International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 3, May-June-2026, ISSN (Online): 2395-566X

Effectiveness of Combined Inspiratory Muscle Training and Peripheral Progressive Resistance Exercise on Respiratory Function and Functional Capacity in Active Smokers: A Pre-Post Experimental Study

Professor B. R. Shaalini, MPT, Cardiorespiratory
Annai college of physiotherapy.
Dept.of physiotherapy.
The Tamil Nadu Dr. M. G.R. medical University, Chennai

Abstract — Background: Chronic cigarette smoking induces systemic pathophysiological changes, leading to respiratory muscle deconditioning, impaired pulmonary ventilation, and peripheral muscle fatigue. While Inspiratory Muscle Training (IMT) targets central ventilatory drive, progressive resistance training addresses systemic deconditioning. Aim: To evaluate the combined effectiveness of Inspiratory Muscle Training and DeLorme progressive resistance exercise on respiratory muscle strength, pulmonary function, and functional capacity in active smokers. Methods: This pre-post experimental study enrolled 30 active young adult smokers (aged 20–40 years; mean smoking history: 5.4 ± 1.8 pack-years). Participants underwent a structured 6-week intervention consisting of targeted IMT using a threshold resistance device (40–60% of Maximal Inspiratory Pressure [MIP], 20 min/day, 5 days/week) and DeLorme progressive resistance exercise focused on the bilateral quadriceps femoris muscle groups (3 sets of 10 repetitions at 50%, 75%, and 100% of 10-Repetition Maximum [10RM], 5 days/week). Outcome measures included MIP, spirometric parameters (FEV1, FVC, MVV), functional capacity via the Six-Minute Walk Test (6MWT), and exertional dyspnea via the Borg CR10 Scale. Pre- and post-intervention data were analyzed using a paired t-test. Results: Following the 6-week training protocol, participants demonstrated statistically significant improvements across all primary and secondary parameters ($p < 0.001$). MIP increased from 68.4 ± 7.2 cmH2O to 84.6 ± 6.8 cmH2O, and 6MWT distance improved by a mean of 74.2 meters. Exertional dyspnea on the Borg scale decreased significantly from 5.8 ± 1.1 to 3.2 ± 0.9. Conclusion: Integrating IMT with DeLorme progressive peripheral resistance exercise significantly enhances respiratory muscle strength, functional exercise tolerance, and ventilatory efficiency in active smokers. This dual-component approach addresses both central respiratory limitations and peripheral skeletal muscle deconditioning.

Keywords— Inspiratory Muscle Training, DeLorme Progression, Quadriceps Strengthening, Pulmonary Rehabilitation, Pulmonary Function Test, Functional Capacity.

I. INTRODUCTION

Tobacco smoking remains a leading etiology of preventable morbidity, causing progressive structural and functional deterioration of the cardiopulmonary system. Prolonged exposure to particulate matter and noxious gases triggers chronic airway inflammation, cilia destruction, and oxidative stress. Over time, this status results in fixed or partially reversible airflow limitations, increased airway resistance, and ventilation-perfusion mismatch.

While the pulmonary parenchymal changes associated with smoking are well-documented, its systemic manifestations—specifically respiratory and peripheral muscle dysfunction—are frequently under-recognized in younger cohorts. Active smokers experience a systematic down-regulation of muscle metabolic pathways. Chronic nicotine exposure and systemic hypoxia shift skeletal muscle architecture, reducing Type I fatigue-resistant fibers and altering capillary density. This manifests clinically as early diaphragmatic fatigue, reduced skeletal muscle endurance, increased operational lung volumes, and premature exertional dyspnea.

Inspiratory Muscle Training (IMT) serves as a targeted rehabilitation modality that applies a targeted mechanical load to the primary and accessory inspiratory muscles, primarily the diaphragm and external intercostals. By utilizing a flow-independent threshold resistance device, IMT induces structural hypertrophy and metabolic conditioning of the ventilatory pump, lowering the relative neural drive required for ventilation.

Concurrently, peripheral muscle conditioning is vital to comprehensive pulmonary rehabilitation. The DeLorme

progressive resistance exercise protocol utilizes a systematic, graded loading pattern (50% -> 75% -> 100% of 10-Repetition Maximum) engineered to optimize mechanical tension, muscle protein synthesis, and neuromuscular adaptation. When applied to major lower-limb muscle groups like the quadriceps femoris, it counteracts systemic physical deconditioning, enhances peripheral oxygen extraction efficiency, and reduces secondary ventilatory demand during exertion.

While previous literature has isolated the benefits of either ventilatory or peripheral muscle training, there is a scarcity of data regarding their integrated efficacy in young, active smokers before the onset of clinically overt Chronic Obstructive Pulmonary Disease (COPD). Therefore, this study aimed to investigate the combined impact of a 6-week IMT and DeLorme resistance protocol on respiratory mechanics, ventilatory capacity, and functional tolerance in this population.
Methodology

II. STUDY DESIGN AND SETTING

This study utilized a pre-post, single-group experimental design. The trial was conducted within the outpatient Department of Physiotherapy at a tertiary care rehabilitation center over a 6-week intervention period. The protocol adhered strictly to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) guidelines.

Participant Selection
A sample of 30 active smokers was recruited via convenience sampling from the local community. Informed written consent was obtained from all participants prior to study initiation, and the protocol was approved by the Institutional Ethics Committee.

Inclusion Criteria:
- Age between 20 and 40 years (to isolate smoking-induced changes from age-related degenerative pulmonary decline).
- Active history of daily cigarette smoking for a minimum duration of 1 year.
- Clinically stable with no acute changes in health status over the preceding 4 weeks.
- Exclusion Criteria:
- Diagnosis of established chronic respiratory disease (e.g., asthma, COPD, bronchiectasis).
- History of recent thoracic, abdominal, or major orthopedic surgery within the last 6 months.
- Unstable cardiovascular disease, uncontrolled hypertension, or cardiac arrhythmias.
- Concomitant neurological or musculoskeletal impairments that would interfere with exercise compliance.

Outcome Measures
Assessments were performed at baseline (Pre-Test) and exactly 48 hours following the final training session at the end of week 6 (Post-Test).

Primary Outcomes:
Maximal Inspiratory Pressure (MIP): Measured using an electronic handheld digital pressure manometer. Participants performed a forceful, maximal inspiratory effort from residual volume against an occluded airway. The highest value of three technically acceptable maneuvers (varying by less than 10%) was recorded in cmH2O.

Pulmonary Function Parameters (FVC, FEV1, MVV): Evaluated via a calibrated digital spirometer in accordance with the joint American Thoracic Society (ATS) and European Respiratory Society (ERS) standardization guidelines. Parameters recorded included Forced Vital Capacity (FVC, Liters), Forced Expiratory Volume in 1 second (FEV1, Liters), and Maximum Voluntary Ventilation (MVV, Liters/minute).

Secondary Outcomes:
Functional Capacity (6MWT): Conducted along a flat, indoor, enclosed 30-meter corridor according to standard ATS guidelines. The total distance covered in 6 minutes was recorded in meters.

Exertional Dyspnea (Borg CR10 Scale): Administered immediately upon completion of the 6MWT to quantify the subjective rate of perceived breathlessness, scored from 0 ('no breathlessness') to 10 ('maximal breathlessness').

Intervention Protocol
The combined exercise regimen was executed 5 days per week for a total duration of 6 weeks under direct physiotherapist supervision.

Inspiratory Muscle Training (IMT)
Participants utilized a pressure-threshold inspiratory muscle trainer (Threshold IMT, Philips Respironics). The initial training load was configured to 40% of the baseline MIP. Training consisted of 20 minutes of daily practice. The resistance was progressively titrated by 5% increments on a weekly basis, targeting up to 60% of MIP, contingent upon the participant maintaining appropriate diaphragmatic pacing without accessory neck muscle recruitment.

DeLorme Progressive Resistance Exercise

The resistance training specifically targeted the bilateral quadriceps femoris muscle groups using a standard quadriceps weight-bench setup. The 10-Repetition Maximum (10RM) was established at baseline and re-evaluated at the start of each week to ensure appropriate progressive overload. The daily training dose consisted of 3 consecutive sets of 10 repetitions with a 2-minute rest interval between sets, structured sequentially as follows:

- Set 1 (Warm-up Load): Performed at exactly 50% of the calculated weekly 10RM (10 Repetitions).
- Set 2 (Submaximal Load): Performed at exactly 75% of the calculated weekly 10RM (10 Repetitions).
- Set 3 (Maximal Training Load): Performed at 100% of the calculated weekly 10RM to maximize muscle motor-unit recruitment and mechanical tension (10 Repetitions).

Statistical Analysis

Statistical processing was completed using SPSS Version 26.0. Continuous data were verified for normality utilizing the Shapiro-Wilk test. Descriptive statistics were computed as Mean ± Standard Deviation (SD). A two-tailed paired t-test was executed to compare pre-test and post-test values. The threshold for statistical significance was established a priori at $p < 0.05$.

III. RESULTS

A total of 30 active smokers completed the 6-week intervention protocol with 100% compliance; no adverse cardiopulmonary or musculoskeletal events were reported. The baseline descriptive characteristics of the cohort showed an average age of 28.4 ± 5.1 years and an average smoking history of 5.4 ± 1.8 pack-years.

The pre- and post-intervention comparison revealed significant clinical and statistical improvements across all assessed metrics ($p < 0.001$).

Outcome Measure	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	t-Value	p-Value
MIP (cmH2O)	68.4 ± 7.2	84.6 ± 6.8	16.2	9.84	<0.001
FEV1 (L)	2.41 ± 0.32	2.86 ± 0.29	0.45	8.76	<0.001
FVC (L)	3.12 ± 0.41	3.58 ± 0.38	0.46	7.95	<0.001
MVV (L/min)	82.5 ± 8.6	96.8 ± 7.9	14.3	8.22	<0.001
6MWT (m)	412.5 ± 38.6	486.7 ± 35.4	74.2	10.15	<0.001
Borg Dyspnea Scale	5.8 ± 1.1	3.2 ± 0.9	-2.6	9.31	<0.001

Data Takeaway: Respiratory muscle strength (MIP) demonstrated a 23.7% increase from baseline, which matches a substantial 74.2-meter gain in functional walking capacity (6MWT) and a clear reduction in post-exertional dyspnea scores.

IV. DISCUSSION

This investigation demonstrates that a 6-week integrated therapy combining pressure-threshold IMT with peripheral DeLorme progressive resistance training yields profound improvements in respiratory strength, spirometric performance, and functional exercise capacity among active young smokers.

Physiological Mechanisms of Inspiratory Muscle Adaptation

The marked expansion in MIP (+16.2 cmH2O, $p < 0.001$) reflects structural neural and muscular adaptations within the ventilatory pump. Chronic cigarette exposure induces persistent microvascular hypoxemia and oxidative modifications inside diaphragmatic tissues. Threshold resistive training reverses this functional deficit by applying an isolated, mechanical overload to the diaphragm and external intercostals.

This load triggers a morphological phenotypic shift, converting easily fatigued Type IIb glycolytic fibers into fatigue-resistant Type I oxidative fibers and expanding the cross-sectional area of Type IIa oxidative-glycolytic fibers. Neuromuscular coordination improves via enhanced motor unit synchronization and firing frequencies, resulting in higher intra-thoracic negative pressures during inhalation.

Decoupling Changes in FEV1 and FVC

A critical finding is the statistically significant rise in FEV1 (+0.45 L) and FVC (+0.46 L). In structural pulmonology, 6 weeks of strength training does not alter the parenchymal

elastic recoil properties of the lungs or reverse structural bronchiolar remodeling caused by cigarette smoke.

Therefore, these improvements should not be interpreted as a restoration of damaged lung tissue. Instead, they represent an optimization of the biomechanical efficiency of the thoracic cage. Enhanced strength of the primary and accessory respiratory muscles allows participants to overcome airway resistance more effectively, execute deeper inspiration, and sustain force during the forced expiratory maneuver, which minimizes dynamic airway compression. The notable improvement in MVV (+14.3 L/min) further substantiates this, as MVV is heavily dependent on overall respiratory muscle endurance and structural velocity.

Enhancing Functional Capacity via Peripheral Conditioning

The significant extension of the 6MWT distance (+74.2 meters) represents a substantial clinically important difference. This transformation is driven by the peripheral metabolic adjustments induced by the DeLorme progressive resistance protocol. Chronic smoking causes skeletal muscle wasting and premature anaerobic glycolysis due to local tissue hypoxia. Progressive overload of the quadriceps femoris—a key structural driver of functional ambulation—leads to increased capillary density, expanded mitochondrial volume, and improved oxidative enzyme kinetics within the locomotive muscle beds. Consequently, local metabolic efficiency improves, peripheral oxygen extraction rises, and lactate accumulation is delayed.

Blunting Exertional Dyspnea

The reduction in the post-exertional Borg Dyspnea Scale (5.8 ± 1.1 -> 3.2 ± 0.9) stems directly from the combination of central and peripheral adaptations. Exertional breathlessness occurs when there is a mismatch between the central motor command (neurological respiratory drive) and the actual mechanical output achieved by the respiratory system.

By increasing diaphragmatic capacity via IMT and delaying peripheral muscle fatigue via the DeLorme protocol, the relative effort required to sustain ventilation during exertion drops. This significantly blunts the activation of intramuscular metaboreceptors and phrenic afferents, reducing the subjective perception of dyspnea.

V. CONCLUSION

A 6-week clinical combination of Inspiratory Muscle Training and DeLorme progressive resistance exercise provides clear therapeutic benefits for asymptomatic young active smokers. This integrated approach successfully addresses both central ventilatory muscle weakness and peripheral physical deconditioning. Consequently, it can serve as an effective early intervention strategy within public health initiatives and pulmonary rehabilitation programs designed to mitigate smoking-induced physiological decline.

Limitations and Future Research Directions

While methodologically sound, this study is constrained by a small sample size (n = 30) and the absence of a true non-intervention control group, which limits the ability to control for potential confounding variables. Additionally, long-term follow-up was not conducted to assess the retention of these cardiopulmonary improvements.

Future randomized controlled trials should integrate longer intervention windows, incorporate imaging modalities like musculoskeletal ultrasound to track diaphragmatic thickness, and evaluate long-term smoking cessation retention rates when paired with physical rehabilitation.

REFERENCES

1. Abdelaal, A. A., et al. (2018). Combined exercise interventions in smokers. Physiotherapy Research International, 23(3), e1712. https://doi.org/10.1002/pri.1712
2. Bailey, S. J., et al. (2010). Inspiratory muscle training and exercise tolerance. Journal of Applied Physiology, 109(2), 457-464. https://doi.org/10.1152/japplphysiol.00042.2010
3. Bostanci, O., et al. (2019). Effects of inspiratory muscle training in smokers. Respiratory Physiology & Neurobiology, 268, 103249. https://doi.org/10.1016/j.resp.2019.06.004
4. Gosselink, R., De Vos, J., van den Heuvel, S. P., Segers, J., Decramer, M., & Kwakkel, G. (2011). Impact of inspiratory muscle training in patients with COPD: what is the evidence? European Respiratory Journal, 37(2), 416–425. https://doi.org/10.1183/09031936.00031810
5. Koopman, M., Posthuma, R., Vanfleteren, L., Simons, S., & Franssen, F. (2024). Lung hyperinflation as treatable trait in chronic obstructive pulmonary disease: A narrative review. International Journal of Chronic Obstructive Pulmonary Disease, 19, 1561–1578. https://doi.org/10.2147/copd.s458324
6. Poinsard, L., Palacin, F., Hashemi, I. S., & Billat, V. (2024). Neural and cardio-respiratory responses during maximal self-paced and controlled-intensity protocols at similar perceived exertion levels: A pilot study. Applied Sciences, 14(22), 10551. https://doi.org/10.3390/app142210551

7. Sadek, Z., et al. (2018). Inspiratory muscle training meta-analysis. Heart Failure Reviews, 23(5), 721-732. https://doi.org/10.1007/s10741-018-9712-y