Inspiratory muscle training in cardiac rehabilitation: evidence, prescription, and clinical applications

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Abstract:
Inspiratory muscle training (IMT) is a targeted respiratory exercise intervention that may complement conventional cardiac rehabilitation by improving the strength and endurance of the diaphragm and other inspiratory muscles. Respiratory muscle weakness is frequently observed in patients with chronic heart failure and may also develop after cardiac surgery because of anaesthesia, mechanical ventilation, and postoperative pain, reduced mobility, and altered thoracic mechanics. These impairments can increase the work of breathing, intensify exertional dyspnea, and restrict participation in aerobic exercise and daily activities. IMT generally uses a threshold-loading or resistive-breathing device to provide a controlled inspiratory workload, commonly prescribed as a percentage of maximal inspiratory pressure (MIP). Recent systematic reviews and meta-analyses suggest that IMT can improve MIP and may produce additional benefits in six-minute walk distance, peak oxygen uptake, ventilatory efficiency, dyspnea, and health-related quality of life, particularly in selected patients with heart failure and individuals undergoing coronary artery bypass graft surgery. Preoperative respiratory muscle training may also reduce postoperative pulmonary complications and hospital stay, although the certainty of evidence varies among outcomes and interventions. This review discusses the physiological rationale, clinical evidence, patient assessment, training prescription, practical technique, and clinical applications of IMT in cardiac rehabilitation. It also examines its integration with aerobic and resistance exercise, safety precautions, adherence strategies, outcome monitoring, and the role of physiotherapists in individualized programme delivery. Current evidence supports IMT as a complementary intervention for appropriately selected and clinically stable patients rather than a replacement for comprehensive cardiac rehabilitation or guideline-directed medical treatment. Further high-quality trials are required to establish optimal training intensity, identify patients most likely to benefit, and determine whether improvements in respiratory muscle performance translate into sustained reductions in cardiovascular events, hospitalization, and long-term disability.

Keywords:
Inspiratory muscle training, cardiac rehabilitation, Heart failure, Respiratory muscle strength, Maximal inspiratory pressure, Exercise capacity, Physiotherapy, Dyspnea, Coronary artery disease, Postoperative rehabilitation.

1. Introduction:

Cardiovascular diseases are a major cause of morbidity, mortality, and functional disability worldwide, and improvements in acute cardiac care have increased the number of individuals living with chronic cardiovascular conditions and requiring long-term rehabilitation. Cardiac rehabilitation is a comprehensive, multidisciplinary intervention designed to improve functional capacity, reduce cardiovascular risk, support psychological recovery, and promote sustained participation in physical activity through individualized exercise, education, nutritional guidance, medication adherence, and lifestyle modification. Aerobic and resistance exercise are established components of rehabilitation; however, exercise intolerance is not determined exclusively by cardiac output or peripheral skeletal muscle performance. Respiratory muscle

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weakness, increased ventilatory demand, abnormal breathing patterns, and heightened perception of respiratory effort may also contribute to activity limitation, particularly in patients with chronic heart failure and those recovering from cardiac surgery. Inspiratory muscle training (IMT) has therefore gained attention as a targeted intervention that may address respiratory limitations alongside conventional cardiovascular conditioning. IMT involves repeated inspirations against a controlled external resistance, usually delivered through a threshold-loading device, to stimulate adaptation in the diaphragm and accessory inspiratory muscles. The training load is commonly prescribed in relation to maximal inspiratory pressure (MIP), allowing the programme to be individualized and progressively adjusted as respiratory muscle strength improves. Patients with heart failure may demonstrate reduced inspiratory muscle strength, increased work of breathing, ventilatory inefficiency, and exertional dyspnea, while individuals after coronary artery bypass graft surgery may experience temporary respiratory impairment due to anaesthesia, mechanical ventilation, pain, reduced mobility, and changes in thoracic mechanics. Recent evidence supports the potential value of IMT in these groups. A 2025 systematic review and meta-analysis of 17 studies involving 510 patients with heart failure reported improvements in MIP, six-minute walk distance, quality of life, and ventilatory efficiency following IMT (Siddiqi et al., 2025). Another meta-analysis of 15 randomized trials involving 494 patients found improvements in MIP, peak oxygen uptake, exercise performance, and patient-reported outcomes (Yang et al., 2025). Evidence following coronary artery bypass graft surgery also indicates improvements in inspiratory muscle strength and functional exercise capacity, with possible reductions in hospital stay (Araújo et al., 2024, The Effects of Inspiratory Muscle Training, 2023). These findings suggest that respiratory muscle conditioning may provide additional benefits for selected patients who experience persistent dyspnea or demonstrate inspiratory muscle weakness despite receiving conventional cardiac rehabilitation. The proposed framework illustrates how cardiovascular disease, deconditioning, altered respiratory muscle perfusion, and increased ventilatory demand may contribute to inspiratory muscle weakness, increased work of breathing, dyspnea, and reduced exercise tolerance, while structured IMT may improve inspiratory muscle strength and endurance and support participation in physical activity. The purpose of this review is to examine the physiological basis, clinical evidence, assessment procedures, and practical prescription of IMT in cardiac rehabilitation, with particular attention to chronic heart failure, coronary artery disease, and postoperative cardiac recovery. The review also discusses patient selection, device selection, training intensity, progression, monitoring, safety considerations, and the integration of IMT with conventional exercise-based rehabilitation.

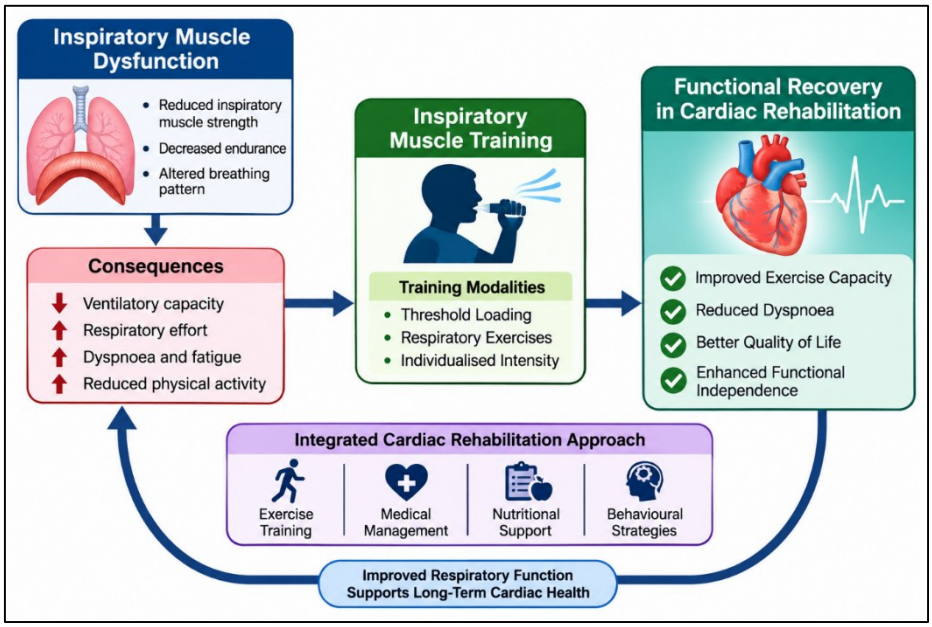


Figure. 1: Conceptual framework of inspiratory muscle dysfunction and the potential contribution of inspiratory muscle training to functional recovery in cardiac rehabilitation

2. Physiological Basis of Inspiratory Muscle Dysfunction in Cardiovascular Disease:

2.1. Respiratory Muscle Function and Cardiovascular Performance:

The respiratory muscles maintain ventilation by generating pressure changes that permit air to enter and leave the lungs, with the diaphragm acting as the principal inspiratory muscle and the external intercostal and accessory muscles contributing during increased ventilatory demand. During physical activity, respiratory

muscle activation increases to maintain oxygen uptake and carbon dioxide elimination, and healthy individuals generally tolerate this increased workload because of adequate muscle strength, endurance, and perfusion. In cardiovascular disease, however, the relationship between respiratory muscle activity and systemic circulation may become less efficient because reduced cardiac output, pulmonary vascular abnormalities, neurohormonal activation, systemic inflammation, and peripheral deconditioning can increase the physiological burden of breathing. Patients with heart failure may demonstrate increased ventilation at relatively low workloads, requiring the respiratory muscles to perform greater work during ordinary activities. In addition, respiratory muscles and locomotor muscles may compete for blood flow during strenuous exercise, particularly when cardiac reserve is limited. The respiratory muscle metaboreflex is a physiological response that can occur when respiratory muscles sustain high levels of work, resulting in activation of group III and IV muscle afferents, increased sympathetic activity, and vasoconstriction in peripheral skeletal muscles. This response may contribute to reduced limb perfusion and earlier fatigue during exercise. IMT is proposed to improve respiratory muscle conditioning and reduce the relative effort required to sustain ventilation, potentially delaying respiratory muscle fatigue and attenuating the respiratory muscle metaboreflex. Although this mechanism provides a plausible physiological explanation for improved exercise tolerance, its contribution to clinical improvements in cardiac populations requires further investigation.

2.2. Inspiratory Muscle Weakness in Heart Failure:

Inspiratory muscle weakness is frequently reported in patients with chronic heart failure and may be associated with reduced MIP, impaired endurance, increased respiratory effort, and greater perception of dyspnea. Potential mechanisms include reduced physical activity, systemic inflammation, altered skeletal muscle metabolism, impaired respiratory muscle perfusion, changes in muscle fibre composition, and diaphragmatic dysfunction. A reduction in inspiratory muscle strength means that a greater proportion of the available muscle capacity is required to maintain ventilation, and this relative workload may increase further during exercise. Patients may consequently experience breathlessness during walking, stair climbing, bathing, and other daily activities, leading to avoidance of physical activity and progressive deconditioning. The 2025 meta-analysis by Yang et al. included 15 randomized controlled trials and 494 participants with chronic heart failure and reported significant improvements in MIP and peak oxygen uptake following IMT, with additional benefits in exercise performance and quality of life. Siddiqi et al. (2025) also reported improvements in MIP, six-minute walk distance, ventilatory efficiency, and health-related quality of life. These findings support the importance of assessing respiratory muscle function in patients whose breathlessness or exercise limitation appears disproportionate to their conventional exercise performance.

2.3. Respiratory Muscle Metaboreflex and Exercise Limitation:

The respiratory muscle metaboreflex may contribute to exercise limitation when inspiratory muscles are required to sustain high levels of ventilation for prolonged periods. Increased respiratory muscle work can result in local metabolite accumulation and activation of sensory afferents, which may increase sympathetic nervous system activity and redistribute blood flow away from exercising peripheral muscles. In individuals with cardiovascular disease, this response may be particularly relevant because peripheral perfusion may already be compromised by reduced cardiac output, endothelial dysfunction, vascular abnormalities, or skeletal muscle deconditioning. A conditioned respiratory muscle system may require a lower relative effort to achieve the same ventilatory demand, potentially reducing respiratory muscle fatigue and limiting the degree of sympathetic vasoconstrictor activation. IMT is therefore proposed as a method of improving respiratory muscle reserve and reducing the relative burden of breathing during exercise. However, improvements in walking distance or peak oxygen uptake should not automatically be attributed to this mechanism, because cardiac function, peripheral muscle adaptation, medication, motivation, and concurrent aerobic training may also influence the clinical response.

2.4. Ventilatory Inefficiency and Dyspnea:

Ventilatory inefficiency is common in heart failure and may be reflected by an increased relationship between minute ventilation and carbon dioxide production during cardiopulmonary exercise testing. Increased physiological dead-space ventilation, abnormal chemoreceptor sensitivity, pulmonary congestion, pulmonary vascular dysfunction, and altered respiratory control may contribute to this pattern. Patients with ventilatory inefficiency often experience breathlessness at relatively low workloads, and inspiratory muscle weakness may further increase the perceived effort of breathing. IMT does not directly correct every cause of ventilatory inefficiency, but it may improve the muscular capacity to generate inspiratory pressure and sustain ventilation. Siddiqi et al. (2025) reported an improvement in the VE/VCO_2 response following IMT in patients with heart

failure, suggesting a possible benefit in ventilatory efficiency. Nevertheless, IMT should not be interpreted as a treatment that independently reverses pulmonary congestion, abnormal cardiac filling pressures, or pulmonary vascular disease. Its role is to address a potentially modifiable muscular component of the overall respiratory limitation.

2.5. Respiratory Muscle Dysfunction after Cardiac Surgery:

Cardiac surgery, particularly coronary artery bypass grafting and valve surgery, may temporarily impair respiratory muscle performance because of anaesthesia, mechanical ventilation, postoperative pain, reduced mobility, altered thoracic mechanics, and changes in lung volume. Patients may demonstrate shallow breathing, reduced inspiratory capacity, ineffective cough, and difficulty performing deep inspiration during early recovery. Respiratory impairment can contribute to atelectasis, secretion retention, and postoperative pulmonary complications, particularly in individuals with pre-existing respiratory weakness or other comorbidities. IMT may be used before surgery as a prehabilitation intervention or after surgery as part of a structured respiratory rehabilitation programme. Preoperative training aims to improve inspiratory muscle reserve before surgical stress, whereas postoperative training aims to restore respiratory strength and support functional recovery. The intervention must be adapted to pain, wound healing, haemodynamic stability, sternal precautions, and the patient's ability to perform the manoeuvre safely. A 2024 systematic review by Araújo et al. found that IMT during Phase I and Phase II postoperative cardiac rehabilitation after coronary artery bypass graft surgery improved selected outcomes, including inspiratory muscle strength and six-minute walk distance, although evidence certainty varied across outcomes.

2.6. Definition and Principles of Inspiratory Muscle Training:

Inspiratory muscle training is a respiratory conditioning intervention in which the patient repeatedly inhales against an external resistance to overload the inspiratory muscles in a controlled and progressive manner. It is most commonly delivered through threshold-loading devices that require the patient to generate a minimum inspiratory pressure before airflow occurs, allowing the training resistance to be prescribed according to baseline MIP and adjusted as muscle strength improves. Unlike unresisted deep-breathing exercises, threshold IMT provides a measurable pressure load and can therefore be used as a structured exercise intervention. The main training approaches include threshold loading, flow-resistive training, and sustained hyperpnoea training. Threshold devices provide a relatively fixed inspiratory pressure load through a spring-loaded valve or similar mechanism, and this method is commonly used in clinical research because the resistance can be adjusted in relation to MIP. Flow-resistive devices create resistance as air passes through a narrowed opening, meaning that the workload may vary with inspiratory flow and can be more difficult to standardize unless the device provides a validated measurement system. Isocapnic or normocapnic hyperpnoea involves sustained breathing at increased minute ventilation while maintaining carbon dioxide levels within a controlled range and is primarily intended to improve respiratory muscle endurance, however, this approach requires more specialized equipment and is less commonly used in routine cardiac rehabilitation. Strength-oriented IMT generally uses higher inspiratory resistance with fewer repetitions or shorter bouts, whereas endurance-oriented training uses lower resistance and longer periods of sustained breathing. Many clinical programmes combine these objectives through repeated sets of controlled inspirations against a moderate or progressively increased threshold load. The choice of method should reflect the patient's principal limitation, baseline MIP, symptoms, functional capacity, and ability to tolerate sustained respiratory effort.

3. Assessment before Initiating Inspiratory Muscle Training:

3.1. Clinical History and Symptom Assessment:

A structured clinical assessment is essential before prescribing IMT because the intervention should be introduced only when the patient's cardiovascular condition is sufficiently stable and the expected benefit is clinically meaningful. The therapist should review the cardiovascular diagnosis, recent cardiac events, surgical history, medication profile, exercise tolerance, previous rehabilitation, and current symptoms. Particular attention should be given to recent decompensated heart failure, unstable angina, uncontrolled arrhythmias, uncontrolled blood pressure, unexplained deterioration in breathlessness, syncope, and other symptoms requiring medical reassessment. Dyspnea may be assessed using the modified Borg scale or the Medical Research Council dyspnea scale, while fatigue, chest discomfort, palpitations, dizziness, cough, and recovery time should also be documented. The patient's ability to understand instructions, operate a training device, maintain an adequate mouth seal, and follow a home programme should be evaluated because cognitive, visual, and manual limitations may affect adherence and safety.

3.2. Maximal Inspiratory Pressure:

Maximal inspiratory pressure is the most commonly used clinical measure of inspiratory muscle strength and provides the basis for individualized IMT load calculation. It is generally assessed using a calibrated pressure manometer or validated respiratory pressure measurement device, with the patient performing a maximal inspiratory effort against an occluded airway, usually beginning near residual volume. Several technically acceptable attempts should be obtained with adequate rest between efforts, and the highest reproducible value should be recorded. MIP measurement can be influenced by technique, mouth leakage, inadequate effort, starting lung volume, and patient understanding, therefore, standardized instructions and consistent testing conditions are important. The result should be interpreted in relation to appropriate reference values and the patient's clinical condition. A reliable baseline MIP allows the therapist to prescribe a percentage-based training load and repeat the measurement to assess adaptation and guide progression.

3.3. Inspiratory Muscle Endurance:

Inspiratory muscle endurance can be assessed using sustained threshold loading or standardized respiratory muscle endurance tests, which provide additional information about the ability to maintain inspiratory effort over time. Endurance testing may be particularly useful when a patient has relatively preserved MIP but experiences respiratory fatigue during prolonged exercise or sustained ventilation. However, it is not essential for every patient, and routine clinical assessment may rely on MIP, symptom evaluation, functional exercise testing, and observation of breathing pattern. If an endurance test is used, the protocol should be standardized and repeated under similar conditions so that changes can be interpreted meaningfully.

3.4. Functional Exercise Assessment:

Functional exercise capacity should be assessed using an appropriate test such as the six-minute walk test, incremental shuttle walk test, or cardiopulmonary exercise testing when available and clinically indicated. These assessments establish baseline functional performance and help determine whether respiratory muscle impairment may be contributing to exercise limitation. Cardiopulmonary exercise testing can provide information about peak oxygen uptake, ventilatory efficiency, breathing reserve, and the relationship between symptoms and workload, while the six-minute walk test offers a practical measure of submaximal functional capacity in many outpatient settings. Exercise assessment should be performed according to established safety procedures and should be interpreted alongside the patient's cardiovascular diagnosis, symptoms, and comorbidities.

3.5. Pulmonary and Cardiovascular Screening:

Although IMT targets inspiratory muscle function, coexisting pulmonary disease may influence both training tolerance and clinical response. Relevant conditions include chronic obstructive pulmonary disease, restrictive lung disease, uncontrolled asthma, recent respiratory infection, and significant oxygen desaturation. Resting oxygen saturation, respiratory rate, heart rate, and blood pressure should be documented when clinically appropriate. The therapist should also consider postoperative restrictions, chest wall pain, sternotomy discomfort, and the patient's ability to perform an effective inspiratory manoeuvre without excessive strain. The table 1 summarizes the clinical, respiratory, and functional measures that can guide patient selection, initial load calculation, and subsequent evaluation.

Table. 1: Recommended baseline assessment before initiating inspiratory muscle training in cardiac rehabilitation

Assessment domain	Recommended measure	Clinical purpose
Cardiovascular status	Diagnosis, symptoms, haemodynamic stability, medication review	Identify suitability and precautions
Inspiratory muscle strength	MIP/PImax	Establish baseline strength and training load
Respiratory symptoms	Modified Borg scale, dyspnea history	Quantify perceived breathing difficulty
Respiratory function	Spirometry when indicated	Identify coexisting pulmonary impairment
Oxygenation	Resting and exertional SpO_2 when indicated	Identify desaturation risk

Functional capacity	Six-minute walk test or CPET	Establish baseline exercise performance
Quality of life	Disease-specific questionnaire	Assess patient-reported impact
Training readiness	Technique, cognition, motivation, device handling	Determine ability to perform IMT safely

4. Clinical Evidence for Inspiratory Muscle Training in Cardiac Rehabilitation:

4.1. Evidence in Chronic Heart Failure:

Chronic heart failure is one of the most extensively studied clinical applications of IMT because patients may develop inspiratory muscle weakness, reduced respiratory endurance, increased ventilatory demand, and exertional dyspnea that limit participation in conventional exercise rehabilitation. The 2025 systematic review and meta-analysis by Siddiqi et al. included 17 studies involving 510 patients and reported significant improvements in six-minute walk distance, MIP, quality of life, and ventilatory efficiency following IMT. The pooled improvement in six-minute walk distance was approximately 72.72 metres, while MIP improved by approximately 13.77 cmH_2O. Yang et al. (2025) analysed 15 randomized controlled trials involving 494 patients with chronic heart failure and reported improvements in MIP and peak oxygen uptake, with additional benefits in walking performance, dyspnea, and quality of life. The pooled improvement in MIP was approximately 16.36 cmH_2O and peak oxygen uptake increased by approximately 1.66 mL/kg/min. These findings indicate that IMT can improve inspiratory muscle performance and may support functional exercise capacity in selected patients with heart failure. However, the estimates from separate meta-analyses should not be directly compared because their study selection, inclusion criteria, outcome definitions, and statistical methods may differ. Furthermore, the available studies do not establish that IMT independently reduces mortality or prevents recurrent heart failure hospitalization. Its most defensible clinical role is as an additional rehabilitation intervention for patients with inspiratory muscle weakness or persistent respiratory limitation after clinical stabilization (Siddiqi et al., 2025, Yang et al., 2025).

4.2. Evidence in Coronary Artery Disease:

Patients with coronary artery disease may experience reduced exercise tolerance because of myocardial ischemia, altered cardiac output, peripheral muscle deconditioning, and associated respiratory limitations. Although IMT has been investigated less extensively in stable coronary artery disease than in heart failure and postoperative cardiac surgery, respiratory muscle conditioning may be relevant in selected patients who demonstrate inspiratory weakness or disproportionate breathlessness during exercise. The potential benefits include improved inspiratory pressure generation, reduced relative respiratory effort, and better tolerance of physical activity. IMT should be considered an adjunct to conventional aerobic and resistance training rather than a substitute for ischemia-aware exercise prescription, medication adherence, smoking cessation, and cardiovascular risk-factor management. Patients with new or worsening angina, unstable symptoms, unexplained breathlessness, or suspected myocardial ischemia require medical assessment before continuing exercise or respiratory muscle training. The evidence is not yet sufficient to recommend routine IMT for every patient with stable coronary artery disease, and clinical selection should be based on respiratory assessment and the individual's functional limitations.

4.3. Evidence after Coronary Artery Bypass Graft Surgery:

Coronary artery bypass graft surgery is associated with postoperative changes in respiratory mechanics, reduced lung volumes, pain-related restriction of deep inspiration, and temporary reductions in inspiratory muscle strength. IMT has therefore been studied as a preoperative and postoperative intervention to improve respiratory muscle reserve and functional recovery. A systematic review and meta-analysis of 12 randomized clinical trials involving 918 patients undergoing CABG reported that postoperative IMT improved MIP and six-minute walking performance and was associated with a reduction in hospital length of stay. Preoperative IMT was associated with improvements in MIP, selected spirometric outcomes, postoperative pulmonary complications, and length of stay (The Effects of Inspiratory Muscle Training, 2023). Araújo et al. (2024) reviewed IMT during Phase I and Phase II postoperative cardiac rehabilitation and found improvements in selected outcomes, including MIP and six-minute walk distance. In Phase I rehabilitation, the pooled improvement in six-minute walk distance was approximately 75.46 metres, while MIP increased by approximately 10.46 cmH_2O. In Phase II rehabilitation, improvements were also reported in walking distance,

respiratory muscle strength, and quality of life, although the certainty of evidence ranged from very low to moderate and some studies had a high risk of bias. These findings support the potential role of IMT in postoperative cardiac rehabilitation, but the intervention should be coordinated with the surgical team and modified according to pain, wound healing, haemodynamic stability, and the patient's ability to perform controlled inspiration without excessive straining (Araújo et al., 2024, The Effects of Inspiratory Muscle Training, 2023).

4.4. Evidence for Preoperative Respiratory Muscle Training:

Preoperative respiratory muscle training may be particularly useful for patients awaiting elective cardiac surgery who have sufficient time and clinical stability to complete a structured programme. The objective is to improve respiratory muscle reserve before the physiological stress of surgery and potentially reduce postoperative pulmonary complications. De Moura et al. (2024) reviewed randomized trials involving adults undergoing elective open cardiac surgery and reported that preoperative respiratory muscle training was associated with a lower risk of postoperative pulmonary complications and pneumonia, a shorter hospital stay, and improved MIP. The pooled risk ratio for postoperative pulmonary complications was approximately 0.51, while the risk ratio for pneumonia was approximately 0.44. These results are clinically relevant because postoperative pulmonary complications can delay mobilization, increase hospital resource use, and interfere with functional recovery. However, the interventions included respiratory muscle training approaches that may not all represent identical threshold-based IMT protocols, and therefore the findings should be interpreted as evidence for preoperative respiratory muscle conditioning rather than proof that one specific device or loading strategy is superior. Cook et al. (2023) also examined preoperative threshold IMT in adults undergoing cardiac surgery and found that some included studies reported reductions in postoperative hospital stay and pulmonary complications, although methodological limitations and risk of bias restricted the certainty of the conclusions. Preoperative IMT may therefore be considered in selected patients as part of a broader prehabilitation programme, particularly when inspiratory muscle weakness or reduced respiratory reserve is identified (Cook et al., 2023, de Moura et al., 2024).

4.5. Evidence in Valvular Heart Disease and Other Cardiovascular Conditions:

The potential application of IMT extends to patients undergoing valve surgery and individuals with other cardiovascular conditions associated with respiratory muscle weakness or exercise intolerance. Patients undergoing valve replacement may experience postoperative respiratory impairment due to anaesthesia, mechanical ventilation, thoracic surgery, pain, and reduced mobility. IMT may be considered when inspiratory muscle weakness is documented, but the evidence is less developed than in chronic heart failure and CABG populations. Patients with pulmonary hypertension, congenital heart disease, or complex cardiovascular conditions may also demonstrate altered ventilatory responses and reduced exercise capacity, but condition-specific evidence is insufficient to support a universal IMT protocol. Clinical decisions should therefore be based on the patient's haemodynamic status, respiratory muscle assessment, symptoms, coexisting pulmonary disease, and the recommendations of the treating medical team. Extrapolating findings from heart failure or CABG trials to every cardiovascular diagnosis may result in inappropriate prescription, particularly when the underlying mechanism of breathlessness differs.

4.6. Overall Interpretation of the Evidence:

The available clinical evidence suggests that IMT can improve inspiratory muscle strength and may provide additional benefits in functional exercise capacity, dyspnea, ventilatory efficiency, and quality of life in selected cardiac rehabilitation populations. The strongest current evidence is concentrated in chronic heart failure and patients undergoing CABG or other open cardiac surgery. Nevertheless, improvement in MIP does not necessarily produce a proportional improvement in peak oxygen uptake, cardiovascular events, or long-term survival. Studies vary in participant characteristics, training intensity, duration, frequency, supervision, device type, and outcome measures, making direct comparison difficult. IMT should consequently be prescribed according to individual respiratory impairment and clinical goals, with outcomes evaluated using a combination of respiratory, functional, symptom-based, and patient-reported measures.

5. Principles of IMT Prescription:

5.1. Training Intensity:

Training intensity is commonly prescribed as a percentage of baseline MIP, allowing the external inspiratory load to reflect the patient's respiratory muscle strength. Published cardiac rehabilitation protocols have used

different intensities, often beginning around 30% of MIP and progressing according to tolerance and clinical response. Some programmes use lower initial loads in patients with marked weakness, postoperative discomfort, frailty, or limited exercise tolerance, while higher intensities may be considered in stable patients who demonstrate good technique and adequate recovery. The Physical Therapist Clinical Practice Guideline for the Management of Individuals With Heart Failure describes threshold or similar IMT for selected stable patients with NYHA Class II and III heart failure, with training above 30% of MIP for up to 30 minutes per day, five to seven days per week, over at least 8–12 weeks. Higher training loads may require shorter training periods and closer monitoring. These recommendations should be interpreted as a clinical framework rather than a fixed prescription for every patient, because the appropriate intensity depends on baseline MIP, symptoms, cardiovascular stability, concurrent exercise workload, and the device used.

5.2. Training Duration and Frequency:

A typical IMT session may involve approximately 10–30 minutes of repeated inspirations against resistance, depending on the training intensity and the patient's tolerance. Some protocols use continuous breathing against the threshold load, whereas others divide the session into shorter sets separated by rest periods. Many research programmes prescribe training on five to seven days per week, but frequency should be individualized according to fatigue, symptoms, adherence, and the patient's overall rehabilitation schedule. Patients who complete aerobic and resistance exercise on the same day may benefit from scheduling IMT at a separate time if combined sessions produce excessive fatigue. The programme should begin with a duration that the patient can complete with correct technique and should progress gradually rather than requiring the full target duration from the first session.

5.3. Programme Duration:

An initial training period of 8–12 weeks is commonly used in clinical studies and rehabilitation practice. Some patients may require a longer programme to achieve meaningful improvement in inspiratory strength, while others may demonstrate early adaptation and require adjustment of the training load. Reassessment should occur at planned intervals so that the therapist can determine whether the original resistance remains appropriate. Continuing the same load indefinitely despite improvement in MIP may reduce the relative training stimulus, whereas increasing resistance too quickly may cause fatigue, poor technique, or reduced adherence. The overall programme duration should therefore reflect the patient's clinical response, rehabilitation goals, and ability to maintain the intervention safely.

5.4. Progression of Resistance:

Resistance should be increased gradually when the patient can complete the prescribed number of inspirations with appropriate technique and without excessive dyspnea, dizziness, chest discomfort, or prolonged fatigue. Progression may be guided by repeat MIP measurement, the patient's ability to sustain the training session, symptom response, and perceived exertion. A patient should not be encouraged to increase resistance solely to achieve a higher device setting. If the current load produces breath-holding, facial straining, excessive accessory muscle activity, or an inability to complete the session, the resistance should be reduced and technique reviewed. The table 2 presents a general starting framework based on published IMT protocols and clinical practice guidance, it is not a substitute for individualized assessment or medical supervision.

Table. 2: Practical framework for prescribing inspiratory muscle training in stable cardiac rehabilitation patients

Prescription component	Practical starting framework	Progression considerations
Device	Threshold-loading IMT device	Confirm appropriate fit and reliable resistance setting
Baseline measurement	MIP/PImax	Repeat using consistent testing technique
Initial intensity	Commonly around 30% MIP, lower when clinically indicated	Increase gradually according to tolerance
Session duration	Approximately 10–30 minutes	Begin with shorter bouts when needed
Frequency	Five to seven days per week in established protocols	Adjust for fatigue and concurrent exercise

Programme length	At least 8–12 weeks is commonly studied	Extend when clinically appropriate
Breathing pattern	Controlled inspiration and relaxed expiration	Avoid breath-holding and forceful straining
Monitoring	Symptoms and vital signs when indicated	Stop and reassess abnormal responses
Reassessment	MIP, dyspnea, functional capacity, adherence	Adjust load according to progress

5.5. Example of Individualized Load Calculation:
If a patient has a baseline MIP of 70 cmH_2O and the therapist selects an initial training intensity of 30%, the approximate threshold load would be 21 cmH_2O. If the patient's MIP improves to 90 cmH_2O at reassessment, a 30% training load would correspond to 27 cmH_2O. The therapist may then consider increasing the device setting if the patient remains clinically stable and can complete the prescribed session with appropriate technique. This example illustrates the principle of relative-load prescription and should not be used without reliable MIP measurement, suitable device calibration, and clinical review. The calculated training load is not a direct measure of the patient's cardiac workload, and the therapist should continue to monitor symptoms and cardiovascular response independently of the device setting.

6. Practical IMT Training Technique:

6.1. Patient Positioning:
The patient should initially perform IMT in a comfortable upright sitting position with the trunk supported and shoulders relaxed, because this position may facilitate diaphragmatic movement and reduce unnecessary accessory muscle activity. Patients with orthopnea or severe breathlessness may require a modified position that allows comfortable breathing, and the therapist should ensure that the patient can maintain the position throughout the training session without excessive fatigue. The head and neck should remain in a neutral position, and the patient should avoid leaning forward excessively or elevating the shoulders during inspiration. Positioning should be adjusted according to postoperative restrictions, chest discomfort, and the patient's overall functional status.

6.2. Device Preparation:
The therapist should inspect the device, confirm the prescribed resistance, and ensure that the mouthpiece is clean and properly fitted. The patient should be taught to maintain a firm lip seal around the mouthpiece and use a nose clip when required by the device protocol. The therapist should explain how to assemble, adjust, clean, and store the equipment, particularly when the device will be used at home. Resistance should be checked before each session because an incorrect setting may result in an inadequate training stimulus or excessive inspiratory loading.

6.3. Breathing Manoeuvre:
The patient should exhale gently and then inhale through the mouthpiece against the prescribed resistance using a controlled and sufficiently deep inspiratory effort. Expiration should generally be relaxed and unforced, and the patient should avoid breath-holding, Valsalva manoeuvres, or unnecessary accessory muscle tension. The therapist should observe the breathing pattern and correct excessive shoulder elevation, neck muscle recruitment, facial straining, or inconsistent inspiratory effort. Patients should be encouraged to prioritize the quality of each breath rather than completing a high number of repetitions with poor technique.

6.4. Session Structure:
A session may consist of repeated inspirations with short pauses between breaths or sets, depending on the device and the patient's tolerance. The number of breaths, rest intervals, and total session duration should be adapted to the prescribed training method. Patients with significant weakness or fatigue may begin with shorter sets and longer recovery periods, progressing as technique and tolerance improve. The therapist should document the resistance, session duration, symptoms, and any modifications so that subsequent sessions can be adjusted consistently.

6.5. Supervision and Home Practice:

Initial sessions should be supervised to confirm correct technique, appropriate resistance, and acceptable symptom response. Once the patient can use the device safely and independently, home practice may be appropriate, supported by written instructions and a simple training diary. The therapist should review device use during follow-up rather than assuming that the prescribed sessions have been completed. Home-based IMT may improve accessibility for patients who have difficulty attending frequent supervised appointments, but the programme still requires periodic reassessment of MIP, symptoms, training load, and adherence.

7. Integration of IMT with Conventional Cardiac Rehabilitation:

7.1. IMT Combined With Aerobic Exercise:

Aerobic exercise improves cardiovascular fitness, peripheral muscle oxidative capacity, and functional endurance, while IMT targets inspiratory muscle strength and endurance. Combining these interventions may address both respiratory and locomotor contributors to exercise intolerance, particularly in patients with heart failure who experience dyspnea during walking or cycling. Patients may perform IMT before or after aerobic exercise, or at a separate time of day, depending on fatigue and clinical response. The optimal sequence has not been established for all cardiac populations. If IMT causes fatigue that interferes with walking or cycling performance, it may be preferable to schedule it separately, whereas patients who tolerate both interventions may complete them within a structured rehabilitation session. The therapist should monitor total exercise workload and avoid increasing both IMT resistance and aerobic intensity simultaneously when this would make it difficult to identify the cause of symptom deterioration.

7.2. IMT Combined With Resistance Training:

Resistance training improves peripheral muscle strength, functional performance, and the ability to complete daily activities. In cardiac patients with generalized deconditioning, combining peripheral resistance exercise with IMT may provide a more comprehensive approach to physical conditioning. The training programme should be designed according to the patient's cardiovascular status, muscle strength, functional limitations, and recovery capacity. Patients with frailty, multiple comorbidities, or advanced heart failure may require shorter sessions and more gradual progression. The therapist should recognize that improvement in respiratory muscle strength does not automatically justify an increase in peripheral resistance training load, and each component should be progressed according to its own clinical response.

7.3. IMT during Phase I Cardiac Rehabilitation:

Phase I rehabilitation generally occurs during hospitalization after an acute cardiac event or cardiac surgery, with priorities including early mobilization, prevention of complications, education, and restoration of basic functional independence. IMT may be considered when the patient is clinically stable and the treating team identifies respiratory muscle weakness or a specific postoperative indication. After cardiac surgery, training must account for pain, wound healing, sternal precautions, haemodynamic status, and the patient's ability to perform an effective inspiratory effort. The intervention should be stopped if it produces chest discomfort, marked breathlessness, dizziness, or an abnormal cardiovascular response. In this phase, IMT should not interfere with essential mobilization, airway clearance, medical treatment, or postoperative monitoring.

7.4. IMT during Phase II Cardiac Rehabilitation:

Phase II rehabilitation typically involves structured outpatient exercise and education after hospital discharge and may provide an appropriate setting for systematic IMT assessment and progression. Patients with reduced MIP, persistent dyspnea, or difficulty progressing through aerobic exercise may be considered for an individualized programme. The therapist should establish baseline respiratory and functional measures, introduce the device under supervision, and integrate IMT with aerobic and resistance exercise. Patient education should emphasize that IMT is an additional component of secondary prevention and does not replace medication, physical activity, nutritional management, smoking cessation, or routine medical follow-up.

7.5. IMT during Long-Term Maintenance:

Some patients may continue IMT after completing supervised rehabilitation, particularly when inspiratory muscle weakness persists or a meaningful response has been demonstrated. Long-term continuation should be reviewed periodically to ensure that the intervention remains appropriate and does not create an unnecessary treatment burden. Patients should be encouraged to maintain regular physical activity and other evidence-based secondary-prevention behaviours, with IMT serving as a targeted component rather than the central focus of

long-term cardiovascular health maintenance. The pathway shows how cardiovascular screening and MIP assessment inform individualized threshold loading, supervised familiarization, progressive training, and reassessment alongside conventional aerobic and resistance exercise.

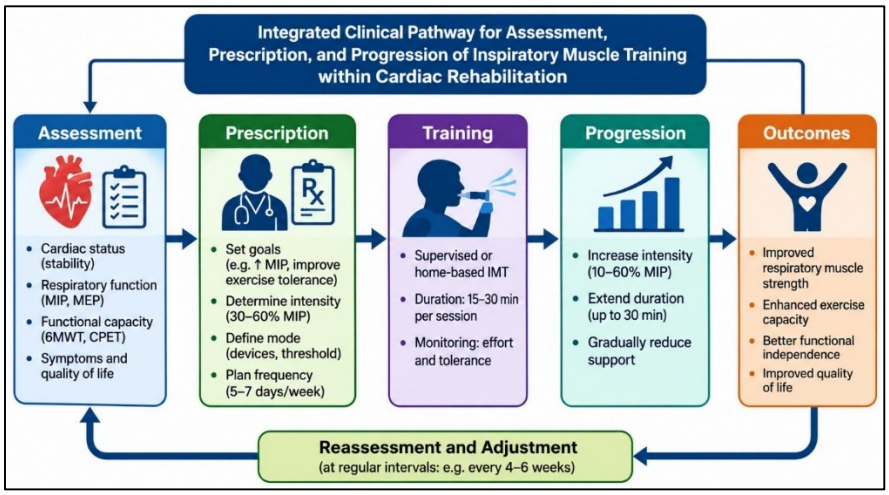


Figure. 2: Integrated clinical pathway for assessment, prescription, and progression of inspiratory muscle training within cardiac rehabilitation

8. Clinical Applications across Cardiovascular Conditions:

8.1. Chronic Heart Failure:

Patients with stable chronic heart failure and reduced inspiratory muscle strength represent an important group for IMT because respiratory muscle weakness may contribute to exertional dyspnea, fatigue, and difficulty progressing through conventional exercise rehabilitation. A baseline MIP measurement can help identify inspiratory weakness and guide the initial threshold load, while NYHA functional class, recent hospitalization, fluid status, medication changes, blood pressure, and symptom stability should inform the overall prescription. Patients with acute decompensated heart failure should not begin an unsupervised IMT programme, and those who have recently experienced clinical deterioration require medical reassessment before training. Following stabilization, IMT may be introduced as a complementary intervention alongside guideline-directed medical treatment, aerobic exercise, resistance training, and self-management education. The therapist should monitor breathlessness, fatigue, exercise tolerance, and training adherence because an improvement in inspiratory strength may not necessarily indicate an equivalent improvement in cardiac function or overall disease severity.

8.2. Heart Failure with Preserved Ejection Fraction:

Heart failure with preserved ejection fraction is frequently associated with exercise intolerance, increased ventilatory demand, impaired peripheral oxygen utilization, obesity or frailty, and multiple comorbidities. IMT may be relevant in patients who demonstrate inspiratory muscle weakness or disproportionate dyspnea, but evidence specifically involving HFpEF remains less extensive than evidence involving mixed heart failure populations. The 2025 meta-analysis by Siddiqi et al. included patients with preserved and reduced ejection fraction and reported improvements in respiratory muscle strength and selected functional outcomes, but subgroup findings should be interpreted cautiously. IMT should therefore be selected according to the individual's respiratory assessment and functional limitations rather than prescribed routinely to every patient with HFpEF. The therapist should also consider obesity, pulmonary disease, anaemia, atrial fibrillation, chronotropic incompetence, and other factors that may contribute to breathlessness and exercise limitation.

8.3. Coronary Artery Disease:

In stable coronary artery disease, IMT may be considered when respiratory muscle weakness contributes to breathlessness or limits exercise participation. The programme should remain integrated with ischemia-aware aerobic training, appropriate resistance exercise, medication adherence, smoking cessation, dietary management, and cardiovascular risk-factor control. Patients with new or worsening angina, unstable symptoms, unexplained breathlessness, or suspected myocardial ischemia require medical reassessment before continuing training. IMT is not a method for treating active myocardial ischemia and should not be used to encourage patients to exercise through chest pain or other warning symptoms. In selected stable patients,

respiratory muscle conditioning may help address a modifiable component of exercise intolerance, but the current evidence does not support routine prescription for every individual with coronary artery disease.

8.4. Post-Coronary Artery Bypass Graft Rehabilitation:

After CABG, IMT may be considered during preoperative preparation or postoperative rehabilitation. Preoperative training aims to improve inspiratory muscle reserve before surgery, while postoperative training may help restore respiratory muscle strength and walking capacity. The timing and intensity should be coordinated with the surgical and rehabilitation teams, particularly when patients experience pain, reduced lung volumes, wound-related discomfort, or postoperative complications. The systematic review by Araújo et al. (2024) supports the potential benefits of IMT during Phase I and Phase II postoperative cardiac rehabilitation, although the authors identified variability in study quality and evidence certainty. The therapist should monitor respiratory symptoms, inspiratory technique, pain, fatigue, and haemodynamic response, and should avoid excessive inspiratory effort during early recovery.

8.5. Valvular Heart Disease and Valve Surgery:

Patients undergoing valve surgery may experience postoperative respiratory impairment and reduced functional capacity because of anaesthesia, mechanical ventilation, thoracic surgery, pain, and reduced mobility. IMT could be considered when inspiratory muscle weakness is identified, but condition-specific evidence remains limited and should not be assumed to be equivalent to the evidence available for CABG. The therapist should consider the type of valve procedure, haemodynamic status, associated pulmonary hypertension, postoperative complications, and the patient's overall recovery before prescribing training. Patients with persistent dyspnea after valve surgery require appropriate clinical evaluation because breathlessness may reflect residual valve dysfunction, arrhythmia, pulmonary hypertension, anaemia, or other causes that cannot be corrected by respiratory muscle training alone.

8.6. Older Adults with Cardiovascular Disease:

Older adults may have age-related reductions in respiratory muscle strength, frailty, reduced mobility, impaired balance, and multiple comorbidities that influence their ability to participate in cardiac rehabilitation. IMT may be useful when inspiratory weakness contributes to functional limitation, but training should start at a tolerable resistance and progress gradually. The therapist should consider cognition, hand strength, visual function, device handling, fatigue, and the availability of caregiver support. A simplified device, clear written instructions, and shorter training sessions may improve feasibility. In frail individuals, the expected benefit should be balanced against the overall treatment burden, and IMT should be integrated with mobility training, lower-limb strengthening, balance exercise, and functional activity practice.

8.7. Patients with Coexisting Pulmonary Disease:

Some cardiac rehabilitation participants also have chronic obstructive pulmonary disease, restrictive lung disease, asthma, or other respiratory conditions. These patients may have additional respiratory muscle limitations, but their IMT prescription may need to be coordinated with pulmonary rehabilitation and the management of their underlying respiratory disease. Airflow limitation, dynamic hyperinflation, oxygenation, cough, secretion burden, and symptom response should be considered before training. Patients with marked desaturation, uncontrolled bronchospasm, active respiratory infection, or unexplained respiratory deterioration require clinical review before IMT is initiated. When appropriate, combined cardiac and pulmonary rehabilitation may provide a more comprehensive approach to exercise limitation than isolated respiratory muscle training.

9. Monitoring and Outcome Measurement:

9.1. Maximal Inspiratory Pressure:

MIP is the primary outcome measure for evaluating inspiratory muscle strength and should be repeated using the same equipment, testing position, instructions, and technique whenever possible. An increase in MIP may indicate improved inspiratory pressure-generating capacity, although learning effects, effort, and measurement variability should be considered. The therapist should compare the result with baseline values and interpret it alongside symptoms and functional performance rather than treating MIP improvement as the sole indicator of clinical success.

9.2. Six-Minute Walk Distance:

The six-minute walk test provides a practical measure of submaximal functional exercise capacity and is particularly useful in outpatient cardiac rehabilitation settings where cardiopulmonary exercise testing may not be available. Changes in walking distance should be interpreted alongside perceived dyspnea, fatigue, heart rate response, oxygen saturation when indicated, and the patient's clinical condition. The test should be performed using a standardized corridor, instructions, encouragement, and safety procedures to improve comparability between assessments.

9.3. Cardiopulmonary Exercise Testing:

When available and clinically appropriate, cardiopulmonary exercise testing can provide detailed information about peak oxygen uptake, ventilatory efficiency, breathing reserve, heart rate response, and exercise-related symptoms. It may help determine whether improvements following IMT extend beyond respiratory muscle strength and are associated with changes in whole-body exercise performance. The test can also assist in identifying other contributors to exercise intolerance, including chronotropic incompetence, ischemic symptoms, abnormal blood pressure response, or ventilatory limitation.

9.4. Dyspnea and Perceived Exertion:

Dyspnea can be monitored using the modified Borg scale or another validated symptom measure, with the therapist documenting breathlessness at rest, during IMT, during aerobic exercise, and during recovery. A reduction in perceived breathlessness may be clinically meaningful even when changes in walking distance or peak oxygen uptake are modest. Perceived exertion should also be recorded because patients may experience respiratory muscle fatigue or general exercise fatigue that is not fully captured by physiological measurements.

9.5. Quality of Life:

Disease-specific questionnaires such as the Minnesota Living with Heart Failure Questionnaire and the Kansas City Cardiomyopathy Questionnaire may be used in heart failure populations to evaluate the impact of symptoms and functional limitations on daily life. Generic measures such as the EQ-5D or SF-36 may provide additional information about broader health-related quality of life. The same questionnaire should be used at baseline and follow-up whenever possible, and changes should be interpreted according to the established scoring guidance for that instrument.

9.6. Adherence and Training Dose:

Adherence should be monitored through training diaries, supervised-session records, device counters when available, and periodic patient interviews. The therapist should distinguish between the prescribed training dose and the training actually completed, because missed sessions may reduce the intended training stimulus. Poor adherence may reflect dyspnea, fatigue, lack of motivation, device difficulty, inadequate understanding, or competing medical and family responsibilities. Recording resistance, session duration, symptoms, and missed sessions can help identify barriers and support appropriate modification of the programme. The table 3 outlines practical outcome domains and their relevance to treatment evaluation.

Table. 3: Outcome measures for monitoring the effectiveness of inspiratory muscle training in cardiac rehabilitation

Outcome domain	Measurement tool	Expected clinical information
Inspiratory muscle strength	MIP/PImax	Change in inspiratory pressure-generating capacity
Respiratory endurance	Sustained threshold or endurance test	Ability to sustain inspiratory loading
Functional exercise capacity	Six-minute walk test	Change in submaximal walking performance
Peak aerobic capacity	Cardiopulmonary exercise testing	Change in peak VO_2 and exercise physiology
Ventilatory efficiency	VE/VCO_2 slope	Ventilatory response during exercise
Dyspnea	Modified Borg scale or MRC scale	Perceived breathing difficulty

Quality of life	MLHFQ or KCCQ	Patient-reported health status
Safety	Symptoms, HR, BP, SpO_2 when indicated	Tolerance and adverse responses
Adherence	Training diary or session records	Completion of prescribed training

10. Safety Considerations and Precautions:

10.1. Cardiovascular Stability:

Patients should be clinically stable before beginning a structured IMT programme, and acute decompensated heart failure, unstable angina, uncontrolled arrhythmias, severe uncontrolled hypertension, unexplained syncope, or new cardiovascular symptoms require medical assessment before training. The patient should be instructed to stop IMT and report new chest pain, marked breathlessness, dizziness, palpitations, presyncope, or unusual fatigue. The therapist should not assume that IMT is automatically safe because the intervention involves respiratory rather than limb exercise, inspiratory loading still produces physiological effort and may be inappropriate during unstable cardiovascular conditions.

10.2. Excessive Inspiratory Loading:

An excessive initial resistance may cause marked respiratory effort, fatigue, dizziness, or poor technique. The load should be reduced if the patient cannot complete the prescribed manoeuvre comfortably or repeatedly demonstrates breath-holding, excessive accessory muscle recruitment, or facial straining. Higher intensity is not automatically better, particularly in older adults, patients with advanced heart failure, and individuals recovering from surgery. The therapist should prioritize controlled breathing and consistent training rather than maximal effort during every session.

10.3. Avoidance of Valsalva Manoeuvres:

Patients should be instructed to avoid breath-holding and forceful straining during IMT. Inspiration should be controlled against the prescribed resistance, while expiration should remain relaxed. Excessive straining may produce unwanted cardiovascular responses and can interfere with the intended respiratory muscle training pattern. The therapist should observe the patient during initial sessions and provide immediate correction when an inappropriate breathing pattern develops.

10.4. Postoperative Considerations:

After cardiac surgery, pain, wound healing, sternal precautions, and postoperative complications must be considered before IMT is initiated. Training should be coordinated with the surgical team, particularly during early postoperative recovery. The patient should not be required to generate forceful inspiratory efforts that aggravate chest discomfort or compromise adherence to surgical precautions. If pain prevents effective breathing, the cause should be addressed through the postoperative care plan before resistance is increased.

10.5. Conditions Requiring Additional Caution:

Additional clinical consideration may be needed in patients with recent pneumothorax, active respiratory infection, severe uncontrolled bronchospasm, significant oxygen desaturation, unstable pulmonary disease, or other conditions that make forceful inspiratory efforts inappropriate. The specific precautions depend on the patient's diagnosis, clinical stability, and the device used. Patients with coexisting pulmonary disease may require coordination between cardiac rehabilitation and respiratory care teams to ensure that IMT does not aggravate symptoms or interfere with other treatment.

10.6. Monitoring During Training:

Initial sessions should include observation of breathing pattern, facial colour, symptoms, and the patient's ability to maintain the prescribed technique. Heart rate, blood pressure, and oxygen saturation may be monitored when indicated by cardiovascular or respiratory risk. If abnormal symptoms occur, training should be stopped and the patient assessed according to the rehabilitation centre's clinical procedures. The therapist should document adverse responses, modify the prescription when appropriate, and seek medical review when symptoms suggest cardiovascular or respiratory deterioration.

11. Role of the Physiotherapist in IMT-Based Cardiac Rehabilitation:

11.1. Identification of Suitable Patients:

Physiotherapists play a central role in identifying patients who may benefit from IMT by assessing persistent dyspnea, reduced exercise tolerance, respiratory muscle fatigue, and difficulty progressing through conventional exercise training. MIP assessment can help determine whether inspiratory muscle weakness is present, but symptoms alone should not be used to diagnose respiratory muscle impairment because breathlessness may arise from cardiac dysfunction, pulmonary disease, anaemia, deconditioning, anxiety, or other causes. The physiotherapist should integrate respiratory assessment with the patient's cardiovascular history, exercise response, functional status, and medical stability before recommending IMT.

11.2. Individualized Exercise Prescription:

The physiotherapist should calculate the training load using the patient's measured MIP and select an appropriate device, session structure, intensity, and progression strategy. Prescription should account for cardiovascular stability, functional capacity, age, comorbidities, postoperative restrictions, and the patient's ability to use the device correctly. The training plan should be reviewed regularly rather than maintaining a fixed resistance throughout the entire programme. The physiotherapist should also coordinate IMT with aerobic and resistance exercise so that the total rehabilitation workload remains appropriate.

11.3. Patient Education:

Education should explain the purpose of IMT, the expected training sensations, correct breathing technique, device hygiene, and symptoms that require the patient to stop training. Patients should understand that IMT is an additional component of cardiac rehabilitation and does not replace medication, aerobic exercise, resistance training, dietary management, smoking cessation, or medical follow-up. Clear instructions should be provided for home practice, including the prescribed resistance, session duration, frequency, and circumstances requiring contact with the rehabilitation team.

11.4. Adherence Support:

Adherence may be improved through achievable goals, simple training logs, regular feedback, and scheduled reassessment. Patients who train at home should be taught how to recognize incorrect technique and when to seek advice. Device use should be reviewed during follow-up rather than assuming that the programme has been completed as prescribed. The physiotherapist should discuss barriers without blaming the patient and should modify the training schedule when symptoms, fatigue, work commitments, or device-related difficulties interfere with regular practice.

11.5. Multidisciplinary Coordination:

IMT should be coordinated with cardiologists, cardiac nurses, respiratory therapists, occupational therapists, dietitians, psychologists, and other rehabilitation professionals as appropriate. This is particularly important in patients with complex heart failure, recent cardiac surgery, coexisting pulmonary disease, repeated hospital admissions, or substantial psychosocial barriers. Multidisciplinary communication helps ensure that respiratory muscle training complements rather than conflicts with the patient's medical treatment, exercise prescription, and postoperative care plan.

12. Barriers to Implementation and Strategies to Improve Adherence:

12.1. Lack of Awareness:

Some patients and healthcare professionals may be unfamiliar with IMT or may not recognize respiratory muscle weakness as a potentially modifiable contributor to exercise intolerance. Education and practical demonstrations can help establish its role as a targeted rehabilitation intervention. Clinical teams should understand that IMT is not required for every cardiac patient and that its strongest rationale is in selected individuals with documented or suspected respiratory muscle impairment.

12.2. Device-Related Difficulties:

Patients may find it difficult to maintain a mouth seal, generate the prescribed inspiratory pressure, or clean and handle the device. The therapist should select a device that is suitable for the patient's dexterity, cognition, vision, and respiratory ability. Initial supervised practice can reduce these difficulties, and simplified written

instructions may improve independent use. Patients should be encouraged to report discomfort or device malfunction rather than continuing with an incorrect resistance setting.

12.3. Fatigue and Competing Exercise Demands:

Patients may already have a demanding rehabilitation schedule involving walking, cycling, resistance exercise, education, and medical appointments. IMT may become an additional burden if it is not integrated appropriately. Shorter sessions, gradual progression, flexible scheduling, and coordination with conventional exercise can improve feasibility. If the patient experiences excessive fatigue, the therapist should review the total training dose rather than assuming that reduced adherence reflects a lack of motivation.

12.4. Limited Access to Equipment:

Access to threshold devices and respiratory pressure measurement equipment may be limited in some rehabilitation centres, particularly in low-resource settings. Lower-cost devices may improve accessibility, but resistance settings should be reliable and equipment should be used according to manufacturer instructions. Where MIP measurement is unavailable, the limitations of load estimation should be acknowledged and the programme should be supervised more closely. Investment in basic respiratory assessment equipment may improve patient selection and allow more consistent prescription.

12.5. Strategies to Support Long-Term Adherence:

Adherence can be strengthened through clear explanations, individualized goals, and patient involvement in scheduling, periodic review, and feedback about measurable changes in MIP or symptoms. A simple home-training record can help the patient and therapist identify missed sessions and barriers. Digital reminders and remote consultations may support home-based practice, but they should supplement rather than replace clinical assessment and follow-up. Patients should also be encouraged to maintain broader cardiac rehabilitation behaviours, including regular aerobic activity, resistance exercise, medication adherence, healthy nutrition, and smoking cessation.

13. Special Considerations in Clinical Practice:

13.1. Patients with Low Baseline MIP:

Patients with reduced MIP may have greater potential for measurable improvement in inspiratory muscle strength, but very low baseline strength may also limit the ability to tolerate a conventional starting load. A lower initial resistance and shorter training bouts may be appropriate, with gradual progression as technique and tolerance improve. The therapist should consider whether the low MIP is reproducible and whether it may be influenced by pain, poor effort, neuromuscular impairment, or other clinical factors before prescribing a training programme.

13.2. Patients with Preserved MIP but Persistent Dyspnea:

Not all patients with breathlessness have inspiratory muscle weakness. If MIP is within an expected range, the therapist should consider other explanations, including cardiac limitation, pulmonary congestion, abnormal ventilatory response, lung disease, anaemia, anxiety, or peripheral deconditioning. IMT may still be considered in selected circumstances, but the expected benefit should be discussed carefully and the patient should not be given the impression that respiratory muscle training will resolve every cause of dyspnea. Persistent or worsening breathlessness requires appropriate medical evaluation.

13.3. Patients with Implanted Cardiac Devices:

Patients with pacemakers or implantable cardioverter-defibrillators may participate in cardiac rehabilitation when clinically stable and appropriately assessed. IMT does not involve the same limb loading as conventional resistance exercise, but the overall rehabilitation plan should follow the patient's device-related and cardiovascular precautions. New palpitations, presyncope, syncope, or device-related symptoms require clinical review. The presence of an implanted device should not automatically exclude a patient from IMT, but training should be coordinated with the treating team when clinical concerns exist.

13.4. Patients With Frailty and Multimorbidity:

Frailty, cognitive impairment, arthritis, reduced hand strength, and visual limitations can affect the patient's ability to operate an IMT device. Simplified instructions, caregiver involvement, modified positioning, and shorter sessions may improve feasibility. The potential benefit should be balanced against the patient's overall

treatment burden and personal goals. In some individuals, improving mobility, balance, lower-limb strength, and confidence with daily activities may take priority over a separate respiratory training programme.

13.5. Patients with Anxiety-Related Breathing Symptoms:

Some patients experience anxiety, panic symptoms, or heightened awareness of breathing, which may influence their response to respiratory exercise. IMT should not be introduced as a way to force deeper or faster breathing. Calm instruction, controlled breathing, reassurance, and a gradual introduction to resistance may improve comfort. Persistent or new dyspnea should still be clinically evaluated rather than automatically attributed to anxiety. Where anxiety substantially interferes with rehabilitation, psychological support may be appropriate alongside physical training.

13.6. Limitations of Current Evidence:

Despite encouraging findings, several limitations affect interpretation of the current IMT literature. Many trials in cardiac populations have relatively small sample sizes, which may produce unstable estimates and may not adequately detect uncommon adverse events or long-term clinical outcomes. Training protocols vary considerably in starting intensity, progression, repetitions, session duration, frequency, device type, programme length, and level of supervision, making it difficult to identify one optimal prescription for all patients. Patient populations are also heterogeneous, with studies including individuals with chronic heart failure, mixed ejection-fraction categories, coronary artery disease, and patients recovering from cardiac surgery, differences in age, NYHA class, baseline MIP, comorbidities, medication, and concurrent exercise training may influence the response. Outcome measures are not consistently reported, and although MIP and six-minute walk distance are common, studies differ in their use of peak oxygen uptake, ventilatory efficiency, dyspnea scores, quality-of-life instruments, and hospital outcomes. Long-term follow-up is often limited, making it difficult to determine whether improvements are maintained after supervised training ends. The specific contribution of IMT may also be difficult to isolate when it is combined with aerobic exercise, resistance training, or other respiratory interventions. Finally, improvements in respiratory muscle strength or walking distance should not be interpreted as proof of reduced cardiovascular mortality, recurrent cardiac events, or hospitalization. Larger trials with adequate follow-up and standardized training protocols are required to establish the long-term clinical value of IMT.

14. Future Directions:

Future research should focus on establishing standardized, clinically meaningful IMT prescription protocols for different cardiovascular populations. Trials should compare low-, moderate-, and higher-intensity programmes using clearly defined MIP-based loading, consistent progression criteria, and transparent reporting of adherence and adverse events. A further priority is identifying which patients benefit most, because baseline inspiratory muscle weakness may be an important treatment-selection factor, while dyspnea severity, ventilatory inefficiency, frailty, exercise intolerance, and postoperative respiratory risk may also influence response. Stratified trials could help determine whether IMT should be prescribed routinely or targeted to specific patient subgroups. The role of IMT in HFpEF requires additional investigation, because although early evidence suggests possible improvements in functional capacity and symptoms, larger trials are needed to establish the magnitude and durability of benefit. Research should also examine whether IMT provides additional value when combined with contemporary pharmacological treatment and comprehensive exercise-based cardiac rehabilitation. Digital monitoring may provide opportunities to improve adherence and support home-based IMT through devices that record training load, session duration, and completion, allowing clinicians to review patient performance remotely. However, digital systems should be validated for accuracy, usability, data security, and safety before routine clinical adoption. Postoperative research should compare preoperative, postoperative, and combined perioperative IMT strategies using clinically relevant outcomes such as pulmonary complications, length of stay, functional recovery, quality of life, and longer-term exercise capacity. Future studies should also include cost-effectiveness, health service utilization, patient preference, and implementation outcomes to determine whether IMT can be delivered effectively across different healthcare settings.

15. Practical Clinical Recommendations:

The current evidence supports a selective, assessment-led approach to IMT in cardiac rehabilitation, with consideration given to clinically stable patients who demonstrate inspiratory muscle weakness, persistent respiratory muscle limitation, or selected postoperative rehabilitation needs. Baseline MIP should be measured using a standardized method before prescribing a percentage-based threshold load, and the initial resistance

should be selected according to the patient's strength, symptoms, and ability to perform the manoeuvre correctly. Training should begin at a tolerable intensity and progress gradually according to technique, symptoms, and repeat assessment. IMT should be integrated with aerobic and resistance exercise rather than replacing conventional cardiac rehabilitation, and initial sessions should be supervised to ensure appropriate device use and identify abnormal responses. Monitoring should include MIP, dyspnea, functional exercise capacity, quality of life, adherence, and adverse symptoms, with periodic reassessment to determine whether the intervention should be continued, modified, or discontinued. These recommendations should be applied alongside current cardiovascular guidelines and local clinical protocols. Contemporary heart failure and chronic coronary disease guidelines support exercise-based rehabilitation and physical activity for eligible patients, while IMT may be considered an additional targeted intervention when clinically indicated rather than a replacement for established secondary-prevention components (Heidenreich et al., 2022, Virani et al., 2023).

16. Conclusion:

Inspiratory muscle training is a promising adjunct to comprehensive cardiac rehabilitation because it targets a component of exercise limitation that may remain insufficiently addressed by conventional aerobic and resistance training. Respiratory muscle weakness, increased work of breathing, ventilatory inefficiency, and exertional dyspnea can contribute to reduced functional capacity in patients with heart failure and in individuals recovering from cardiac surgery. Current systematic reviews and clinical trials indicate that IMT can improve MIP and may provide additional benefits in walking capacity, peak oxygen uptake, dyspnea, ventilatory efficiency, and health-related quality of life in selected populations. The most important practical elements are appropriate patient selection, baseline MIP assessment, individualized threshold loading, gradual progression, correct technique, and regular reassessment. IMT appears particularly relevant for stable patients with heart failure and patients undergoing postoperative cardiac rehabilitation, although evidence is less developed for several other cardiovascular conditions. It should be integrated with established cardiac rehabilitation components and coordinated with the multidisciplinary team. Despite encouraging findings, variations in study design and training protocols, small sample sizes, and limited long-term follow-up prevent the establishment of a single universal IMT prescription. Future high-quality randomized trials should determine optimal training intensity, identify patients most likely to benefit, and evaluate long-term cardiovascular and healthcare outcomes. At present, IMT is best viewed as an individualized, evidence-informed complementary strategy that may enhance respiratory muscle function and support functional recovery in cardiac rehabilitation.

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