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Pulmonary Rehabilitation Improves Physical Fitness and Pulmonary Functions after Posterior Approach Surgical Correction of Adolescent Idiopathic Scoliosis

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ABSTRACT

Adolescent idiopathic scoliosis (AIS) usually associated with the development of restrictive lung defect and exercise capacity is usually decreased, even in patients with mild scoliosis. The aim of this study was to determine the effects of a designed pulmonary rehabilitation program on exercise tolerance and pulmonary functions after posterior surgical correction approach for AIS. Twenty subjects with AIS participated in this study. They received inspiratory muscle training by incentive spirometer in addition to aerobic exercise on treadmill and upper limbs exercises with the cycle ergometer. Measurements of VC, MVV, SaO_2 and VO_2 max. were done pre-operatively and postoperatively (after 3 months, 6 months and 12 months). The results of this study indicated that there were significant improvements in the measurements of VC, MVV, SaO_2 and VO_2 max. through 12 months of cardiopulmonary rehabilitation program after posterior surgical correction approach for AIS. Pulmonary rehabilitation program improves pulmonary functions and exercise tolerance continued for 12 months after posterior surgical correction approach for AIS.

Key words: Pulmonary rehabilitation, adolescent idiopathic scoliosis, posterior surgical approach.

Erişkin İdiopatik Skolyozlu Hastaların Cerrahi Düzeltmelerinde Post Yaklaşım Sonrası Pulmoner Rehabilitasyon Programı Solunum Fonksiyon ve Fiziksel Aktiviteyi Düzeltir

ÖZET

Adolesan idiyopatik skolyoz (AIS) hafif skolyoz hastalarında bile genellikle restriktif akciğer defekti ve egzersiz kapasitesinde azalma ilişkili gelişimi ile ilişkilidir. Bu çalışmanın amacı, AIS'de posterior cerrahi düzeltme yaklaşımı sonrası egzersiz toleransı ve solunum fonksiyonları üzerine pulmoner rehabilitasyon programının etkilerini belirlemektir. AIS'li yirmi olgu bu çalışmaya katıldı. Hastalar bisiklet ergometresi ile üst ekstremite egzersizleri ve koşu bandında aerobik egzersize ek olarak insentiv spirometre ile solunum kas eğitimi aldı. VC, MVV, SaO_2 ve VO_2 max ölçümleri ameliyat öncesi ve sonrası 3 ay, 6 ay ve 12 ay'larda yapılmıştır. Bu çalışmanın sonuçları AIS posterior cerrahi düzeltme yaklaşımı sonrası kardiyopulmoner rehabilitasyon programının 12 ay boyunca VC, MVV, SaO_2 ve VO_2 max ölçümlerinde önemli iyileşmeler olduğunu gösterdi. Pulmoner rehabilitasyon programı AIS posterior cerrahi düzeltme yaklaşımı sonrası solunum fonksiyonlarını düzeltir ve egzersiz toleransını 12 ay boyunca devam ettirir.

Anahtar kelimeler: Pulmoner rehabilitasyon, erişkin idiopatik skolyoz, posterior cerrahi yaklaşımı

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Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of the growing spine, affecting 2%–3% of adolescents (1). Where scoliosis was reported to be 1.16% among Saudi Arabian school aged male children (2,3) , but the curve progression more than 30° occurs in only 5% of these patients, with a gender ratio of 4:1 female: male (4) which require surgical intervention (5). However, Most cases of scoliosis are diagnosed and treated during adolescence; many are detected in school screening programs (6). Potential complications of scoliosis include back pain, curve progression, psychosocial effects and, in severe cases, pulmonary symptoms (7). Scoliosis impedes on the movement of the ribs, places the respiratory muscles at a mechanical disadvantage and displaces the various organs of the thoracic cavity. Scoliosis decreases the chest wall compliance directly and the lung compliance indirectly (due to progressive atelectasis and air-trapping), causing a significant increase in the work of breathing that, because of the associated respiratory muscle weakness may lead to chronic respiratory failure (8).

Restrictive pulmonary function abnormalities are reported in children and adolescents with AIS. The severity of the pulmonary function impairment is correlated to the degree of spinal curvature (9). Increase in residual volume, reduction of total lung capacity, forced vital capacity, forced expiratory volume, total lung capacity and oxygen saturation (SaO2) ` has all been reported (10). Exercise capacity is usually decreased, even in patients with mild scoliosis, and dyspnea on exertion may be one of the first clinical manifestations of scoliosis (8).

Surgery for idiopathic scoliosis is suggested when a primary curve greater than a Cobb angle of 45° or more in either the previously untreated patient or in one who fails brace treatment. The goals of surgery are to prevent spinal deformity progression or correction of deformity. The techniques for correction include direct posterior spinal fusion with instrumentation and bone graft (Posterior instrumentation remains the mainstay of treatment for most idiopathic curves) or double approach which is posterior spinal fusion proceeded by anterior release. Post-operative casting and bracing are not required in most cases and patients are rapidly ambulated (11).

Incentive spirometry and inspiratory muscle training after surgical correction of AIS applied for 6 months increased forced expiratory volume in the first second significantly (12). Upper and lower limbs exercise training are the main components of any pulmonary rehabilitation program .The effects of combined inspiratory muscle training and upper limb exercise in a form of cycle ergometer training for 8 weeks increased the maximal power out put and oxygen up take (13).

The aim of this study was to determine the effects of a designed pulmonary rehabilitation program on exercise tolerance and pulmonary functions after posterior surgical correction approach for AIS.

Material and Methods

Subjects

Twenty subjects with idiopathic scoliosis (Cobb's angle

Table 1. Analysis of variance of VC %, MVV, SaO_2 and VO_2max preoperative and 3, 6 and 12 months postoperativ

Source of variation	Sum of squares	Degree of freedom	Mean of squares	f-ratio	p value
VC %					
Between Groups	4168.51	3	1389.50	25.51	< 0.05
Within Groups	4139.64	76	54.46		
Total	8308.15	79			
MVV					
Between Groups	3897.41	3	1299.13	24.73	< 0.05
Within Groups	3992.49	76	52.53		
Total	7889.91	79			
SaO_2					
Between Groups	3372.20	3	1124.06	23.17	< 0.05
Within Groups	3687.06	76	48.51		
Total	7059.27	79			
VO_2max					
Between Groups	237.066	3	79.02	20.15	< 0.05
Within Groups	298.04	76	3.92		
Total	535.11	79			

Table 2. Least significance difference of VC % preoperative and 3, 6 and 12 months postoperative

Program	Stat. values		
	Standard error of means	L.S.D. "calculated" value	p value
VC%[a]			
Pre-3 months post	3.58	8.55	< 0.05
Pre-6 months post	2.83	15.95	< 0.05
Pre-12months post	2.44	23.25	< 0.05
MVV[b]			
Pre-3 months post	3.51	8.85	< 0.05
Pre-6 months post	3.30	12.92	< 0.05
Pre-12months post	3.33	31.3	< 0.05
SaO_2[c]			
Pre-3 months post	1.33	6.47	< 0.05
Pre-6 months post	1.36	8.95	< 0.05
Pre-12months post	1.26	11.15	< 0.05
VO_2max[d]			
Pre-3 months post	2.23	3.75	< 0.05
Pre-6 months post	1.20	2.0	< 0.05
Pre-12months post	1.69	8.5	< 0.05

[a]L.S.D." tabulated "value equal 6.271, [b] L.S.D." tabulated "value equal 6.275, [c] L.S.D." tabulated "value equal 6.14, [d] L.S.D." tabulated "value equal 1.682

≥ 40˚) of both sexes, their ages ranged between 13-17 years. Their weights ranged between 35-65kg. Their heights ranged between 115-165 cm free from cardiopulmonary or vascular disorders which may alter the pulmonary function. Informed consent was obtained from all participants. All participants were free to withdraw from the study at any time. If any adverse effects had occurred, the experiment would have been stopped. However, no adverse effects occurred, and so the data of all the participants were available for analysis.

Evaluated parameters

Cardiopulmonary exercise test procedure: Before conducting the exercise tolerance test, all subjects had to visit the laboratory to be familiarized with the equipment in order to be cooperative during conducting the test. Treadmill (Track master 400E, gas fitness system, England) it was used in exercise stress test with other exercise test equipment to estimate exercise capacity and in aerobic exercise training. The treadmill has front and side rails to aid in subject stability. Each subject underwent continuous progressive exercise tolerance test according to Bruce standard protocol which consists of warming up phase and five active phases and recovery phase. Measurements which were recorded included VO_2max., anaerobic threshold and work capacity.

Pulmonary function test: Vital capacity (VC), maximum voluntary ventilation (MVV) and arterial oxygen saturation (SaO_2) were measured using spirometer (Schiller-Spirovit Sp-10, Swizerland) with a special sensor to measure arterial oxygen saturation (SaO_2).

Procedures

The aerobic treadmill exercise training: The aerobic treadmill-based training program (PRECOR 9.1/ 9.2, China) was set to 60% - 75 % of the maximum heart rate (HRmax) achieved in a reference ST performed according to a modified Bruce protocol. This rate was defined as the training heart rate (THR).After an initial, 5-minute warm-up phase performed on the treadmill at a low load, each endurance training session lasted 30 minutes and ended with 5-minute recovery and relaxation phase. All patients performed three weekly sessions (14).

The aerobic Cycle ergometer exercise training: The aerobic Cycle ergometer exercise training (Tunturi, Holand) was used for upper limbs. The patient was in standing position and he moved the arm of the ergometer in a circular maneuver for exercising and strengthening the muscles of both upper limbs. It was started for 10min. and increased gradually till 30min. It was divided into 10min. of warm up, 10min. of circuit training and 10min. to cool down. Intensity was increased gradually according to patient tolerance. It was repeated three days per week till the end of one year post-operatively (13).

Breathing exercise training with incentive spirometer: Incentive spirometer (volydyne volumetric manufactured by Sherwood medical company U.S.A) is a respiratory therapy device that provides visual feedback in term of volumetric success as a patient performs a deep breath. It is considered as a mechanical aid to lung expansion and was applied for five minutes, five times a day (15).

Statistical analysis

The mean values of VC, MVV, SaO_2 and VO_2 max. have been measured pre-operative and postoperative (after 3, 6 and 12 months) ,then analysis of variance was performed followed by post hoc testing with the least significance test in case of significant differences between the repeated measurements ($p<0.05$).

Results

This study was designed to detect the effects of a prolonged pulmonary rehabilitation program on exercise tolerance and pulmonary functions after posterior surgical correction approach for adolescent idiopathic scoliosis. Measurements of vital capacity (VC) %, maximum voluntary ventilation (MVV), arterial oxygen saturation (SaO_2) and maximum oxygen consumption (VO2max.) preoperative and their changes through one year post operative after posterior approach. Concerning the comparison between values of VC (%), MVV, SaO_2 and VO2max. preoperative and 3, 6 and 12 months postoperative after posterior approach there was a significant difference ("F" values were 25.51, 24.73, 23.17 and 20.15 respectively, $p< 0.05$) (Table 1). The post hoc testing values with the least significance test of VC (%), MVV, SaO_2 and VO_2max. preoperative and 3, 6 and 12 months postoperative were significant (Table 2).

These results confirm that prolonged pulmonary rehabilitation program improves pulmonary functions and exercise tolerance if it continued for 12 months after posterior surgical correction approach for adolescent idiopathic scoliosis.

Discussion

The aim of this study was to determine the effects of a designed pulmonary rehabilitation program on exercise tolerance and pulmonary functions after posterior surgical correction approach for AIS .The results of this study showed the maximum improvement in VC, MVV, SaO_2 and VO_2max. after the 6th and 12 months. While during the 3rd month, there was slight improvement. This proved the importance of the duration of the program to give a maximum response. These results agreed with who stated that patients gained a significant improvement in pulmonary functions through 2 years postoperatively(13) , also a same opinion who stated that the pulmonary functions were in average only equal 17% after 3 months and reached 95% in 2 years follow up(16).

Improvement in VC, MVV, SaO_2 and VO_2max. was mainly due to increase in thoracic cage diameters; vertical, lateral & antroposterior and increase in the respiratory muscle mechanical efficiency to generate power and to inspire more deeply. Breathing exercises enhanced strength of the respiratory muscles and reduction of air trapping that increase vital capacity (VC). While, increased respiratory muscle efficiency improves maximum voluntary ventilation (MVV) (17). Respiratory muscle training by incentive spirometry increases production of surfactant which leads to reducing surface tension, increasing lung compliance, decreasing the work of breathing and opening of collapsed alveoli to prevent atelectasis .The improvement of total lung and thoracic compliance may contribute to increases arterial oxygen (12).

Application of treadmill walking exercise three times weekly for 8 weeks resulted in increased exercise endurance, less dyspnea, improved vital capacity (VC), maximum voluntary ventilation (MVV) and twelve minute walking test (18). Lower extremities exercise training was shown to improve exercise tolerance and dyspnea during exercise in the laboratory and with the activities of the daily living .The possible mechanisms for improved exercise capacity and reduced severity of breathlessness were: increased in lactate threshold, improved skeletal muscle oxidative activity, corresponding fall in ventilatory demand during exercise as a result of enhanced mechanical efficiency and improved respiratory muscle function (17).

Evaluation of exercise training for one hour, three times a week for eight weeks showed that limb training was limb specific .Thus, it was only in the group that trained with the upper extremity that upper extremity endurance increased, while walk distance improved in the lower limb trained group, the walk distance improved in the lower limb trained group, the combination trained group showed improvements in both upper and lower limbs endurance (19).

The results of this study supported by a previous study stated that moderate intensity exercise had a significant increase in maximum oxygen consumption (VO_2 max.) (20). Significant increase in maximum oxygen consumption (VO_2 max.) is related to improved respiratory function as vital capacity, inspiratory reserve volume and expiratory reserve volume also stroke volume of the heart increased by regular exercise. This respiratory adaptation facilitates oxygen supply to the tissues and adds further evidence to the improvement of respiratory fitness (21).

Ventilatory muscle training in addition to lower extremity exercise training resulted in reduction in dyspnea, improved respiratory muscle strength and endurance, increased exercise ability and improved health related quality of life (22). Application of exercise training for upper and lower limbs improved dyspnea, exercise capacity and quality of life in patients with COPD (19). In a comparative study between the effect of inspiratory muscle training combined with bicycle ergometer training with bicycle ergometer training alone on inspiratory muscle performance and general exercise capacity .Both training regimens increased maximal power output and oxygen uptake, but the improvement was greater in the patients with inspiratory muscle training than those without (23).

In conclusion, pulmonary rehabilitation program improves pulmonary functions and exercise tolerance continued for 12 months after posterior surgical correction approach for AIS.

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