Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 6, 8186-8194

Impact Of Positive End Expiratory Pressure Device On Maximum Expiratory Pressure, Maximum Voluntary Ventilation And Dyspnea Index In Patients After Valvular Heart Surgery: Randomized Controlled Trial

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Abstract

Background
Rheumatic heart disease (RHD) is the most common cause of acquired heart disease in children and young adults globally In Egypt, the prevalence of RHD is still high and the use of devices and prosthetic materials is increasing dramatically.
So this experiment was conducted to investigate the efficacy of PEEP device on respiratory muscle strength in patients who underwent valve surgery.

Methods

Evaluation Procedure
1- Measurement of MEP: This is the most widely used noninvasive method in the clinic for evaluation of respiratory muscle strength (RMS) **[13].**
Steps of measuring: Respiratory pressure meter device:
CareFusion UK 232 Ltd, ME4 4QY.UK, SN: (064-02857) used to measure MEP.
1-The device is at zero and calibrated before each measurement.
2- The patient maximally exhales from TLC. Nose clips are required. The patient is coached to ensure adequate lip seal around the mouthpiece and achieve maximum voluntary effort, and the effort is repeated until at least three measurements have <20% variability between them. The highest mouth pressure achieved which could be maintained for at least 1 sec was collected for data processing.

Conclusion
Patients who underwent valvular heart surgery exhibited reductions in postoperative respiratory muscle strength and lung function. So it is advisable to add expiratory training using PEEP device with mouthpiece to routine chest physiotherapy for those patients after valvular heart surgery.

Introduction

Rheumatic heart disease (RHD) is the most common cause of acquired heart disease in children and young adults globally In Egypt, the prevalence of RHD is still high and the use of devices and prosthetic materials is increasing dramatically. This may put the population at high risk for infective endocarditis[1].

The World Heart Federation (WHF) released in 2013 a position statement on the prevention and control of RHD, with the ambitious goal of achieving a 25% reduction of premature deaths from ARF and RHD among individuals aged less than 25 years by 2025[2].

RHD is a chronic sequela of acute rheumatic fever (ARF) resulting from an autoimmune reaction to group A streptococcal (GAS) pharyngitis in genetically susceptible individuals[3].

Clinically, RHD causes silent valvular disease with severe permanent damage where individuals with RHD are at increased risk of complications such as congestive heart failure, arrhythmias including atrial fibrillation, stroke, infective endocarditis, poor maternal and fetal outcomes, and premature death[4].

The order of involvement of valves was mitral (60.2%), followed by aortic, tricuspid, and pulmonary valves. Mitral stenosis, predominantly seen in females, was almost exclusively of rheumatic etiology (97.4%) [5] .

Exertional dyspnea and poor exercise tolerance are the common symptoms in patients with mitral stenosis (MS), associated with affected lung functions. MS manifests as typical restrictive abnormalities of pulmonary functions due to reduced compliance, increased airway resistance, and reduced diffusing capacity resulting from pulmonary congestion and pulmonary vascular disease[6].

Pulmonary complications are common following heart surgeries and replacement of diseased valves is often associated with more significant morbidity, prolonged hospital stay, and mortality. However, the risk of postoperative pulmonary complications (POPC) is different in all patients[7]. The factors affecting the development of POPC are related to the previous health status of the patient, the effects of anesthesia, and procedural events. Because of these wide and varied factors, incidence rates of pulmonary complications vary dramatically after cardiac surgery[8].

Chest physiotherapy has long been a standard component of postoperative care, to prevent or reduce postoperative pulmonary complications[9]. The theoretical basis of encouraging patients to inspire deeply is that deep breathing opens collapsed alveoli, prevents atelectasis, restores lung volume, and averts a restrictive postoperative breathing pattern [10] .

PEEP therapy looks like the pursed lips breathing technique; it generates an increase in transluminal airway pressure by creating resistance to airflow during expiration. This increase in airway pressure prevents airway collapse, increases lung volumes, assists with secretion clearance, and improves alveolar ventilation[11] .

The PEP technique is thought to slow down expiration and increase lung volume, and may prevent or reduce airway collapse[12].

In healthy subjects, PEEP increases tidal volume by the activity of both expiratory and inspiratory muscles. Various PEP devices have been used in postoperative cardiac surgery patients[12].

So this experiment was conducted to investigate the efficacy of PEEP device on respiratory muscle strength in patients who underwent valve surgery.

Materials And Methods:

An experimental experimental design was conducted at the National Heart Institute, with a sample of thirty patients who underwent valvular heart surgery, aged 12 to 18 years old. They were referred from the physician and randomly assigned into two matched groups; experimental (15 patients) received PEEP with a mouthpiece in addition to routine chest physiotherapy (postural drainage followed by percussion and vibration, then deep breathing exercises). Control group (15 patients) received routine chest physiotherapy alone as shown in figure (1). The practical part continued from September 2021 to January 2022.

Ethical Consideration:

The purposes of the experimental, methodology, and experiment protocol were explained to every patient who participated in the experimental. Informed consent was signed by the parents of the patients who participated in the experimental. Confidentiality was assured.

Ethical committee:

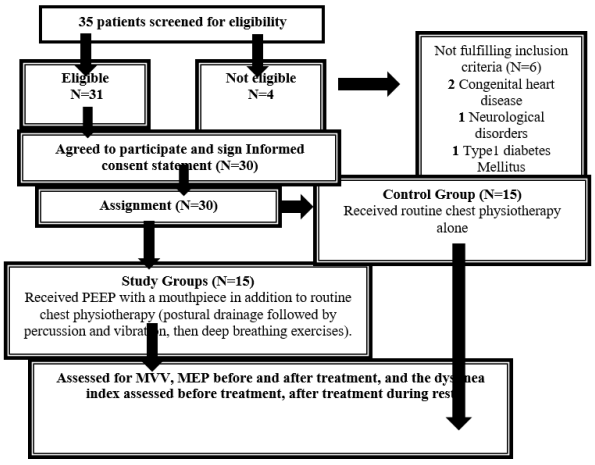
The experimental was approved from ethical committee of the Faculty of Physical Therapy NO:P.T.REC/012/002630
Clinical Trials.gov Identifier :NCT05267067

Inclusion criteria:

The inclusion criteria were as follows: Male patients underwent valve surgery (repair or replacement) for mitral valve stenosis; hemodynamically stable, their ages ranged from 12 to 18 years old, their BMI ranges from 18.5 to 24.9 with reduced MEP, MVV and complaining from shortness of breath with exertion.

Exclusion criteria:

Patients with previous cardiac surgery, congenital heart disease, neurological disorders, type1 diabetes mellitus, smoker, pacemaker implantation, atrial fibrillation and utilization of mechanical ventilation longer than 24 hours.



Procedure of the Experimental:

Initial medical screening was performed for each patient by the physician.
Demographic data, clinical characteristics and all medical history were collected from patients' file.

Evaluation Procedure:

1- Measurement of MEP: This is the most widely used noninvasive method in the clinic for evaluation of respiratory muscle strength (RMS) [13].
Steps of measuring: Respiratory pressure meter device:
CareFusion UK 232 Ltd, ME4 4QY.UK, SN: (064-02857) used to measure MEP.
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2- MVV:

Is the largest amount of air that a person can inhale and then exhale during a 12- to 15-s interval with maximal voluntary effort [14]. Spirometry used to obtain pulmonary function specially MVV (Spiro spectrum, High-accuracy PC-based Spirometer High accuracy for low flows 3-liter calibration syringe).
The MVV was determined with the patient in the sitting position. Each trial lasted 15 seconds and the volume achieved in this period was automatically extrapolated to 1 minute. The volunteers were instructed to breathe quickly and strongly during the test. All the patients received the same verbal encouragement during all 15 seconds of the test. A minimum of three maneuvers was evaluated, with an interval of 60 seconds between trials. The volunteers were instructed to breathe quickly and strongly during the test. All the volunteers received the same verbal encouragement during all the 15 seconds of the test. A minimum of three maneuvers was evaluated, with an interval of 60 seconds between trials. The reproducibility criterion was a difference of less than 10% between the two highest MVV values[15]

3- Dyspnea index

The Borg scale is a psychophysical measure in which a subject reports symptoms associated with current physical activity, e.g., exercise. The Borg scale rates dyspnea on a scale of 0-10 to quantify the intensity of dyspnea during activity. It is measured before intervention and posttreatment at rest[16].

Treatment procedure:

A- PEEP device: (Astra Tech AB, Export Department, PO Box 14, SE- 431 21 Molndal, Sweden) consists of Valve, Mouthpiece/face mask, Resistors, Manometer (-30: +30) with t-connector. Verbal explanations, about the importance of the treatment program as a whole and specifically of this modality, were given to all patients. Each patient in the experimental group was trained to use the device for 15-20 minutes (gradual increase up to 20 minutes) with two sessions daily for four consecutive weeks.

Steps of application are as follows:

1. The patients sat comfortably and upright while holding the mouthpiece tightly between the lips.
2. Adjustment was done for the expiratory resistor dial to the prescribed setting.
3. The patients had to breathe from the diaphragm, taking in a larger than normal tidal breath, but not to total lung capacity.
4. The patients had to exhale gently, the pressure in the current experimental was detected by the diameter of the valve used which was 1.5-2.0mm, this estimated diameter according to the manufacturing company was chosen in this experimental to normalize the reduced lung volumes and oxygenation which are most common complications after cardiac surgery.
5. Exhalation time lasted approximately 3 times longer than inhalation.
6. The patients had to perform 10–20 PEP breaths and then performed 2–3 forced exhalation maneuvers or huffs.
7. The patients had to repeat steps 3–6 until secretions were cleared, or until the predetermined treatment, the period had elapsed [17,18]breathing exercises using PEEP device done during long sitting, sitting upright, standing, walking in the corridor, descending and ascending stairs to control breathing and reduce exertional dyspnea.

B- Inpatient phase cardiac rehabilitation focused on routine chest physiotherapy as follows: Postural drainage includes placing a patient in a gravity-dependent position and percussing the chest wall over the area being drained, for typically between 3–5 minutes. The patient is then asked to inhale deeply 3–4 times and on exhalation, the chest wall is vibrated; this is followed by directed coughing [19]**.** Percussion is clapping of the chest wall (at a frequency of about 5 Hz) producing a shock wave that is transmitted through the thorax and is believed to loosen mucus from the airway's walls .To reduce any adverse consequences, the technique should be performed for about 30 seconds [20]**.**Vibration is shaking of the chest (at a frequency of about 12-16 Hz) and is another way of transmitting phasic energy through the thorax, usually on expiration **.**Besides, shoulder range of motion exercises is intended to improve ventilation and preserve thorax mobility **.** Arm ergometer and walking in a corridor to improve exercise tolerance[21] .

Statistical analysis:

Collected data were recorded, coded, verified, and then analyzed using SPSS (v.18; SPSS Inc., Chicago, Illinois, USA) software for Microsoft Windows 7. Data were expressed in the form of mean, standard deviation, and percentage of change. Data were checked for normality using the Kolmogorov-Smirnov test of normality before running any statistical test. Unpaired t-test was used to compare between groups regarding independent variables (demographic data, MEP, MVV, and dyspnea index). Paired t-test was used to compare between pretreatment and post-treatment data of MEP, MVV, and dyspnea index in each group.

Results:

1- Demographic data:

Unpaired t-test revealed that there was no significant difference between groups regarding age, height, and weight, where the p-value equal (0.31, 0.34, 0.41) respectively. Table (1): unpaired t test of Demographic data:

Variable	Experimental group	Control group	T value	P value
Age	15.93±1.58	15.67±1.39	0.49	0.31
Height	159.87±7.11	158.8±7.02	0.41	0.34
Weight	56.67±7.67	57.27±6.47	-0.23	0.41

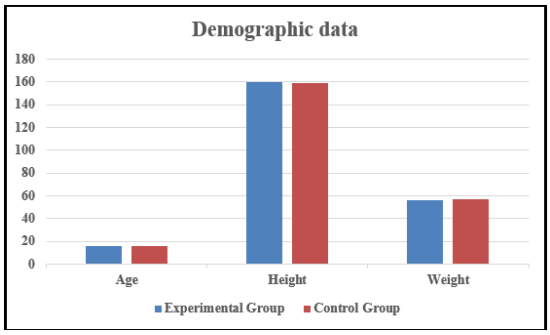

Figure (2): Mean values of demographic data

1- MVV and MEP results

Paired t test of MVV and MEP revealed that there was a statistical significant difference between pretreatment and posttreatment data in both experimental and control groups where p value less than 0.00001 with a percentage of change of MVV of 24.6% in the experimental group and 12.8% in the control group. Whereas, the percentage of change of MEP was 21.52% in the experimental group and 11.51% in the control group. Unpaired t test revealed that there was no significant difference between groups regarding pretreatment data of MEP and MVV where p value equal (0.8009, 0.622) respectively. In addition, there was no statistically significant difference between groups regarding posttreatment data of MEP where p value equal 0.852. While there was a statistically significant difference between groups regarding posttreatment data of MVV (P=0.005).

Table (2): Paired and Unpaired t test of MVV results:

Group	Mean ± SD (Pre)	Mean ± SD (Post)	Percentage of change	T value	P value	Significance
Experimental	94.47±11.15	117.73±11.09	24.6%	24.79	<0.00001	S
Control	93.33±13.15	105.27±11.39	12.8%	13.38	<0.00001	S
T value	0.254	3.04				
P value	0.8009	0.005				
Significance	NS	S				

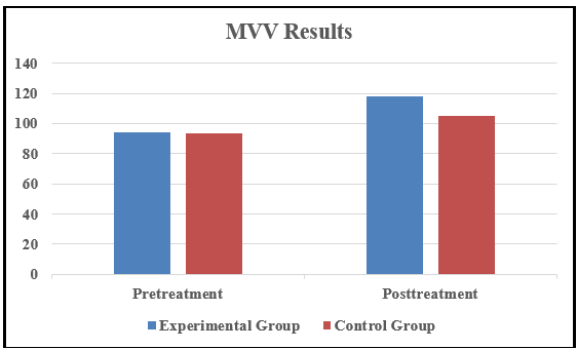

Figure (3): Pretreatment and posttreatment mean values of MVV

Table (3): Paired and Unpaired t test of MEP results:

Group	Mean (Pre)	Mean (Post)	Percentage of change	T value	P value	Significance
Experimental	66.27±25.83	80.53±25.66	21.52%	10.71	<0.00001	S
Control	70.73±25.14	78.87±22.86	11.51%	9.38	<0.00001	S
T value	0.499	- 0.187				
P value	0.622	0.852				
Significance	NS	NS				

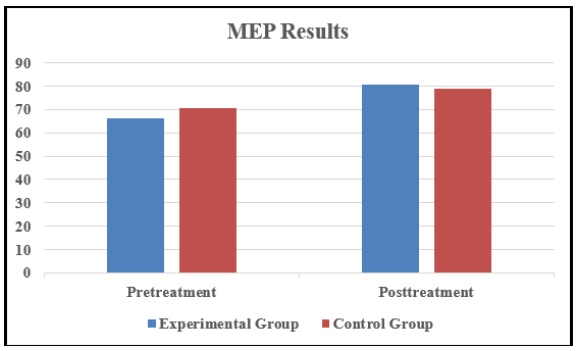

Figure (4): Pretreatment and posttreatment mean values of MEP

2- Dyspnea index results:

Paired t test of Dyspnea index revealed that there was a statistical significant difference between pretreatment and posttreatment data in both experimental and control groups where p value less than 0.0001 with a percentage of change 58.3% in the experimental group and 31.5% in the control group. Regarding pretreatment data, unpaired t test revealed that there was no statistical significant difference between groups (P= 0.509). While, there was a statistically significant difference between groups regarding posttreatment data (P=0 .035).

Table (4): Paired and Unpaired t test of dyspnea index results:

Group	Mean ± SD (Pre)	Mean ± SD (Post)	Percentage of change	T value	P value	Significance
Experimental	2.4±1.1	1±0.33	58.3%	-4.906	0.00023	S
Control	2±1.06	1.37±0.55	31.5%	-4.3802	0.00063	S
T value	-0.667	-2.22				
P value	0.509	0 .035				
Significance	NS	S				

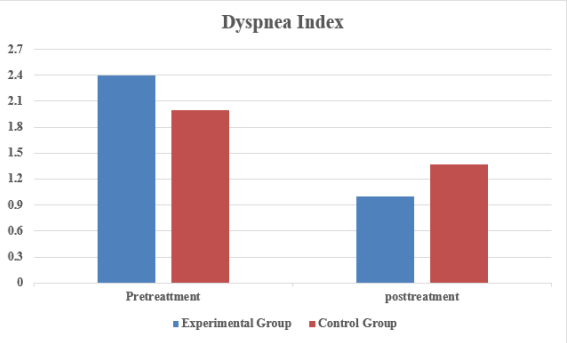

Figure (5): Pretreatment and posttreatment mean values of dyspnea index

Discussion:

The aim of this experimental was to imvestigate the impact of positive end expiratory pressure device on respiratory muscle strength in patients underwent valvular heart surgery.

The current experimental showed that there was no statistical significant difference between groups regarding posttreatment data of MEP where p value equal 0.852, while there was a statistical significant difference between groups regarding posttreatment data of MVV (P=0.005). However, a experimental conducted by **Sontakke** et al., 2010 demonstrated that there is a strong correlation between respiratory muscle strength (MIP, MEP) and MVV. Moreover, in a experimental conducted by [21] MVV used to estimate respiratory muscle endurance in pediatric population. As well as a experimental conducted by[20] showed that there is a relationship between lung function and respiratory muscle strength after discharge following cardiac surgery. But, a meta-analysis done by [8]showed that a small significant increase in maximum expiratory pressure following expiratory muscle strength training (EMST) that's why improvement in maximum expiratory pressure did not lead to improvement in cough or pulmonary function, which supported the results of the current experimental.

The possible explanations beyond the improvement of MVV within the experimental group are: PEEP device applies more positive pressure at the end of expiration that helps to activate or recruit more alveoli, keep them open, consequently increase functional residual capacity, and improves ventilation-perfusion matching.

PEEP Encourages patients to huff or cough for getting rid of secretions, so preventing airway collapse and atelectasis which is the most common complication after cardiac surgery.[7]

PEEP redistributes the extra-vascular lung water due to the positive pressure applied which help to move fluid from peri-vascular lymph vessels (less compliant) which has less capacitance to more compliant peri- bronchial lymph vessels, hence PEEP reduces the incidence of pulmonary edema which is another postoperative pulmonary complication after cardiac surgery[4].

An experimental conducted by **Ferreira et al., 2010**[22] concluded that patients who were submitted to Incentive Spirometer in addition to Expiratory Positive Airway Pressure presented less dyspnea and lower sensation of effort after 6 Minute Walking Test, as well as improvement in life quality 18 months after coronary artery bypass graft. This conclusion may explain the non-significance difference regarding dyspnea index in control group.

The present experimental has limitations that should be considered, such as restriction to short term follow up, so it is recommended in future studies to extend the period of expiratory training.

Conclusion:

Patients who underwent valvular heart surgery exhibited reductions in postoperative respiratory muscle strength and lung function. So it is advisable to add expiratory training using PEEP device with mouthpiece to routine chest physiotherapy for those patients after valvular heart surgery.

Implications of physiotherapy practice:

The current study findings show that the same

procedures should be followed as a routine gender, and age to substantiate the evidence. As a result, it is suggested that the study intervention be performed with a larger sample.

Conflict of interest: Authors declare no conflict of interest.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding: not applicable.

Ethical Approval: The experimental was approved from ethical committee of the Faculty of Physical Therapy, **NO:P.T.REC/012/002630. Clinical Trials.gov Identifier :NCT05267067.**

Consent For patients: All patients are assigned consent forms.

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