Efficacy of Breathing Retraining Using Modified Incentive Spirometeric Biofeedback System on Ventilatory function in Moderate Versus Severe Asthmatic Children

Farag A. Aly*, Mona Essa**
*Department of physical therapy for cardiopulmonary disorder and geriatric, faculty of physical therapy, Cairo University.
**Department of pediatric, faculty of medicine, Cairo University

ABSTRACT

The aim of this study was to investigate and compare the effect of breathing exercises by the use of the modified incentive spirometeric biofeedback system on ventilatory function in children with moderate and severe persistent asthma. Twenty asthmatic children (11 boys and 9 girls) were participated in the study, their age ranged from 6 to 13 years. They were divided into two groups. The group A comprised of 10 children who have moderate persistent asthma and group B comprised of 10 children with severe persistent asthma. Both groups received breathing exercises with the modified incentive spirometeric biofeedback system three times per week for four weeks with measurement of ventilatory function before starting, after two weeks and finally at the end of the program. The results showed that the forced expiratory volume at one second (FEV_1), the forced vital capacity (FVC), the peak expiratory flow(PEF) and the forced mid expiratory flow(FEV_{25-75}) were improved in both groups but the percentage of improvement of all the variables were significantly higher in group B.

Key words: *asthma, children, breathing retraining.*

INTRODUCTION

Bronchial asthma is defined as a complex respiratory disease characterized by airways inflammation and hyper-responsiveness of bronchial smooth muscle, leading to reversible bronchospasm.[5,11] Asthmatic attacks are associated with many symptoms as wheezing–high-pitched whistling sounds when breathing out, cough particularly at night or in the early morning, chest tightness, and breathlessness. These symptoms aggravated by the presence of animals with fur, exercise, aerosol chemicals, pollen, changes in temperature, respiratory (viral) infections, smoke, drugs (aspirin, beta blockers) and strong emotional expression[8].

Asthma is a growing problem throughout the world as its prevalence has increased over the last decades. It is the most common chronic chest illness of childhood, and despite advances in therapy, asthma prevalence, morbidity, and mortality are all still increasing[1,15]. Children less than 18 years of age suffer from repeated asthmatic attacks at a rate of 11-15 %. Consequently the economic burden is huge, 83% of the annual costs of asthma are spent on asthma medications therefore the development and evaluations of non-pharmacological interventions to prevent asthma, to reduce its severity or improve its prognosis are essential[11,12].

Spirometry is indicated in all children with clinical diagnosis of asthma, chronic/recurrent cough or wheeze, exercise induced cough or breathlessness.[2] In asthma

spirometeric measurements reveal low forced expiratory flow rates, FEV_1, forced midexpiratory flow ($FEF_{25-75\%}$) and peak expiratory flow (PEF) with normal or increased lung volumes, Functional residual capacity (FRC), residual volume (RV) and total lung capacity (TLC)[6].

Comprehensive management of asthma includes proper use of medication, adjustments in patient lifestyle, exercise conditioning, and patient education to maximize self-management capabilities.[4] It has been stated also that Physical therapy is another part of the treatment of asthma , where physiotherapeutic interventions in asthma management include breathing control and re-education, relaxed breathing postures, education about the disease and instructions about the correct use of inhalers and nebulisers[10].

There is increasing interest in using breathing retraining techniques in management of asthmatic patients, as a recent survey by the National Asthma Campaign in the United Kingdom (UK) showed that 30% of responders were using breathing techniques to relieve their symptoms.[7] The modified incentive spirometeric biofeedback system had been used previously in improving lung functions post-operatively; it had advantages of reusability, less cost and equal emphasis of both inspiration and expiration so it provides the child and his parents' easy feedback about expiratory flow rate and relaxation[18].

The aim of this study was to investigate and compare the different effects on ventilatory function after breathing retraining by the use of the modified incentive spirometeric biofeedback system in children with moderate persistent versus severe persistent asthma.

MATERAL AND METHODS

Subjects

Twenty asthmatic children of both genders were chosen from the Pediatric Department of Abbasia Chest Diseases Hospital and from the Allergy Clinic of the Specialized Hospital of Pediatrics, Cairo University. Ten of them diagnosed as having moderate persistent and the other ten children were of severe persistent asthma according to the GINA guidelines[8].

All children were within the normal average of weight for their age according to BMI- for- age percentiles with BMI < 95^{th} percentile[3]. The child who had one or more of the following diseases was excluded: congenital heart disease, neurological disorders, mental disorders, metabolic disorders and pleural diseases. Children with recent thoracic or vertebral fractures and those with kyphosis or scoliosis were also excluded. They were divided according to their severity of asthma into two groups: Group A comprised of ten children (8 male, and 2 females) with moderate persistent asthma, the mean values of their age, height, and weight were 8.7+2.5 years, 133+13 centimeters, and 27+6.67 kilograms respectively. group B comprised of ten children with severe persistent asthma (3 male, and 7 females with the mean values of their age, height, and weight were 7.8+1.3 years, 127.2+11.5 centimeters, and 28.3+11 kilograms respectively.

Instrumentations

Electronic Spirometer: Datospir 120-Sibelmed, made in Barcelona. It was used for ventilatory functions measurements.

Weight and Height scale: Health made in China. It was used for measuring the weight and the height of each child in order to

determine the predicted values of ventilatory function and to exclude obese children.

The modified incentive spirometeric biofeedback system: is a wooden frame with a fine paper hanged from it one side[18].

Methods

The study has been conducted at the allergy Clinic of the Specialized Hospital of Pediatrics, Cairo University. The children were examined by specialist physician to exclude subjects with any disorder that could prohibit them from participating in this study. The data sheets were filled for each child to ensure that they met the inclusion criteria which was previously determined. All the parents of the children gave their written consent form to allow their children to participate in the study and they received a thorough explanation about the significance of the study, the procedures and the duration of the study.

Evaluation

1) Measurements of body weight, and height.
2) Measurement of Ventilatory function by Spirometer: including FVC, FEV_1, PEF and $FEF_{25-75\%}$. from standing position, where the child was wearing the nose clips and firmly closing his mouth around the mouthpiece. The procedures were repeated 3-5 times with 2-3 minutes rest in between and the maximum value was recorded for evaluation.

*** The ventilatory function measurements were conducted in both groups at three occasions**

1) Initially before receiving any treatment as a data base of values.
2) After 2 weeks (after 6 sessions). 3) At the end of the exercise program (after 4 weeks)

Training program

For both groups, each child received supervised 12 sessions and a home program for 4 weeks

I) through the first 2 weeks: they were given three sessions a week.
II) Through the following 2 weeks: he/she received 3 sessions per week plus a home training program daily.

Training procedures for breathing exercises using the modified incentive spirometeric biofeedback system:

The child assumed a comfortable sitting position with shoulders relaxed, arms and back well supported. The therapist positioned the apparatus at 10 centimeters distance from the mouth of the child, with the upper edge of the apparatus at the level of the nose of the child and therapist's hand at the abdomen of the child to guide the movement and to ensure that expiration was a relaxed process without contraction of the abdominal muscles. Then the child was instructed to take a deep and slow inspiration through the nose followed by holding the breath for 5 seconds, then blow out slowly and evenly with O-shaped mouth to keep the paper attached to the horizontal bar as long as possible. Every session the child performed 30 repetitions of the breathing technique divided into several sets, each set contains 3-5 repetitions with rest about 1-2 minutes in between sets[18].

Home Program

The mothers of children of both groups were educated about the selected technique and they were instructed to apply the technique with their children as a daily home program 3 times /day, each time 30 repetitions in sets, each set 3-5 repetitions with relaxation about one minute between sets. -Mothers of the children received educational sessions at

the first two weeks about asthma, its symptoms, predisposing factors, and warning signs of acute attack, management and how to avoid common irritants of asthma in order to perform the home program accurately[13].

Statistical analysis

Results were expressed as mean + SD. Statistical analysis on baseline differences between pre, and after 2 weeks of treatment, and then between pretreatment and after weeks of treatment were performed using an unpaired student-t test. The percentage of improvement of all the variables after 2 weeks, and 4 weeks of treatment were determined by using the equation of percentage of change =

$$\frac{\text{post-pre}}{\text{pre}} \times 100$$

RESULTS

Concerning the demographic characters of both groups there were no statistical significant differences between the child of both groups as regard their age, height and weight before starting the study (P >0.05).

Ventilatory function analysis of group A

Analysis and comparison of the ventilatory function measurements before treatment program and after 2 weeks as shown in table (1) and figure (1) revealed that the value of PEF had increased significantly after 2 weeks with P value <0.05, While the mean values of FVC, FEV_1 and $FEF_{25-75\%}$ had showed a very high significant statistical improvement after 2 weeks of treatment with P <0.001.

On the other hand, comparing the ventilatory function measurements between the pretreatment values and after 4 weeks of treatment, had revealed Avery highly significant improvement in all variables in group A with P <0.001.Table (1) and figure (1)

Table (1): Comparison of the ventilatory function variables between pretreatment versus after 2 weeks values, and between pre treatment versus after 4 weeks values for group A

Variable	Pre.	(after 2 weeks)		After 4 weeks	
	$\chi \pm SD$	$\chi \pm SD$	P-Value	$\chi \pm SD$	<0.001
FVC/L	63.2±9.34	83.2±12.14	<0.001	95.7±12.6	<0.001
FEV_1/L	65.2±3.26	87.2±7.15	<0.001	99.1±8.62	<0.001
PEF/L	48.5±11.09	64.1±10.94	<0.05	83.4±17.87	<0.001
$FEF_{25-75\%}$	54.5±12.55	71.9±9.83	<0.001	91.5±17.13	<0.001

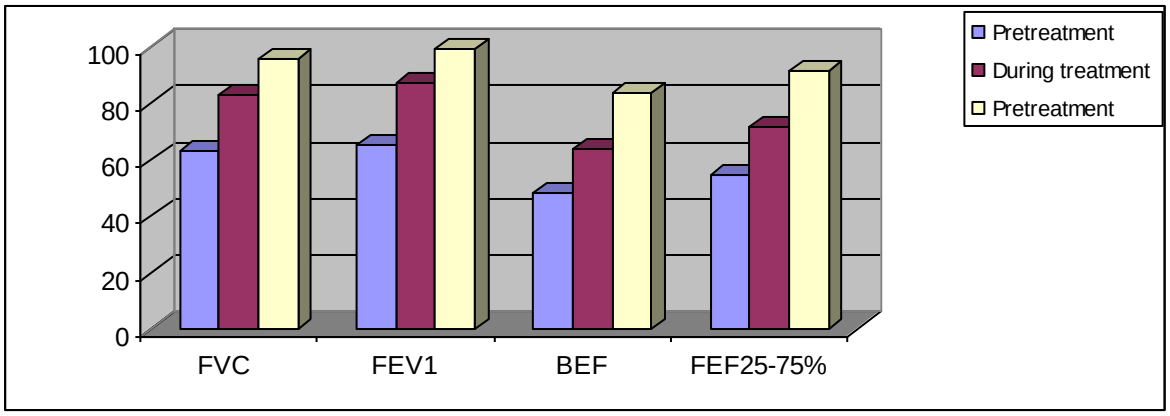

Fig. (1): Mean values of ventilatory function in group (A) before, during and after Treatment

Ventilatory function analysis of group B

On comparing the ventilatory function measurements between before treatment values, and after 2 weeks, a high statistical significant improvements occurred in FVC, FEV_1 and PEF (P <0.001) while $FEF_{25-75\%}$ had significantly improved (P<0.05) as shown in table (2) and figure (2).Analysis of the ventilatory function measurements between pretreatment values and after 4 weeks revealed a high statistical significant improvements of all the ventilatory function measured (FVC, FEV_1, PEF, and $FEF_{25-76\%}$) with P<0.001 as displayed in table (2) and figure (2).

Table (2): Comparison of the ventilatory function variables between pretreatment versus after 2 weeks of treatment, and between pretreatment versus 4 weeks of treatment

Variable	Pre.	(after 2 weeks)		After 4 weeks	
	$\chi \pm SD$	$\chi \pm SD$	P-Value	$\chi \pm SD$	P-Value
FVC/L	44.4±8	75.2±15.1	<0.001	86.3±18.5	<0.001
FEV_1/L	48.3±6.6	73.6±15.4	≤0.001	89.3±18.4	<0.001
PEF/L	44.4±8	66.8±10.5	<0.001	90.8±15.9	<0.001
$FEF_{25-75\%}$	37.2±10	60.3±17.7	<0.05	79.9±29	≤0.001

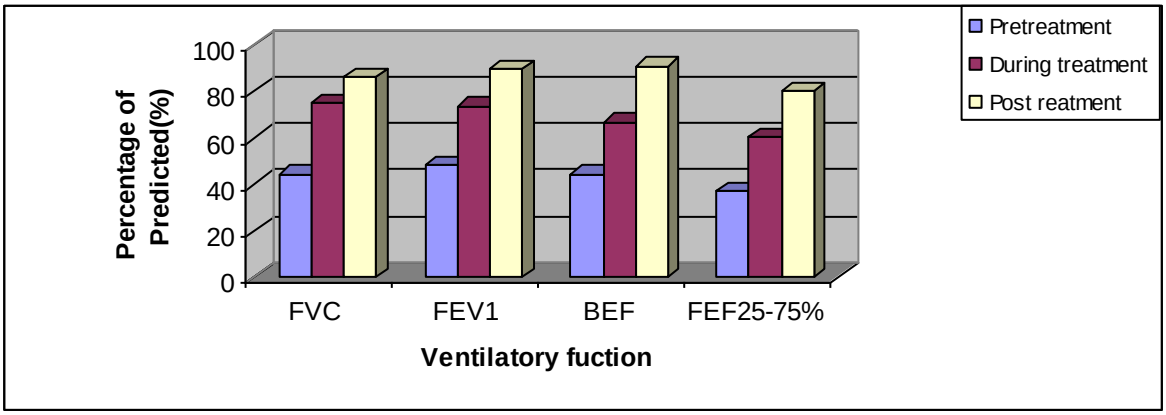

Fig. (2): Mean values of ventilatory function in group (B) before, during and post treatment

Percentage of improvement in all the variables at the end of the treatment in both groups

Percentage of improvement after 4 weeks in both groups

Analysis of the percentages of improvements in ventilatory function measured after 4 weeks in both groups as presented in table (3) and figur (3) showed that FVC was increased by 51.4% in group A and 94.4% in group B. For FEV_1 was 51.9% in group A and 84.9% in group B. While PEF was 71.9% in group A and 104.5% in group B. Finally, $FEF_{25-75\%}$ was 67.8% in group A and 114% in group B. P< 0.001.

Table-3: Percentage of improvements at the end of the treatment in both groups

variables	Group A	Group B	P value
FVC	51.4%	94.4%	< 0.001
FEV_1	51.9%	84.9%	< 0.001
PEF	71.9%	104.5%	< 0.001
$FEF_{25-75\%}$	67.8%	114.8%	< 0.001

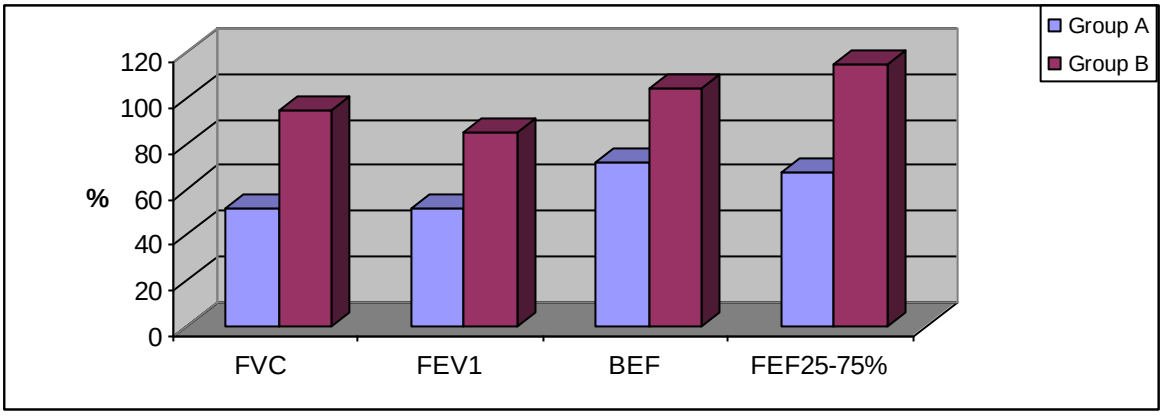

Fig (3): Percentage of improvements at the end of the treatment in both groups.

DISCUSSION

The results of the present study proved that breathing retraining with the use of modified incentive spirometeric feedback system in children with either moderate or severe persistent asthma produced significant improvement in forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow (PEF) and forced mid expiratory flow ($FEF_{25-75\%}$) after 4 weeks duration.

The improvement of FVC following the breathing retraining by the use of the modified incentive spirometeric feedback system could be explained by the improvement in the strength of respiratory muscles, in particularly diaphragm and abdominal muscles, as a result of training, which leads to increase in the tidal volume and more efficient expiratory maneuvers[9,19]. The improvement of FEV_1 may be also attributed to the improvement in the strength of the diaphragm as a result of the training program, In addition, to the greater motivation of the patients due to the feedback they received from the apparatus and also due to increased alveolar ventilation during the breath holding time that included in the

technique of training. This is in addition to the reduction in upper airway narrowing as a result of O-shaped mouth expiration which increase the intratracheal pressure and maintain opening of large airways[14].

The results of this study came in agreement with a previous study where it had been found that FEV_1 and FVC increased significantly after a six months program of inspiratory muscles training in patients with bronchial asthma. This improvement was explained by the reduction in the degree of hyperinflation in asthmatic patients with exercise induced asthma which had an advantageous effect on the respiratory muscles. Also this improvement may be related to enhanced strength and endurance of the inspiratory muscles following the training. Another mechanism of increasing FEV_1 and FVC may be related to the increase in the lung volumes which occurs with training and leads consequently to increase in the flow of air out of the lungs[19, 20].

The greater improvement of peak expiratory flow following the training program of breathing exercises by the use of the modified incentive spirometeric feedback system explained by increasing the tidal volume as a result of the training, reduction of the resistance to airflow and increased the excursion of diaphragm in expiration. It could be also attributed to decreasing the vagal efferent impulses to the lung which induce bronchodiltation of the constricted airways[16.17,20].

One of the most important findings of this study is the significant increase in $FEF_{25-75\%}$ as a result of breathing retraining program by the modified incentive spirometeric feedback system in both groups. This increase in $FEF_{25-75\%}$ could be explained by improvement of inhalation volumes and reduction of airway collapse so the airflow in the small airways was improved. As $FEF_{25-75\%}$ is considered a sensitive measure to small airways, effort and independence and is affected even in mild obstruction, the improvement in this parameter reflects the greater efficacy of the breathing technique in asthmatic patients with different degrees of asthma .[2]

The statistical analysis of the results between the pre, during and post treatment values in both groups showed a significant improvement of all variables after 4 weeks, while on comparing the results of each group regarding the percentage of improvement of each variable separately, extreme difference can be noted in the percentage of improvement between both groups.

Concerning the percentage of improvement of FVC in group A and group B after 2 weeks of training, the results revealed greater improvement in group B than group A with improvement rate of 69.4% for the former and 31.6% for the later. Again, the results showed higher percentage of improvement after 4 weeks, with group B nearly doubles that in group A (94.4%, and 51.4% respectively).

The improvement in FEV_1 in children with severe persistent asthma in group B was 52.4% after 2 weeks and 84.9% after 4 weeks while in the improvement in those with moderate persistent asthma in group A was 33.4% after 2 weeks and reach 51.9% after 4 weeks.

The PEF also increased dramatically in group B than in group A. It was increased by 32.2% in group A and by 50.5% in group B after 2 weeks. After 4 weeks PEF reached 71.9% in group A and 104.5% in group B.

The $FEF_{25-75\%}$ showed more marked improvement in children with severe persistent asthma in group B than those with moderate persistent asthma in group A. In the group of

severe persistent asthma it improved by 62.1% after 2 weeks and 114.8% after 4 weeks while in the group of moderate persistent asthma it improved by 31.9% after 2 weeks and 67.8% after 4 weeks.

The greater improvement of all ventilatory function in children with severe persistent asthma in group B than in those with moderate persistent asthma in group A could be related to the lower original status of children with severe asthma more than those with moderate asthma, and so they were more keen to perform the technique of training which reflected as greater improvement in their ventilatory function. Also, could be based on the more motivation of their parents to perform the home program in order to improve the pulmonary function of their children. Also, the respiratory muscles of children with severe persistent asthma were weaker than that of children with moderate persistent asthma and so the response of training program were more obvious and significance than that of less weaker muscles.

In the children with moderate persistent asthma, the original values of the ventilatory function at the pre treatment test were better than those with severe persistent asthma. So they have limited range for improvement in contrast to those with severe persistent asthma who have wide range for improvement.

Conclusion

Breathing retraining by the use of modified incentive spirometeric feedback system can be an effective non pharmacological modality in dealing with the ventilatory problems of asthmatic children either with moderate, ore severe persistent asthma with the most beneficial effects on the severe degree of asthma. Improving the ventilatory functions could assist in reducing the number of asthmatic episodes and reducing the cost of medications and their side effects, all considered goals for using breathing retraining in asthmatic children.

REFERENCES

1. Aligne C.A., Auinger P., Byrd S.R., and Weitzman M., (2000): Risk factors for pediatric asthma: Contributions of poverty, race, and urban residence. Am J Respir Crit Care Med, 162(3), September, 873-877.
2. Amdekar Y.K. and Ugra D., (1996): Pulmonary function tests. Indian J Pediatr. Mar-Apr; 63(2): 149-52.
3. Batch J.A. and Baur L.A., (2005): Management and prevention of obesity and its complications in children and adolescents. MJA. 182 (3):130-135.
4. Crouches R. and Macintyre N., (1995): Asthma rehabilitation program. Respir Care Clin N Am. Dec; 1(2): 345-55.
5. Elias A.J., Lee G.C., Zheng T., Bing M., Homer J.R., and Zhou Z., (2003): New insights into the pathogenesis of asthma. J Clin Invest. 111: 291- 297.
6. Ellstrom K., Kleerup E.C. , and Tashkin D.P.,(1999): Rehabilitation in asthma population in Altose M. D., and Cherniack N. S., Rehabilitation of the Patient with Respiratory Disease, 1st edn, Ikua Homma, McGraw Hill, Health Professions Division, pp 455-488.
7. Ernst E., (1998): Complementary therapies for asthma: what patients use. J Asthma. 35: 667-671.
8. GINA Pocket Guide for Asthma Management and Prevention in Children (2004).
9. Girodo M., Ekstrand K.A., and Metivier G.J., (1992): Deep diaphragmatic breathing: rehabilitation exercises for the asthmatic patient. Arch Phys Med Rehabil. 73: 717-720.
10. Hough A., (2001): Physiotherapy in Respiratory Care, Nelson Thornes, Cheltenham, 3rd edn. Chap 3, pp: 65-90.

11. Kellett C. and Mullan J., (2002): Breathing control techniques in the management of asthma. Physiotherapy, Dec, 88(12): 751- 758.
12. Mikkilineni S., (1999): Pulmonary rehabilitation in pediatric patients in Altose M. D., and Cherniack N. S., Rehabilitation of the Patient with Respiratory Disease, 1st edn, Ikua Homma, McGraw Hill, Health Professions Division, pp 631-642.
13. Murphy S. (1997): National Asthma Education and Prevention Program, Expert Panel Report II: Guidelines for the Diagnosis and Management of Asthma. Washington DC, National Heart, Lung and Blood Institute.
14. Perez-Padilla R., Cervantes D., Chapela R. and Selman M., (1992): Rating of breathlessness at rest during acute asthma: correlation with Spirometry and usefulness of breath-holding time. Rev Invest Clin. Jul-Sep; 41(3): 209-213.
15. Robichaud P., Laberge A., Allen M., Boutin H., Rossi C., Lajoie P., and Boulet L., (2004): Evaluation of a program aimed at increasing referrals for asthma education of patients consulting at the emergency department for acute asthma. Chest, 126: 1495- 1501.
16. Singh V., (1987): Effect of respiratory exercises on asthma. The Pink City Lung Exerciser. J Asthma. 24: 355-359.
17. Singh V., Wisniewski A., Britton J., and Tattersfield A., (1990): Effect of yoga breathing exercises (pranayama) on airway reactivity in subjects with asthma. Lancet. 335: 1381-1383.
18. Su M.Y., Chiang C.D., Huang W.L., Li S.J., King S.L. and Penh F.K. (1991):A new device of incentive Spirometry. Zhonghua Yi Xue Za Zhi (Taipei).Oct; 48(4):274-7.
19. Weiner P., Azgad Y., Ganam R., and Weiner M., (1992): Inspiratory muscle training in patients with bronchial asthma. Chest. 102: 1357-61.
20. Weiner P., Yanay B.N., Dacidocich A., Magadle R., and Weiner M., (2000): Specific inspiratory muscle training in patients with mild asthma with high consumption of inhaled β_2- agonists. Chest. 117: 722-727.

الملخص العربى

تأثير تمرينات التنفس بواسطة نظام متخصص للرد الفعلي الانعكاسي على وظائف التهوية الرئوية عند الأطفال المصابين بالربو الشعبى ذى الدرجه المتوسطة مقابل الدرجه الشديده

أجريت هذه الدراسة لبحث ومقارنة تأثير تمرينات التنفس بواسطة نظام متخصص للرد الفعلي الانعكاسي على وظائف التهوية الرئوية عند الأطفال المصابين بالربو الشعبى ذى الدرجه المتوسطة والشديده. أجريت هذه الدراسة على عشرون مريضا بالربو الشعبى من البنين (إحدى عشر) والبنات (تسعة) حيث كانت اعمارهم تتراوح ما بين ستة وثلاثة عشر عام . تم تقسم المرضى عشوائيا الى مجموعتين ، مجموعة (أ) والتي تضم عشرة مرضى من الذى يعانون من الربو الشعبى ذو الشدة المتوسطة ومجموعة (ب) والتى تضم عشرة مرضى من الذى يعانون من الربو الشعبى من الدرجة القصوى حيث تم اجراء برنامج تمرينات التنفس بواسطة النظام المتخصص والرد الفعلى الانعكاسى على المجموعتين بموجب ثلاث مرات فى الأسبوع لمدة أربعة أسابيع مع تقييم وظائف التهوية الرئوية قبل العلاج ويعد أسبوعين ثم فى نهاية البرنامج. لقد أظهرت نتائج البحث وجود تحسن ذو دلالة إحصائيه فى جميع المتغيرات الخاصة بوظائف التهوية للرئة فى المجموعتين ولكن بنسبة تحسن أعلى فى المجموعة (ب).

الكلمات الدالة: الربو الشعبى - الاطفال - تمرينات التنفس .