Comparative Effectiveness of Inspiratory Muscle Training Combined with Conventional Exercise on Exercise Tolerance: A Six-Minute Walk Test Study

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Introduction

The goal of respiratory muscle strength training (RMST) is to improve the strength and stamina of the diaphragm and intercostal muscles, among other respiratory muscles. Dysfunctional inspiration, expiration, or both can result from a variety of clinical illnesses that impact the respiratory system both directly and indirectly. RMST is very useful for athletes. For patients with respiratory disorders that adversely affect respiratory muscles, such as those with critical illness, asthma, chronic obstructive pulmonary disease (COPD), or respiratory muscle weakness, RMST is a useful therapeutic or rehabilitative technique. To address respiratory dysfunction and improve therapeutic outcomes, RMST may be used alone or in conjunction with other pulmonary rehabilitation techniques [1].

This exercise describes the physiological underpinnings of respiratory muscle strengthening, covers the key elements of an RMST program, and discusses the therapeutic advantages of RMST for a range of clinical disorders. Furthermore, it facilitates the identification of patients who will benefit from this therapeutic intervention by providing interprofessional healthcare team members with the information and resources to recognise the indications and contraindications of RMST.

The physiology and function of respiratory muscle strengthening

The structure of respiratory muscles is comparable to that of other skeletal muscles. However, because their contraction alters chest wall motion during inspiration and expiration, respiratory muscles are unique [2]. During resistance and endurance training, respiratory muscles exhibit plasticity by changing their cross-sectional area, muscle fibre phenotype (fast-twitch, slow-twitch), and activation threshold, just as the musculature of the upper and lower limbs does [3]. One method of providing progressive overload is to expose the respiratory muscles to resistive loads for extended periods and adjust the loads based on tolerance. Increasing the power and endurance of the respiratory muscles improves lung volumes and chest wall mechanics while reducing the clinical incidence of pulmonary illnesses, including pneumonia and atelectasis. The physiological response of the respiratory muscles to increased workload is hypertrophy, which increases contractile force.[4]

Respiratory Muscle Strength Training Definition

To increase the strength and endurance of the inspiratory and expiratory muscles, RMST is used in medical facilities, including intensive care units and outpatient and inpatient rehabilitation centers. To participate in a time-limited planned treatment program involving inspiratory muscle strength (IMS) training, expiratory muscle strength (EMS) training, or both, patients must challenge inhalation or expiration during RMST. To develop the strength and endurance of the inspiratory musculature, which includes the diaphragm, external intercostal, and parasternal intercostal muscles, patients undergoing IMS training must perform exercises with portable equipment.[5] As part of EMS training, patients must perform exercises that increase the strength and stamina of expiratory muscles, such as the abdominal and internal intercostal muscles.[6]

Training Tools and Procedures for Respiratory Muscle Strength

The following types of equipment are used in EMS and IMS training: resistance devices, pressure threshold devices, and incentive spirometry (IS). A spring-loaded, one-way calibrated valve in pressure-threshold devices targets a specific threshold of maximal pressure on the muscles during inhalation or exhalation; adjusting the spring raises or lowers the threshold.[7] For air to pass through the device and aid in intake or exhalation, the target pressure must be attained. The volume and velocity of airflow through the device have no bearing on the resistance it applies during inspiration or expiration.[8] Airflow is continuously resisted by resistance devices. By altering the number or size of the apertures that allow air to pass, users can change the resistance.[9] Based on input from the device to the predetermined airflow during inspiration, incentive spirometry systems encourage natural deep, leisurely breathing that increases lung volumes.[10]

A pressure-measuring tool, such as a digital manometer, peak flow meter, or pressure threshold device, is needed to determine the initial training load for either IMS or EMS training. Exercises are initiated at a proportion of the maximum inspiratory pressure to maximum expiratory pressure, depending on the RMST protocol's objective.[11] Loads between 55% and 80% of this ratio are commonly used in strengthening programs with fewer repetitions.[12] With additional repeats, endurance regimens can utilise 30% to 40% of maximal inspiratory/maximum expiratory pressure.[13]

The clinical indication for training, underlying diseases, and therapeutic tolerance are all taken into account in the RMST protocol. Under the supervision of a speech-language pathologist, patients complete more than 10 repetitions during training sessions, which are usually held 2 to 3 times a day, 3 to 5 days a week, for 5 to 6 weeks. These exercises can also be done by patients at home.[14] To encourage muscular adaptation and enhance respiratory muscle strength or endurance, training intensity may be adjusted by varying the number of training sessions, sets, or repetitions, as well as the session length.

Reasons to Strengthen Your Respiratory Muscles

Strengthening of the inspiratory muscles

IMS training is recommended in the following situations, among others:
Weaning off of mechanical breathing

- Multiple sclerosis damage to the spinal cord
- Heart failure that is congestive
- Chronic pulmonary obstruction
- Vocal fold motion that is paradoxical
- Parkinson's disease [15]

Methodology

Study Design and Setting

The present study was executed using a prospective, randomized controlled experimental design, carefully structured to ensure methodological rigor, internal validity, and reproducibility. A parallel-group design was adopted to compare the effects of Inspiratory Muscle Training (IMT) combined with conventional exercise therapy versus conventional exercise therapy alone in individuals diagnosed with Chronic Obstructive Pulmonary Disease (COPD). The study was conducted in the Department of Pulmonology, which includes both outpatient and inpatient services, thereby allowing the inclusion of patients with a broad spectrum of disease severity and functional status.

Small sample size (**n = 67**). The methodological framework followed a sequential and standardized approach, encompassing participant identification and recruitment, baseline evaluation, randomization, structured intervention delivery, monitoring and follow-up, post-intervention assessment, and systematic data handling. This structured progression was designed to minimize bias, ensure consistency in intervention delivery, and facilitate accurate interpretation of outcomes.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Ethics Committee prior to the commencement of recruitment. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki for research involving human participants. All participants were treated with respect for autonomy, confidentiality, and safety throughout the study period.

Eligible participants were provided with a comprehensive explanation of the study objectives, intervention procedures, participation duration, anticipated benefits, and potential risks. Adequate time was allowed for participants to clarify doubts before consenting. Written informed consent was obtained prior to enrollment. Participants were explicitly informed that participation was entirely voluntary and that refusal to participate or withdrawal at any stage would not influence their routine medical care or therapeutic management.

Confidentiality was maintained by assigning unique identification codes to each participant. Personal identifiers were removed from data files, and access to raw data
was restricted to the principal investigator. All records were securely stored and used solely for research purposes.

Participant Identification and Recruitment

Patients with a confirmed diagnosis of COPD attending the outpatient and inpatient services of the Department of Pulmonology were screened consecutively for eligibility. Diagnosis was established by the treating pulmonologist based on clinical history, physical examination, and spirometric confirmation, in accordance with the Global Initiative for **Chronic Obstructive**

Eligible patients were approached individually in a quiet and private setting to ensure comfort and confidentiality. Information was conveyed in simple, comprehensible language, and patients were encouraged to ask questions. Only those who provided voluntary written consent were enrolled in the study.

Statistical method

Statistical analysis was performed using paired Student's *t*-test to compare pre- and post-intervention Six-Minute Walk Test (6MWT) distances within each group, while an independent Student's *t*-test was used to compare the mean changes between the inspiratory muscle training plus conventional exercise group and the conventional exercise alone group. A *p*-value of <0.05 was considered statistically significant.

Results

Pulmonary Function

Pulmonary function assessed by forced expiratory volume in one second (FEV_1 % predicted) was comparable at baseline between the IMT group (58.2 ± 12.6%) and the control group (57.5 ± 13.1%). At the 8-week follow-up, only marginal improvements were observed in both groups (IMT: 59.6 ± 12.9%; control: 58.4 ± 13.3%). The between-group difference of 1.2% was not statistically significant (p = 0.41), indicating that the intervention did not result in significant short-term changes in airway obstruction.

Overall, the addition of inspiratory muscle training to conventional exercise resulted in significantly greater improvements in functional exercise capacity, dyspnea (both resting and exertional), and health-related quality of life, compared to conventional exercise alone. However, no significant between-group differences were observed in pulmonary function, as measured by FEV_1, suggesting that the benefits of IMT were primarily functional rather than spirometric.

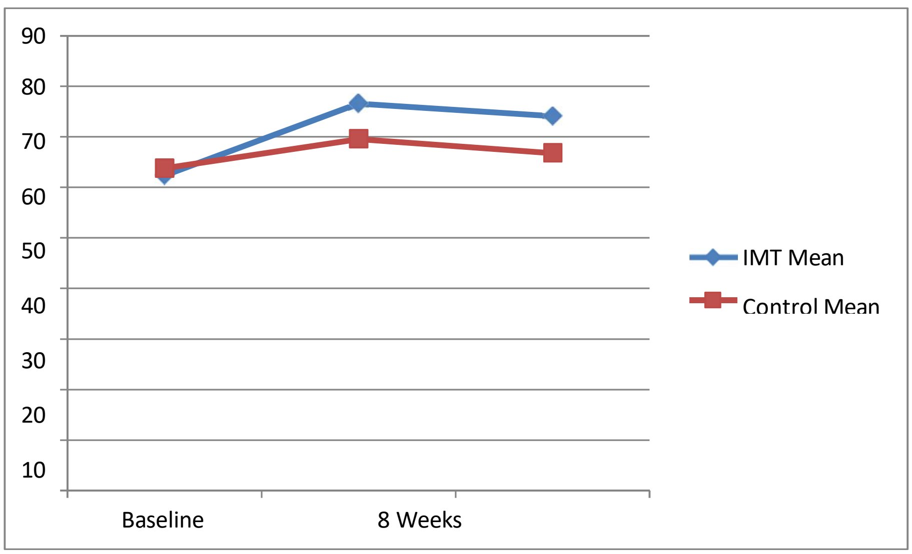

Figure 1. Maximum Inspiratory Pressure (MIP)

Figure 1. Changes in maximum inspiratory pressure (MIP) at baseline, 8 weeks, and 3-month follow-up in the inspiratory muscle training (IMT) plus conventional exercise group and the conventional exercise–alone group. The IMT group demonstrated significantly greater improvements at 8 weeks and sustained gains at follow-up compared with controls.

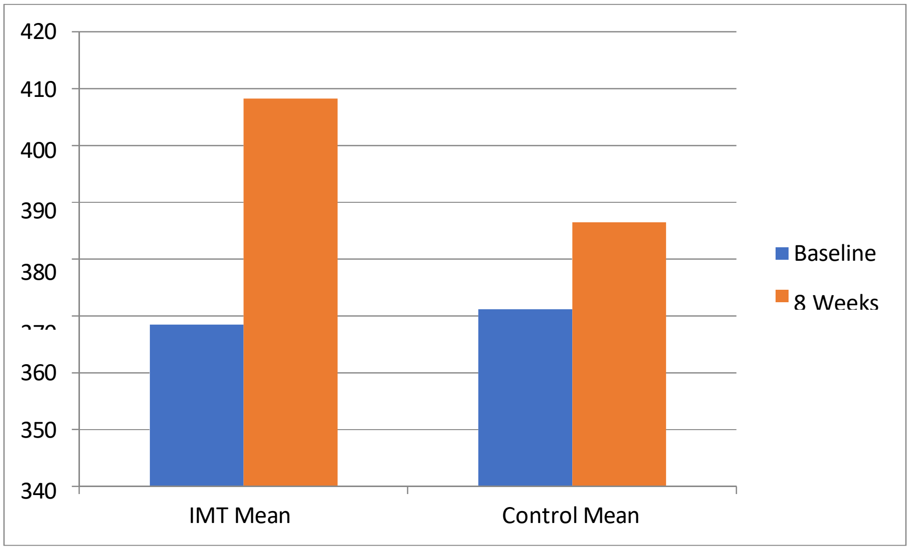

Figure 2. Six-Minute Walk Distance (6MWD)

Figure 2. Comparison of six-minute walk distance (6MWD) at baseline and after 8 weeks of intervention between the IMT group and the conventional exercise group. A significantly greater increase in functional exercise capacity was observed in the IMT group at 8 weeks.

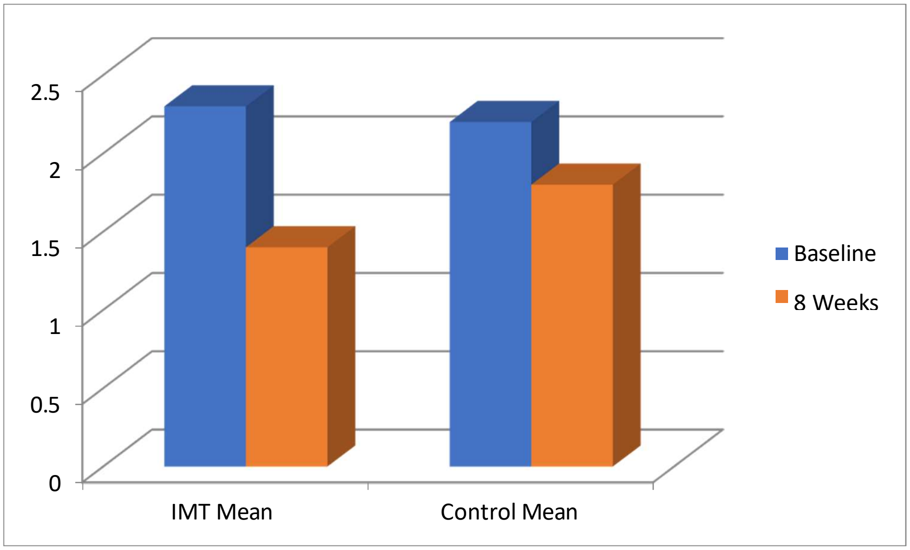

Figure 3. Dyspnea Severity (mMRC Scale)

Figure 3. Changes in dyspnea severity measured using the modified Medical Research Council (mMRC) scale at baseline and 8 weeks in both groups. The IMT group showed a significantly greater reduction in perceived dyspnea compared with the control group.

Discussion

Quality of Life

Health-related quality of life improved significantly in both groups, with greater improvements observed in the IMT group. The reduction in SGRQ scores exceeded the minimal clinically important difference, indicating clinically meaningful benefits. These results align with findings from Ozsoy et al. (2), who reported improved quality of life following functional IMT integrated into exercise programs in older adults with and without COPD.

Meta-analyses by Cacciante et al. (4) and Khan et al. (10) further support the positive impact of respiratory muscle training on quality of life outcomes, emphasizing that improvements in symptom burden and physical function translate into better patient-reported outcomes.

Pulmonary Function

Despite significant functional improvements, spirometric parameters such as FEV_1 and FVC did not demonstrate significant between-group differences. This finding is consistent with existing literature, which suggests that pulmonary rehabilitation and IMT primarily influence functional capacity and symptom perception rather than reversing airflow limitation (1,7,27). Eldaous et al. (17) similarly reported minimal spirometric changes following IMT in patients with COPD, despite improvements in respiratory muscle strength.

Maintenance of Benefits

Improvements in inspiratory muscle strength, exercise capacity, and quality of life were largely maintained at the 3-month follow-up in the IMT group. This finding is in agreement with Dosbaba et al. (6), who demonstrated sustained benefits of home-based IMT in COPD patients over extended periods. The persistence of benefits highlights the feasibility of incorporating IMT into long-term self-management strategies.

Limitations of the Study: This study has several limitations. The relatively small sample size may limit the generalizability of the findings to a broader population. The intervention and follow-up period were short, preventing assessment of the long-term effects of inspiratory muscle training. Exercise tolerance was evaluated primarily using the Six-Minute Walk Test (6MWT), and additional physiological parameters, such as maximal oxygen uptake (VO_2max), respiratory muscle strength, or quality-of-life measures, were not assessed. Furthermore, the study was conducted at a single center, which may restrict the external validity of the results.

Conclusion

These findings support incorporating inspiratory muscle training as an effective adjunct to standard pulmonary rehabilitation programs, particularly for patients with inspiratory muscle weakness or persistent dyspnea. Future research with larger, multicenter samples and longer follow-up periods is warranted to confirm long-term benefits and to establish optimal training protocols across different stages of disease severity.

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