LITERATURE REVIEW

Preoperative Inspiratory Muscle Training in Patients Undergoing Coronary Artery Bypass Graft Surgery: It's Impact on Postoperative Pulmonary Complication and Respiratory Muscle Function

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ABSTRACT

Introduction: Coronary artery bypass graft (CABG) surgery increases the life expectancy of coronary artery disease patients, but the surgery itself causes postoperative pulmonary complications (PPC). PPC was associated with a decrease in respiratory muscle and lung function. Inspiratory muscle training (IMT) has been used in cardiac rehabilitation for post-CABG surgery patients. This review aimed to describe preoperative IMT impacts on PPC and respiratory muscle function in patients undergoing CABG surgery.

Methods: Articles written in English were searched using PubMed, EBSCOhost, and Google Scholar databases without limitation of year of publication used search query and keywords such "(Inspiratory Muscle Training) AND (Respiratory Muscle Training) AND (Coronary Artery Bypass Graft) AND (Cardiac Surgery)". The inclusion criteria were participants undergoing CABG surgery in the pre-operative period and were given threshold IMT.

Result and Discussion: Preoperative IMT did not increase lung function, but it prevented a decrease in lung function postoperatively. The incidence of PPC was lower and the length of stay was shorter in patients who were given preoperative IMT compared to the control. Preoperative IMT also increased the strength and endurance of inspiratory muscles associated with decreased PPC.

Conclusion: Preoperative IMT given to patients undergoing CABG surgery has been proven to prevent PPC and increase respiratory muscle function. A practical guidance was developed for preoperative IMT administration to improve outcomes of patients undergoing CABG surgery.

Keywords: Coronary Artery Bypass, Coronary Artery Disease, Length of Stay, Breathing Exercise, Respiratory Muscles

ABSTRAK

Pendahuluan: *Bedah Pintas Arteri Koroner* (BPAK) meningkatkan angka harapan hidup pasien penyakit arteri koroner, namun tindakan operasi itu sendiri menimbulkan komplikasi paru pasca operasi (KPPO). KPPO dikaitkan dengan penurunan fungsi otot pernapasan dan paru-paru. Latihan otot inspirasi (LOI) telah digunakan dalam rehabilitasi jantung untuk pasien pasca BPAK. Tinjauan ini bertujuan untuk menjelaskan dampak IMT terhadap KPPO dan fungsi otot pernapasan pada pasien yang menjalani operasi BPAK.

Metode: Artikel yang ditulis dalam bahasa Inggris dicari menggunakan database PubMed, EBSCOhost, dan Google Scholar tanpa pembatasan tahun penerbitan menggunakan algorima dan kata kunci pencarian sebagai berikut "*(Inspiratory Muscle Training) AND (Respiratory Muscle Training) AND (Coronary Artery Bypass Graft) AND (Cardiac Surgery)*". Kriteria inklusinya adalah pasien yang menjalani BPAK pada masa pra operasi dan diberikan LOI dengan alat *threshold* IMT.

Hasil dan Pembahasan: LOI pra operasi tidak meningkatkan fungsi paru, namun mencegah penurunan fungsi paru pasca operasi. Angka kejadian KPPO lebih rendah dan lama rawat inap lebih pendek pada pasien yang diberikan LOI pra operasi dibandingkan dengan kontrol. LOI pra operasi juga meningkatkan kekuatan dan daya tahan otot inspirasi yang berhubungan dengan penurunan KPPO.

Kesimpulan: Penggunaan IMT pra operasi pada pasien yang menjalani BPAK terbukti dapat mencegah KPPO dan meningkatkan fungsi otot pernafasan. Tinjauan ini memberikan panduan praktis untuk LOI pra operasi untuk meningkatkan luaran pasien yang menjalani BPAK.

Kata kunci: Bedah Pintas Arteri Koroner, Penyakit Arteri Koroner, Lama Perawatan, Latihan Pernapasan, Otot Respirasi

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INTRODUCTION

Coronary artery bypass graft (CABG) surgery, which is the main treatment procedure for patients with coronary artery disease (CAD), has been known to increase the life expectancy of CAD patients who experience acute coronary syndrome. However, the surgery itself can cause complications, ranging from mild complications to catastrophic events such as death and stroke.[1-4]

Postoperative pulmonary complication (PPC) is a common CABG complication that occurs due to decreased lung function and respiratory muscle function after surgery. Several factors are thought to cause a decrease in lung function due to CABG surgery, namely a decrease in chest wall mechanics, impaired diffusion and hypoxemia, failure of the diaphragm due to phrenic nerve compression, and surgical wound pain in addition to aging.[5, 6]

Decreased lung function can be in the form of a decline in *vital capacity* (VC), *forced vital capacity* (FVC), *forced expiration volume in 1 second* (FEV1), *inspiratory capacity* (IC), *functional residual capacity* (FRC), *total lung capacity* (TLC), and *peak expiratory flow* (PEF).[5, 7, 8] The decrease in VC can reach 70% of the preoperative baseline value one day after surgery.[7] Lung function will gradually increase after surgery, but the improvement in lung function parameters after surgery generally did not reach the baseline value. Several studies even found that the decline in lung function after CABG surgery lasted several months.[5, 8]

Decreased respiratory muscle function, especially the diaphragm, is thought to be a factor that contributes to restrictive changes in the form of a significant decrease in lung function after CABG surgery. After surgery, there was a decrease in the value of maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) which indicated a decrease in inspiratory and expiratory muscle function.[9] One of the predictive values that acts as a protective factor for the development of PPC is an MIP or MEP value above 75%.[10]

Inspiratory muscle training with an inspiratory muscle trainer (IMT) has been used in cardiac rehabilitation (CR) programs for a long time. A study found that the incidence of PPC and ventilator use for more than 24 hours was lower in the group of patients who were given preoperative IMT compared to the control group.[11] A review on the use of IMT in patients undergoing CABG surgery summarized that this exercise was useful in increasing inspiratory muscle endurance and strength, lung function, and distance covered in the 6-minute walk test as well as reducing the incidence of PPC and shortening the length of hospital stay (LOS).[12]

This review explored previous research regarding preoperative IMT impacts on PPC and respiratory muscle function in patients undergoing CABG surgery. The results of this review combined with existing literature on IMT devices were used to provide practical guidance in the preoperative IMT administration in patients undergoing CABG surgery.

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were adhered to for this review. Articles written in English were searched using PubMed, EBSCOhost, and Google Scholar databases without limitation of year of publication. Search query and keywords used were "(Inspiratory Muscle Training) AND (Respiratory Muscle Training) AND (Coronary Artery Bypass Graft) AND (Cardiac Surgery)". The inclusion criteria were participants undergoing CABG and in the pre-operative period were given threshold IMT. Training impacts and outcomes searched in this study were postoperative complication, lung function, length of stay and respiratory muscle function. Data on IMT (indication, contraindication, physiological effect, technique, devices, and user manual), intervention protocols, clinical and functional outcomes, and results were obtained as a basis for the practical guidance.

RESULTS

The initial search based on the search query yielded 140 results and seven articles were eligible for this review (Figure 1). As for IMT outcomes, 5 articles study PPC, 3 articles elaborate lung function, 3 articles see hospital length of stay and 7 articles study the respiratory muscle function. A resume of this findings served in Table 6. Practical guideline synthesized from the findings also shown in Table 7.

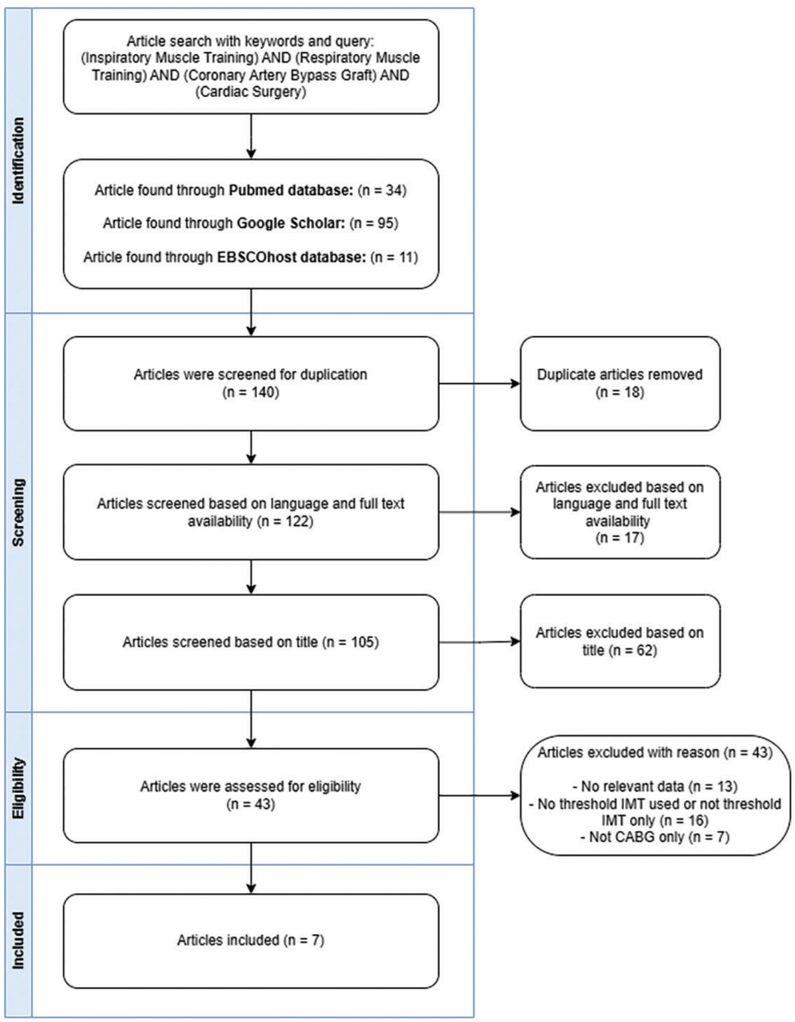

Figure 1 PRISMA Flow Chart

DISCUSSION

1. Overview of Inspiratory Muscle Trainer

1.1 The Goal and Benefits

IMT is a training device used to increase the strength and endurance of the inspiratory muscles, especially the diaphragm. Increasing inspiratory muscle strength results in improved exercise capacity, symptoms, and health-related quality of life (HRQoL) in chronic respiratory disease patients. The use of IMT is not a standard regimen or component of pulmonary rehabilitation.[13] In clinical populations, administration of IMT improves the clinical and functional status of patients.[14]

1.2 Indication and Contraindication

IMT can be given to treat pathologies associated with respiratory system diseases such as weakness of the respiratory muscle, decreased postoperative volume of the lung, and limitation of expiratory flow.[14] Since IMT requires the creation of substantial negative intrathoracic pressure, it is contraindicated for several conditions (Table 1).[15]

Table 1 Contraindication of Inspiratory Muscle Trainer

General and Specific Contraindications
General Contraindication • Individuals at risk of spontaneous pneumothorax • Individuals at risk of rib fractures • COPD patients requiring long-term oxygen therapy, recent exacerbation, and with significant cardiovascular comorbidities or neurological conditions
Specific Contraindication • Recent pneumothorax that has not drained yet • Large bullae on chest X-ray • Recurrent spontaneous pneumothorax history • Lung surgery history within the last 12 months • Signs of osteoporosis accompanied by spontaneous rib fracture history

COPD, chronic obstructive pulmonary disease

1.3 Physiological Adaptations Results from Inspiratory Muscle Training

Regular use of IMT over a certain period causes physiological adaptations in the respiratory system (Table 2). Although these physiological adaptations are well known, several studies show conflicting results such as a decrease in the work of breathing after IMT. The effect of IMT on functional capacity or exercise capacity and respiratory muscle function was found to be different in certain groups of individuals.[14]

1.4 Type of IMT

Devices for inspiratory muscle training are available in three types, namely: 1) Threshold IMT (Figure 2). Exercises with threshold IMT are performed with a handheld device. This device allows airflow after reaching inspiratory pressure during inspiration. This device is an inspiration tool adjusted with a spring. The spring tension determines the valve opening at a fixed pressure, ranging from zero to 45 cm H2O. No significant flow will occur below the threshold pressure; 2) Resistive load device (Figure 2) consisting of a circular dial and a funnel The size of the hole used for breathing can be changed by turning the knob. The smaller the opening, the greater the inspiratory resistance. This device has six inspiration openings or resistors that regulate the air entry into the device body. The opening diameters are 0.45 mm, 1.9 mm, 2.7 mm, 3.5 mm, 4.5 mm, and 5.35 mm. PowerBreathe® is one device that is widely used; and 3) Voluntary isocapnic hyperpnea. The device increases ventilation to a predetermined level. Increased ventilation causes the respiratory frequency to increase to reach 50–60 rpm. The patient has to perform prolonged hyperpnea exercises for up to 15 minutes. The frequency is twice a day, three times per week. Program duration is 4-5 weeks. Exercise is performed on a circuit of isocapnic, which keeps carbon dioxide levels stable, to avoid hypocapnia.[13, 16, 17]

Table 2 Physiological Adaptations Results from Inspiratory Muscle Training

Physiological Adaptation
Diaphragm hypertrophy
Increased the size of type II fibers and the proportion of type I fibers in the external intercostal muscles
Weakening of respiratory muscle metaboreflexes
Decreased motor drive of inspiratory muscle with maintained pressure generation
Improved respiratory muscle economy
Decreased level of perceived shortness of breath or perceived exertion
Decreased work of breathing
Increased respiratory muscle endurance
Increased ventilation efficiency
Resetting of respiratory muscle recruitment patterns
Improved breathing patterns during exercise hyperpnea
Reduction of cytokine release

1.5 IMT Protocol

1.5.1 Determining Exercise Intensity

Before initiating a pulmonary rehabilitation program, it is recommended to determine the weakness of the inspiratory muscle by measuring the MIP value with a micro-respiratory pressure meter (microRPM) which is used as the basis for determining IMT intensity (Figure 3). The MicroRPM is a portable, lightweight, small, and non-invasive resistive load device, containing an oral pressure manometer and rubber-banded mouthpiece. The test results are displayed on the monitor. Calculation of MIP and MEP values is done using software and presented in cmH2O. The result is obtained from the mean maximum pressure in one second. MicroRPM requires different adapters to adjust exhalation and inhalation. It does not require specific disinfection and cleaning processes. It only needs a simple adjustment of the removable mouthpiece and respective inhalation and exhalation adapters.[16, 18]

Threshold inspiratory muscle trainer

Resistive load device

Figure 2 Inspiratory Muscle Trainer Devices

Cited from: A primer on inspiratory muscle trainers [Internet]. 2006 [cited on February 20, 2024]. Available from: https://www.researchgate.net/profile/W-Darlene-Reid-2/publication/228373385_A_primer_on_inspiratory_muscle_trainers/links/0c960532858c72419b000000/A-primer-on-inspiratory-muscle-trainers.pdf.

1.5.2 Protocol Recommendation

The general recommendation of exercise with IMT is presented in Table 3.[13]

1.6 Technique of Exercise using Threshold IMT

Determine the initial training intensity to be provided based on MIP measured by microRPM. Attach the mouthpiece to the device. Attach a nose clip to cover the nose, then the patient inhales through the mouth via a mouthpiece and two-way valve. The patient inhales deeply through the mouthpiece repeatedly according to the specified number of repetitions without removing the device from the mouth. After completing the exercise, the patient is asked to record the results of the exercise in an exercise diary.[19]

Table 3 Recommendation of IMT Prescription

Exercise Parameter	Prescription Recommendation
Frequency	1 to 2 exercise sessions a day, depending on the individual's exercise capacity 4 to 6 days a week as tolerated
Intensity	• 30 to 70% MIP • For patients with severe COPD, initiating with lower intensity is recommended
Session Duration	• Total 30 minutes a day (divided into 1 to 2 sessions) • Initial session lasting for 3 to 5 minutes
Mode (Type)	• Threshold IMT • Resistive load device
Program Duration	• To maintain the benefits of exercise, the program should be continued indefinitely • Adaptive structural changes and functional improvements may occur after exercise for 5 weeks • The benefits of exercise are mostly lost after 6 months of exercise termination
Progression	• Increase intensity by 5% MIP per week as tolerated • Measurement of MIP should be performed at least monthly to adjust the exercise intensity to a new MIP achieved

MIP, *maximum inspiratory pressure;* IMT, *inspiratory muscle trainer*

1.7 Safety Issue

Exercise with IMT has been proven to be safe and well tolerated by patients.[1,3] Supervised exercise is recommended for patients who are just starting exercise. Prescribing appropriate exercise apart from preventing patients from possible adverse events also ensures the achievement of the desired physiological effects. Parameters for the occurrence of adverse events must be closely monitored at each training session (Table 4).[13]

Figure 3 MicroRPM

Cited from: Respiratory pressure meter – RP Check [Internet]. MD Diagnostics Ltd – The Breath Test Experts. 2024 [cited on February 23, 2024]. Available from: https://www.mdd.org.uk/products/respiratory-pressure-meter-rp-check/.

Previous studies found that giving exercise with IMT was safe because no side effects or adverse events were found during exercise, either preoperatively and during phase I or phase II CR.[20-23] One previous study that gave preoperative IMT obtained one patient experienced chest pain during prolonged exercise which no longer occurred when the training mode was changed to interval training. There was also one subject who experienced increased perceived fatigue and one person experienced dyspnea, but was able to complete the exercise until the end of the program.[24]

Table 4 Exercise Monitoring for the Prevention of Adverse Events

Adverse Event	Parameter Should be Monitored
Exercise Intolerance	• Cardiovascular abnormalities (blood pressure, heart rate) • Increase respiratory rate • Other symptoms of breathing distress • The inability to perform the exercise prescribed
Respiratory muscle fatigue	• Uncoordinated movement of the thoracic wall • Excessive dyspnea during exercise • Prolonged fatigue after exercise
Musculoskeletal injury	• Signs of delayed onset muscle soreness • Decreased strength • Decreased muscle endurance
Hypercapnea	• Increased end-tidal carbon dioxide • Decreased arterial oxygen saturation • Symptoms of headache and confusion

1.8 Functional Outcomes

Several functional outcomes used to evaluate the effects of IMT administration and its measurement tools are depicted in Table 5.[13]

Table 5 Functional Outcomes of Using the Inspiratory Muscle Trainer

Functional Outcomes	Outcome Parameters
Inspiratory muscle strength	Maximum inspiratory pressure (MIP), most commonly used
Endurance of the inspiratory muscle	• Sustained time on the training device, the simplest for clinical application • Maximum sustained ventilatory capacity • Incremental threshold loading • Maximum sustainable inspiratory mouth pressure
Shortness of breath	• Borg scale, determined during activity or exercise • Baseline dyspnea index • Transition dyspnea index
Exercise capacity	• Maximal oxygen consumption (VO2max) • 6-minute walk test, most effective and can be implemented in the clinical setting • 12-minute walk test • Borg scale for respiratory effort (modified Borg scale)
Health-related quality of life	• St. George's Questionnaire • Chronic Respiratory Disease Questionnaire

2. Practical Guidance to the Use of Preoperative IMT

This review included seven randomized controlled trials that provided preoperative IMT in patients undergoing CABG surgery (Table 6). Based on Table 6, it is known that although preoperative IMT did not increase FEV1 and FVC values, the group given IMT did not experience a decrease in these functions after surgery as was found in the control group.[11] In almost all studies reviewed, preoperative IMT increased MIP and endurance of the inspiratory muscle. In the control group, MIP and inspiratory muscle endurance generally did not change or even decrease.[11, 22, 23, 25-27] Only one of the seven studies reviewed could not conclude the role of IMT in increasing MIP and decreasing PPC. However, in this study, the incidence of pneumonia was found to be lower in the intervention group given IMT.[24] A lower incidence of PPC in the intervention group was also found in most studies.[11, 22, 26, 27] Of the 3 studies that assessed LOS and length of ICU stay, 2 found shorter LOS and intensive care unit stays in the intervention group than the control group. Only one study found no significant differences in these parameters.[22, 24, 25]

Based on the description of previous research results in Table 6, practical guidance for the use of preoperative IMT in patients undergoing CABG surgery is summarized in Table 7.

Table 6 Summary of Previous Research on Preoperative IMT Administration in Patients Undergoing CABG Surgery

Author (s) (Year)	Exercise Protocol	Exclusion Criteria	Research Outcomes			
			Postoperative Complication	Lung Function	Length of Stay	Respiratory Muscle Function
Weiner et al. (1998) [11]	• Intensity: 15% MIP, increased gradually by 5% per session until 60% MIP • Session duration: 30 minutes/day • Frequency: 6 days/week • Program duration: 2–4 weeks		2 and 11 participants in the intervention and control group experienced PPC and used a ventilator for >24 hours respectively	• After exercise, lung function did not change • After surgery, FEV1 and FVC were significantly decreased in the control group, and the intervention group did not		Intervention group: • After exercise, MIP and endurance of the inspiratory muscle increased significantly to the point of slightly below baseline Control group: • MIP and endurance of the inspiratory muscle decreased significantly after surgery
Hulzebos et al. (2006) [22]	• Intensity: 30% MIP, increased gradually by 5% per session based on the Borg RPE scale • Session duration: 20 minutes/day • Frequency: 7 days/week • Program duration: 2–4 weeks	• Cerebrovascular accident history • Surgery within the last 2 weeks • 30-day immunosuppressive medication used before surgery • Unstable cardiovascular status • Neuromuscular disorder • Aneurysm	Intervention group: • PPC incidence was 18% • The incidence of pneumonia was lower than the control group • Control group: • PPC occurred in 35% of participants • Respiratory failure was experienced by 22 out of 137 participants • One participant died due to cardiac failure		The median LOS was 7 and 8 days in the intervention and control groups respectively	Intervention group: • Strength and endurance of the inspiratory muscle increased significantly Control group: • Inspiratory muscle strength and endurance were not increased
Savci et al. (2011) [25]	• Intensity: 15% MIP, increased gradually by 15-45% according to patient tolerance • Session duration: 30 minutes/day • Program duration: 10 days (5 days pre-op, 5 days post-op)	• Stroke • Atrial fibrillation • Valvular diseases • Previous cardiac surgery • Pulmonary disease		In both groups, FEV1 and FVC decreased and FEV1/FVC did not change at hospital discharge	Longer duration of ICU care in the control group	Intervention group: • MIP increased significantly • MEP decreased Control group: • MIP and MEP decreased
Elmarakby et al. (2016) [26]	• Intensity: 30% MIP, increased progressively until reaching 60-80% preoperative MIP based on the Borg scale • Session duration: 15 minutes/day • Frequency: 2 times a day until hospital discharge	• Neuromuscular disorder • Cerebrovascular accident • Aneurysm • Cardiovascular instability • Lung surgery • Chest disease	The incidence of atelectasis was lower in the intervention group			Intervention group: • MIP increased significantly after exercise • Post-op day 1 and at discharge, MIP greater than the control group Control group: • MIP did not change after exercise

Table 6 Summary of Previous Research on Preoperative IMT Administration in Patients Undergoing CABG Surgery

Author (s) (Year)	Exercise Protocol	Exclusion Criteria	Research Outcomes			
			Postoperative Complication	Lung Function	Length of Stay	Respiratory Muscle Function
Mishra et al. (2016) [23]	• 60% MIP, increased gradually by 5% based on the Borg scale • Session duration: 20 minutes/day • Frequency: 7 days/week • Program duration: 2-4 weeks	• Presence of neuromuscular disorders • Previous pulmonary surgery • Cardiovascular instability • History of cerebrovascular accident • Aneurysm		FEV1, IVC, and FEV1/IVC did not change during the training period and before surgery in both groups		Intervention group: • MIP increased significantly by 36% after exercise and 1 day after surgery Control group: • MIP increased by 15%
Turky et al. (2017) [27]	• Intensity: 30% MIP, increased gradually by 2 cmH2O based on the Borg scale • Session duration: 3 sets, 10 breaths with 30-60 seconds rest between each set • Frequency: 2 times a day, 7 days/week, until hospital discharge	• No history of smoking • Had quit smoking (at least 6 months before the study)	In the intervention group, PPC incidence was lower			Intervention group: • A significant increase in MIP from baseline to pre-op • A decrease in MIP at post-op day 1 • An increase in MIP at hospital discharge to reach baseline values Control group: • No change in MIP from baseline to pre-op • A significant decrease of MIP at post-op day 1 • A significant increase in MIP at hospital discharge
Valkenet et al. (2017) [28]	• Intensity: 30% MIP, increased gradually by 2 cmH2O based on the Borg scale • Session duration: 20 minutes/day • Frequency: 7 days/week, once a day until the operation	• Cerebrovascular accident • Underwent CABG within the last 2 weeks • Neuromuscular disorder • Immunosuppressive medication used within 30 days before surgery • Aneurysm • Unstable cardiovascular	Pneumonia incidence was 1.1% (1 participant) and 3.2% (8 participants) in the intervention control groups respectively		No significant difference in the LOS and duration of ventilator use	The role of IMT in increasing MIP and reducing PPC cannot be concluded

Abbreviation in alphabetical sequence: CABG, coronary artery bypass graft; FEV1, forced expiration volume in 1 second; FVC, forced vital capacity; ICU, intensive care unit; IMT, inspiratory muscle training; IVC, inspiratory vital capacity: LOS, length of stay; MEP, maximum expiratory pressure; MIP, maximum inspiratory pressure, POC, postoperative complication.

Table 7 Practical Guidance for the Use of Preoperative IMT in Patients Undergoing CABG Surgery

Rehabilitation Assessment and Intervention	Guidance
Patients Selection	• Patients who are willing to take part in the exercise and sign informed consent are candidates for preoperative IMT • Conduct a safety and feasibility assessment of the exercise • Exclude patients with a history of cerebrovascular accident, surgery performed within the last 2 weeks, 30-day of immunosuppressive medication used before surgery, unstable cardiovascular status, neuromuscular disorder, aneurysm, pulmonary diseases, atrial fibrillation, valvular heart disease, lung surgery, and smoker
Goal Setting	• To prevent a decrease in lung function postoperatively • To increase respiratory muscle function
Patients Education	• Educate patients about the impact of disease and surgery on functioning and how to prevent decline in function • Educate patients about post-op pulmonary complications, the effect of prolonged bed rest, the benefits of early mobilization • Educate patients about the exercise given (the benefits, technique, dosage, preparation, and adverse events)
Exercise Prescription	• Determine exercise intensity based on MIP using a microRPM device • Baseline measurement: FEV1, FVC, PEF, MIP, and MEP • Prescribe exercise with intensity: 30% MIP, increased gradually by 5% per session based on the Borg RPE scale. Session duration: 20 minutes/day. Frequency: 7 days/week. Program duration: 2–4 weeks • Provide an exercise diary
Training Program	• Supervised-initial exercise: The first and second exercises are carried out under supervision to ensure that the technique and dosage are appropriate • Monitored exercise: Patients can do the exercises themselves without supervision by monitoring via an exercise diary
Program Evaluation	• Evaluation of exercise diary: Carried out when measuring outcomes before surgery • Evaluation of outcome: Reassessment of FEV1, FVC, PEF, MIP, and MEP
Program Maintenance and Continuity	• The exercise program is continued after surgery until discharge from the hospital • Re-evaluation of outcomes is carried out upon discharge from the hospital • If necessary, patients are asked to continue the exercise until they have completed the phase II cardiac rehabilitation program • Re-education regarding the impact of disease and surgery on functioning and how to prevent decline in function

CONCLUSION

The use of preoperative IMT in patients undergoing CABG surgery has been proven to prevent PPC and increase respiratory muscle function. A practical guidance was developed for preoperative IMT administration to improve outcomes of patients undergoing CABG surgery.

Conflict of Interest
The author declared no conflict of interest.

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REFERENCES

1. Fortier JH, Ferrari G, Glineur D, Gaudino M, Shaw RE, Ruel M, et al. Implications of coronary artery bypass grafting and percutaneous coronary intervention on disease progression and the resulting changes to the physiology and pathology of the native coronary arteries. Eur J Cardiothorac Surg. 2018;54(5):809-16.
2. Charlson ME, Isom OW. Care after coronary-artery bypass surgery. N Engl J Med. 2003;348(15):1456-63.
3. Hämäläinen L, Kohonen M, Laurikka J. Health-related quality of life is improved after coronary artery bypass graft surgery: a 1-year follow-up study. Scand Cardiovasc J. 2023;57(1):2284083.
4. Hussain SMA, Harky A. Complications of coronary artery bypass grafting. Int J Med Rev. 2019;6(1):1-5.
5. Westerdahl E, Lindmark B, Bryngelsson I, Tenling A. Pulmonary function 4 months after coronary artery bypass graft surgery. Respir Med. 2003;97(4):317-22.
6. Rouhi-Boroujeni H, Rouhi-Boroujeni H, Rouhi-Boroujeni P, Sedehi M. Long-term pulmonary functional status following coronary artery bypass grafting surgery. ARYA Atheroscler. 2015;11(2):163-6.
7. Vargas F, Terra-Filho M, Hueb W, Teixeira L, Cukier A, Light R. Pulmonary function after coronary artery bypass surgery. Respir Med. 1997;91(10):629-33.
8. Shenkman Z, Shir Y, Weiss Y, Bleiberg B, Gross D. The effects of cardiac surgery on early and late pulmonary functions. Acta Anaesthesiol Scand. 1997;41(9):1193-9.
9. Van Belle A, Wesseling G, Penn O, Wouters E. Postoperative pulmonary function abnormalities after coronary artery bypass surgery. Respir Med. 1992;86(3):195-9.
10. Naseer BA, Al-Shenqiti AM, Ali ARH, Aljeraisi T. Effect of cardiac surgery on respiratory muscle strength. J Taibah Univ Med Sci. 2019;14(4):337-42.
11. Weiner P, Zeidan F, Zamir D, Pelled B, Waizman J, Beckerman M, et al. Prophylactic inspiratory muscle training in patients undergoing coronary artery bypass graft. World J Surg. 1998;22(5):427-31.
12. Zhang S, Li B, Meng X, Zuo H, Hu D. The effects of inspiratory muscle training (IMT) on patients undergoing coronary artery

bypass graft (CABG) surgery: a systematic review and meta-analysis. Rev Cardiovasc Med. 2023;24(1):16.

13. Aprimeroninspiratorymuscletrainers[Internet]. 2006 [cited February 20, 2024]. Available from: https://www.researchgate.net/profile/W-Darlene-Reid-2/publication/228373385_A_primer_on_inspiratory_muscle_trainers/links/0c960532858c72419b000000/A-primer-on-inspiratory-muscle-trainers.pdf.
14. Shei R-J, Paris HL, Sogard AS, Mickleborough TD. Time to move beyond a "one-size fits all" approach to inspiratory muscle training. Front Physiol. 2022;12:766346.
15. Hill K, Cecins NM, Eastwood PR, Jenkins SC. Inspiratory muscle training for patients with chronic obstructive pulmonary disease: a practical guide for clinicians. Arch Phys Med Rehabil. 2010;91(9):1466-70.
16. Vázquez-Gandullo E, Hidalgo-Molina A, Montoro-Ballesteros F, Morales-González M, Muñoz-Ramírez I, Arnedillo-Muñoz A. Inspiratory muscle training in patients with chronic obstructive pulmonary disease (COPD) as part of a respiratory rehabilitation program implementation of mechanical devices: a systematic review. Int J Environ Res Public Health. 2022;19(9):5564.
17. Madariaga VB, Iturri JBG, Manterola AG, Buey JC, Sebastián NT, Peña VS. Comparison of 2 methods for inspiratory muscle training in patients with chronic obstructive pulmonary disease. Arch Bronconeumol. 2007;43(8):431-8.
18. Respiratory pressure meter – RP Check [Internet]. MD Diagnostics Ltd – The Breath Test Experts. 2024 [cited February 23, 2024]. Available from: https://www.mdd.org.uk/products/respiratory-pressure-meter-rp-check/.
19. Nield MA. Inspiratory muscle training protocol using a pressure threshold device: effect on dyspnea in chronic obstructive pulmonary disease. Arch Phys Med Rehabil. 1999;80(1):100-2.
20. Hermes BM, Cardoso DM, Gomes TJN, Santos TDd, Vicente MS, Pereira SN, et al. Short-term inspiratory muscle training potentiates the benefits of aerobic and resistance training in patients undergoing CABG in phase II cardiac rehabilitation program. Rev Bras Cir Cardiovasc. 2015;30(4):474-81.
21. Dos Santos TD, Pereira SN, Portela LOC, Cardoso DM, Dal Lago P, dos Santos Guarda N, et al. Moderate-to-high intensity inspiratory muscle training improves the effects of combined training on exercise capacity in patients after coronary artery bypass graft surgery: A randomized clinical trial. Int J Cardiol. 2019;279:40-6.
22. Hulzebos EH, Helders PJ, Favié NJ, De Bie RA, de la Riviere AB, Van Meeteren NL. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA. 2006;296(15):1851-7.
23. Mishra SK, Veena M, Nagaraja P, Singh NG. Preoperative Inspiratory Muscle Training to Prevent Post-Operative Pulmonary Complication Its Effectiveness in Patients Undergoing On Pump Coronary Artery Bypass Grafting (CABG) Surgery. Sch J App Med Sci. 2016;4(12D):4531-5.
24. Valkenet K, Trappenburg J, Hulzebos E, Van Meeteren N, Backx F. Effects of a pre-operative home-based inspiratory muscle training programme on perceived health-

related quality of life in patients undergoing coronary artery bypass graft surgery. Physiotherapy. 2017;103(3):276-82.

25. Savci S, Degirmenci B, Saglam M, Arikan H, Inal-Ince D, Turan HN, et al. Short-term effects of inspiratory muscle training in coronary artery bypass graft surgery: a randomized controlled trial. Scand Cardiovasc J. 2011;45(5):286-93.
26. Elmarakby A. Effect of threshold inspiratory muscle training on maximal inspiratory pressure and pulmonary gas exchange in patients undergoing coronary artery bypass graft surgery. Crit Rev Phys Rehabil Med. 2016;28(4).
27. Turky K, Afify AMA. Effect of preoperative inspiratory muscle training on alveolar-arterial oxygen gradients after coronary artery bypass surgery. J Cardiopulm Rehabil Prev. 2017;37(4):290-4.
28. Valkenet K, De Heer F, Backx FJ, Trappenburg JC, Hulzebos EH, Kwant S, et al. Effect of inspiratory muscle training before cardiac surgery in routine care. Phys Ther. 2013;93(5):611-9.