscle training to the respiratory rehabilitation program in China. Based on this shortfall, in the present study, we combined respiratory muscle training and exercise training to formulate a home rehabilitation program and examined the efficacy of this new strategy.

Methods

Study Design

The study has undergone clinical registration (ChiCTR2100049173) and ethical review ((2021) Lun Shen (Yan) No. (168)).The study was a randomised controlled study. This study has been reported in line with Consolidated Standards of Reporting Trials (CONSORT) Guidelines and complies with the Declaration of Helsinki. Patients were randomly allocated using a random number table. Random allocations were sequentially numbered in sealed opaque envelopes, which were opened before grouping. Asthma clinic nurses generated random sequences, respiratory physicians recruited participants, and specialist pediatric respiratory nurses intervened.

Subjects

Convenience sampling was used to recruit 50 children with asthma who visited the department of respiratory disease of children's hospital of Chongqing medical university in Chongqing between May 2021 and October 2021. A parent or legal guardian of all children provided informed consents.

The inclusion criteria were as follows: (1) 5–12 years-of-age; (2) met the diagnostic criteria described by the "Recommendations for Standardized Diagnosis and Treatment of Bronchial Asthma in Children (2020 Edition)";[10] (3) dysfunctional lung function despite standardized inhaled asthma drugs for ≥12 months with a positive provocation test; (4) No previous respiratory rehabilitation treatment; (5) family members of the children had sufficient communication skills (reading and writing), and (6) voluntary enrollment.

The exclusion criteria were as follows: (1) acute exacerbation of asthma; (2) the co-existence of other respiratory system diseases (such as bronchopneumonia and bronchopulmonary dysplasia), cardiovascular system diseases (myocarditis and congenital heart disease), motor nervous system diseases; (3) the presence of mental disorders or the patient had psychological abnormalities and could not cooperate.

Withdrawal and termination criteria were two-fold: (1) if a child was not suitable to continue with the trial for any reason or (2) if the child or the family wished to withdraw or terminate the trial under any circumstances.

The children were randomly divided into an experimental group and a control group using a random number table. There were 25 cases in the rehabilitation group (18 males and 7 females) and 25 cases in the control group (14 males and 11 females).

Intervention Methods

Control Group Intervention

Specialist pediatric respiratory nurses evaluated the medication for each child and guided each child on a one-to-one basis so that they mastered the correct medication process and methods. The nurses also informed the children and their parents that they should follow the doctor's advice for long-term, standardized and personalized medication. Children diagnosed with allergic asthma were instructed to avoid contact with allergens to prevent asthma attacks. The nurses also distributed asthma health booklets and videos regarding to the use of asthma medicines.

Rehabilitation Group Intervention

Research Team

The research team included three pediatric respiratory specialists, three pediatric respiratory specialist nurses, two nursing postgraduate students and one pediatric rehabilitation specialist.

Development of a Home Rehabilitation Plan

The home-based rehabilitation plan was revised based on the "Home-based Implementation Plan for Respiratory Rehabilitation in Children with Bronchial Asthma" constructed by a previous research group in collaboration with Delphi experts, and was determined after reviewing a large amount of literature, summarizing previous clinical intervention experiences and by discussion with members of our research group. The rehabilitation program content featured respiratory muscle training with a threshold pressure load trainer. First, in the outpatient clinic, the maximum inspiratory pressure (MIP)for each child was determined by Breathelink k2 muscle strength tester produced by Suyun Instrument Effective Company in Jiangsu, China. Then, the pediatric rehabilitation specialist selected the appropriate training value for each child. The training load started at 40% MIP. Subsequently, the training situation was evaluated every week. The training gear was adjusted from low to high according to the individual conditions of each child.[11] Muscle strength training was carried out 2 times/day for 15min/time. Children were required to quickly breathe the tricolor balls at the same time and then relax when all the tricolor balls reached the top. When the muscle strength training gear reached the highest value, we commenced alternate weeks of muscle endurance and muscle strength training. Muscle endurance training was carried out 2 times/day for 15min/time. During endurance training, each child was required to blow and suck the ball for three seconds or more.

For the exercise training, the child was able to select their aerobic exercise such as jogging, swimming, skipping or playing basketball. The specific form of exercise was determined according to each child's preference. Heart rate should initially reach a moderate intensity of 40–59% of the maximum predicted heart rate (208-[0.7 × age]) and then gradually increase to a high intensity of 60–70% of the maximum predicted heart rate; the specific protocol was as follows: 3–5 times/week, at least 30 min/time, including 5–10 min in the warm-up stage, more than 20 min in the formal training stage, and 5–10 min in the relaxation stage.[12] Several factors needed to be considered. First, respiratory muscle training: The training gear should not cause the child to move his/her shoulder or feel that the task is laborious; this prevents respiratory muscle fatigue and the formation of conflicting behavior. In addition, the speed should not be too fast: if the respiratory rate is too fast, then the patient will be forced to pause for a few seconds after each forced breath to avoid excessive breathing and lightheadedness. Secondly, for the exercise training, it is important to avoid exercise-induced bronchoconstriction (EIB). After enrollment, children were given a peak flow meter and taught how to use it. A peak expiratory flow (PEF) $\geq$ 80% of the predicted value was required. It was important to select a suitable exercise environment (for example, to avoid inhaling supercooled air to stimulate the bronchi), conduct adequate warm-up preparations before exercise and, if necessary, use inhaled short-acting β2 receptor agonists or oral leukotriene antagonists 10–15 minutes before exercise. Furthermore, exercise training needs to be carried out in the company of family members. If there are adverse reactions such as chest tightness, cough, and shortness of breath during exercise, the exercise should be stopped immediately and a short-acting β2 receptor agonist should be used if necessary.

Implementation of Home Rehabilitation Programs

Combined respiratory muscle training and exercise training was undertaken on the basis of the routine drug treatment and health education. Specialist pediatric respiratory nurses guided and evaluated the training videos uploaded by the children in the rehabilitation group every day and conducted online or telephone follow-up visits for the two groups of children and their families every week. One-to-one follow-ups were carried out in outpatient clinics after three months when children are reexamined in outpatient clinics.

Outcomes

On the day of enrollment and 3 months later, outcomes were measured by specialist pediatric respiratory nurses in the asthma clinic.

Primary Outcome Measures

Inspiratory Muscle Strength

Inspiratory muscle strength can be determined by measuring the MIP.[13] MIP was measured using the Breathlink k2. Prior to the muscle strength test, we taught each child the specific operation method. For example, we instructed the child to

take an upright position, exhale slowly to the end of expiration, then immediately wrap the mouthpiece and inhale quickly to the end of inspiration; the speed was ≥ 30L/min. After the child had mastered the procedure, he/she performed five effective inhalations; the mean and maximum values for the MIP were measured by the muscle strength tester.

Athletic Ability

Exercise capacity was measured using the 6 minutes walking test (6MWT). The children walked back and forth as fast as possible in a straight line (30 m long) on flat ground for 6 min; the last step when the researcher shouted "stop" was used as the end point to measure the 6 minutes walking distance (6MWD). During the walking process, the children were reminded of the remaining time every 1 min and were stopped immediately if symptoms occurred, such as shortness of breath, dyspnea and chest tightness.

Spirometry Measurements

Spirometry measurements was measured using a lung function tester (JAEGER, Germany).We instructed the child to take an upright position, keep their head level, attach a nose clip, wrap the inflator tightly with their lips, and exhale at the fastest speed after the maximum inhalation. Measurement indicators were as follows: forced vital capacity (FVC), forced expiratory volume in one second (FEV1), one-second rate (FEV1/FVC), peak expiratory flow (PEF), maximum expiratory flow at 75% of vital capacity (MEF75), the maximum expiratory flow at 50% of vital capacity (MEF50), the maximum expiratory flow at 25% of vital capacity (MEF25) and the mid-forced expiratory flow rate (MMEF75/25). The percentage (%) of the actual value to the expected value was used for data analysis.

Secondary Outcome Measures

Asthma Control

The level of asthma control was measured using the children-asthma control test (C-ACT) which was answered by recalling the severity of clinical symptoms over the past 4 weeks. The C-ACT questionnaire was used for children aged 4–11 years, with a total of 27 points and 7 questions. Questions 1–4 were completed by the children and questions 5–7 were completed by the parents.

Quality-of-Life

Quality-of-life was measured using the pediatric quality of life inventory ™ (PedsQL™) 3.0 asthma module and 4.0 generic core scales; these were answered by recalling the severity of problems over the past 4 weeks.[14] The PedsQL™ 3.0 asthma module has a total of 112 points and 28 questions, including four dimensions: asthma, treatment, worry and communication. The PedsQL™ 4.0 generic core scale features 92 points and 23 questions, including four dimensions: physical, emotional, social and school functioning. Children aged 5–7 years filled out the forms with the help of medical staff while children aged ≥8 years filled out the forms by themselves.

Statistical Analysis

The IBM SPSS, version 23 was used for statistical analysis. If the data were continuous variables and conformed to a normal distribution, then the paired-samples *t*-test was used for intra-group comparisons; the independent-samples *t*-test was used for between-group comparisons. Data are expressed as mean ± standard deviation. The Mann–Whitney test was used along with the *U*-test or Wilcoxon rank-sum test and expressed as median and quartile. Categorical data were expressed by frequency distribution, constituent ratios and percentages. The Chi-squared test was used and rank data were analyzed by the rank sum test. $p<0.05$ was considered statistically significant.

Results

Normal Information

All patients completed testing and trials (Figure 1). There was no significant difference between the two groups in baseline ($p>0.05$), see Table 1

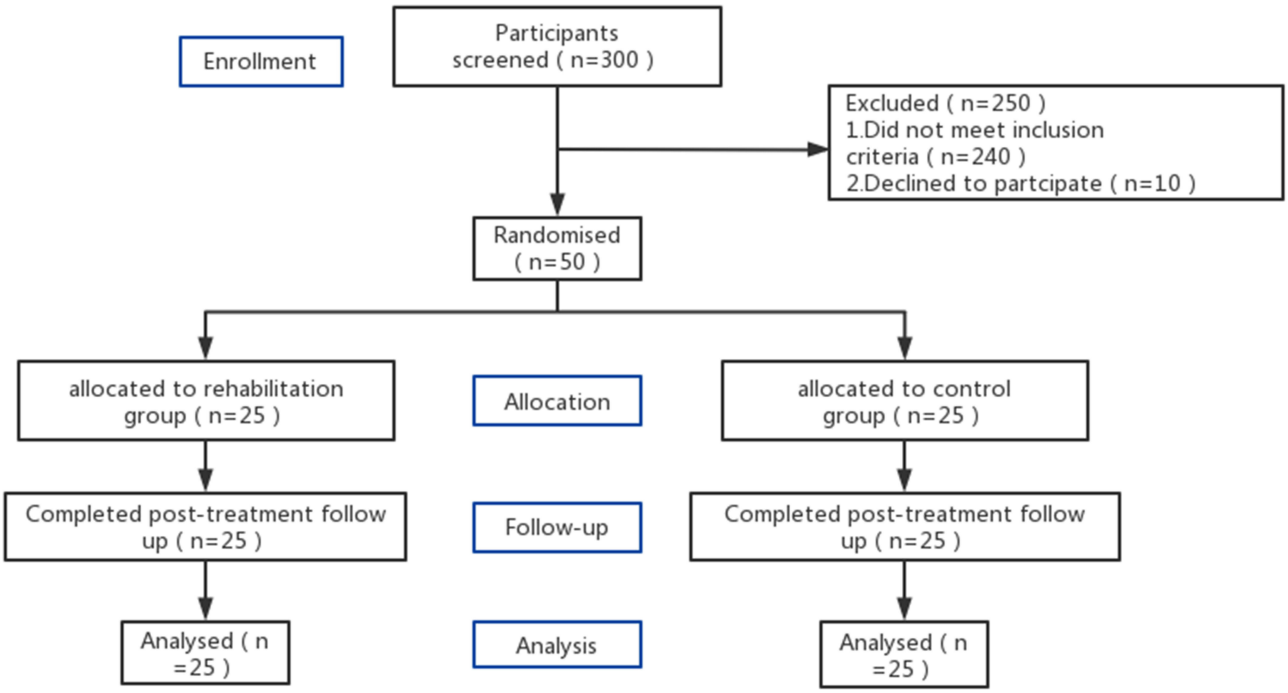

Figure 1 A flowchart illustrating children's recruitment and retention.

Comparison of MIP Between the Two Groups Pre- and Post-Treatment

Before treatment, there were no significant differences in the mean and maximum values of MIP between the two groups (P>0.05), see Supplementary Table 1. After treatment, the mean and maximum values of MIP in the rehabilitation group were higher than those in the control group and before treatment (P<0.001). The mean value of MIP in the control group was higher than that before treatment (P<0.001), see Table 2.

Comparison of the 6MWD Between the Two Groups Pre- and Post-Treatment

There was no significant difference in the 6WMD between the two groups when compared before and after treatment (p>0.05), see Supplementary Table 1. However, after treatment, the 6MWD of the rehabilitation group was significantly improved when compared with that before treatment (p<0.001), see Table 2.

Table 1 Comparison of General Data Between the Two Groups

Projects		Rehabilitation Group (n=25)	Control Group (n=25)	p
Age, years Mean (SD)		9.08±2.25	9.45±2.56	0.597
Gender n(%)	Male	18 (72)	7 (28)	0.239
	Female	14 (56)	11 (44)	
Disease duration, years Median (IQR)		4 (2.75~6.00)	4 (2.50~5.00)	0.667
Height, cm Mean (SD)		139.40±15.96	137.04±16.08	0.605
Weight, kg Median (IQR)		32 (24.00~41.00)	30 (23.00~37.00)	0.331
BMI Mean (SD)		17.09±2.54	16.00±1.91	0.091
Primary caregiver education level n (%)	Elementary school and below	0 (0)	2 (8)	0.424
	Junior school	3 (12)	3 (12)	
	High school/technical Secondary school	8 (28)	9 (36)	
	University/college	13 (56)	9 (36)	
	Postgraduate	1 (36)	2 (8)	
Impact of asthma on family economy n (%)	No impact	11 (44)	5 (20)	0.266
	Mild impact	10 (40)	18 (72)	
	Moderate impact	4 (16)	1 (4)	
	Severe impact	0 (0)	1 (4)	

Table 2 Comparisons of Outcome Measures Between the Two Groups Post-Treatment

Outcome Measures	Pre-Treatment		Post-Treatment		Post-Treatment P-value
	Rehabilitation Group	Control Group	Rehabilitation Group	Control Group	
MIPmean Median (IQR)	39.1 (30.88~49.66)	39.56 (32.09~44.25)	53.11 (41.91~64.89)	45.81 (36.70~52.70)	0.031*
MIPmax Median (IQR)	52.3 (44.84~63.63)	49.39 (42.46~56.39)	61.27 (56.99~76.57)	50.92 (42.28~63.88)	0.003*
6MWD Mean (SD)	564.80±75.04	580.72±74.02	599.68±64.39	588.14±50.03	0.483
C-ACT Median (IQR)	25.0 (23.00~25.00)	25.00 (23.00~26.00)	25.00 (25.00~27.00)	25.00 (24.00~25.50)	0.038*

Note: *P<0.05.
Abbreviations: MIP, maximum inspiratory pressure; 6MWD, 6 minutes walking distance; C-ACT, Children-Asthma Control Test.

Comparison of Spirometry Measurements Between the Two Groups Pre- and Post-Treatment

There were no significant differences in the indices of spirometry measurements between the two groups when compared before and after the treatment (p>0.05), see Supplementary Table 1. However, after treatment, all indices in the rehabilitation group were significantly improved when compared with those before treatment (p<0.05). Some indices in the control group (FEV1/FVC%, MEF50%, MEF25%, and MEF75/25%) were significantly improved when compared with those before treatment (p<0.05), as shown in Table 3.

Comparison of the Level of Asthma Control Between the Two Groups Pre- and Post-Treatment

Before treatment, there was no significant difference in the level of asthma control between the two groups (p>0.05), see Supplementary Table 1. After treatment, the level of asthma control in the rehabilitation group was significantly higher than that in the control group and before the treatment (p=0.002), as shown in Table 2.

Comparison of the Quality-of-Life Between the Two Groups Pre- and Post-Treatment

Before treatment, there was no significant difference in the total scores of the asthma module and the generic core scales and the scores of each dimension when compared between the two groups (p>0.05), see Supplementary Table 1. After treatment, the total scores of the asthma modules and the generic core scales in the rehabilitation group were significantly lower than those in the control group and before treatment (p<0.05). The scores for treatment and worry in the asthma modules of the rehabilitation group were significantly lower than those of the control group; the scores for each dimension of the asthma module in the

Table 3 Comparison of Spirometry Measurements Between the Two Groups Post-Treatment

Dependent Variables	Pre-Treatment		Post-Treatment		Post-Treatment P-value
	Rehabilitation Group	Control Group	Rehabilitation Group	Control Group	
FVC% Mean (SD)	90.71±12.09	95.46±14.65	95.01±10.90	96.48±12.93	0.665
FEV1% Mean (SD)	84.56±9.83	91.48±9.32	87.88±15.54	88.69±19.48	0.520
FEV1/FVC% Mean (SD)	93.10±6.20	92.04±7.97	96.22±7.48	95.72±6.07	0.796
PEF% Mean (SD)	87.91±15.56	88.70±13.98	99.63±14.65	92.37±14.96	0.089
MEF75% Mean (SD)	78.20±13.67	76.81±17.68	91.71±19.41	84.35±15.17	0.142
MEF50% Mean (SD)	59.29±9.99	59.32±16.66	70.32±15.93	66.36±14.41	0.362
MEF25% Mean (SD)	47.93±10.71	48.32±13.60	59.98±17.39	57.31±12.66	0.539
MMEF75/25% Mean (SD)	56.44±10.18	57.11±15.83	69.85±17.26	66.24±13.28	0.412

Notes: FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEV1/FVC, one-second rate; PEF, peak expiratory flow; MEF75, maximum expiratory flow at 75% of vital capacity; MEF50, maximum expiratory flow at 50% of vital capacity; MEF25, maximum expiratory flow at 25% of vital capacity; MMEF75/25, mid-forced expiratory flow rate.

rehabilitation group were significantly lower than those before treatment ($p<0.05$). The scores for school functioning in the generic core scales in the rehabilitation group were significantly lower than those of the control group; The scores for physical functioning and emotional functioning in the rehabilitation group were significantly lower than those before the treatment ($p<0.05$), as shown in Table 4.

Discussion

Rehabilitation Training Improved Inspiratory Muscle Strength in Children with Asthma

The results of this study showed that the mean and maximum values of MIP in the rehabilitation group were higher than those in the control group and before treatment, thus suggesting that rehabilitation training can effectively improve the inspiratory muscle strength of children; this findings were consistently with those reported previously.[11] The increase in the mean value of MIP in the control group relative to that before treatment may be related to the growth and development stage of the children involved. Other studies have shown that asthma can lead to reduced inspiratory muscle strength and that patients with weak muscle strength should be trained to effectively improve muscle strength and reduce dyspnea.[9,13,15] However, according to the current literature, only two researchers have applied respiratory muscle training to children with asthma.[11,16] Follow-up studies should be carried out to further demonstrate the efficacy of respiratory muscle training in children with asthma. Exercise training has also been found to be beneficial in improving respiratory muscle function. Exercise training can increase breathing frequency and can exercise the respiratory muscles.[17] Both Li and Morton found that exercise training improved the dysfunction caused by oxidative stress while protecting and improving the diaphragm.[18,19]

Rehabilitation Training Did Not Significantly Improve Ability in Children

The results of this study showed that the 6MWD did not differ significantly when compared between the rehabilitation group and the control group after treatment, but was higher than that before treatment. At present, exercise training is regarded as the cornerstone of rehabilitation training. Studies have shown that exercise training can improve both exercise ability and quality- of-life in asthma patients and rarely causes adverse events such as airway hyper-responsiveness.[20–22] Reimberg,[23] Lingling[24] and others applied exercise training to children with asthma and found that this practice increased the 6MWD and reduced the fatigue index. Moreover, in this study, we applied respiratory muscle training based on exercise training. Enhanced respiratory muscle function will reduce the occurrence of the respiratory muscle taking away blood flow from the exercising muscles, improve the energy supply of the exercising muscles and improve exercise endurance.[12] Duruturk found that patients with asthma who used respiratory muscle training not only improved in muscle strength, but also gained improved exercise ability when compared with those who did not use respiratory muscle training.[15] Although the 6MWD in this study was improved compared with that before the

Table 4 Comparison of the Quality-of-Life Between the Two Groups Post-Treatment

Dependent Variables	Pre-Treatment		Post-Treatment		Post-Treatment P-value
	Rehabilitation Group	Control Group	Rehabilitation Group	Control Group	
3.0 Asthma module Mean (SD)	19.12±9.36	15.20±8.41	11.04±5.30	15.32±8.88	0.044*
Asthma Median (IQR)	7.00(6.00~8.50)	5.00(4.00~8.50)	4.00(4.00~6.00)	6.00(3.00~7.00)	0.437
Treatment Median (IQR)	5.00(5.00~8.00)	4.00(2.00~8.00)	2.00(1.5~4.00)	4.00(2.00~9.50)	0.027*
Worry Median (IQR)	1.00(0.00~4.00)	2.00(0.00~4.00)	0.00(0.00~2.00)	2.00(0.00~4.00)	0.040*
Communication Median (IQR)	3.00(0.00~5.50)	2.00(1.00~3.00)	2.00(0.00~4.00)	2.00(0.00~4.00)	0.691
4.0 Generic core scales Mean (SD)	16.72±8.60	17.92±8.76	12.08±6.98	17.20±8.56	0.025*
Physical functioning Median (IQR)	7.00(4.00~8.50)	7.00(4.50~8.00)	4.00(2.00~6.00)	6.00(4.00~8.00)	0.093
Emotional functioning Median (IQR)	3.00(1.00~5.50)	2.00(0.00~6.00)	2.00(0.00~4.00)	3.00(1.00~6.50)	0.186
Social functioning Median (IQR)	1.00(0.00~4.00)	2.00(0.00~5.00)	0.00(0.00~4.00)	0.00(0.00~4.50)	0.940
School functioning Median (IQR)	6.00(2.50~7.00)	5.00(3.50~6.50)	4.00(2.00~6.00)	6.00(3.00~7.50)	0.028*

Note: *$p<0.05$.

treatment, there was no statistical difference with the control group. This may be related to short treatment time and insufficient supervision due to home exercise; this may have led to the improvement in exercise ability not reaching the expected level. Subsequent research can improve the implementation of rehabilitation training and enhance the effect of rehabilitation training by extending rehabilitation time, by adding related theories to improve compliance, and by ensuring that patients return to the hospital for rehabilitation.

Rehabilitation Training Did Not Significantly Improve Spirometry Measurements in Children

Our results showed that there was no significant difference in spirometry measurements when compared between the rehabilitation group and the control group after the treatment although it was improved when compared with that before the treatment. The population included in this study were asthmatic children undergoing long-term standardized treatments but with poor improvements in spirometry measurements. We aimed to enhance the muscle strength of these children through rehabilitation training and to understand whether the poor efficacy was related to the low strength of the inspiratory muscle. We need to consider that it is difficult to inhale drugs forcefully and persistently. But after treatment, the indices of the rehabilitation group were improved when compared with those before the treatment; however, there was no statistical difference when compared with the control group; this may be due to the shorter treatment time or longer course of disease in some children. Airway remodeling may have led to fixed and irreversible airway obstruction. The improvement of some indices in the control group after treatment may be related to the efficacy of the asthma drugs used. Lipej also reported that rehabilitation training did not improve spirometry measurements in children.[25]

At present, it remains controversial as to whether rehabilitation training can improve spirometry measurements. Haixia found that rehabilitation training could improve FEV1%, PEF% and MMEF75/25% in children.[7] Kirkby also proposed that rehabilitation training could improve FEV1% in children.[8] These differences in further information is needed in the future to verify these observations.

Rehabilitation Training Improved the Level of Asthma Control in Children

Our results showed that the level of asthma control in the rehabilitation group after treatment was higher than that of the control group and before the treatment, thus suggesting that rehabilitation training improved the level of asthma control in children; these findings are consistent with those reported by Türk and Li.[21,26] The level of asthma control in children was determined by asking the children to recall whether they had asthma-related symptoms over the past month. In this study, three months of rehabilitation training was shown to improve the children's own physical fitness, reduce the severity of the disease and improve the level of asthma control. At present, the main questionnaires used to determine the level of asthma control in children are the test for respiratory and asthma control in kids(TRACK), asthma control questionnaire(ACQ), C-ACT and ACT. Medical staffs should select the corresponding questionnaire according to the age of the children.

Rehabilitation Training Improved the Quality-of-Life in Children

Our results showed that after the treatment, the rehabilitation group scored lower than the control group in the total scores of the asthma module and the generic core scales, and the treatment, worry and school functioning terms. The total score of the asthma module, the total score of the generic core scales, the scores for each dimension of the asthma module and the scores for physical functioning and emotional functioning on the generic core scales in the rehabilitation group were lower than those before treatment, thus suggesting that rehabilitation training can improve quality-of-life in children. These qualities were consistent with the results reported by Lingling and Liu.[24,27] The improvements in the quality-of-life may be related to the fact that three months of rehabilitation training improved the overall health of the children, reduced the numbers of asthma attacks and leaves the school, thereby reducing the psychological burden. Asthma is incurable but controllable and prone to repeated attacks; these factors create a certain economic and mental burden to both children and their families. The pathological changes brought about by asthma lead to low

respiratory muscle function, exercise intolerance and other problems cause by the joint effects of these factors. Therefore, the health evaluation of asthma by medical staff should actively shift from the measurement of single physical health to the comprehensive evaluation of multi-dimensional physiological, psychological and social adaptation.[20]

At present, although rehabilitation training has been widely used for patients with chronic obstructive pulmonary disease and asthma, little is known about the specific effects of this strategy on children. Further research on children with asthma is needed in the future. Furthermore, our rehabilitation training program will be continuously improved in order to achieve better results.

Limitations

In this study, the sample size is small, the outcome indicators are not comprehensive enough, and some children have poor compliance, which affects the rehabilitation effect.

Conclusions

In conclusion, the combination of respiratory muscle training and exercise training based on routine drug treatment and health education can improve inspiratory muscle strength, the level of asthma control and the quality-of-life of children with asthma; however, the improvements in exercise capacity and spirometry measurements are not obvious. Subsequent researches can investigate the clinical value of applying rehabilitation training in the treatment of childhood asthma by expanding sample size, increasing the number of relevant outcome indicators (eg, anxiety, depression and the number of acute attacks), prolonging the recovery time, and improving compliance through recall.

Relevance to Clinical Practice

In this study, on the basis of conventional asthma treatment, a combination of respiratory muscle training and exercise training was applied to children with asthma. Currently, asthma is the most common chronic respiratory disease in children. Some cross-sectional studies have shown that it is difficult for children with asthma to achieve good therapeutic effects only with conventional treatment, and long-term treatment will have a certain impact on children's physiology and psychology. This study found that this regimen can effectively improve respiratory muscle strength, asthma control and quality-of-life in children. Therefore, clinicians can apply rehabilitation training to children with asthma to improve clinical symptoms and psychological conditions, and shorten the treatment time.

Abbreviations

GINA, Global Initiative for Asthma; MIP, maximum inspiratory pressure; EIB, exercise-induced bronchoconstriction; PEF, peak expiratory flow; 6MWT, 6 minutes walking test; 6MWD, 6 minutes walking distance; FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEV1/FVC, one-second rate; MEF75, maximum expiratory flow at 75% of vital capacity; MEF50, maximum expiratory flow at 50% of vital capacity; MEF25, maximum expiratory flow at 25% of vital capacity; MMEF75/25, mid-forced expiratory flow rate; ACT, asthma control test; C-ACT, children-asthma control test; PedsQL^{TM}, pediatric quality of life inventory TM; TRACK, test for respiratory and asthma control in kids; ACQ, asthma control questionnaire.

Data Sharing Statement

All data generated or analysed during this study are included in this published article.

Ethical Approval Number

Institution Review Road of Children's Hospital of Chongqing Medical University: (2021) Lun Shen (Yan) No.(168).

Consent for Publication

A parent or legal guardian of all children provided informed consents.

Trial Registration

Chinese clinical trial registry, ChiCTR2100049173. http:// www.chictr.org.cn/listbycreater.aspx

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Disclosure

All authors report no conflict of interest.

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