Int J Cardiovasc Sci. 2023;36:e20210238

ORIGINAL ARTICLE

Ventilatory Muscle Strength Six Months After Coronary Artery Bypass Grafting in Patients Submitted to Inspiratory Muscular Training Based on Anaerobioc Threshold: A Clinical Trial

André Luiz Lisboa Cordeiro,[1,2] Larissa Costa Almeida,[1] Jackeline Ferreira Dos Santos Leite,[1] Hayssa de Cássia Mascarenhas Barbosa,[1,2] André Raimundo França Guimarães,[3] Luiz Alberto Forgiarini Junior,[4] Jandesson Cena,[1] Jefferson Petto[2]

Centro Universitário Nobre,[1] Feira de Santana, BA - Brazil
Bahian School of Medicine and Public Health,[2] Salvador, BA - Brazil
Instituto Nobre de Cardiologia,[3] Feira de Santana, BA - Brazil
La Salle University,[4] Canoas, RS - Brazil

Abstract

Introduction: Coronary artery bypass grafting (CABG) surgery is associated with a decline in ventilatory muscle strength and lung function. Inspiratory muscle training (IMT) based on anaerobic threshold (AT) has been used to minimize the impact of CABG on these parameters, but the long-term impact is unknown.

Objective: To test the hypothesis that AT-based IMT improves inspiratory muscle strength and lung function even six months after CABG.

Methods: This is a randomized controlled clinical trial. In the preoperative period, maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP), vital capacity (VC) and peak expiratory flow (PEF) rate were assessed. On the first postoperative day, patients were randomized into two groups: AT-based IMT (IMT-AT) (n=21) where the load was prescribed based on glycemic threshold and conventional IMT (IMT-C) (n=21), with load of 40% of MIP. Patients were trained during hospitalization until the day of discharge and were assessed at discharge and six months later. For within-group comparison, paired Student's t-test or Wilcoxon test was used, and independent Student's t-test or the Mann-Whitney test was used to analyze the different time points. A $p<0.05$ was considered significant.

Results: At six months after CABG surgery, statistical difference was found between the IMT-AT and the IMT-C groups in MIP (difference between the means of -5cmH2; 95% CI=- 8.21to-1.79) and VC (difference between the means of -2ml/kg;95%CI=-3.87to-0.13). No difference was found between groups in the other variables analyzed.

Conclusion: IMT-AT promoted greater recovery of inspiratory muscle strength and VC after six months of CABG when compared to conventional training.

Keywords: Muscular Strength; Respiratory Muscles; Anaerobiosis; Breathing Exercises; Myocardial Revascularization/surgery; Hospital Discharge.

Introduction

Patients undergoing coronary artery bypass grafting (CABG) experience a reduction in ventilatory muscle strength and pulmonary function, which persists until hospital discharge.[1,2] In a previous study, our group observed this decline is maintained even one month after the procedure, and other authors have shown it up to one year.[2,3] Our group also found that the application of the inspiratory muscle training (IMT), based on the glycemic threshold, is effective in minimizing these effects during the hospital stay.[4]

The surgical procedure is associated with worsening of pulmonary capacity and muscle strength due to surgical incision, time of cardiopulmonary bypass, mechanical

Mailing Address: André Luiz Lisboa Cordeiro
Travessa Pássaro Vermelho, 47, Salvador Dali Condominium. Postal code: 44082-320. Lagoa Salgada, Feira de Santana, BA – Brazil
E-mail: andrelisboacordeiro@gmail.com

DOI: https://doi.org/10.36660/ijcs.20210238

Manuscript received October 1, 2021; revised manuscript August 11, 2022; accepted August 26, 2022.

ventilation and postoperative pain.[5-7] This impairment can increase the incidence of pulmonary complications and hospital stay.[8] In this context, IMT appears to be a differential tool, as it causes attenuation of the metaboreflex and, consequently, improvement of functional capacity and associated outcomes.

IMT can be prescribed with a load based on 40% of the MIP,[9] however our group proved that the use of the anaerobic threshold (AT) is more specific for this population, reducing the loss of muscle strength, functional capacity and length of stay hospital.[4,9] This study has external validity since the prevalence of patients undergoing CABG is high and these changes are potentially harmful, impacting their quality of life.

Despite these benefits associated with IMT performed based on the glycemic threshold, there is still a gap in the understanding of its positive effects after hospital discharge. Therefore, the primary objective of this study was to test the hypothesis that IMT based on the glycemic threshold modifies ventilatory muscle strength and pulmonary function in patients undergoing CABG even six months after discharge.

Methods

Study Design

This was a controlled, randomized clinical trial.

Eligibility criteria

A total of 60 patients undergoing cardiac surgery at *Instituto Nobre de Cardiologia*, Feira de Santana, Brazil, were considered eligible for the study. Of these, 18 were excluded due to death (n=4), valve disease (n=5) and lack of understanding of the techniques (n=9), and the final sample consisted of 42 patients (Figure 1). There were no losses to follow-up.

Inclusion criteria were individual of both genders, age from 30 to 70 years old submitted to CABG procedure with cardiopulmonary bypass and median sternotomy. Exclusion criteria included use of an intra-aortic balloon, surgical reintervention, death, heart valve disease, previous lung disease, patients who did not understand how to perform the proposed techniques, patients with hemodynamic

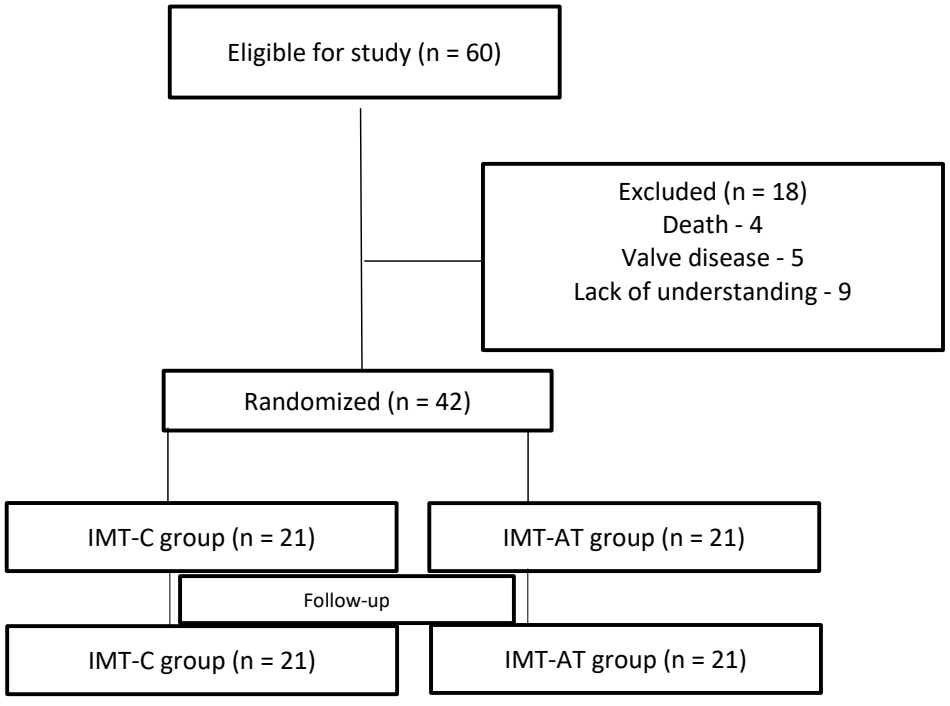

Figure 1 – Study flowchart. IMT-C: conventional inspiratory muscle training; IMT-AT: inspiratory muscle training group based on the anaerobic threshold.

instability during the assessment or during the IMT and physical limitation. The present study was approved by the Ethics and Research Committee of *Faculdade Nobre* (FAN) in Feira de Santana-Bahia, Brazil, under approval number 2,088,639. All patients signed a consent form. This study is registered in the Brazilian Registry of Clinical Trials (ReBEC) (number RBR-8dqrdq).

Surgical and postoperative treatment

Surgery was performed through median sternotomy. For CABG, saphenous vein grafts and / or left or right internal mammary artery grafts were used. During anesthesia and after surgery, patients received 40-80% oxygen. Postoperatively, patients were artificially ventilated with a positive end-expiratory pressure of 5 cmH2O. After extubation, all patients received paracetamol (1g) four times a day during hospitalization and if necessary after discharge. Demographic and descriptive data were collected from medical records.

Study protocol

After meeting the inclusion criteria, patients had their lung function assessed preoperatively by measurement of MIP, maximum expiratory pressure (MEP), vital capacity (VC) and peak expiratory flow (PEF). On the next day, patients were taken to the operating room and, later, to the intensive care unit (ICU). On the first postoperative day, the research participants were allocated randomly to the conventional IMT group (IMT-C) or to the IMT with anaerobic threshold (IMT-AT) group. The intervention group was decided by drawing a ball on which there was a piece of paper indicating it. Patients were managed for non-invasive ventilation, breathing exercises, kinesiotherapy, cycle ergometry and ambulation following the institution's protocol.

In the IMT-C group, patients underwent MIP assessment and started IMT with a continuous flow resistance, using the PowerBreathe Kinectic Series®, HaB International, UK), with 40% of the MIP, performing three sets with 15 repetitions. This training was done twice a day until the patient was discharged.

For the IMT-AT patients, exercise was prescribed according to the glycemic threshold. Resistance of the inspiratory muscles was determined by a progressive test performed using the PowerBreathe Kinectic Series® (HaB International, UK) device. This IMT, with a non-continuous incremental characteristic, consisted of up to 10 sets of 15 repetitions with increasing load. After the end of each set, there was an interval of two minutes.

Using the same evaluation equipment, 10% of the MIP value was started and increased 10% at each test level. At the end of each load level, capillary blood glucose was assessed using the Accu-Chek Performa® device, from Roche.

The test was interrupted when the individual was no longer able to overcome the load imposed by the device or continue the test.[4] The load used for training corresponded to that of the lowest glycemic value. The load was measured every four days, and 40% of the load was adjusted according to the new muscle strength measured. The training consisted of three series of 15 repetitions, twice a day until discharge.

The physical therapy of patients in both groups was performed three times a day in the ICU and twice a day in the ward. The therapy was conducted by the physical therapist of the unit, with a total time of 30 to 35 minutes.

Pulmonary function was evaluated by the same examiner for muscle strength, VC and late expiratory flow peak on day of hospital discharge and at six months after surgery. The examiner was trained and blinded during the study.

Measurement of MIP, MEP, VC and PEF

The preoperative assessment of MIP was performed using an analogue manometer (Indumed®) During the evaluation, a maximum forced expiration (residual volume) was requested, followed by maximum and low inspiratory effort until total pulmonary capacity. The unidirectional valve method was used; the gases expired passed through a hole of one millimeter to exclude the action of the buccinator. The test was repeated for three times, and the highest value reached was used for analysis, as long as this value was not the last.[10]

Subsequently, for the maximum expiratory pressure (MEP), the same device was used. The patient was instructed to perform a maximum inspiration (total lung capacity); then the mask was placed, and the patient was asked to exhale until residual capacity was reached. The test was repeated three times and the highest value reached was used for analysis, as long as this value was not the last.[10]

Patient's VC was measured using a Ferraris - Mark 8 Wright Respirometer (Louisville, CO, USA) was used and the patient was instructed on all phases of the test. The

respirometer was unlocked, reset and then the face mask was placed on patient's face. The patient was instructed to inhale maximally to total lung capacity, and exhale as completely as possible until the residual volume was reached. Then, the respirometer was locked and the result registered. The test was repeated three times, with an interval of one minute between them, and the highest value was included in the analysis.[11]

PEF was assessed using the Mini Wright® peak flow meter. Measurements were taken with patient seated, with the head in a neutral position and a nose clip to prevent air from escaping through the nostrils. The patient was asked to hold the device with both hands and place it in the mouth, inhale deeply to total lung capacity, and then exhale completely into the device. The test was repeated three times, and the highest value was used for analysis, with no difference greater than 40 liters between measurements.[11]

Primary and secondary outcome

The primary outcome was muscle strength after six months of surgery and the secondary outcome was pulmonary function. Registry of test results, patient selection and patient allocation to interventions were carried out by different examiners.

Sample calculation

The sample calculation was based on our previous study.[4] For a 5% alpha and a power of 80%, 42 patients were necessary, 21 in each group.

Statistical analysis

A double entry of data was performed, and the analysis followed the principles of intention-to-treat analysis. Data normality was tested by Shapiro-Wilk test. Continuous variables were expressed as mean and standard deviation. Variables with non-normal distribution were expressed as median and interquartile range. The confidence interval was set at 95% for all analyses. Estimates of average effects (*i.e.* between-group differences) for all outcomes were calculated using linear mixed models. For categorical variables, the chi-square test was used. For intra-group comparison, the paired Student's t-test was used and the independent Student's t-test or the Mann-Whitney was used to analyze the different time points. A $p<0.05$ was adopted as significant. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0.

Results

A total of 42 patients completed the pulmonary function tests six months after cardiac surgery. Demographic and surgical variables are shown in Tables 1 and 2.

Table 3 shows parameters of muscle strength and lung function in the preoperative and six months later. Statistical difference was found between the IMT-C group and the IMT-AT group in MIP (difference between the means of -5 cmH2; 95% CI = - 8.21 to -1.79) and VC (difference between the means of -2 mL / kg; 95% CI = - 3.87 to -0.13) at six months of follow-up. No difference was found between groups in the other variables analyzed.

Discussion

In the present study, we found that IMT-AT resulted in higher recovery of inspiratory muscle strength and VC when compared to IMT-C. There was no difference between groups when assessing expiratory muscle strength and PEF.

The application of IMT-AT reduced the loss of inspiratory muscle strength at hospital discharge and promoted faster recovery six months after the surgical procedure. VC at the time of hospital discharge did not differ between the groups but was significantly different at six months as compared with the preoperative period. Patients after cardiac surgery are afraid of inhaling deeply because of pain, which leads to a decrease in VC during the hospital stay.[12,13] A short hospital stay in addition to patient's fear and the absence of a specific protocol make it difficult to recover this variable. Also, VC is dependent not only on muscle strength, but also on the expansion of the rib cage and elastic components, which are altered in the early postoperative period.[14,15]

After six months of procedure, the patient feels more confident to perform exercises and deep breathing, promoting an improvement in lung capacity, as expressed by the VC in this study.[16,17] It is worth mentioning that after hospital discharge patients did not continue to perform IMT, and the effects after six months possibly reflected the strength gained during their hospital stay. Due to our study design, it was not possible to eliminate the Hawthorne effect since there was no follow-up during the six months, despite the fact that the level of physical activity in both groups was similar.

Studies have shown that IMT can reduce the loss of inspiratory muscle strength, functional capacity, pulmonary complications and length of hospital stay,[18,19]

Table 1 – Clinical data of patients undergoing CABG

Variables	IMT-C Group (n - 21)	IMT-AT Group (n - 21)	p
Gender			0.67[a]
Male	13 (62%)	14 (67%)	
Female	8 (38%)	7 (23%)	
Age (years)	62 ± 10	61 ± 9.6	0.45[b]
BMI (kg/m²)	27 ± 3.9	27 ± 3.2	0.87[b]
Comorbidities			
DM	13 (62%)	9 (43%)	0.23[a]
SAH	11 (52%)	13 (62%)	0.65[a]
DLP	12 (57%)	8 (38%)	0.34[a]
Sedentary lifestyle	13 (62%)	11 (52%)	0.75[a]
AMI	8 (38%)	7 (33%)	0.84[a]
NYHA Class			0.32[a]
I-II	13 (62%)	12 (57%)	
III - IV	8 (38%)	9 (43%)	
EuroScore	4 ± 2	4 ± 1	0.87[b]
Left ventricular ejection fraction (%)	57 ± 8	54 ± 10	0.78[b]
Post-high physical activity level (minutes per week)	120 ± 9	125 ± 8	0.64[b]
Average load for IMT (cmH2O)	40	25 ± 5	0.02[b]
Hospital stay time (days)	8.2 ± 1.3	7 ± 1.3	<0.01[b]

a: Chi-square test; b: Independent Student's t-test; DLP: dyslipidemia; DM: diabetes mellitus; SAH: systemic arterial hypertension; AMI: acute myocardial infarction; BMI: body mass index; CABG: coronary artery bypass grafting; NYHA: New York Heart Association; IMT-C: conventional inspiratory muscle training; IMT-AT: inspiratory muscle training group based on the anaerobic threshold.

Table 2 – Surgical data of patients undergoing CABG

Variables	IMT-C Group (n - 21)	IMT-AT Group (n - 21)	p
Operation time (h)	3 ± 1	3 ± 2	0.87[a]
Ao time (min)	84 (60 - 94)	86 (64 - 95)	0.79[b]
MV time (hours)	7.6 ± 2.1	8.1 ± 2.1	0.23[a]
CPB time (min)	85.7 (74 - 97)	88.8 (71 - 99)	0.54[b]
Number of grafts	2.6 ± 0.8	2.5 ± 0.6	0.76[a]

a: Independent Student's t-test; b: Mann-Whitney test. Ao time: aortic clamping time; MV: mechanical ventilation; CABG: coronary artery bypass grafting; CPB: Cardiopulmonary bypass; IMT-C: conventional inspiratory muscle training; IMT-AT: inspiratory muscle training group based on the anaerobic threshold.

Table 3 – Mean (standard deviation) of continuous variables at all times of the study in the different groups

Results	Groups						Difference within the group				Difference between groups	
	Preoperative		Hospital discharge		Six months		Hospital discharge minus preoperative		Six months minus preoperative		Hospital discharge minus preoperative	Six months minus preoperative
	IMT-C (n = 21)	IMT-AT (n = 21)	IMT-C (n = 21)	IMT-AT (n = 21)	IMT-C (n = 21)	IMT-AT (n = 21)	IMT-C	IMT-LA	IMT-C	IMT-LA	IMI-AT minus IMT-C	IMT-AT minus IMT-C
MIP (cmH2O)	101 (15)	103 (19)	77(14)	92 (15)	95 (6)	102 (5)	-24 (15)	-11 (14)	-6 (2)	-1 (7)	-13 (-22.05 a -3.95)	-5 (-8.21 a -1.79)
MEP (cmH2O)	77 (16)	85 (17)	61 (11)	68 (16)	70 (8)	81 (5)	-16 (12)	-17 (14)	-7 (9)	-4 (8)	1 (-7.13 a 9.13)	-3 (-8.31 a 2.31)
VC (ml/kg)	53 (5)	51 (9)	46 (5)	44 (6)	49 (3)	49 (3)	-7 (5)	-7 (7)	-4 (3)	-2 (3)	0 (-3.79 a 3.79)	-2 (-3.87 a -0.13)
PEF (L/Min)	420 (137)	384 (131)	312 (108)	347 (106)	382 (87)	371 (69)	-108 (111)	-37 (101)	-38 (88)	-13 (77)	-71 (-137.19 a -4.81)	-25 (-76.57 a 26.57)

Estimates of average effects (i.e. between-group differences) of the outcomes were calculated using linear mixed models. For intra-group comparison, the paired Student's t-test was used and the independent Student's t-test or the Mann-Whitney test was used to compare between time points. MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; VC: vital capacity; PEF: peak expiratory flow. IMT-C: conventional inspiratory muscle training; IMT-AT: inspiratory muscle training group based on the anaerobic threshold.

In our study, we found that patients exposed to the IMT-AT program recovered inspiratory muscle strength six months after discharge. This is particularly important because the training performed was prescribed with a lower load than the conventional group and for a shorter time. This lower loss in the hospital and greater recovery after six months can be attributed to the type and load level of training that were compatible with characteristics of the diaphragm. This muscle is predominantly composed of type I, followed by type IIa muscle fibers, so that the lower load, specific for these types of fibers, generated greater resistance gain, with consequent increase in strength and attenuation of the metaboreflex.[20]

Zanini et al.,[21] demonstrated that the application of IMT alone or as part of an exercise protocol, improved pulmonary function after CABG. It should be noted that the IMT must be an integral part of the rehabilitation protocol during and after hospital discharge.

The variables MEP and PEF were not different between the groups, neither at hospital discharge nor six months after the procedure, which may be associated with an absence of a specific protocol. However, from the first postoperative day, patients are encouraged to cough to eliminate secretion and reduce the incidence of respiratory infections. This stimulation promotes contraction of the expiratory muscles, increasing the strength of these variables.

There is a need to analyze muscle strength and lung function parameters when IMT-AT is performed preoperatively and / or after hospital discharge.

One limitation of our study is the lack of application of an instrument to assess postoperative pain, although analgesia has been optimized for all patients. Also, we did not evaluate confounding variables, such as pain, and the lack of correlation between pulmonary function and clinical and functional results.

Conclusion

IMT-AT promoted greater recovery of inspiratory muscle strength and VC after six months of myocardial revascularization when compared to conventional training.

Author contributions

Conception and design of the research and analysis and interpretation of the data: Cordeiro ALL, Petto J; acquisition of data: Cordeiro ALL, Almeida LC, Leite JFS, Barbosa HCM; statistical analysis: Cordeiro ALL; writing of the manuscript:

Cordeiro ALL, Almeida LC, Leite JFS, Barbosa HCM, Cena J; critical revision of the manuscript for intellectual content: Guimarães ARF, Forgiarini Júnior AL, Cena J, Petto J.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Ethics and Research Committee of Faculdade Nobre (FAN) under the protocol number 2,088,639. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

References

1. Westerdahl E, Jonsson M, Emtner M. Pulmonary function and health-related quality of life 1-year follow up after cardiac surgery. J Cardiothorac Surg. 2016 Jul 8;11(1):99. doi: 10.1186/s13019-016-0491-2.
2. Westerdahl E, Urell C, Jonsson M, Bryngelsson I, Hedenström H, Emtner M. Deep breathing exercises performed 2 months following cardiac surgery: a randomized controlled trial. J Cardiopulm Rehabil Prev. Jan-Feb 2014;34(1):34-42. doi: 10.1097/HCR.0000000000000020.
3. Cordeiro ALL, Silva LGR, Pinto MO, Araújo JS, Guimarães AR, Petto J. Behavior of Pulmonary Function after Hospital Discharge in Patients Submitted to Myocardial Revascularization. Int J Cardiovasc Sci. 2018 Mar/Apr;32(2):104-9. doi: 10.5935/2359-4802.20180092.
4. Cordeiro ALL, Mascarenhas HC, Landerson L, Araújo JS, Borges DL, Melo TA, et al. Inspiratory Muscle Training Based on Anaerobic Threshold on the Functional Capacity of Patients After Coronary Artery Bypass Grafting: Clinical Trial. Braz J Cardiovasc Surg. 2020;35(6):942-9. doi: 10.21470/1678-9741-2019-0448.
5. Wang G, Xiao S, Gao C. The effects of cardiopulmonary bypass on pulmonary function during robotic cardiac surgery. Perfusion. 2015 Apr;30(3):213-8. doi: 10.1177/0267659114537327.
6. Cipriano Júnior G, Carvalho ACC, Bernardelli GF, Peres PAT. Short-term transcutaneous electrical nerve stimulation after cardiac surgery: effect on pain, pulmonary function and electrical muscle activity. Interact Cardiovasc Thorac Surg. 2008 Aug;7(4):539-43. doi: 10.1510/icvts.2007.168542.
7. Wang Y, Huang C, Tu Y. Effects of Positive Airway Pressure and Mechanical Ventilation of the Lungs During Cardiopulmonary Bypass on Pulmonary Adverse Events After Cardiac Surgery: A Systematic Review and Meta-Analysis. J Cardiothorac Vasc Anesth. 2018 Apr;32(2):748-759. doi: 10.1053/j.jvca.2017.09.013.
8. Mathis MR, Duggal NM, Likosky DS, Haft JW, Douville NJ, Vaughn MT, et al. Intraoperative Mechanical Ventilation and Postoperative Pulmonary Complications after Cardiac Surgery. Anesthesiology. 2019 Nov;131(5):1046-1062. doi: 10.1097/ALN.0000000000002909.
9. Cordeiro ALL, Melo TA, Neves D, Luna J, Esquivel MS, Guimarães ARF, et al. Inspiratory Muscle Training and Functional Capacity in Patients Undergoing Cardiac Surgery. Braz J Cardiovasc Surg. 2016;31(2):140-4. doi: 10.5935/1678-9741.20160035.
10. Neder JA. References values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res. 1999; 32(6): 719-27.
11. American Thoracic Society, European Respiratory Society. ATS/ERS. Statement on Respiratory Muscle Testing. Am J Respir Crit Care Med. 2002;166(4):518-624. doi:10.1164/rccm.166.4.518
12. Nachiyunde B, Lam L. The efficacy of different modes of analgesia in postoperative pain management and early mobilization in postoperative cardiac surgical patients: A systematic review. Ann Card Anaesth. 2018;21(4):363-70. doi:10.4103/aca.ACA_186_17.
13. Jahangirifard A, Razavi M, Ahmadi ZH, Forozeshfard M. Effect of TENS on Postoperative Pain and Pulmonary Function in Patients Undergoing Coronary Artery Bypass Surgery. Pain Manag Nurs. 2018;19(4):408-14. doi:10.1016/j.pmn.2017.10.018.
14. Romberg K, Fagevik Olsén M, Kjellby-Wendt G, Lofdahl Hallerman K, Danielsson A. Thoracic mobility and its relation to pulmonary function and rib-cage deformity in patients with early onset idiopathic scoliosis: a long-term follow-up. Spine Deform. 2020;8(2):257-68. doi:10.1007/s43390-019-00018-y.
15. Sanchis-Gimeno JA, Lois-Zlolniski S, González-Ruiz JM, Palancar CA, Torres-Tamayo N, García-Martinez D, et al. Association between ribs shape and pulmonary function in patients with Osteogenesis Imperfecta. J Adv Res. 2019;21:177-85. doi:10.1016/j.jare.2019.10.007.
16. Westerdahl E. Optimal technique for deep breathing exercises after cardiac surgery. Minerva Anestesiol. 2015;81(6):678-83.
17. Kristjánsdóttir A, Ragnarsdóttir M, Hannesson P, Beck HJ, Torfason B. Respiratory movements are altered three months and one year following cardiac surgery. Scand Cardiovasc J. 2004;38(2):98-103. doi:10.1080/14017430410028492.
18. Gomes Neto M, Martinez BP, Reis HF, Carvalho VO. Pre- and postoperative inspiratory muscle training in patients undergoing cardiac surgery: systematic review and meta-analysis. Clin Rehabil. 2017;31(4):454-64. doi:10.1177/0269215516648754.
19. Katsura M, Kuriyama A, Takeshima T, Fukuhara S, Furukawa TA. Preoperative inspiratory muscle training for postoperative pulmonary complications in adults undergoing cardiac and major abdominal surgery. Cochrane Database Syst Rev. 2015;(10):CD010356. doi:10.1002/14651858.CD010356.pub2.
20. Dot I, Pérez-Teran P, Samper MA, Masclans JR. Diaphragm dysfunction in mechanically ventilated patients. Arch Bronconeumol. 2017;53(3):150-6. doi:10.1016/j.arbres.2016.07.008.
21. Zanini M, Nery RM, de Lima JB, Buhler RP, da Silveira AD, Stein R. Effects of Different Rehabilitation Protocols in Inpatient Cardiac Rehabilitation After Coronary Artery Bypass Graft Surgery: A Randomized Clinical Trial. J Cardiopulm Rehabil Prev. 2019;39(6):E19-E25. doi:10.1097/HCR.0000000000000431.