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Effect of Oscillatory Positive Expiratory Pressure in Sputum Retention, Pulmonary Function, and Thoracic Expansion in Open Abdominal Surgery -A Randomized Controlled Trial

[1]Sudarshan Chaugale
[*1]Varun Naik
[2]Aishwarya Gaonkar

ABSTRACT

Background: Thoracic and abdominal procedures have a higher incidence of postoperative pulmonary problems, which range from 12% to 70%. Between 45% and 85% of patients may experience it. It is well known that abdominal surgery affects the way the breathing muscles work both during and after the procedure. This study aimed to assess and compare the effectiveness of conventional physiotherapy and OPEP (Vibrapep) in patients recovering from open abdominal surgeries.

Method: A comparative study was performed with 36 patients aged 20 to 60 who underwent open abdominal surgery. The participants were divided into two groups. Assessments included maximal inspiratory pressure, chest expansion measurements, and peak expiratory flow. Group A received Vibrapep alongside standard exercises, whereas Group B underwent conventional exercises. The intervention was conducted twice daily for five days.

Results: Statistical analysis was done using SPSS 23. The within-group analysis showed that both groups made statistically significant improvements in all parameters except at the xiphoid and T4 levels ($p>0.05$). However, the experimental group was more effective in improving secretion clearance, thoracic expansion, maximal inspiratory pressure, and peak expiratory rate as depicted by significant differences ($p<0.05$).

Conclusion: The study concluded that Vibrapep is an effective adjunct to conventional physiotherapy in bronchial hygiene therapy for patients recovering from open abdominal surgeries. Its use demonstrated significant improvements in sputum clearance, pulmonary function, and thoracic expansion, highlighting its potential as a valuable therapeutic device in postoperative respiratory care.

Keywords: Vibrapep, Peak Flow meter, Maximal inspiratory Pressure, Open abdominal surgery.

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[1]Department of Surgical Gastroenterology, JNMC Campus, KLE's Prabhakar Kore Hospital, Belagavi, Karnataka, India.
Email: Sudarshanchaugale14@gmail.com
[2]Department of Cardiovascular and Pulmonary Physiotherapy, KLE Institute of Physiotherapy, Belagavi, Karnataka, India.
Email: aishudg99@gmail.com

CORRESPONDING AUTHOR

[*1]Varun Naik

Associate Professor, Department of Cardiovascular and Pulmonary Physiotherapy, KLE Institute of Physiotherapy, Belagavi, Karnataka, India.
Email: varunnaik@klekipt.edu.in

INTRODUCTION

Pulmonary complications refer to pulmonary abnormalities that occur after surgery and result in clinically significant, identifiable illness or dysfunction that adversely affects the patient's course of treatment [1]. It has been discovered that there is a small percentage (2–5%) of substantial respiratory muscle dysfunction after lower abdomen surgery. Nonetheless, 20–40% of cases may involve upper abdominal surgery [2].

The incidence of postoperative complications (PPCs) declines with the extent of the surgical incision from the diaphragm, rendering patients undergoing thoracic and abdominal surgeries more susceptible to PPCs. The amount and complexity of thoraco-abdominal surgical procedures have increased, in addition to the types of surgery performed. The prevalence of PPCs significantly influences postsurgical outcomes, the patient's preoperative health condition, and their age [3].

The primary factors that lead to sputum retention in patients following surgery include a poor expulsive system, a decrease in bronchial Caliber, and qualitative or quantitative alterations in bronchial secretion. As a result, the normal system for eliminating secretions from the large and small bronchi is severely compromised [4], leading to difficulty actively coughing out. Poor ventilation and inadequate expectoration result in post-operative failure to expand or advancement of lung segment collapse, which promotes infection. Following abdominal surgery, all patients exhibit considerable changes in respiratory volumes, with a loss in functional residual capacity (FRC) but little change in closing volume (CV) [5].

Any respiratory disease, whether acute or chronic, associated with increased mucus production requires an effective mucus mobilization and evacuation curve [6]. Therapy for bronchial hygiene must also include an effective curve. The normal curve involves taking a deep breath, closing the glottis, tightening the abdominal and thoracic muscles (to produce pressure greater than 80 mm hg), and exhaling when the glottis opens [6].

Due to muscle atrophy or altered mucociliary function, life-threatening situations may arise when a cough fails to generate phlegm. Techniques are required to support or compensate for the patient's ineffective coughing [7]. Expiratory oscillations reduce the airways' susceptibility to collapsing and increase airflow by causing vibrations in the airway walls that release mucus, facilitating mucus migration up the airways, enhancing lung function, and increasing oxygenation. It produces a percussive action that lessens mucus adhesion to the airway walls, lowers mucus viscoelasticity, and moves mucus toward the larger airways [8].

With various physical therapy modalities, it has been established that measured pulmonary function can improve and substantially prevent pulmonary problems [5]. However, there is a dearth of research supporting Vibrapep (OPEP) use in open abdominal surgery in the literature in addition to diaphragmatic breathing, thoracic expansion exercise, and nebulization therapy. This investigation aimed to examine and compare the impact of OPEP and conventional physical therapy treatments on thoracic expansion, pulmonary function, and sputum retention in patients undergoing open abdominal surgery.

MATERIALS AND METHODOLOGY

The study was performed at the Health Care Institution Tertiary Care Hospital in Belagavi City between January and July 2023. An Institutional Ethical Committee ethical clearance was acquired. Clinical Trial Registry India (CTRI) registration was done. The CTRI number obtained was CTRI/2023/03/051192. All of the COVID-19 precautions were implemented according to ICMR guidelines. The Target population was patients who underwent open abdominal surgery aged between 20 to 60 years of both genders. The study design was Experimental, and the study type was a Randomized Controlled trial. The study was convenient, non-probability sampling with the study duration being 6 months. Thirty-six patients who fulfilled the eligibility requirements were chosen to participate in the study. Subjects who fulfilled the evaluation criteria were considered for inclusion: those willing to participate in the study, individuals between the ages of 20 and 60, and those who had undergone open abdominal surgeries.

Participants who have cough (productive sputum) post abdominal surgery. Exclusion criteria: Subjects having throat irritation, who have undergone surgery for obstetrics and gynaecological conditions, who couldn't comprehend or handle the equipment properly were excluded to participate in the trial.

The methodology included pre- and post-tests evaluating outcome measures such as peak expiratory flow rate, chest expansion measurement, and maximal inspiratory pressure.

Outcome Measures:

1. Peak flow meter: This device records lung capacity and measures the maximum airflow rate out of the lungs throughout forced expiration. The patient is directed to sit in a semi-Fowler position, grip the PEFR with both hands, place the mouthpiece between their teeth, and tightly close their lips. They are then told to take a full, maximal inspiration and forcefully exhale into the device. Three accurate readings are collected.

2. Chest circumference measurement: After the participant was instructed to breathe in and out while sitting comfortably upright, the chest wall diameter at the axillary, T4, and xiphoid processes was measured for any increase using a measuring tape. At each level, three reproducible and acceptable readings were obtained.

3. Pulmonary functions: Maximal inspiratory pressure—An essential aspect of maximal inspiratory effort is consistently reproducing maximal inspiratory pressure (MIP), a measure of inspiratory muscle strength. The subject was instructed to sit up straight and use the manometer to inspire as much as possible to obtain the

measurements. A total of three readable and repeatable measurements were obtained [9].

The envelope method allocated the participants randomly to Group A (INTERVENTIONAL GROUP) and Group B (CONTROL GROUP). Before the intervention, the subjects underwent a brief introduction to the study's device. Pulmonary function assessments, peak expiratory flow rate, and chest expansion were performed on the first day before treatment. On the fifth day after the intervention, post-intervention evaluations were carried out. The intervention was given twice daily from the first post-operative day for five days [10]. Outcome measures were measured with patients in long sitting/semi-Fowler's position.

Group A received the Vibrapep Device in addition to conventional treatment, including diaphragmatic breathing, thoracic expansion, and nebulization therapy. Group B received conventional treatment, i.e., Diaphragmatic breathing exercise, thoracic expansion exercise, and nebulization therapy alone.

Nebulization therapy:

Vibrapep (OPEP) intervention: Step 1: The patient received nebulization in a propped-up bed position, followed by using the Vibrapep (OPEP) device to assist in clearing the secretions. Step 2: The patient was advised to be relaxed, long sitting. Step 3: After exhaling normally, the patient was instructed to take a deeper breath than usual. They were then asked to hold the device with the mouthpiece and briefly hold their breath for about two seconds. Step 4: The patient was instructed to exhale for approximately four seconds through the Vibrapep. This process was repeated for 10-20 breaths, with 5-6 huff coughs in between, sessions over a 15–20-minute treatment time, the intervention was given for 10x3 sets of repetitions. A four-second expiratory time was maintained by regulating the resistance [12].

Diaphragmatic Breathing Exercise:

Semi-Fowler's position was used for diaphragmatic exercises. The patients were told to put their hands on their upper abdomen, take a deep breath for two to three seconds, rest for a moment, and then take another breath for two to three seconds. There were five sets of the exercise, with five to six repetitions per set [11].

Thoracic expansion exercise: Participants were asked to sit comfortably, take a deep breath in and out, hold for three seconds, and gently exhale while returning to the starting position. The exercise was done in three sets, with 7 to 10 repetitions each [22].

General Mobility Exercise: Following breathing exercises, the patient was instructed to perform hand pumps, 10 repetitions, 3 sets, and Ankle and foot pumping exercises, 10 repetitions, 3 sets. Hip and knee bending for 10 repetitions 3 sets, Bed side sitting for 15 mins followed by Ambulation 1-2 laps [12].

Statistical Analysis:

A complete statistical analysis was done using SPSS software after compiling the study data in an Excel spreadsheet and tabulating it per the study protocol. Shapiro-Wilk test was used for normal distribution, and a non-parametric test was used for data analysis. The independent Mann-Whitney test was used to analyze both groups. The paired sample Wilcoxon test was used to compare the results before and after the test, with $P<0.005$ of probability considered significant and $P<0.001$ of probability considered highly significant.

RESULTS

A total of 36 participants were included and analysed, with 18 in each group. The demographic characteristics of the study participants with dependent variables like gender and age. In the gender category, both groups showed male predominance, with 61.1% (11) in group A and 66.6% (12) in group B, respectively. The females were 38.8% (7) and 33.3% (6) in groups A and B respectively.

Table 1: Shows the age, height, weight, and BMI of both the groups. There was no significant difference observed in this variable in post intervention($p<0.05$) except for weight ($p=0.023$).

Variables	Group A	Group B	P value
Age in years	48.00 + 10.80	48.33 + 11.18	0.836.
Weight in kgs	59.17 + 6.49	65.11 + 7.36	0.023
Height in cm	158.83 + 1.76	159.39 + 4.94	0.293
BMI	24.13 + 2.86	25.50 + 3.43	0.311

Table 2: Within group analysis of maximal inspiratory pressure, there was a significant statistical difference seen between pre and post-treatment values in interventional group A ($p = 0.001$) and Control group B ($P =0.026$).

Groups	Times	Mean	SD	Mean Difference	SD Diff	z-value	p- value
GROUP A	Pre	5.42	2.39	9.97	4.19	3.729	0.001
	Post	15.39	5.03				
GROUP B	Pre	6.00	4.16	0.478	0.777	2.232	0.026
	Post	6.48	4.35				

Table 3: Shows within group analysis of axillary, T4 LEVEL and xiphoid level, it was seen that interventional group showed statistically significant improvement at axillary level ($p = 0.001$) when compared to control group, within group analysis of Xiphoid process showed a statistical difference in interventional group as compared to control group, with P value 0.003. Group B showed a difference in post-treatment value, but no significant difference was seen ($p = 0.233$). When compared within group analysis of T4 level, no statistical significance was seen in Group A and Group B, but the interventional group showed clinical difference in post-treatment.

GROUPS	Times	Mean	SD	Mean diff	SD diff	z- value	p- value
Group A (Axillary)	PRE	1.03	0.10	0.25	0.12	3.873	0.001
	POST	1.25	0.12				
Group B (Axillary)	PRE	1.01	0.14	0.039	0.182	1.079	0.281
	POST	1.05	0.10				
Group A (T4 LEVEL)	PRE	1.13	0.15	0.02	0.24	0.302	0.763
	POST	1.15	0.15				
Group B (T4 LEVEL)	PRE	1.02	0.15	0.009	0.166	0.634	0.526
	POST	10.1	0.09				
Group A (Xiphoid Process)	PRE	1.05	0.12	0.15	0.15	3.000	0.003
	POST	1.20	0.18				
Group B (Xiphoid Process)	PRE	1.08	0.19	0.031	0.117	1.194	0.233
	POST	1.12	0.20				

Table 4: Within group analysis of peak flow meter showed significant difference in both interventional group (P =0.001*) and control group(P=0.001). However, the interventional group showed more statistical difference as compared to a control group with effect size 1.34

Comparison of Pretest and Post Test of Peak Flow in Two Groups by paired Sample Wilcoxon Test.

GROUPS	TIMES	MEAN	SD	MEAN DIFF	SD DIFF	Z- VALUE	P-VALUE
GROUP A	PRE	87.99	21.26	20.21	15.12	3.681	0.001
	POST	108.19	12.66				
GROUP B	PRE	102.06	10.96	5.306	11.656	3.433	0.001
	POST	107.36	14.79				

Table 5: When compared in between Groups analysis the maximal inspiratory pressure showed statistical difference in both groups with P value 0.001*, but compared to control group, interventional group showed more statistical difference with mean 15.39 $\pm$ 5.03.

Between-group independent test for group statistics using independent Mann Whitney test for Maximal Inspiratory Pressure.

TIME	GROUP	MEAN	SD	Z-VALUE	P-VALUE
PRE	GRP A	5.42	2.98	0.128	0.898
	GRP B	6.00	4.16		
POST	GRP A	15.39	5.03	4.072	0.001
	GRP B	6.48	4.35		
DIFFERNCE	GRP A	9.97	4.19	5.228	0.001
	GRP B	0.48	0.78		

Table 6: When compared between group analyses, the axillary level showed a statistical difference in group A (P =0.000) compared to group B. At T4 LEVEL, the group analysis showed no statistical significance in both groups. Group A showed more statistical difference at the xiphoid level than group B.

Between group analysis test for axilla, T4 level, xiphoid process using independent man Whitney u test.

VARIABLE	TIME	GROUP	MEAN	SD	Z-VALUE	P-VALUE
AXILLA	PRE	GRP A	1.03	0.10	0.916	0.360
		GRP B	1.01	0.14		
	POST	GRP A	1.28	0.12	4.508	0.000
		GRP B	1.05	0.10		
	DIFFERENCE	GRP A	0.25	0.12	3.706	0.000
		GRP B	0.04	0.18		
T4 LEVEL	PRE	GRP A	1.13	0.15	1.472	0.141
		GRP B	1.02	0.15		
	POST	GRP A	1.15	0.15	2.369	0.018
		GRP B	1.01	0.09		
	DIFFRENCE	GRP A	0.02	0.24	0.504	0.614
		GRP B	0.01	0.17		
XIPHOID PROCESS	PRE	GRP A	1.05	0.12	0.885	0.376
		GRP B	1.08	0.19		
	POST	GRP A	1.20	0.18	0.984	0.325
		GRP B	1.12	0.20		
	DIFFRENCE	GRP A	0.15	0.15	2.053	0.040
		GRP B	0.03	0.12		

Table 7: Group analysis of peak flow meter showed more significant difference in group A compared to group B with mean value of 20.21 $\pm$ 15.12, with p value difference between group of 0.001.

Between Group Analysis Test For peak flow meter using independent Mann Whitney U Test.

TIME	GROUP	MEAN	SD	Z-VALUE	P-VALUE
PRE	GRP A	87.99	21.26	1.570	0.116
	GRP B	102.06	10.96		
POST	GRP A	107.36	12.66	0.602	0.547
	GRP B	108.19	14.79		
DIFFERNCE	GRP A	20.21	15.12	3.760	0.001
	GRP B	5.31	11.66		

DISCUSSION

The current study aimed to assess and compare the impact of conventional physiotherapy exercises and the Vibrapep (OPEP) device after open abdominal surgeries.

Optically-induced positive expiratory pressure (OPEP) therapy for separating and evacuating pulmonary secretions is made accessible by the novel Vibrapep device. Patients understand optimal effectiveness according to their therapeutic demands through adjustable pressure settings. To create pressure and oscillatory vibrations, the Vibrapep utilized the patient's whole expired air volume [13]. The Vibrapep is an airway clearance device which works on the principle of higher level of PEP which promotes collateral ventilation by stabilizing and enlarging the airway. Whenever pressure and flow fluctuate, these Asynchronous dynamic oscillations facilitate the removal of mucus from the bronchial walls, generating a continuous positive expiratory pressure (PEP) that exceeds the baseline [13].

Because expiratory flow rate is closely correlated with lung capacity, coughing will be less effective when lung volumes

are decreased during the postoperative phase. The Vibrapep potentially helped increase functional residual capacity by elevating intrapulmonary pressures, subsequently enhancing peak expiratory flow rate. Removing secretions from the lungs has increased lung capacity and peak expiratory flow rate [14]. This justifies the results obtained in both the groups, where significant improvement was seen in peak expiratory flow rate post-intervention and standard physiotherapy exercises.

A comparable study on the impact of incentive spirometry and breathing exercises on chest expansion and flow rates in patients recovering from abdominal surgery was carried out by Shridhar Shirodkar et al. in 2022. Compared to breathing exercises and ExPAP, this study revealed that both groups' post-treatment PEFRs improved [15].

"Surgery and the respiratory muscles" underwent a comprehensive review. According to the review's findings, there are quite a variety of ways that surgery might impact how well the respiratory muscles work. As a result, suitable steps should be made to lessen the severity and implications of these effects. So, the present study used a maximal inspiratory pressure to evaluate the inspiratory muscle strength pre- and post-operatively [16].

The maximal inspiratory pressure in group A significantly improved during the present study, it may be due to the exposure of inspiratory muscles to being attributed to load of resistance with 0 to 4 pressure settings in which the Vibrapep provides gradual rising of pressure followed by a sudden pressure drop by rapid onset of high velocity airflow. (3 and 4), which is regularly repeated 10 times with huff coughing in between, so there will be an increase in sarcomere, expansion of muscular mass, and a strengthening and tension-generating capacity of the muscles [17]. Furthermore, the physiological changes brought on by Vibrapep may have elevated the respiratory muscles' aerobic capacity and increased the number of type 1 fibres, which could cause the increase in the muscles' inspiratory strength [17].

In accordance with this study, a similar result was obtained in post-operated congenital diaphragmatic hernia, which showed a significant improvement in inspiratory muscle strength [17]. Hernandez-Alvarez et al in 2018, who evaluated the correlation between respiratory muscle strength and lung function observed a significant rise in FEV1 associated with respiratory muscle strength [18].

In the current research, Group A (the interventional group) exhibited significant enhancement in thoracic expansion at the axillary and xiphoid processes because the thoracic expansion exercise stimulated the collateral ventilatory system, which let air flow distal to mucus congestion in the peripheral airway [19]. The enhancement in mechanical properties may be due to the movement of the rib cage and a reduction in the tension of the rib cage muscles.[17]

The underlying mechanism of Vibrapep has helped promote lung expansion since it pertains to the peak force generated at the mucus surface and a capacity of constantly fluctuating air pressure to disrupt the connections that hold the mucus layer and afflicted airways together [15]. Additionally, the capacity of the thorax, which is augmented by the pliability of the skeletal muscle and the surrounding soft tissue, affects how much the lungs can expand or contract during breathing. The thorax is an elastic structure that grows and contracts. At the same time, breathing [17]. Rehman et al. (2020) performed a similar study to assess the effectiveness of passively stretching the respiratory muscles in improving inspiratory muscular strength and chest expansion [20].

A literature suggests that, on the effect of an OPEP, in patients with COPD and bronchiectasis, a six-week cross-over study. The study included parameters such as Pulmonary function tests, and other parameters; the study showed Aerobika demonstrated a noteworthy alleviation in sputum production ease, FVC, quality of life, and 6MWD [21].

Through compensatory flow the interalveolar pores and bronchial alveolar canals, OPEP therapy aids to produce vibrations behind secretions that are present in the lower airways. This enables secretion elimination with huffing and coughing [21]. The Vibrapep helped in obtaining sustained maximal inspiration by encouraging deep, slow, and prolonged breathing from the patient. The pulmonary volume increased as the outcome, thus helping prevent complications and assisting in sputum clearance.

The study's limitations included the lack of follow-up or long-term effects, which made it challenging to establish how the course of therapy could impact patients in the future. The research was conducted on a small sample of people (n = 36). The future scope of the study would be to determine the long-term impact of Vibrapep in post-abdominal surgery. More research with a bigger sample size and patients with additional concurrent pulmonary disorders is recommended with various physiotherapy outcome measures.

As far as we know, no other study has been carried out to evaluate OPEP(Vibrapep) in open abdominal surgeries. The study concluded that Vibrapep, along with conventional physiotherapy exercise techniques, showed an effectiveness in improving reduction of sputum, enhancing chest expansion and pulmonary function in post-operative open abdominal surgeries.

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REFERENCES

[1] Fagevik Olsén M, Hahn I, Nordgren S, Lonroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. British Journal of Surgery. 1997 Nov 1;84(11):1535-8.

[2] Siafakas NM, Mitrouska I, Bouros D, Georgopoulos D. Surgery and the respiratory muscles. Thorax 1999 May 1;54(5):458-65.

[3] Tadyanemhandu C, Mukombachoto R, Nhunzvi C,

Kaseke F, Chikwasha V, Chengetanai S, Manie S. The prevalence of pulmonary complications after thoracic and abdominal surgery and associated risk factors in patients admitted at a government hospital in Harare, Zimbabwe-a retrospective study. Perioperative Medicine. 2017 Dec;6(1):1-8.

[4] Palmer KN. Post-operative pulmonary complications. Postgraduate Medical Journal. 1955 Jan;31(351):25.

[5] Richardson J, Sabanathan S. Prevention of respiratory complications after abdominal surgery. Thorax. 1997 Aug;52(Suppl 3): S35.

[6] 6.Shaikh S, GD VV. Effect of Lung Flute Device versus Autogenic Drainage in Pulmonary Tuberculosis -A Comparative Study. tuberculosis.;10:11.

[7] Fernández-Carmona A, Olivencia -Pena L, Yuste-Ossorio ME, Penas -Maldonado L. Ineffective cough and mechanical mucociliary clearance techniques. Medicina Intensiva (English Edition). 2018 Jan 1;42(1):50-9.

[8] Airway clearance therapy (ACT) is indicated for individuals whose function of the mucociliary escalator and or cough mechanics are altered and whole ability to mobilize and expectorate airways secretions is compromised. LIT-3346 REV.A 03/02/2021.

[9] Aldrich TK, Spiro P. Maximal inspiratory pressure: does reproducibility indicate full effort? Thorax. 1995 Jan 1;50(1):40-3.

[10] 10.Pursley D. Analysis of tidal volume and expiratory pressure during oscillatory PEP therapy in healthy subjects. Respiratory Therapy. 2016;11(2):35.

[11] 11. Alaparthi GK, Augustine AJ, Anand R, Mahale A. Comparison of diaphragmatic breathing exercise, volume and flow incentive spirometry, on diaphragm excursion and pulmonary function in patients undergoing laparoscopic surgery: a randomized controlled trial. Minimally invasive surgery. 2016 Jan 1;2016.

[12] 12. Alexandra Hough. Physiotherapy In Respiratory Care, Second Edition; 1996.

[13] 13. VibraPEP® With OscValve™ technology Oscillating PEP Therapy System.

[14] 14. Chaudhary S, Chaudhary NI, Ghewade B, Mahajan G. The Immediate Effects of Breathing Exercises with Acapella and Incentive Spirometer on Preventing Early Pulmonary Complications Following Cabg.-A Comparitive Study. International Journal of Current Research and Review. 2020 Sep;12(17):51-8.

[15] 15. Shirodkar S, Deo M, Joshi M. The Effect of Breathing Exercise and Incentive Spirometry versus Breathing Exercise and EzPAP® on Flow Rates and Chest Expansion in Post Abdominal Surgery Patients: A Randomized Controlled Trial.

[16] 16. Siafakas NM, Mitrouska I, Bouros D, Georgopoulos D. Surgery and the respiratory muscles. Thorax. 1999 May 1;54(5):458-65.

[17] Lunardi AC, Paisani DM, da Silva CC, Cano DP, Tanaka C, Carvalho CR. Comparison of lung expansion techniques on thoracoabdominal mechanics and incidence of pulmonary complications after upper abdominal surgery: a randomized and controlled trial. Chest. 2015 Oct 1;148(4):1003-10.

[18] 17. Azab AR, Abdelbasset WK, Alrawaili SM, Elsayed AE, Hajelbashir MI, Kamel FH, Basha MA. Effect of chest resistance and expansion exercises on respiratory muscle strength, lung function, and thoracic excursion in children with a post-operative congenital diaphragmatic hernia. International Journal of Environmental Research and Public Health. 2022 May 17;19(10):6101.

[19] 18. Hernández-Álvarez ED, Guzmán-David CA, Ruiz-González JC, Ortega-Hernández AM, Ortiz-González DC. Effect of a respiratory muscle training program on lung function, respiratory muscle strength and resting oxygen consumption in sedentary young people. Revista de la Facultad de Medicina. 2018 Dec;66(4):605-10.

[20] 19. Lunardi AC, Paisani DM, da Silva CC, Cano DP, Tanaka C, Carvalho CR. Comparison of lung expansion techniques on thoracoabdominal mechanics and incidence of pulmonary complications after upper abdominal surgery: a randomized and controlled trial. Chest. 2015 Oct 1;148(4):1003-10.

[21] 20. Rehman A, Ganai J, Aggarwal R, Alghadir AH, Iqbal ZA. Effect of passive stretching of respiratory muscles on chest expansion and 6-minute walk distance in copd patients. International Journal of Environmental Research and Public Health. 2020 Sep;17(18):6480.

[22] 21. Svenningsen S, Paulin GA, Sheikh K, Guo F, Hasany A, Kirby M, Etemad Rezai R, McCormack DG, Parraga G. Oscillatory positive expiratory pressure in chronic obstructive pulmonary disease. COPD: Journal of Chronic Obstructive Pulmonary Disease. 2016 Jan 2;13(1):66-74.

[23] 22. Amin R, Alaparthi GK, Samuel SR, Bairapareddy KC, Raghavan H, Vaishali K. Effects of three pulmonary ventilation regimes in patients undergoing coronary artery bypass graft surgery: a randomized clinical trial. Scientific Reports. 2021 Mar 24;11(1):6730. https://doi.org/10.1038/s41598-021-86281-4