

Effect of Power Breath Device on Arterial Blood Gases and Diaphragmatic Excursion After Valve Surgery

Hend Mahdy Hassan^{1*}, Mohamed S. Zidan², Hany E. Obaya¹, Ahmed Mohamed Naguib³, Ehab Mohamed El Shehy⁴, Khaled Ahmed Mohamed Abdel Wahab⁵, Manal Nasser Hussein Wahba⁶, Mona Abdelraouf Ghallab¹, Mona Ahmed Mohamed Abd El-Wahab¹

1. Department of Physical Therapy for Cardiovascular/ Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Egypt.
2. Department of Physical Therapy, Faculty of Applied Medical Science, Al-Zaytoonah University of Jordan, Amman, Jordan
3. Lecturer, Department of Internal Medicine, Faculty of Medicine, Cairo University, Egypt.
4. Department of Cardio Thoracic Surgery, Faculty of Medicine, Cairo University, Egypt.
5. Lecturer, Department of Anesthesia and Surgical ICU, Faculty of Medicine, Cairo University, Egypt.
6. Lecturer, Department of Physiotherapy for Internal Medicine and Geriatrics, Head of Internal Medicine department, Alryada university for Science and Technology, Egypt.

ABSTRACT

Background: Pulmonary complications are a common result of heart surgeries, even though surgical methods and postoperative care have improved greatly. Pulmonary complications contribute to high rates of morbidity and mortality as well as longer hospital stays and higher health care expenses. Inspiratory muscle training (IMT) is a therapeutic modality that aims to improve inspiratory muscle conditioning via respiratory muscle overload. Respiratory muscle training devices, such as power breath, strengthen the respiratory muscle, improve endurance, and increase exercise capacity (Nora et al., 2018, and Nadia et al., 2016).

Aim: To evaluate the impact of the power breath device on arterial blood gases as well as diaphragmatic excursion following cardiac valve surgery.

Methods: Fifty female patients aged 25 to 35 years who had undergone valve surgery (either valve replacement or repair via a median sternotomy) were recruited from the Cardiothoracic Surgery Department at Kasr El-Aini Hospital and randomly assigned to two groups. These patients participated in daily inspiratory muscle training sessions, carried out once daily for seven days after surgery, beginning on the second day.

group I (intervention group): This group consisted of 30 female patients who performed inspiratory muscle training using a Power Breathe device in addition to treatment by incentive spirometer, beginning the day following surgery, once daily for seven days a week

group II (control group): This group consisted of 20 female patients who participated in a diaphragmatic breathing exercise program using an incentive spirometer (IS) only. The training was performed once daily, seven days per week, starting from the second day after surgery as part of inspiratory muscle training.

Beginning in December 2022 and ending in February 2024, the study's practical work was conducted.

Results: After management in both groups, there was no substantial difference among groups at pretreatment ($p > 0.05$). The post-treatment comparison among groups indicated a substantial elevation in PO_2 levels (ES (Effect size) = 1.99), diaphragmatic excursion (ES = 0.71), and 6MWT distance (ES = 1.73), and a significant decrease in PCO_2 (ES = 0.84) in group I compared with group II ($p < 0.01$). There was no substantial difference regarding pH levels (ES=0.13) as well as SpO_2 levels (ES=0.37) among groups ($p > 0.05$).

Conclusion: It was concluded that IMT (inspiratory muscles training) by power breath revealed significant improvements in both PaO_2 and $PaCO_2$, as well as enhanced diaphragmatic excursion among the intervention group compared to the control. While there was no statistically significant difference in pH levels as well as SpO_2 among groups.

Keywords: Valve surgery -Diaphragmatic excursion- Arterial blood gases – Power breath.

How to cite this article: Hassan HM, Zidan MS, Obaya HE, Naguib AM, El Shehy EM, Abdel Wahab KAM, Wahba MNH, Ghallab MA, Abd El-Wahab MAM. Effect of Power Breath Device on Arterial Blood Gases and Diaphragmatic Excursion After Valve Surgery. Int J Drug Deliv Technol. 2026;16(32s):794-800. DOI: 10.25258/ijddt.16.32s.87

Source of support: None

Conflict of interest: None

INTRODUCTION

*Author for Correspondence: Hend Mahdy Hassan

The World Health Organization (WHO) has recently published the World Health Statistics 2022 report, emphasizing cardiovascular disease as a significant factor in the worldwide illness burden. Cardiac surgery, an open-heart surgical procedure, directly affects the diaphragm, intercostal muscles, along with accessory respiratory muscles at the incision site. Factors such as extensive surgical incisions, prolonged operative duration, and extended exposure to general anesthesia collectively contribute to reductions in respiratory muscle strength, functional residual capacity, and overall lung volume. These physiological alterations lead to diminished ventilatory and non-ventilatory functions, thereby increasing postoperative pulmonary complications. Consequently, the strengthening of respiratory muscles is particularly crucial for patients undergoing such surgical procedures. (World health organization, 2019).

Cardiopulmonary physiotherapy approaches employ procedures to restore pulmonary volume, enhance respiratory muscle strength, improve capacity to function, as well as mitigate post-surgical problems (Bruno et al., 2013).

Valvular heart disease represents the second leading cause of heart failure after ischemic heart disease, accounting for approximately one-quarter of all heart failure cases (Ghada Youssef, 2021).

Valve replacement surgery, similar to other cardiovascular procedures, involves invasive interventions such as median sternotomy and cardiopulmonary bypass, both of which are associated with characteristic postoperative complications. These complications may include cardiac abnormalities, neurological injury, coagulopathies, renal impairment, and pulmonary disorders as atelectasis, pulmonary edema, pleural effusion, bronchospasm, and pneumonia. Pulmonary problems are a primary cause of postoperative mortality and morbidity. Shallow breathing and consequent impairment of lung function are considered the primary factors contributing to these respiratory complications. Moreover, the incidence of valvular heart disease has significantly escalated in the last ten years, leading to an increased demand for valve replacement surgeries. Rheumatic fever is widespread in Egypt, and rheumatic heart disorders significantly contribute to morbidity as well as mortality among young Egyptians. Valve replacement surgery necessitates invasive techniques, such as median sternotomy as well as cardiopulmonary bypass, which can result in various complications, including cardiac disorders, neurological impairment, coagulopathies, renal failure, as well as pulmonary complications. (Ana et al., 2017 and Bangi et al., 2019)

Cardiopulmonary physical therapy serves a crucial function in both the prevention and management of postoperative complications following cardiac surgery. A range of interventions, including physical therapy, inspiratory muscle training (IMT), continuous positive airway pressure (CPAP), and respiratory stimulants, has demonstrated efficacy in reducing these complications. These therapeutic approaches are generally regarded as safe, easily administered, and highly effective in facilitating postoperative recovery. (João V. et al., 2020)

Respiratory muscle training devices improve the endurance, strength, and exercise capacity of respiratory muscles. It is categorized into two primary types: inspiratory muscle training (IMT) as well as expiratory muscle training devices (EMT). IMT devices enhance the strength of both expiratory and inspiratory muscles. Conversely, EMT devices solely enhance the strength of the expiratory muscle (Nora et al., 2018)

Pulmonary rehabilitation aims to alleviate the physical and mental symptoms of lung disorders, increase oxygen exchange, and prevent lung collapse through the use of breathing exercises, along with respiratory muscle training techniques such as diaphragmatic breathing, as well as body positioning exercises. (Mona et al. 2024)

The evaluation of physical capacity is an important part of cardiopulmonary assessment. 6 MWT (The 6-minute walk test) has been recommended for the evaluation of submaximal exercise testing among patients suffering from chronic respiratory as well as heart diseases, such as assessing the performance of patients who have undergone open heart surgery. (Kornanong et al., 2019)

METHODS

Study Design:

This study is a randomized controlled trial (RCT) designed to investigate the effect of inspiratory muscle training using a Power Breathe device on arterial blood gases and diaphragmatic excursion following valve surgery. The study's practical work was conducted between December 2022 and February 2024. The Physical Therapy Faculty's Ethical Review Board (ref. P.T.REC/012/004209). All patients were randomly allocated into two groups:

group I (the intervention group): consisted of thirty patients who were trained to use the Power Breathe device in addition to incentive spirometer, to strengthen their inspiratory muscles once a day for seven days. Group II (the control group) consisted of twenty patients. These patients underwent an exercise protocol of diaphragmatic breathing exercises administered by IS once daily for a duration of 7 days.

Included patient were: Female patients who underwent valve surgery (either valve replacement or repair via a median sternotomy). Eligible participants were aged between 25 and 35 years and had a body mass index (BMI) ranging from 18.5 to 24.5 kg/m².

Exclusion Criteria: were unmanaged hypertension (SBP >230 mmHg or DBP >120 mmHg), presence of coronary artery disease or heart failure, necessity for mechanical ventilation exceeding 24 hours or reintubation, renal or hepatic disorders, contaminated or unstable sternum, postoperative pneumothorax, metabolic disorders, pregnancy, lactation, or a history of smoking.

Procedures:

1-Evaluation procedures: Patient ages, heights, and weights were measured, and body mass index was calculated in all patients.

1-1 Arterial Blood gases analysis (blood gas analyzer (A Abbott Laboratories Pharmaceutical Company, Singapore,

was utilized to evaluate acid-base balance, ventilation, along with oxygenation status among critically ill patients.

1-2 Diaphragmatic excursion, respiratory muscle ultrasound: (Philips Ultrasound, Inc., 22100 Bothell Everett Highway, Bothell, WA 9801-8431 USA) that was used to assess diaphragmatic excursion, anatomy, and function of the respiratory muscle pump.

1-3 Six minutes-walk test, used to measure functional exercise capacity and evaluate response to treatment, and was applied according to the guidelines of the American Thoracic Society (ATS Statement: Guidelines for the Six-Minute Walk Test 2002)

2-Therapeutic procedures:

2-1 Power breath Inspiratory Muscle Training:

The training started second day after surgery, while the patient assumed a high supine 45 degree. Patients were instructed to exhale calmly, subsequently, execute a maximal forced inspiration to total lung capacity utilizing a mouthpiece plus a nasal clip to prevent air leaking.

They were asked to complete 10 breaths per set for three sets once daily over seven consecutive days, with a two-minute rest period between sets. (Amal et al., 2019).

2-2 Incentive spirometer Inspiratory Muscle Training:

Patients were instructed to loosen any tight clothing, particularly around the neck, and to maintain an upright posture when use the IS positioned at mouth level to facilitate optimal lung expansion during use. Each patient was instructed to exhale completely, then close their lips firmly around the spirometer's mouthpiece. They were then guided to inhale slowly and deeply until reaching their maximum capacity, causing the balls in the spirometer to

rise to the top of the column. Patients were instructed to hold their breath for a minimum of 3 seconds prior to exhaling gradually. Each session consisted of 30 repetitions divided into 3 sets of 10 breaths, with a one-minute rest period between sets. The exercise intensity was progressively increased based on the patient's condition by extending the session duration, prolonging the breath-hold time, along with increasing the number of repetitions (Hadeer et al., 2018).

Statistical analysis

An unpaired t-test was performed to compare subject characteristics among groups. The Shapiro-Wilk test was employed to assess the normal distribution of the data. Levene's test for homogeneity of variances was performed to assess the homogeneity of variances among groups. A mixed design MANOVA was conducted to analyze within as well as between-group impacts on arterial blood gases, diaphragmatic excursion, as well as the 6MWT. Post-hoc analyses utilizing the Bonferroni correction were conducted for subsequent multiple comparisons. The significance criterion for all statistical tests was established at $p < 0.05$. All statistical analyses were performed using the Statistical Package for the Social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA).

- Results

- Subject characteristics:

Table (1) shows the subject characteristics of group I as well as II. No substantial differences were observed among the groups regarding age, weight, height, as well as BMI ($p > 0.05$).

Table 1. Subject characteristics.

	Group I	Group II	MD	t- value	p-value
	Mean \pm SD	Mean \pm SD			
Age (years)	27.87 \pm 4.78	28.95 \pm 4.52	-1.08	-0.80	0.43
Weight (kg)	54.93 \pm 6.15	56.70 \pm 6.05	-1.77	-1.01	0.32
Height (cm)	156 \pm 6.72	156.25 \pm 5.29	-0.25	-0.14	0.89
BMI (kg/m ²)	22.57 \pm 2.06	23.19 \pm 1.75	-0.62	-1.11	0.28

SD, standard deviation; MD, mean difference; p-value, probability value.

Effect of treatment on arterial blood gases, diaphragmatic excursion, and 6MWT:

There was a substantial interaction of treatment as well as

time ($F = 10.84$, $p = 0.001$, $\eta^2 = 0.60$). There was a

substantial main effect of time ($F = 204.82$, $p = 0.001$, $\eta^2 = 0.97$). There was a substantial main effect of treatment (F

$= 4.97$, $p = 0.001$, $\eta^2 = 0.41$).

- Within group comparison

There was a substantial improvement in PO_2 as well as SpO_2 in addition a substantial reduction in PCO_2 in both groups post-treatment in comparison with pre-treatment ($p < 0.001$). The percentage of change in PO_2 group I as well as group II was 14.67% & 7.50%, whereas the percentage of change in PCO_2 was 18.54% & 12.48%. SpO_2 increased, with a percentage of change of 9.13% in group I & 7.50%

in group II ($p < 0.001$). However, there was no substantial change in pH in both groups ($p > 0.05$). (Table 2).

There was a substantial improvement in diaphragmatic excursion as well as 6MWT distance in both groups post-treatment in comparison with pre-treatment ($p < 0.001$). The percentage of change in diaphragmatic excursion in group I as well as group II were 79.20% & 53.44%, whereas the percentage of change in 6MWT was 56.44% & 29.61%. (Table 3).

- Between groups comparison:

There was no substantial difference among groups pre treatment ($p > 0.05$). Comparison among groups post treatment revealed a substantial improvement in PO_2 (ES = 1.99), diaphragmatic excursion (ES = 0.71) as well as 6MWT distance (ES = 1.73), in addition a substantial reduction in PCO_2 (ES = 0.84) in group I in comparison with the group II ($p < 0.01$). Whereas there was no

significant difference in pH levels as well as SpO₂ among groups ($p > 0.05$). (Table 2-3).

Table 2. Mean pH, PO₂, PCO₂ and SpO₂pre and post treatment of group I and II:

	Group I	Group II	MD (95% CI)	P value	ES
	Mean \pm SD	Mean \pm SD			
Ph					
Pre treatment	7.36 \pm 0.08	7.35 \pm 0.06	0.01 (-0.04: 0.05)	0.81	
Post treatment	7.38 \pm 0.10	7.37 \pm 0.05	0.01 (-0.04: 0.06)	0.74	0.13
MD (95% CI)	-0.02 (-0.06: 0.01)	-0.02 (-0.06: 0.02)			
% of change	0.27	0.27			
	$p = 0.16$	$p = 0.32$			
PO₂ (mmHg)					
Pre treatment	81.80 \pm 4.92	80.05 \pm 4.12	1.75 (-0.93: 4.43)	0.19	
Post treatment	93.80 \pm 3.63	86.05 \pm 4.15	7.75 (5.52: 9.98)	0.001	1.99
MD (95% CI)	-12.00 (-13.47: -10.53)	-6.00 (-7.80: -4.20)			
% of change	14.67	7.50			
	$p = 0.001$	$p = 0.001$			
PCO₂ (mmHg)					
Pre treatment	41.21 \pm 2.94	40.45 \pm 3.73	0.76 (-1.14: 2.67)	0.42	
Post treatment	33.57 \pm 2.11	35.40 \pm 2.26	-1.83 (-3.09: -0.57)	0.005	0.84
MD (95% CI)	7.64 (6.57: 8.72)	5.05 (3.74: 6.36)			
% of change	18.54	12.48			
	$p = 0.001$	$p = 0.001$			
SpO₂ (%)					
Pre treatment	89.13 \pm 3.06	90.00 \pm 3.32	-0.87 (-2.70: 0.97)	0.34	
Post treatment	97.27 \pm 1.36	96.75 \pm 1.45	0.52 (-0.29: 1.33)	0.21	0.37
MD (95% CI)	-8.14 (-9.28: -6.98)	-6.75 (-8.16: -5.34)			
% of change	9.13	7.50			
	$p = 0.001$	$p = 0.001$			

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, probability value; ES, Effect size

Table 3. Mean diaphragmatic excursion, and 6MWT pre and post treatment of group I and II:

	Group I	Group II	MD (95% CI)	P value	ES
	Mean \pm SD	Mean \pm SD			
Diaphragmatic excursion (cm)					
Pre treatment	1.25 \pm 0.15	1.31 \pm 0.18	-0.06 (-0.15: 0.04)	0.24	
Post treatment	2.24 \pm 0.34	2.01 \pm 0.31	0.23 (0.04: 0.42)	0.02	0.71
MD (95% CI)	-0.99 (-1.10: -0.88)	-0.7 (-0.84: 0.56)			
% of change	79.20	53.44			
	$p = 0.001$	$p = 0.001$			
6MWT (m)					
Pre treatment	239.07 \pm 32.54	241.10 \pm 36.01	-2.03 (-21.74: 17.68)	0.83	
Post treatment	374.00 \pm 36.98	312.50 \pm 34.01	61.50 (40.70: 82.30)	0.001	1.73
MD (95% CI)	-134.93 (-149.26: -120.61)	-71.40 (-88.95: -53.85)			
% of change	56.44	29.61			
	$p = 0.001$	$p = 0.001$			

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, probability value; ES, Effect size

DISCUSSION:

The present study was designed to examine the impacts of a seven-days inspiratory muscle training (IMT) program using a Power Breathe device on arterial blood gases, diaphragmatic excursion, as well as six-minute walk test (6MWT) performance following cardiac valve surgery.

The findings of the present study showed that inspiratory muscle training by power breath revealed significant improvements in both PaO₂ and PaCO₂, as well as enhanced

diaphragmatic excursion and 6MWT among the intervention group compared to the control. However, there was no statistically substantial variation in SpO₂ or pH levels between the groups. Although the rate of improvement in the control group was clearly substantially lower than that in the intervention group received IMT, this does not mean that the use of IS was useless in the control group.

The findings of the present study align with those of Enright et al., who assessed the impacts of high-intensity IMT on diaphragmatic thickness as well as exercise capacity. Their investigation included twenty moderately trained healthy adults (nine males and eleven females), all of whom were students at the University of Salford, United Kingdom. Participants engaged in training sessions three times per week, on alternate days, over an eight-week period. The results indicated that high-intensity IMT led to significant increases in contracted diaphragmatic thickness and improvements in exercise capacity among healthy individuals. (Enright et al. 2006)

The findings of the current study align with those revealed by Mahmoud et al., who demonstrated that IMT significantly improved diaphragmatic excursion in patients recovering from thoracotomy. In their study, thirty post-thoracotomy patients were randomly allocated into two equal groups: the intervention group were given both IMT and traditional physical therapy, while the control group underwent only traditional physical therapy. Diaphragmatic excursion was assessed in all participants using ultrasonography post-operatively after being discharged from the ICU on the third day following surgery, and after completing the training program (one month). The training program was conducted for patients in both groups three times a week, twice a day for one month. (Mahmoud et al. 2012)

Our findings diverge from those of Gehad A. et al., who reported that breathing exercises produced a more substantial effect on respiratory muscle conditioning than inspiratory muscle training (IMT) performed with the Power Lung device in healthy adult participants. The study comprised participants aged 20 to 30 years with a BMI between 18 and 25 kg/m². All participants were free from cardiovascular, pulmonary, and neurological disorders. They were randomly allocated to either a study or a control group. The study group, comprising nineteen participants (ten females and nine males), underwent respiratory muscle training using the Power Lung device for six consecutive weeks, with three sessions per week, each lasting 10 to 15 minutes. The control group consisted of eighteen participants (nine females and nine males) who received conventional chest physiotherapy, including diaphragmatic breathing, belt breathing, and localized breathing exercises, for the same duration and frequency, with each session lasting 15 to 20 minutes. The result of Gehad were reductions in expiratory muscle thickness of 18.56% and 1.18% were observed in the study and control groups, respectively. Inspiratory muscle thickness decreased by 3.29% in the study group, while it enhanced by 5.03% in the control group. Diaphragmatic excursion declined by 1.40% & 3.03% in the study as well as control groups. Post-intervention measurements revealed significant differences between groups in both inspiratory and expiratory muscle thickness. The discrepancies between the findings of this study and the present research may be attributed to variations in participants' gender distribution, health status, or intervention duration. (Gehad A. et al. 2018).

In contrast, our findings differ from those of Barbalho-Moulim et al., who investigated the effects of IMT on sixty-five obese women aged 21 to 52 years, candidates for elective open bariatric surgery. Diaphragmatic excursion was measured, and the results indicated no significant improvement in diaphragmatic excursion following the training period. The difference between our result and this result might be due to the effect of obesity on their result and variations in participants' ages. (Barbalho-Moulim et al. 2011),

Furthermore, the improvements observed in functional capacity, as evaluated by the 6MWT, are corroborated by the findings of Fatma A., who reported that prolonged, high-intensity postoperative inspiratory muscle training effectively improved lung function, inspiratory muscle strength, and overall functional capacity following mitral valve replacement surgery. Significantly, these enhancements were not present in the control group, which exhibited minimal recovery of functional capacity to preoperative levels by the eighth postoperative week. (Fatma A. 2021)

Cordeiro et al., evaluated fifty patients who were allocated randomly into two groups. One group performed inspiratory muscle training (IMT) using a device twice daily, consisting of three sets of ten repetitions, while the other group were given only traditional ICU treatment. Together interventions were continued until hospital discharge. The authors found that the IMT group maintained their maximum inspiratory pressure (MIP) values in comparison to the control group. These results align with the findings of the present study. (Cordeiro et al. 2016).

The findings of the present study align with those reported by Khalid Taha, who demonstrated that diaphragmatic muscle strengthening through threshold load inspiratory muscle training in patients undergoing coronary revascularization resulted in significant increases in maximum inspiratory pressure. Additionally, improvements were observed in pulmonary gas exchange, as measured by the alveolar-arterial gradient, alongside enhanced oxygen saturation. (Khalid Taha. 2017).

The findings related to diaphragmatic excursion are further supported by Paulin et al., who reported that inspiratory muscle training (IMT), both alone and combined with a general exercise program, significantly improve diaphragmatic thickness and excursion. (Paulin et al. 2007). Similarly, the outcomes of the current study are in agreement with those that have been revealed by Amal K. Hassan, who investigated forty-four postoperative patients of both sexes with cervical spinal cord injury (SCI) at levels C3, C4, and C5. These patients were recruited from the inpatient department of Kasr Al-Aini Hospital, Cairo University, following referral by their neurosurgeon. Participants were randomly assigned to two groups: Group A (n = 21) received training with the Power Breathe device in addition to conventional chest physiotherapy, which included diaphragmatic breathing, costal (localized) breathing exercises, suction, percussion, and vibration administered three times daily for two weeks. Group B (n = 23) received conventional chest physiotherapy alone with

the same frequency and duration. Arterial blood gases were assessed before and after the intervention. Upon the conclusion of the study, Group A demonstrated substantial improvements in pH, partial pressure of oxygen (PO₂), partial pressure of carbon dioxide (PCO₂), and bicarbonate (HCO₃⁻) levels ($p < 0.05$), confirming the superior effectiveness of combined therapy compared to traditional physiotherapy alone. (Amal K. Hassan et al. 2019).

Hegazy et al, demonstrated that the implementation of IMT among patients undergoing valve replacement surgery resulted in significant enhancements in pulmonary function, inspiratory muscle strength, as well as functional capacity. These outcomes further strengthen the evidence for the advantageous impacts of IMT among patients having cardiac surgical procedures. (Hegazy et al. 2021)

BOTTOM OF FORM

Strengths and Limitations:

To our knowledge, there are a small number of studies that find out the impacts of IMT among cardiac surgery patients utilizing a power breath device till the 7th postoperative day. Nonetheless, there are drawbacks concerning the limited patient group and the quantity of training sessions (just seven). Most studies including IMT following heart surgery conduct training until the patient is discharged from the hospital. A further drawback of the current study was the lack of reassessment of inspiratory muscle strength post-discharge, resulting in a comparison solely with the values obtained on the 7th postoperative day. Consequently, additional random control studys with bigger sample sizes are required to contrast their findings with those of the current study.

CONCLUSION

IMT with a power breath device shown efficacy in increasing PaO₂ and decreasing PaCO₂ levels, in addition to enhancing diaphragmatic excursion and functional capacity in the intervention group relative to the control group.

REFERENCE

1. Amal K., Nesreen G., Heba A. and Amr A. (2019): effect of respiratory
2. Ana I., Maria J., and Mercedes R., et al (2017): Preoperative Respiratory Physiotherapy and Postoperative Complications Following Valve Replacement Surgery. *EC Pulmonology and Respiratory Medicine* 4.3: 92-100.
3. Bangi A., Abdullah M. and Abdul Rahman H. (2019): Effect of cardiac surgery on respiratory muscle strength. *Journal of Taibah Univ Med Sciences*;14(4):337
4. Barbalho-Moulim MC, Miguel GP, Forti EM, Campos Fdo A and Costa D, (2011). Effects of preoperative inspiratory muscle training in obese women undergoing open bariatric surgery: respiratory muscle strength, lung volumes, and diaphragmatic excursion. *Clinics (Sao Paulo)* 66(10):1721-1727.
5. Bruno A., Rodrigo P. Simões, and Renata G. et al., (2013): Acute effects of different inspiratory resistive loading on heart rate variability in healthy elderly patients. *Braz J Phys Ther.*; 17(4):401-408
6. Cordeiro ALL, de Melo TA, Neves D, Luna J, Esquivel MS, Guimarães ARF, et al. (2016) Inspiratory muscle training and functional capacity in patients undergoing cardiac surgery. *Brazilian Journal of Cardiovascular Surgery.* . pp. 140–144.
7. Enright SJ, Unnithan VB, Heward C, Withnall L and Davies DH, (2006) Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. *Physical Therapy* 86(3): 345-354.
8. Fatma A. Hegazy, Sara M. Mohamed Kamel, and Ahmed S. Abdelhamid, (2012.) Response of diaphragmatic excursion to inspiratory muscle trainer post thoracotomy. Msc Thesis, Faculty of Physical Therapy, Cairo University, Giza, Egypt. *PLoS ONE* 16(8).
9. Fatma A., Sara M., Ahmed S. and Emad A. et al (2021): Effect of
10. Gehad A., Hala M., Khaled M., and Nesreen G. (2019) Diaphragmatic thickness responses in relation to inspiratory and expiratory muscles training in adults *BIOSCIENCE RESEARCH*, 15(2): 1289-1296.
11. Ghada Youssef (2021) Valvular heart diseases in women *The Egyptian Heart Journal* 73:58
12. Hadeer S., Hala M., Fatma A., and Tarek F. (2018): Efficacy
13. Hegazy FA Kamel SM, Abdelhamid AS, Aboelnasr EA, Elshazly M, Hassan (2021) AM. Effect of Postoperative High Load Long Duration Inspiratory Muscle Training on Pulmonary Function and Functional Capacity after Mitral Valve Replacement Surgery: A Randomized Controlled Trial with Follow-up. *PLoS One* ;16: e0256609.
14. João V.,Silva F.and Mayara G.,et al (2020) Effects of Inspiratory Muscle Training Using an Electronic Device on Patients Undergoing Cardiac Surgery Randomized Controlled Trial. *International Journal of Cardiovascular Sciences.* [online].ahead print, PP.0-0
15. Khalid Taha Yassin Turkey (2017). Effect of Preoperative Inspiratory Muscle Training on Alveolar-Arterial Oxygen Gradients After Coronary Artery Bypass
16. Kornanong Y., Sasipa B., Khajonsak P. and Chitima K. (2019) Walking Performance in the 6-Min Walk Test and Gait Speed in Patients Undergoing Open Heart Surgery: A Preliminary Cohort Study. *Research*

- in Cardiovascular Medicine Volume 8, Issue 1
17. Mahmoud HH, Abd El-Hady AA, and El-Nahas NG MA, (2012). Response of diaphragmatic excursion to inspiratory muscle trainer post thoracotomy. MSc Thesis, Faculty of Physical Therapy, Cairo University, Giza, Egypt.
 18. Mona Abdelraouf Ghallab1*, Ahmed Fekry Salman2, Neveen Mohammed Nawar3, Karim Ibrahim Saafan1, Amira Ismail Mostafa4, Kerolous Ishak Shehata Kelini5,6, Shaimaa Mohamed Mabrouk Bondok7,8, Mona Ahmed Abdelwahab1(2024). Influence of manual diaphragm release combined with conventional breathing exercises and prone positioning on pulmonary functions in women with covid-19. revista imbrican de psicologia del ejercicio y el deporte Vol. 19 n° 1 pp. 83-88
 19. Nadia E., Afaf B., Hend E. and Elatafy E. (2016): Effect of Inspiratory Muscle Training on Clinical Outcomes of Patients Undergoing Cardiothoracic Surgeries. IOSR Journal of Nursing and Health Science. Volume 5, Issue 4, PP 92-106
 20. Nora S., BushraA., Fay A. and Mashail M. (2018): A Comparison between Two Types of Resistive Inspiratory Muscle Training Devices in Normal Subjects in Regards to Pulmonary Functions. 21 International Journal of Physical Medicine & Rehabilitation. Volume 6, Issue 1
 21. of Incentive Spirometer Training on Diaphragmatic Excursion and Quality of Life in Hemodialysis Patients Med. J. Cairo Univ., Vol.86, No. 7, December: 3997-4002.
 22. Paulin, E., W.P. Yamaguti, M.C. Chammas, S.R.S. Stelmach, A. Cukier and C.R. Carvalho, 2007. Influence of diaphragmatic mobility on exercise tolerance and dyspnea in patients with COPD. Respir. Med., 101: 2113-2118.
 23. postoperative high load long duration inspiratory muscle training on pulmonary function and functional capacity after mitral valve replacement surgery. PLOS ONE journal. pone. August 27.
 24. strengthening exercise on arterial blood gases in post-cervical spinal cord injury patients. ejpmr,6(9), 161-165.
 25. Surgery Journal of Cardiopulmonary Rehabilitation and Prevention · February
 26. World Health Organization (WHO). Cardiovascular Disease. 2019. <http://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseas...> Accessed October 15, 2019.
 27. Yanchun P. Shurong X. and Huan G et al, (2024) Perioperative respiratory muscle exercise in patients undergoing cardiac surgery: An evidence-based review