Exercise Tolerance Responces to Prolonged Pulmonary Rehabilitation Program after Posterior Approach Surgical Correction of Idiopathic Adolescent Scoliosis

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ABSTRACT

Background and purpose: *Restrictive pulmonary function abnormalities are reported in children and adolescents with idiopathic scoliosis (AIS). The severity of the pulmonary function impairment is correlated to the degree of spinal curvature. The purpose of this study was to determine the effects of the designed pulmonary rehabilitation program on exercise tolerance and pulmonary response after posterior approach surgical correction of adolescent scoliosis.* ***Subjects and methods:*** *Twenty subjects from secondary and high school students with idiopathic scoliosis were participated in this study. The students were chosen randomly from the Spine Clinic of the Student Health Insurance Hospital. All patients received breathing exercises via resisted diaphragmatic breathing by abdominal weights and incentive spirometer in addition to aerobic exercise on treadmill and cycle ergometer Measurements of VC, MVV,* SaO_2 *and* VO_2 *max. Have been measured pre-operative and postoperative (after three months, six months and one year).* ***Results:*** *the results of this study proved that surgical treatment of scoliosis affects greatly exercise tolerance and pulmonary functions and corrects the Cobb angle in a great way which subsequently gained improvement of cardiopulmonary functions through one year post-operative. Pulmonary rehabilitation program improves all the pulmonary functions and must be continued for one year post operatively at least for gaining stable values of cardiopulmonary functions.*

INTRODUCTION

Idiopathic scoliosis accounts for 80 to 85% of all lateral spinal curvatures. It is seen with equal frequency in boys and girls at low curve magnitudes. However girls, for unknown reasons, have a significant higher risk for the development of curve progression into large curves than boys (a ratio of 3:1)[14].

The most common symptom of adolescent idiopathic scoliosis (AIS) is difficulty in breathing especially during effort. On the other hand, the common signs on physical examination include; trunk asymmetry, abnormal increase or decrease of lordosis or kyphosis, unequal shoulder heights, increased space between elbow and trunk due to trunk deviation, prominence of the hip, pelvis or breast and discrepancy of lower limbs length[10].

Restrictive pulmonary function abnormalities are reported in children and adolescents with adolescent idiopathic scoliosis (AIS). The severity of the pulmonary function impairment is correlated to the degree of spinal curvature. Increase in residual volume, reduction of total lung capacity, forced vital capacity, forced expiratory volume, and oxygen saturation (SaO_2) has all been reported. In a trail to evaluate the evidence for airflow obstruction and trapped gas which could be associated with restrictive abnormalities in case of idiopathic scoliosis[4,9].

Surgery for idiopathic scoliosis is suggested when curve magnitude is 40˚ 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 or double approach which is posterior spinal fusion (PSF) preceded by anterior release. Post-operative casting and bracing are not required in most cases and patients are rapidly ambulated[16].

The 3 months post-operative pulmonary function test in adolescents with idiopathic scoliosis undergoing posterior spinal fusion with segmental spinal instrumentation showed significant decline about 20% and 27% after 2 years but the chest cage dimensions were improved by 23% post operatively in relation to pre-operative[12].

Regarding the oxygen consumption after surgical straightening of the spine, patients with marked Cobb angle, 80˚ or more, of idiopathic curve consume 20% less oxygen during breathing at rest. During sub-maximal exercise on a treadmill, they also show less oxygen consumption than preoperatively by 30%[11].

The benefits of pulmonary rehabilitation are reduction in dyspnea, reversal of anxiety and depression, improved sense of control over status, enhanced ability to carry out activities of daily living, increased exercise ability, better quality of life, reduction of hospital days required (e.g. from 19 days to 6 days). The core component of pulmonary rehabilitation is (1) medication including aerosol therapy, oxygen therapy and assistance with mechanical ventilation (2) physical therapy modalities including relaxation training, breathing retraining, chest percussion and postural drainage, and exercise conditioning[8,17].

Combination of incentive spirometer and inspiratory muscle training postoperatively especially in idiopathic scoliosis applied for 6 months increased forced expiratory volume in the first second significantly[23].

Upper limbs 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[20].

Then, this study was designed to exhibit the effects of the designed pulmonary rehabilitation program on exercise tolerance and pulmonary functions after surgical correction of adolescent scoliosis.

SUBJECTS, MATERIALS AND METHODS

Subjects

Twenty subjects from secondary and high school students with idiopathic scoliosis were participated in this study. The students were chosen randomly from the Spine Clinic of the Student Health Insurance Hospital. Their ages ranged between 12-18 years. Their weights ranged between 25-75kg. Their heights ranged between 110-170cm. They included both sexes. They presented with idiopathic scoliosis their Cobb angle above 40˚. Before participation all were examined clinically by a chest physician to exclude any cardiopulmonary or vascular disorders which may alter the pulmonary function. All of them did not receive any physical therapy program prior to operation or participation in the study.

Equipments

1-Cardiopulmonary exercise test unit (Zan 800, Germany): It was used to do continuous progressive exercise tolerance test according to Bruce standard protocol, which consists of warming up phase and five active phases and recovery phase to detect maximal oxygen consumption (VO_2 max.).

2-Spirometer (Spirovit, Sp-10, Swizerland): It was a computerized apparatus used for recording forced vital capacity (VC) and maximum voluntary ventilation (MVV) and arterial oxygen saturation (SaO_2) with a special sensor to measure arterial oxygen saturation (SaO_2).

3-Incentive spirometry (Voldyne Volumetric manufactured by Sherwood Medical Company U.S.A.): It is a respiratory therapy device that provides visual feedback in term of volumetric success as a patient performs a deep breath. The Voldyne volume range is from zero to 4000 milliliters.

4-Abdominal weights: It was used for resistive breathing exercise training .It is a sand weight connected with adhesive straps to be applied firmly, their weights were graduated from half kilogram till three kilogram according to patient's ability[6].

5-Treadmill (Enraf Nonium, Model display panel Standard, Nr 1475.801, Holand) was used in performance of walking exercise.

6-Cycle ergometer (Tunturi, Holand) It was used for doing upper limbs exercise. It is a metal device consisting of rounded (circular) stainless part connected with stainless arm for hand grip. The rounded part has a valve for increasing or decreasing the resistance according to patient's ability.

PROCEDURES

All participants received instructions for the right way of breathing, positioning and proper activity of daily living after operation by one day. One week post operatively, they received pulmonary rehabilitation program in a form of:

1-Resisted breathing exercises: This exercise was done for diaphragm through abdominal weights while student was in crock-lying position. Weights were placed on abdomen at the epigastric area to achieve 15% of the patient maximum pulmonary inspiration in the first week of applying this exercise, and the patient was asked to inspire and expire with the weight. The resistance was increased by 5% at each session till 60% at the end of the first month and continued at the same level until the end of treatment. The exercise was applied 10 times per session. It was started after one month of operation till the end of oneyear post operatively.

2-Application of incentive spirometer: It was started after two days of operation till the end of the first year post-operatively. This done from sitting position. The therapist asked the patient to inspire through the mouth piece and evaluate the score gained, also we asked him to inspire and hold breath to fix the piece of plastic in certain area then expire. This was repeated 10 times per session.

3-Treadmill: The student was instructed to walk on treadmill for exercising and strengthening the muscles of lower limbs as well as for walking test. It was started for 10min. and was increased gradually till a maximum of 30min. It was divided into l0min. of warm up, 10min. of walking training and 10min. to cool down. Patient stood in front of a mirror, the speed was fixed at O^o inclination at 400m/sec., intensity of the exercise training was 60%-80% of maximum heart rate. It was used three days per week till the end of one year post-operatively.

4-Cycle ergometer: The student 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.

Ambulation of patients was done after 2 days post operatively; full description of pulmonary rehabilitation program has been explained for the experimental group before starting the program. An agreement concept has been signed by parents of student of the experimental group before participation in the study.

Measurements of VC, MVV,SaO_2 and VO_2 max. have been measured pre-operative and postoperative (after three months, six months and one year)

Statistical analysis

The mean values of VC, MVV, SaO_2 and VO_2 max. have been measured pre-operative and postoperative (after three months, six months and one year), then the analysis of variance was used for comparison between measurements ($p<0.05$).

RESULTS

Table (1) and figure (1): Show mean and standard deviation of vital capacity (VC) %, maximum voluntary ventilation (MVV) L/min, arterial oxygen saturation (SaO_2) and maximum oxygen consumption (VO_2max.) preoperative and changes through one year post operative after posterior approach.

	preoperative	3 month Postoperative	6 month Postoperative	12 month Postoperative
VC (%)	72.6±7.28	64.05±8.76	88.55±5.37	95.85±4.66
MVV (L/min)	80.4±7.98	71.55±7.74	93.35±6.80	111.7±6.92
SaO_2(%)	87.7±3.71	81.23±2.27	95.65±2.38	98.85±1.93
VO_2max.	30.55±2.572	26.8±2.12	32.55±2.16	39.05±2.01

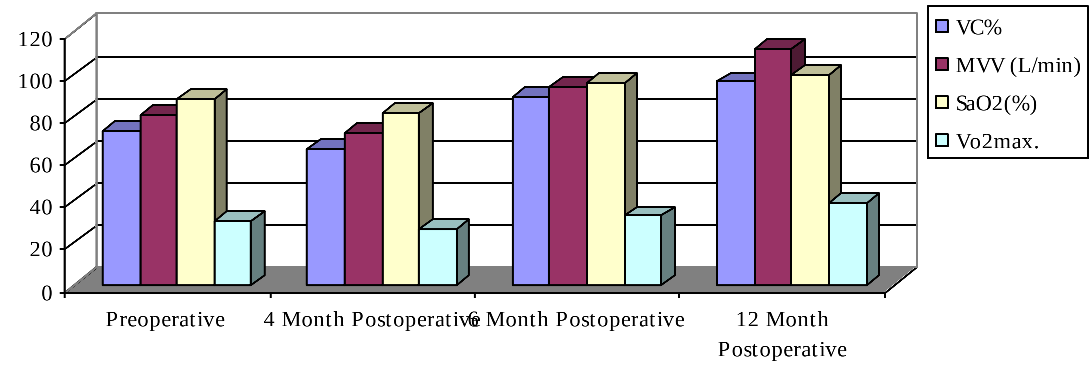

Fig (1)

(1) Vital capacity (VC) %

The preoperative and post operative data of vital capacity by 3,6 and 12 months showed a mean 72.6±7.28 percentage, 64.05±8.76 percentage, 88.55±5.37 percentage and 95.85±4.66 percentage respectively. The difference between the pre and post treatment data after one year showed a statistically significant data with, "F" value was 25.51, $P < 0.05$.

Table (2): Shows analysis of variance of vital capacity (VC)% preoperative and changes through one year post operative after posterior approach.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	4168.51	3	1389.50	25.51	Sig.
Within Groups	4139.64	76	54.46		
Total	8308.15	79			

Level of significance P < 0.05

As shown in table (3) and fig. (2), the least significance difference of the preoperative and post operative data of vital capacity by 3,6 and 12 months there was statistically significant improvement.

Table (3): Shows least significance difference of the preoperative and post operative data of vital capacity by 3, 6 and 12 months.

Program	Stat. values		Significance
	Standard error of means	L.S.D. "calculated" value	
Pre-3 months post	3.58	8.55	Sig.
Pre-6 months post	2.83	15.95	Sig.
Pre-12months post	2.44	23.25	Sig.

L.S.D." tabulated "value equal 6.271

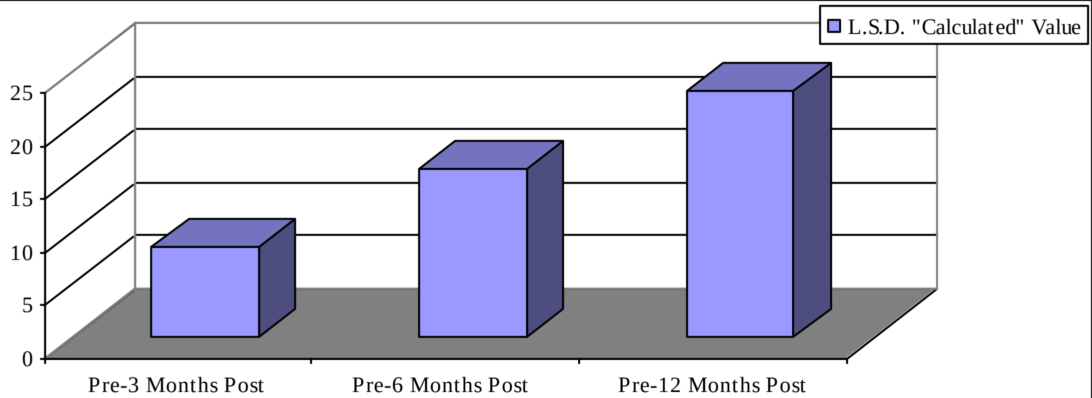

Fig. (2)

(2) Maximum voluntary ventilation (MVV) L/min

The preoperative and post operative data of maximum voluntary ventilation by 3, 6 and 12 months showed a mean 80.4±7.98, 71.55±7.74, 93.35±6.80 and 111.7±6.92 respectively. The difference between the pre and post treatment data after one year showed a statistically significant data with, "F" value was 24.73 , P < 0.05.

Table (4) Shows analysis of variance of maximum voluntary ventilation (MVV) preoperative and changes through one year post operative after posterior approach.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	3897.41	3	1299.13	24.73	Sig.
Within Groups	3992.49	76	52.53		
Total	7889.91	79			

Level of significance P < 0.05

As shown in table (5) and fig. (3), the least significance difference of the preoperative and post operative data of maximum voluntary ventilation by 3, 6 and 12 months there was statistically significant improvement.

Table (5): Shows least significance difference of the preoperative and post operative data of maximum voluntary ventilation by 3, 6 and 12 months.

Program	Stat. values		Significance
	Standard error of means	L.S.D. "calculated" value	
Pre-3 months post	3.51	8.85	Sig.
Pre-6 months post	3.30	12.92	Sig.
Pre-12months post	3.33	31.3	Sig.

L.S.D." tabulated "value equal 6.275

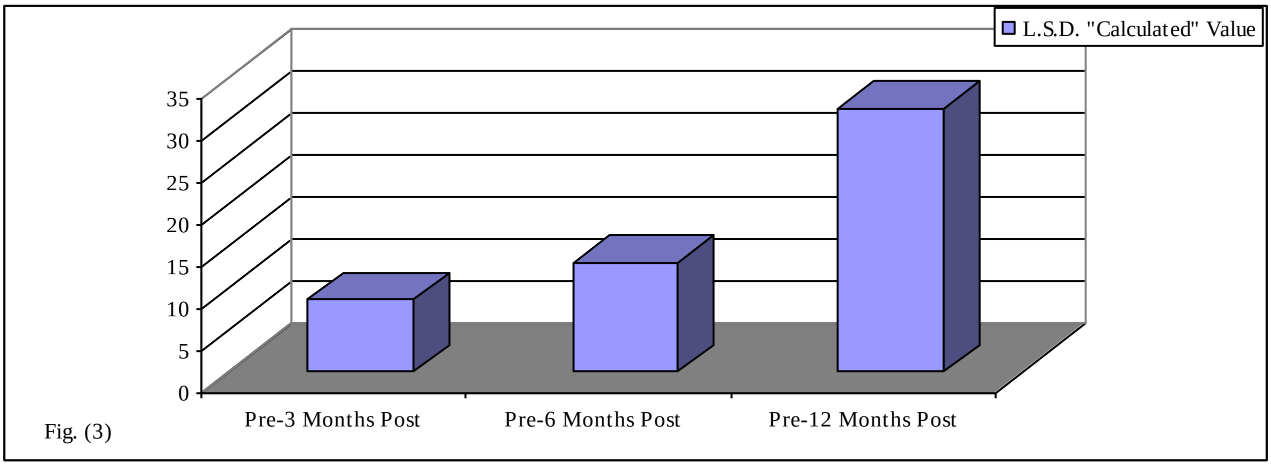

Fig. (3)

(3) Arterial oxygen saturation (%)

The preoperative and post operative data of arterial oxygen saturation by 3, 6 and 12 months showed a mean 87.7±3.71, 81.23±2.27, 95.65±2.38 and 98.85±1.93 respectively. The difference between the pre and post treatment data after one year showed a statistically significant data with, "F" value was 23.17 , P < 0.05.

Table (6): Shows analysis of variance of arterial oxygen saturation (SaO_2) preoperative and changes through one year post operative after posterior approach.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	3372.20	3	1124.06	23.17	Sig.
Within Groups	3687.06	76	48.51		
Total	7059.27	79			

Level of significance P < 0.05

As shown in table (7) and fig. (4), the least significance difference of the preoperative and post operative data of arterial oxygen saturation by 3, 6 and 12 months there was statistically significant improvement.

Table (7): Shows least significance difference of the preoperative and post operative data of arterial oxygen saturation by 3, 6 and 12 months.

Program	Stat. values		Significance
	Standard error of means	L.S.D. "calculated" value	
Pre-3 months post	1.33	6.47	Sig.
Pre-6 months post	1.36	8.95	Sig.
Pre-12months post	1.26	11.15	Sig.

L.S.D." tabulated "value equal 6.14

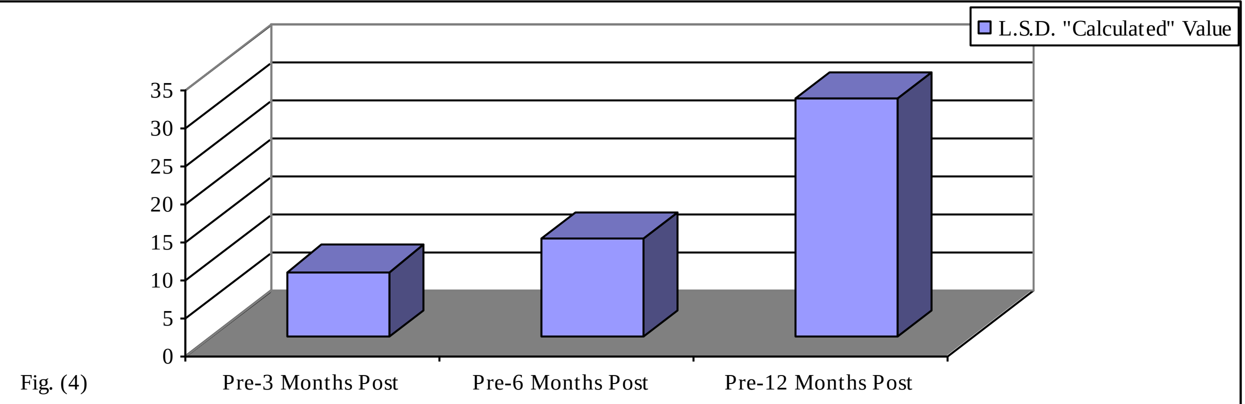

Fig. (4)

(4) Maximum oxygen consumption (VO_2max.)

The preoperative and post operative data of maximum oxygen consumption by 3, 6 and 12 months showed a mean 30.55±2.572, 26.8±2.12, 32.55±2.16 and 39.05±2.01 respectively. The difference between the pre and post treatment data after one year showed a statistically significant data with, “F” value was 20.15, P < 0.05.

Table (8): Shows analysis of variance of maximum oxygen consumption (VO_2max.) preoperative and changes through one year post operative after posterior approach.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	237.066	3	79.02	20.15	Sig.
Within Groups	298.04	76	3.92		
Total	535.11	79			

Level of significance P < 0.05

As shown in table (9) and fig. (5), the least significance difference of the preoperative and post operative data of maximum oxygen consumption by 3, 6 and 12 months there was statistically significant improvement.

Table (9): Shows least significance difference of the preoperative and post operative data of maximum oxygen consumption by 3, 6 and 12 months.

Program	Stat. values		Significance
	Standard error of means	L.S.D. "calculated" value	
Pre-3 months post	2.23	3.75	Sig.
Pre-6 months post	1.20	2.0	Sig.
Pre-12months post	1.69	8.5	Sig.

L.S.D." tabulated "value equal 1.682

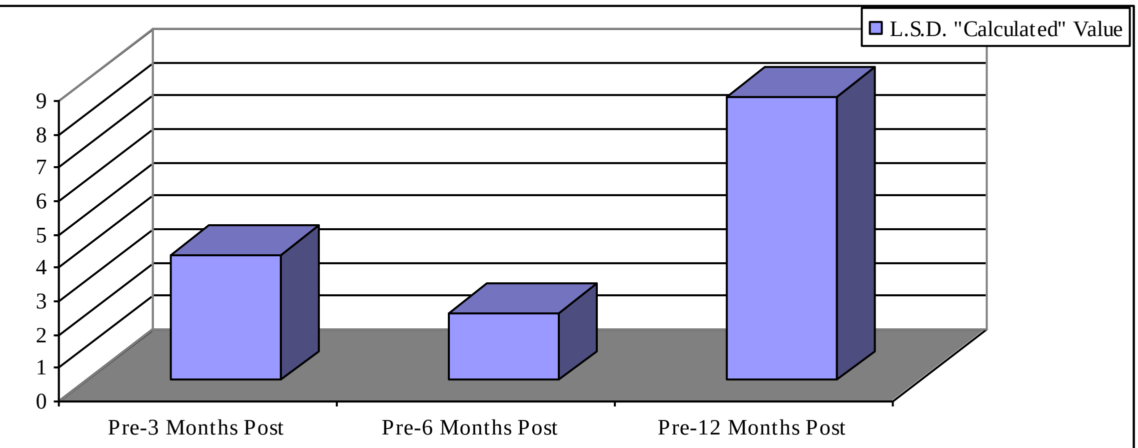

Fig. (5)

DISCUSSION

This study was designed to investigate the changes of cardiopulmonary functions after surgical correction of scoliotic deformity and their changes throughout one year post operative. In addition to investigate the different effects of pulmonary rehabilitation program through this period. All the parameters of evaluation were measured by the same therapist and technique preoperatively, 3, 6 and 12 months posts operatively.

On comparing the VC, MVV, SaO_2 and VO_2max. before and after the rehabilitation program, results showed the maximum improvement after the 6^{th} and 12 months. While during the 3^{rd} month, there was slight improvement. This proved the importance of the duration of the program to give a maximum response. A short duration program, 4-8 weeks, may be not sufficient to cause permanent effects on cardiopulmonary function. So a follow up and home program must be continued up to complete one year post operative.

Explanation of the pulmonary function improvement after the rehabilitation program can be based on mechanical bases. As the improvement in VC, MVV, SaO_2 and VO_2max. was mainly due to increase in thoracic cage diameters; vertical, lateral and antroposterior. While the improvement in FVC mainly indicated an increase in the respiratory muscle mechanical efficiency to generate power and to inspire more deeply.

The increase in vital capacity (V.C) observed in subjects received breathing exercises might be related to the enhanced strength of the respiratory muscles and reduction of air trapping. While, The possible explanation of the improvement in maximum voluntary ventilation (MVV) following breathing exercise is increase in respiratory muscle efficiency[13].

Another scientific explanation, including the relation between VC, MVV,SaO_2, VO2 max. and Cobb angle which is, the decrease in Cobb angle is associated with an increase of vital capacity[7]. These results agreed with who stated that patients gained a significant improvement in pulmonary functions through 2 years postoperatively[20], 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[5].

Application of exercise training for upper and lower limbs improved dyspnea,exercise capacity and quality of life in patients with COPD[1]. 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[21,22].

Application of treadmill walking exercise three times weekly for 8 weeks resulted in increased exercise endurance, less dyspnea, improved vital capacity (V.C), maximum voluntary ventilation (MVV) and twelve minute walking test. Improvements may be due to one or more of the following factors: improved aerobic capacity, or muscle strength or both, increased motivation and improved ventilatory muscle function[15].

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[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 .Finally, psychological factors ,including the development of tolerance and desensitization to dyspnea may enable patients to perform higher levels of work[13].

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[1].

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[23].

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.)[19].

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[3].

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التغير في تحمل التمرينات بعد برنامج التأهيل الرئوي طويل المدى بعد جراحة تقويم العمود الفقري الخلفية لمرضى انحناء العمود الفقري لدى المراهقين

هدف الدراسة هو معرفة تأثير برنامج التأهيل الرئوي طويل المدى على درجة تحمل التمرينات و استجابة الجهاز الدوري التنفسي بعد جراحة تقويم العمود الفقري الخلفية؛ أجريت الدراسة على عشرين مريضا من طلاب المدارس الثانوية من المترددين على مستشفى التأمين الصحي وقد أجريت لهم جراحة تقويم العمود الفقري الخلفية حيث تلقت المجموعة تدريبات التنفس للحجاب الحاجز عن طريق أوزان توضع على البطن وكذلك باستخدام جهاز الحافز التنفسي بالإضافة إلى تمرينات هوائية على سير الجري الألكترونى وعجلة الكتف، وقد أجريت قياسات وظائف الرئة ودرجة تشبع الدم بالأكسيجين و الحد الأقصى لاستهلاك الأكسيجين وقد أظهرت النتائج تحسن كبير في جميع القياسات بعد تطبيق البرنامج لمدة عام ، لذا يوصى بتطبيق برنامج التأهيل الرئوي طويل المدى بعد جراحة تقويم العمود الفقري الخلفية لمرضى لانحناء العمود الفقري .