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Effect of Inspiratory Muscle Training as a Prophylactic Treatment from Pulmonary Complications after Abdominal Surgery in Elderly

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Abstract

Background: Postoperative pulmonary complications are an important cause of morbidity following upper abdominal surgery and pulmonary function is doubtlessly affected after open abdominal surgery especially in elderly patients.

Aim of Study: Tomeasure the effect of inspiratory muscle training as a prophylactic treatment from pulmonary complications after abdominal surgery in elderly patients.

Patients and Methods: Sixty patients with abdominal surgery, their age 60±. They were recruited from Kasr Al-Ainy Medical School. They were assigned randomly into two equal groups. Study Group (A): Included 30 patients subjected to inspiratory muscle training using threshold inspiratory muscles trainer device "TIMT", in combination with incentive spirometer and routine chest physical therapy program. Control Group (B): Included 30 patients subjected to incentive spirometer and routine chest physical therapy program. Treatment applied daily from postoperative day one and continued for two weeks. Pre and post study assessment ofpulmonary function (FVC, FEV1, FEV1/FVC and MVV), functional capacity (6min walk distance), dyspnea (mMRC score) and BODE index score.

Results: This study revealed a statistical significant improvement in (FVC, FEV1, MVV, 6MWD, mMRC and BODE index) post-treatment mean values favor of group A patients than in group B and a non-statistical significant improvement in FEV1/FVC between group A and group B at post-treatment.

Conclusion: Inspiratory muscle training had a significant effect on pulmonary function, functional capacity and dyspnea, so this study support the importance of adding inspiratory muscle training using threshold inspiratory muscles trainer device into the postoperative physiotherapy program after abdominal surgery in elderly patients as a prophylactic treatment from pulmonary complications.

Key Words: *Inspiratory muscle training – Pulmonary complications – Abdominal surgery.*

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Introduction

ABDOMINAL surgery initiates a cascade of pathophysiological responses, potentially causing postoperative pulmonary complications (PPCs), which present high rates of morbidity and mortality, increased hospital costs, and prolonged hospital stays. Surgery and general anaesthesia directly affect the respiratory system. Upper abdominal surgery (UAS) alters postoperative pulmonary function as observed by impairment of lung volumes such as total lung capacity, vital capacity, and tidal volume **[1]**.

Postoperative pulmonary complications remain an important issue after major surgery performed under general anesthesia, especially in elderly patients or patients with lung diseases **[2]**.

Postoperative pulmonary complications are commonly described as "a pulmonary abnormality that produces identifiable disease or dysfunction that is clinically significant and adversely affects the clinical course". This can include pneumonia, severe atelectasis, pulmonary oedema, pneumothorax, pleural effusion, and respiratory failure. A PPCs are the most common complication following UAS, with a reported incidence of 13-53%. Postoperative pulmonary complications significantly increase morbidity, mortality, hospital utilisation, cost, and length of hospital stay. A recent retrospective study found that PPCs were 15 times more likely to occur following UAS when compared to lower abdominal surgery (LAS) **[3]**.

The prevention of pulmonary complications has been investigated and several different respiratory interventions (e.g. breathing exercises, incentive spirometry, breathing with assisted inspiratory flow, and different kinds of positive airway pressure breathing) have been suggested as possible preventive solutions. Furthermore, several studies have focused on preoperative physiotherapy. However, far from all patients have the opportunity to undergo preoperative interventions as a large proportion of patients undergoing abdominal surgery undergo emergency surgery, which emphasises the need for clarification of the benefit of strictly performing postoperative care pathways [4].

Pulmonary function is doubtlessly affected after open abdominal surgery because of the pain caused by incisions and the physiological changes caused by the surgery. A pathophysiological reduction in respiratory muscle function and lung volume due to the effects of anaesthesia and surgical duration leads to a decrease in pulmonary function, functional capacity, and risks of postoperative pulmonary complications after open abdominal surgery. Anesthesia and surgical duration inhibit the cough reflex and depress mucocilliary clearance, which further contributes to PPCs and a decrease in pulmonary function [5].

Chest physiotherapy plays a substantial role in the prevention and management of PPCs. Deep breathing exercises (DBE), percussion, vibration, postural drainage (PD), coughing and huffing techniques, as well as adjunct mechanical devices such as an inspiratory muscle trainer device and an incentive spirometer, are used to reduce PPCs [6].

Inspiratory muscle training (IMT) is described as a remarkable exercise that exerts a significant load on inspiratory muscles to strengthen the muscles of respiration. Incremental increases in respiratory muscle strength can enhance pulmonary function. Respiratory muscles show hypertrophy after proper training and load on the skeletal muscles [7].

Inspiratory muscle training (IMT) consists of resistance and endurance training program. Threshold pressure loading IMT improves both inspiration and expiration by strengthening the muscles of respiration. The diaphragm is morphologically and functionally similar to skeletal muscle and adheres to the strength training principles of overloading, specificity, and reversibility. The threshold pressure loading device contains a spring loaded poppet valve of varying quantifiable intensities, which provides flow independent resistance to inspiration. The resistance in a threshold loading device requires negative pressure to overcome the resistance and, thus, inspiration can be initiated [6].

Incentive spirometry (IS) is a lung expansion technique. It is designed to induce sighing or yawning by making the patient take long, slow, deep breaths. It prevents and treats atelectasis in alert patients who have a predisposition for shallow breathing. It is a simple and relatively safe method for doing it [8].

Exercise capacity and tolerance testing is an important assessment tool to measure the improvement in functional capacity and prognosis of patients. Submaximal tests such as the six-minute walk test are widely used for functional capacity. Decrease Functional capacity affects quality of life. Studies have been done on the pre–rehabilitation of IMT in patients undergoing abdominal and cardio-thoracic surgery, showing better results post-operatively in pulmonary function, functional capacity, and length of hospital stay [6].

Patients and Methods

Patients:

This study was conducted on sixty patients (36 males and 24 females) with abdominal surgeryreferred by surgeon. They were recruited from Kasr Al-Ainy Medical School, through a period of six months (from June 2021 to November 2021). All patients received a complete explanation about procedures of the program of treatment and measurement devices. The Ethics Committee of Faculty of Physical Therapy, Cairo University, Egypt [No:P.T.REC/012/003202]reviewed and approved this study.

Patients were chosen under the following criteria: Male and female patients with abdominal surgery, their age sixty years old and over, conscious patient and respond to verbal command, they were medically controlled and all patients were clinically and medically stable when involved in the study. Patients with one of the following criteria were excluded from the study: Unstable hemodynamics, unstable neurological problems, lack of attention and cooperation, patients on mechanical ventilation, cancer: Lung/oral, recent/ unhealed rib fracture and any disease obstructed our study.

Equipment:

Equipment for Evaluation:

1- Electronic Spirometer (Neurosoft Spiro-Spectrum, Made in Russia) was used for assess the pulmonary function following the methods and criteria recommended by the American Thoracic Society/European Respiratory Society [9].

2- Six min walk test was used for assess the functional capacity following the recommendations of the American Thoracic Society Guidelines for the Six-Minute Walk Test **[10]**.

3- The modified Medical Research Council scale (mMRC) had been used for assess the dyspnea.

4- The BODE indexa multidimensional index, including four independent predictors which are body mass index (kg/m^2), the degree of airflow obstruction assessed by FEV1, the mMRC dyspnea score and the exercise capacity assessed by the 6MWT.

Equipment for Treatment:

1- Threshold inspiratory muscle trainer device (Respironics Philips) was used for training the patients of the study group, it contains: A small plastic handheld device with calibrated spring loaded valve, mouth piece and nose clip. It contains spring loaded one way valve to ensure consistent resistance and an adjustable specific pressure from 7 to 41cmH_2O.

2- Flow-incentive spirometry was used for training the patients in both groups.

Procedure:

A- Assessment procedures:

Measurement and assessment were done before the starting of the treatment program and after two weeks for all patients in both groups.

Pulmonary function was assessed by Electronic Spirometer, forced expiration test and maximal voluntary ventilation test were performed 3 times and the highest values were calculated. The highest values of forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC ratio and maximum voluntary ventilation (MVV) were recorded. These maneuvers were performed while all patients were in the sitting position with the nasal clip attached.

Functional capacity was assessed by six min walk test. The patient was instructed to walk as far as possible in six minute in an enclosed 30-meter long hospital corridor and the distance 6MWD was recorded in meters.

Dyspnea was assessed by the modified Medical-Research Council dyspnea Scale (mMRC).

Once all data were entered, the calculation of the BODE index was carried out.

B- Treatment procedures:

Postoperative physiotherapy was given to all patients daily from postoperative day one and continued for two weeks. Study Group (A): Was received inspiratory muscle training using threshold inspiratory muscles trainer device "threshold IMT", in addition to incentive spirometer and routine chest physical therapy program. Control Group (B): Was received incentive spirometer and routine chest physical therapy program (active cycle of breathing technique (ACBT), deep breathing exercises (DBE), percussion, vibration, postural drainage (PD), coughing and huffing techniques).

Threshold inspiratory muscles training procedure:

The patient was sit in a comfortable position and put the nose clip on the patient's nose so that all of the breathing was done through the mouth and make sure that the lips were sealed around the mouthpiece and the tongue didn't occlude it. The training was started with a low load in the device (9cmH_2O). Patient was taken a full breath in (maximal and deep inspiration) then longer and slow expiration continued this breathing pattern for 10 breath/6 sets. The resistance was increased incrementally, based on a trial-and-error method (gradually increasing intensity until the patient can just complete the 6th breath in each set).

Statistical analysis:

The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). All statistical analyses were significant at level of probability ($p \le 0.05$).

Results

In the current study, a total 60 patients of both genders (36 male and 24 female) were assigned randomly into two groups (30 patients/group). No significant differences ($p>0.05$) in demographic data for age ($p=0.965$), BMI ($p=0.058$), and gender ($p=0.114$) between group A and group B Table (1).

Table (1): Comparison of general characteristics between groups A and B.

Items	Age	BMI	Gender	
	Mean ± SD	Mean ± SD	Males	Females
- Group A (n=30)	66.50±5.93	29.23±4.82	15 (50.00%)	15 (50.00%)
- Group B (n=30)	66.43±5.78	26.33±6.20	21 (70.00%)	9 (30.00%)
p-value	0.965	0.058	0.114	

- Quantitative data (age and BMI) are expressed as mean ± standard deviation and compared by *t*-independent test.
- Qualitative data (gender) are expressed as number (percentage) and compared by chi-square test.

p-value: Probability value.

Multiple pairwise comparison tests (time effect) for outcomes variables inter each group (Table 2) showed that there were significantly (p<0.05) increased in FVC (p=0.0001), FEV1 (p=0.0001), MVV (p=0.0001), and 6MWD (p=0.0001) at post-treatment compared to pre-treatment within group A and group B. Moreover, there were significantly (p<0.05) decreased inmMRC (p=0.0001) and BODE index (p=0.0001). These significant increases in FVC, FEV1, MVV, 6MWD and decrease in mMRC and BODE index at post-treatment favor of group A than group B. While, no significant difference (p>0.05) in FEV1/FVC was noted between pre- and post-treatment within group A and group B.

Table (2): Inter group comparison between pre- and post-treatment for outcomes variables.

Variables	Items	Groups (Mean ± SD)	
		Group A (n=30)	Group B (n=30)
FVC	Pre-treatment	0.60±0.49	0.80±0.40
	Post-treatment	2.30±0.46	2.00±0.58
	Change	1.70	1.20
	% of improvement (Cohen's D)	52.47%	45.20%
	p-value	0.0001*	0.0001*
FEV1	Pre-treatment	0.47±0.30	0.70±0.46
	Post-treatment	2.03±0.18	1.73±0.45
	Change	1.56	1.03
	% of improvement (Cohen's D)	35.76%	20.31%
	p-value	0.0001*	0.0001*
FEV1/FVC	Pre-treatment	90.90±12.71	88.00±16.04
	Post-treatment	88.90±4.68	88.40±7.11
	Change	2.00	0.40
	% of improvement	2.20%	0.45%
	p-value	0.486	0.889
MVV	Pre-treatment	14.57±6.73	16.33±7.10
	Post-treatment	44.37±9.02	38.40±9.57
	Change	29.80	22.06
	% of improvement (Cohen's D)	13.01%	8.94%
	p-value	0.0001*	0.0001*
6MWD	Pre-treatment	79.10±26.75	85.77±20.36
	Post-treatment	279.00±34.92	237.60±39.44
	Change	199.90	151.83
	% of improvement (Cohen's D)	28.53%	17.09%
	p-value	0.0001*	0.0001*
MMRC	Pre-treatment	3.70±0.46	3.70±0.46
	Post-treatment	1.57±0.56	1.83±0.53
	Change	2.13	1.86
	% of improvement	57.57%	50.54%
	p-value	0.0001*	0.0001*
BODE index	Pre-treatment	8.63±0.66	8.63±0.80
	Post-treatment	1.93±0.94	3.27±1.25
	Change	6.70	5.36
	% of improvement	77.64%	62.11%
	p-value	0.0001*	0.0001*

- Data are expressed as mean ± standard deviation (SD).
p-value: Probability value. *Significant (p<0.05).

Multiple pairwise comparison tests (group effect) for outcomes variables intra groups (Table 2) indicated no significant differences (p>0.05) at pre-treatment of FVC, FEV1, MVV, FEV1/FVC, 6MWD, mMRC, and BODE index between both groups. But, there were significant differences (p<0.05) at post-treatment in FVC (p=0.020), FEV1 (p=0.007), MVV (p=0.006), 6MWD (p=0.0001), mMRC (p=0.045), and BODE index (p=0.0001) between group A and group B. No significant difference in FEV1/FVC ratio between groups at post-treatment (p=0.862).

Table (3): Intra comparison between group A and group B at pre- and post-treatment for outcomes variables.

Variables	Items	Groups (Mean ± SD)	
		Pre-treatment	Post-treatment
FVC	Group A (n=30)	0.60±0.49	2.30±0.46
	Group B (n=30)	0.80±0.40	2.00±0.58
	Change	0.20	0.30
	p-value	0.120	0.020*
FEV1	Group A (n=30)	0.47±0.30	2.03±0.18
	Group B (n=30)	0.70±0.46	1.73±0.45
	Change	0.23	0.30
	p-value	0.054	0.007*
FEV1/FVC	Group A (n=30)	90.90±12.71	88.90±4.68
	Group B (n=30)	88.00±16.04	88.40±7.11
	Change	2.90	0.50
	p-value	0.313	0.862
MVV	Group A (n=30)	14.57±6.73	44.37±9.02
	Group B (n=30)	16.33±7.10	38.40±9.57
	Change	1.76	5.96
	p-value	0.406	0.006*
6MWD	Group A (n=30)	79.10±26.75	279.00±34.92
	Group B (n=30)	85.77±20.36	237.60±39.44
	Change	6.67	41.40
	p-value	0.410	0.0001*
MMRC	Group A (n=30)	3.70±0.46	1.57±0.56
	Group B (n=30)	3.70±0.46	1.83±0.53
	Change	0.00	0.26
	p-value	1.000	0.045*
BODE index	Group A (n=30)	8.63±0.66	1.93±0.94
	Group B (n=30)	8.63±0.80	3.27±1.25
	Change	0.00	1.33
	p-value	1.000	0.0001*

- Data are expressed as mean ± standard deviation (SD).
p-value: Probability value. *Significant (p<0.05).

Discussion

This study was conducted to investigate the effect of inspiratory muscle training as a prophylactic treatment from pulmonary complications after abdominal surgery in elderly patientsand to measure the effect of inspiratory muscle training on pulmonary function and functional capacity after abdominal surgery.

The results of our study confirmed that there was a highly statistically significant improvement in pulmonary function, functional capacity and dyspnea in the study group (A) who treated with inspiratory muscle training using threshold device and routine chest physical therapy program compared with control group (B) who treated with routine chest physical therapy program only.

Our study showed that there was a significant increase of FVC with a percentage of improvement about 52.47% and 45.20% for group A and group B respectively. There was a significant increase of FEV1 with percentage of improvement about 35.76% and 20.31% for group A and group B respectively. There was a significant increase of MVV with percentage of improvement about 13.01% and 8.94% for group A and group B respectively. There was a significant increase of 6MWD with percentage of improvement about 28.53% and 17.09% for group A and group B respectively. There was a significant decrease of mMRC score with percentage of improvement about 57.57% and 50.54% for group A and group B respectively. There was a significant decrease of BODE index with percentage of improvement about 77.64% and 62.11% for group A and group B respectively. There wasn'ta significant differenceof FEV1/FVC with percentage of improvement about 2.20% and 0.45% for group A and group B respectively.

Pulmonary function and functional capacity are undoubtedly affected following open abdominal surgery because of the prolonged effects of anaesthesia and surgical duration, which further leads to PPCs [5]. Therefore, IMT might have positive effects on pulmonary function after abdominal surgery. The advantage of IMT helps in preserving pulmonary function, functional capacity and minimizing the risks of PPCs after abdominal surgery.

The respiratory muscles are unique amongskeletal muscles because of their continuousactivity throughout life. There are three trainingprinciples that are well established for skeletalmuscles, namely: "overload," "specificity," and "reversibility". The respiratory muscles respond to the seprinciples in the same manner as other muscles [11]. Therefore, there is a possibility that our study shows improvement in pulmonary function, especially MVV, in group A when treated with Threshold IMT. Hence, our study suggests that an increase in MVV increases the strength of the respiratory muscles.

Our study conducted on elderly patients that Seixas et al., [11] conducted a review on the effects of IMT on the general parameters of health in older adults (>60y). This review reveals that IMT can contribute to an increase in inspiratory muscle strength and diaphragm thickness in older adults. Moreover, it seems that this training modality can contribute to improving exercise and functional capacity, physical activity level, and cardiac autonomic control.

The findings of our study are reinforced by Kamble and GD, [1] who studied the effect of threshold inspiratory muscle training versus incentive spirometry in upper abdominal surgeries. This study concluded that threshold IMT has more effects than incentive spirometry.

Our present study results agreed with Kendall et al., [12] conducted a systematic review and meta-analysis of the effectiveness of inspiratory muscle training (IMT) to reduce postoperative pulmonary complications (PPCs) and length of hospital stay (LOS). For the IMT, most of the RCTs used the same device (Threshold IMT). The main findings of this meta-analysis indicate that IMT significantly reduced the risk of PPCs and LOS, especially in older and high-risk patients and in those undergoing pulmonary surgery.

The results of our study are supported by Taşkin et al., [13] who evaluated the effectiveness of intense respiratory muscle training (RMT) using the "Threshold Inspiratory Muscle Trainer" in addition to chest physiotherapy after pulmonary resection in terms of respiratory muscle strength, exercise capacity, and length of hospital stay rather than postoperative complications. The subjects in the study group received RMT in addition to regular chest physiotherapy in the postoperative period. The subjects in the control group received only regular chest physiotherapy. They concluded that the addition of RMT to chest physiotherapy after pulmonary resection can have positive effects on respiratory muscle strength, exercise capacity, and length of hospital stay.

The findings of our study are reinforced by Duymaz et al., [14] who investigated the effect of chest physiotherapy (CP) applied to patients undergoing bariatric surgery on pulmonary functions, dyspnea levels, functional capacity, and quality of life. CP and mobilisation were applied to the patients in the first group, and only mobilisation was applied to the patients in the second group. The treatment of the patients was started on the first postoperative day and continued until the fourth postoperative day. The results revealed that chest physiotherapy applied postoperatively results in increased respiratory function, oxygen saturation, functional capacity, quality of life, and decreased dyspnea severity in patients after bariatric surgery.

Also, a study by Oliveira et al., [15] applied respiratory physiotherapy to patients after bariatric surgery. They found that their functional capacity increased in the 6-min walk test compared with the control group and their dyspnea levels decreased in the Borg scale.

Our study is supported by Kumar et al., [8] they evaluated the effects of flow and volume incentive spirometry on pulmonary function and exercise tolerance in patients undergoing open abdominal surgery and concluded that flow and volume incentive spirometry can be safely recommended to patients undergoing open abdominal surgery as there have been no adverse events recorded. Also, these led to a demonstrable improvement in pulmonary function and exercise tolerance on the six-minute walk test.

Our study supported by Li et al., [16] reported that the BODE index is an effective multidimensional grading-system tool that is better predictive of disease severity, hospitalisation needs, and risk of death than FEV1, and their study demonstrated the value of examining the BODE index and comorbidities that can predict healthcare resource utilisation in COPD.

In contrast to the findings of our study, Brocki et al., [17] IMT was given to high-risk patients after lung cancer surgery. The mean age was 70±8 years. They found that two weeks of postoperative IMT, compared with standard physiotherapy alone, did not enhance respiratory muscle strength but improved oxygenation in high-risk patients after lung cancer surgery.

In contrast to the findings of our study, Silva et al., [18]; Mackay et al., [19] determined that the addition of DB & C exercises to a physiotherapist-directed program of early mobilisation did not further reduce PPCs compared with mobility alone in high-risk open abdominal surgery subjects.

Conclusion:

Inspiratory muscle training had a significant effect on pulmonary function, functional capacity and dyspnea, so this study support the importance of adding inspiratory muscle training using threshold inspiratory muscles trainer device into the postoperative physiotherapy program after abdominal surgery in elderly patients as a prophylactic treatment from pulmonary complications.

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تأثير تدريب عضلات الشهيق كعلاج وقائى من مضاعفات الرئة بعد جراحة البطن لكبار السن

هدف هذه الرسالة لقياس تأثير تدريب عضلات الشهيق كعلاج وقائى من مضاعفات الرئة بعد جراحة البطن لكبار السن. أجريت الدراسة على ستين مريض خضعوا لجراحة فى البطن. عمرهم ستين سنة فأكثر . تم أختيارهم عشوائياً من مستشفى القصر العينى. تم تقسيمهم عشوائياً إلى مجموعتين متساوتين فى العدد. مجموعة (أ) شملت ٣٠ مريضاً خضعوا لتدريب عضلات الشهيق باستخدام جهاز مدرب عضلات الشهيق مع مقياس التنفس التحفيزى وبرنامج العلاج الطبيعى الروتينى. المجموعة (ب) شملت ٣٠ مريضاً خضعوا لمقياس التنفس التحفيزى وبرنامج العلاج الطبيعى الروتينى. يطبق البرنامج العلاجى يو مياً من اليوم الأول بعد الجراحة ولمدة أسبوعين. تقييم وظائف الرئة، القدرة الوظيفية، ضيق التنفس ودرجة مؤشر BODE لجميع المرضى قبل وبعد الدراسة. أظهرت النتائج وجود تحسن إحصائى كبير فى (القدرة الحيوية القسرية، حجم الزفير القسرى فى الثانية الأولى، التهوية الطوعية القصوى، ٦ دقائق سيراً على الأقدام، درجة mMRC ودرجة مؤشر BODE) بعد العلاج أفضل فى المجموعة (أ) من المجموعة (ب) وتحسن كبير غير إحصائى فى حجم الزفير القسرى فى الثانية الأولى/القدرة الحيوية القسرية بين المجموعة (أ) والمجموعة (ب) بعد العلاج.

نستخلص من هذه الرسالة أن تدريب عضلات الشهيق له تأثير كبير على وظائف الرئة، القدرة الوظيفية وضيق التنفس، لذلك تدعم هذه الدراسة أهمية إضافة تدريب عضلات الشهيق باستخدام جهاز مدرب عضلات الشهيق إلى برنامج العلاج الطبيعى بعد جراحة البطن لكبار السن كعلاج وقائى من مضاعفات الرئة.