Does Inspiratory Muscle Training Following Thoracic Surgery Have an Effect On The Outcomes?

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Abstract: Impairment of the function of the respiratory muscles is the leading cause of respiratory complications after thoracic surgeries. Study Aim: To evaluate the effects of inspiratory muscle training (IMT) using threshold IMT device on the ventilatory function and duration of postoperative hospitalization after thoracic surgeries. Subjects and Methods: Fifty male patients post thoracotomy with age range of 40-60 years were recruited into the study. They were divided into two groups of equal number, both received the traditional physical therapy program while those only in the study group received IMT using threshold IMT. The program was 3times/week for 6 weeks. FEV_1 and FVC were measured by spirometry before beginning and after finishing the program and the length of postoperative hospitalization were calculated. Results: The study group showed significant increase in FEV_1 ($P<0.001$), FVC ($P<0.05$) and their percentage of improvement at the end of the study as compared to the control group. However, within each group significant improvement in the ventilatory function measured was demonstrated from pre to post program measurements ($P<0.001$, in the study group and $P<0.05$ in the control group).The length of postoperative hospitalization was significantly shorter in the study group ($P<0.05$). Conclusion: IMT significantly improves the strength of the diaphragm and shortened the duration of postoperative hospitalization in post thoracotomy patients.
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Introduction

Thoracic surgery reduced respiratory function and caused pulmonary complications. The risk of postoperative pulmonary complications is relatively high following thoracic surgery ranging between 19% and 59%, compared with only 16% and 17% for upper abdominal surgery [(1)]. Postoperative pulmonary complications represent the main postoperative problem following thoracic surgery and are strongly associated with an increased risk of death and a prolonged hospital stay [(2,3)].

The basic mechanism of pulmonary complications following thoracic surgery is a lack of lung inflation that occurs because of a change in breathing to a shallow, monotonous breathing pattern, and diaphragmatic dysfunction [(4)]. The dysfunction of the respiratory muscles induced by a number of different mechanisms including change in thoraco-abdominal mechanics and loss of muscular integrity. As consequences of this dysfunction, there is consistent reduction in pulmonary flows and volumes, leading to atelectasis, reduction of cough efficiency, increase of respiratory work, reduction of mechanical efficiency of the respiratory muscles and sensation of dyspnea [(5)].

The risk and severity of complications can be reduced by the use of therapeutic maneuvers that increase the lung volumes [(6)]. The guidelines of the American College of Chest Physicians and American Association of Cardiovascular and Pulmonary Rehabilitation suggested the use of inspiratory muscle training (IMT) in patients with decreased inspiratory muscle strength and breathlessness as IMT alone significantly improves inspiratory muscle strength and endurance, resulting in reduction of sensation of dyspnea and improvement of ventilatory capacity [(7)].

IMT can be performed with resistance or pressure threshold devices. Resistance-training devices typically consist of breathing through a series of adjustable orifices providing flow-dependent resistances that decrease as airflow decreases, while threshold IMT devices provide a consistent and specific pressure for inspiratory muscle strength and endurance training, regardless of how quickly or slowly patients breathe. These devices incorporate a flow-independent one-way valve to ensure consistent resistance. When patients inhale through Threshold IMT device, a spring-loaded valve provides a resistance that exercises respiratory muscles through conditioning [(8)].

Therefore, the purpose of this study was to evaluate the effects of IMT using threshold IMT device on the following outcomes: ventilatory function, as an outcome reflecting respiratory muscle strength, and the length of postoperative hospital stay in patients underwent thoracic surgery.

2. Subjects and Methods:

Fifty male patients post thoracotomy were incorporated in this study from El Abasseya Chest

Hospital. Their ages ranged from 40 to 60 years with stable medical condition. All of patients were gone through lobectomy via posterolateral thoracotomy incision and have signed a consent of approval to participate in the study. While any patient with unstable medical condition, have another medical condition, taking chemo or radiotherapy or have a history of previous pulmonary lobectomy was excluded from the study.

The patients were divided into two groups of equal number (n= 25 pt.), the study and the control group. Both groups received the routine physical therapy program while the patients in the study group received inspiratory muscle training by the threshold IMT device in addition to the routine program. The patients in both groups continued their medical therapy throughout the study period and have received general explanation about the evaluation and the treatment procedures.

Assessment of Lung Function:

The data sheets were fulfilled for each patient then the height and weight were measured. All patients performed spirometry by electronic spirometer (Viasys Healthcare, Made in UK) in order to determine forced vital capacity (FVC) and forced expiratory volume in first second (FEV_1). During all measurements, patients were seated with back erect and supported. The lung function measurements were performed three times and the best one is reported. Data were expressed as a percentage of the predicted values for age, height, and sex. This measurement was performed twice; before beginning and at the end of the training program for both groups (6 weeks).

The length of postoperative hospitalization have been calculated from the day of surgery to the day of discharge for every patient using the patients' records.

In order to set the IMT intensity in the study group, the maximal inspiratory pressure ($P_I$max) at the residual volume was measured using the MicroRPM™ (Respiratory Pressure Meter). The value obtained from the best of at least three efforts was used.

Intervention:

The training programs were conducted for patients in both groups three times per week for six weeks in Physical Therapy Department of Abasseya Chest Hospital. Both groups received the routine physical therapy program which consisted of breathing exercises, early mobilization, cough training and chest percussion for clearance of pulmonary secretion.

Inspiratory Muscle Training Program:

Patients in the study group received in addition to the routine physical therapy program IMT using threshold IMT device (Respironics, Made in U.S.A). The pressure-threshold setting is provided by an adjustable, spring-loaded, threshold poppet valve. To inhale through the device, the patient must generate an inspiratory pressure greater than the indicated threshold pressure setting to compress the spring and open the poppet valve, and the inspiratory pressure must be maintained above the threshold pressure to keep the poppet valve open. Training bouts consisted of sets each consisted of five repetitions breathing through the IMT device for a total period of 20 minutes with rest between sets. During training, the patient was sit in a comfortable position and put the nasal clip so that all of the breathing is done through the mouth and, making sure the lips are sealed around the mouthpiece. The training resistance was started by 25% of the $P_I$max which was increased weekly by 5-10% according to each patient tolerance.

Statistical Analysis:

Differences were compared with t-tests, and data are shown as the mean ± SD. A p-value ≤ 0.05 was considered significant and a p-value ≤ 0.001 was considered highly significant.

3. Results:

Physical Characteristics of the Subjects

As shown in table (1), there were no statistical significant differences between the study and the control group regarding the age, the weight and the height (P > 0.05).

Table (1): Physical characteristics of the subjects

Items	Study group	Control group	P-value
	Mean ± SD	Mean ±S D	
Age (yrs)	50.13 ± 6.78	51.2 ± 5.99	> 0.05
Weight (Kg)	73.46 ± 13.4	68.73 ± 13.01	> 0.05
Height (cm)	164.46 ± 9.1	163.06 ± 11.45	> 0.05

SD: standard deviation, yrs: years, Kg: kilogram, cm: centimeter, P> 0.05: non-significant

Changes in Ventilatory Function in the Study Group:

Comparison of the ventilatory function in the study group from pretreatment to post treatment measurement revealed a highly statistical significant difference (P-value <0.001) as shown in figure (1). The percentage of improvement of $FEV_1$and FVC was 22.47% and 13.96%, respectively.

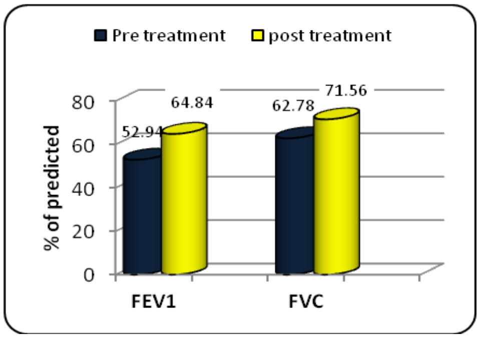

Figure (1): Comparison of ventilatory function at pre and post treatment in the study group

Changes in Ventilatory Function in the Control Group:

As shown in figure (2), the ventilatory function in the control group showed statistical significant difference from pre to post treatment measurement (P-value < 0.05), with percentage of improvement of 5.77% and 3.92% for FEV_1 and FVC respectively.

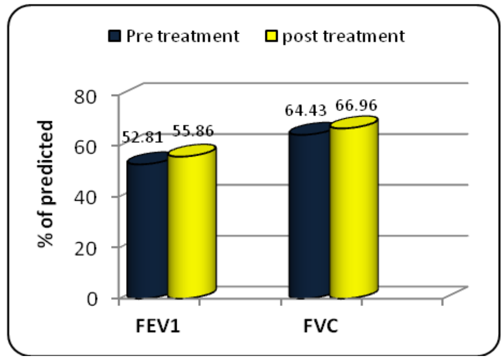

Figure (2): Comparison of ventilatory function at pre and post treatment in the control group

Comparison of Ventilatory Function between Both Groups:

As shown in table (2), non statistical significant difference was found when comparing the ventilatory function between both groups at the pre treatment test (P-value >0.05) which changed into a high statistical significant difference at the post treatment test for FEV_1 (P-value <0.001) and a statistical significant difference for FVC (P-value <0.05) in favor of the study group.

Table(2): Comparison of the ventilatory function between the study and the control group at pre and post treatment

	FEV_1 Mean ± SD			FVC Mean ± SD		
	Pre	Post	% of improvement	Pre	Post	% of improvement
Study group	52.94 ± 4.46	64.84 ± 6.26	22.47	62.78 ±3.28	71.56 ±5.08	13.96
Control group	52.81 ± 2.89	55.86 ± 3.65	5.77	64.43 ±3.18	66.96 ±3.47	3.92
P-value	>0.05	<0.001	<0.001	>0.05	<0.05	<0.05

SD: standard deviation, pre: pretreatment, post: post treatment, FEV_1: forced expiratory volume in one second, FVC: forced vital capacity, P>0.05: non significant, P<0.001: highly significant, P<0.05: significant

The Length of Postoperative Hospitalization:

As shown in figure (3), the mean of duration of postoperative hospitalization was 7 days for the study group and 9 days for the control group with a statistical significant difference (P-value <0.05) between both groups.

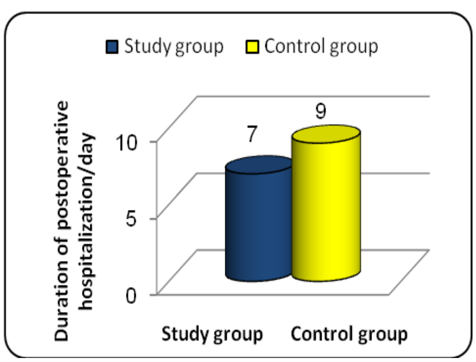

Figure (3): Comparison of duration of postoperative hospitalization between both groups

4. Discussion:

This study was demonstrated that six weeks of post operative IMT using threshold IMT device significantly improved the ventilatory function (FEV_1 and FVC) and shortened the duration of postoperative hospitalization in patients gone through thoracic surgery. This may be attributed to an improvement in the diaphragm strength, as evidenced by the greater percentage of improvement in FEV_1in the study group, and improvement in respiratory mechanics that led to better expansion of the chest which reflected as increase in the ventilatory function leading to early recovery of respiratory function impairment which consequently shortened the duration of postoperative hospitalization.

Patients after thoracic surgery suffer from decreased pulmonary functions; the FVC and the FEV_1 were significantly decreased to 2/3 of the preoperative level after lobectomy [9].

The programs of postoperative inspiratory muscle training arose with the aim of preventing postoperative dysfunction in respiratory muscles and improving their performance thus improve lung volumes so prevent atelectasis [7].

The respiratory muscles can be trained like other skeletal muscles [8], the inspiratory muscle training increases the load imposed on a respiratory muscle, through increments in frequency, duration and intensity of muscular contraction and, as in training of any skeletal muscle, obeys physiological principles of muscular training [10].

Pressure-threshold training was expected to be more effective than resistance training because the threshold device allows the training pressure to be set independently of inspiratory flow and breathing pattern compensation. Threshold inspiratory muscle training devices impose a threshold or critical opening pressure that must be overcome prior to inspiratory flow commencing. During the task, inspiratory muscles initially perform an isometric contraction until the threshold valve opens to allow inspiratory flow, after which the contraction becomes isotonic in nature [11].

IMT is characterized by active recruitment of the diaphragm and other inspiratory muscles, it emphasizes lung inflation, increases lung volume and maintains patency of the smaller airways [8].

The results of the current study came in accordance with the results of *Chatham*, who found that five weeks of IMT in patients with severe restrictive lung disease led to increased lung volumes which have been attributed to increased diaphragm thickness resulting in improvement of inspiratory muscle efficiency, improved pulmonary mechanics, or both [12].

A recommendation was made by adding of IMT to pulmonary rehabilitation programmes directed to chronic obstructive pulmonary disease patients with inspiratory muscle weakness as IMT significantly increased inspiratory muscle strength and endurance and resulted in decrease in dyspnea sensation at rest and during exercise [13].

In agreement with the results of the current study, significant improvement in inspiratory muscle function, diaphragm thickness, lung volumes and exercise performance, which also were associated with improved psychosocial status, were noticed after eight weeks of high intensity IMT in patients with cystic fibrosis which suggest that increasing inspiratory muscle function may have significant long-term health implications for patients with respiratory disability [14].

In healthy people, high-intensity IMT produced an increase in inspiratory muscle function, induced morphological changes in the diaphragm, and increased lung volumes which are associated with an increase in physical work capacity [15].

As pulmonary complications were found to be the most costly and, along with venous thromboembolic complications, required the longest mean hospital stay [16], shortening of the duration of postoperative hospitalization in patients received IMT found in the current study may be an indication of reduction of the incidence or the severity of post-operative pulmonary complications in these patients.

Recently, Casali *et al.*, revealed that IMT in morbidly obese patients submitted to bariatric surgery improved inspiratory muscle strength and endurance that led to early recovery of pulmonary airflows in these patients [17].

Conclusion:

This study has shown that threshold IMT for six weeks in post-operative thoracotomy can significantly improve the ventilatory function and decreased the duration of post-operative hospitalization which may be due to improvement of diaphragm strength in addition to improvement of mechanics of breathing for this group of patients. So, muscle training by IMT device should be recommended for this group of patients to improve the diaphragmatic strength that may reduce the incidence or the severity of postoperative pulmonary complications occurring due to respiratory muscles dysfunction.

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