

Feasibility And Preliminary Effects Of Inspiratory Muscle Training In Hindustani Classical Vocalists: A Pilot Study

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ABSTRACT

Background: Hindustani classical singing requires exceptional breath control and sustained phonation. While Inspiratory Muscle Training (IMT) is known to enhance ventilatory capacity in clinical and athletic populations, its efficacy within the specific pedagogical framework of Indian classical vocalists remains under-explored.

Methods: A pilot study was conducted with 12 trained Hindustani vocalists. Participants underwent a targeted IMT protocol. Assessments included Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), Peak Expiratory Flow Rate (PEFR), and Tidal Volume (TV) via spirometry. Ventilatory endurance was measured through Maximal Voluntary Ventilation (MVV) and phonatory capacity via Maximum Phonation Time (MPT). Data were analyzed using paired t-tests and Cohen's d.

Results: Significant improvements were observed across key parameters. FVC increased from 2.50±0.53 L to 2.78±0.55 L (p=0.0002, d=1.54), and FEV1 rose from 2.41±0.54 L to 2.65±0.54 L (p=0.0017, d=1.19). The most substantial gains occurred in MVV, which increased by 15.25 L/min (p<0.0001, d=1.89), and MPT, which improved from 12.75±2.29 s to 19.33±2.78 s (p<0.0001, d=4.48). PEFR showed a medium effect size (d=0.55) but was not statistically significant (p=0.082). The FEV1/FVC ratio remained stable.

Conclusion: Structured IMT is highly feasible and effective for Hindustani vocalists, yielding transformative improvements in phonatory duration and respiratory endurance. These findings suggest IMT provides a robust physiological foundation for enhancing vocal performance and should be considered an adjunct in vocal pedagogy and pulmonary physiotherapy.

Keywords: Inspiratory Muscle Training, Hindustani Classical Vocalists, Maximum Phonation Time, Pulmonary function

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INTRODUCTION

Inspiratory muscle function plays a critical role in respiratory efficiency, breath control, and phonatory stability in vocalists. Singing, particularly in classical traditions such as Hindustani music, requires precise coordination between respiratory and laryngeal systems to sustain phonation and optimize vocal performance (Titze, 2006). Despite this, structured respiratory muscle training is not routinely integrated into vocal pedagogy.

Inspiratory Muscle Training (IMT) has been widely studied in clinical and athletic populations and has demonstrated improvements in pulmonary function, respiratory muscle strength, and exercise tolerance (Illi et al., 2012; McConnell & Romer, 2004). Improvements in parameters such as maximum voluntary ventilation (MVV), forced vital capacity (FVC), and inspiratory pressure have been consistently

reported following IMT interventions (Shei, 2018). However, evidence in trained vocalists remains limited, particularly within Indian classical music traditions.

Efficient breath control is also associated with improved phonatory performance, including increased maximum phonation time (MPT) and reduced vocal fatigue (Gething et al., 2004). Additionally, breathing-based interventions have been shown to influence psychological parameters such as performance anxiety, which is prevalent among musicians (Wells et al., 2012; Zaccaro et al., 2018).

Despite these findings, there is a lack of structured experimental studies investigating IMT in classical vocalists, especially in the context of Hindustani music. Therefore, a pilot study is warranted to evaluate feasibility, adherence, and preliminary effects prior to

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conducting a full-scale randomized controlled trial (Leon et al., 2011).

The present study aims to investigate the feasibility and preliminary effects of a structured IMT program on pulmonary function and vocal performance in Hindustani classical vocalists.

METHODOLOGY

Study Design

Methods and Materials

This study was designed as a prospective, single-arm pilot interventional study utilizing a pre–post design, an approach consistent with established methodological recommendations for assessing the feasibility of clinical interventions (Leon et al., 2011). Participants were recruited through purposive sampling from Musical Minds School of Music, New Delhi, India. To ensure a homogenous study population, inclusion criteria were restricted to Hindustani classical vocalists aged 18–40 years with a minimum of five years of formal training and a consistent practice schedule of at least three sessions per week. Candidates were excluded if they reported a history of respiratory or cardiovascular disorders, current smoking status, recent respiratory infections, or prior experience with respiratory muscle training (RMT).

The selection of a sample size of 12 participants was grounded in pilot study methodology, which prioritizes the evaluation of procedural feasibility and parameter estimation over the detection of statistically significant treatment effects. This specific cohort size aligns with the "rule of thumb" proposed by Julious (2005), which advocates for 12 participants per group to accurately estimate variability for future power calculations. Furthermore, this sample size falls within the recommended range of 10 to 30 participants identified as adequate for pilot and feasibility frameworks (Hertzog, 2008; Sim & Lewis, 2012). Previous investigations into inspiratory muscle training (IMT) utilizing small cohorts have successfully demonstrated both the feasibility of the intervention and preliminary physiological enhancements in respiratory function (Illi et al., 2012). Consequently, the current sample size was deemed sufficient to evaluate primary feasibility outcomes, participant adherence, and effect size estimation for subsequent large-scale trials.

Intervention

Participants underwent **Inspiratory Muscle Training (IMT)** using a threshold loading device.

- Frequency: 5 days/week
- Duration: 4 weeks
- Intensity: Perceived inspiratory effort and progressive resistance adjustment, (Hill et al., 2010; Van Hollebeke et al., 2020)
- Repetitions: 30 breaths per session
- Device: PowerBreath

The training protocol was based on established IMT guidelines (McConnell & Romer, 2004).

Procedure

1. Baseline assessment
2. IMT intervention (4weeks)

3. Post-intervention assessment

OUTCOME MEASURES

Primary Outcome

- Maximum Voluntary Ventilation (MVV)
- Forced Vital Capacity (FVC)
- Forced Expiratory Volume 1 sec (FEV1)
- FEV1/FVC
- Peak Expiratory Flow Rate (PEFR)

Secondary Outcomes

- Maximum Phonation Time (MPT)

Feasibility Outcomes

- Recruitment rate
- Adherence (%)
- Dropout rate
- Participant feedback

Results

Statistical Analysis

Data were analyzed to compare respiratory and phonatory parameters before and after the Inspiratory Muscle Training (IMT) intervention. For all parameters, a paired t-test was employed to determine statistical significance, with the alpha level set at $\alpha = 0.05$. The magnitude of the treatment effect was quantified using Cohen's d, interpreted as small (0.2), medium (0.5), or large (≥ 0.8).

Respiratory Function and Lung Volumes

The intervention yielded significant improvements in several key markers of respiratory function. The results for spirometry and ventilatory capacity are summarized in Table 1.

There was a statistically significant increase in Forced Vital Capacity (FVC), which rose from 2.50 ± 0.53 L to 2.78 ± 0.55 L ($p = 0.0002$), representing a large effect size ($d = 1.54$). Similarly, Forced Expiratory Volume in 1 second (FEV1) improved significantly from 2.41 ± 0.54 L to 2.65 ± 0.54 L ($p = 0.0017$, $d = 1.19$). Notably, the FEV1/FVC ratio remained stable, changing from $96.50 \pm 5.26\%$ to $95.51 \pm 4.11\%$ ($p = 0.5714$), indicating that the increases in volume were proportional and did not adversely affect airway patency.

The most substantial improvement among respiratory parameters was observed in Maximal Voluntary Ventilation (MVV), which increased by a mean difference of 15.25 L/min (66.33 ± 34.68 L/min to 81.58 ± 36.22 L/min, $p < 0.0001$). This change corresponded to an extremely high effect size ($d = 1.89$), suggesting a robust enhancement in respiratory muscle endurance. Furthermore, Tidal Volume (TV) showed a significant increase from 1.15 ± 0.54 L to 1.60 ± 0.43 L ($p = 0.0006$, $d = 1.37$).

While Peak Expiratory Flow Rate (PEFR) showed a positive trend, increasing by 0.80 L/s, this change did not reach statistical significance ($p = 0.0824$). However, the calculated Cohen's d of 0.55 indicates a medium effect size, suggesting a meaningful clinical trend that might reach significance with a larger sample size.

Phonatory Performance

Maximum Phonation Time (MPT) demonstrated the most dramatic response to the intervention. As shown in Table 2, MPT increased significantly from 12.75 ± 2.29 seconds at baseline to 19.33 ± 2.78 seconds post-intervention. This mean improvement of +6.58 seconds

was highly significant (p < 0.0001) and was associated with a "huge" effect size (d = 4.48), indicating a transformative impact on the participants' ability to sustain phonation through improved respiratory support.

Table 1: Changes in Respiratory and Spirometric Parameters (n=12)

Parameter	Pre-Intervention (Mean ± SD)	Post-Intervention (Mean ± SD)	Mean Diff.	p-value	Cohen's d	Interpretation
FVC (L)	2.50 ± 0.53	2.78 ± 0.55	+0.27	0.0002	1.54	Large
FEV1 (L)	2.41 ± 0.54	2.65 ± 0.54	+0.24	0.0017	1.19	Large
FEV1/FVC (%)	96.50 ± 5.26	95.51 ± 4.11	-0.99	0.5714	-0.17	Negligible
PEFR (L/s)	5.69 ± 1.91	6.48 ± 1.43	+0.80	0.0824	0.55	Medium
MVV (L/min)	66.33 ± 34.68	81.58 ± 36.22	+15.25	<0.0001	1.89	Large
TV (L)	1.15 ± 0.54	1.60 ± 0.43	+0.46	0.0006	1.37	Large

Table 2: Changes in Phonatory Parameters (n=12)

Parameter	Pre-Intervention (Mean ± SD)	Post-Intervention (Mean ± SD)	Mean Diff.	p-value	Cohen's d	Interpretation
MPT (sec)	12.75 ± 2.29	19.33 ± 2.78	+6.58	<0.0001	4.48	Huge Effect

Feasibility Outcomes

The feasibility of the Inspiratory Muscle Training (IMT) protocol was assessed based on recruitment efficiency, participant adherence, attrition, and qualitative feedback. The results indicate that the intervention is highly viable and well-tolerated by Hindustani classical vocalists.

Recruitment Rate

A total of 15 Hindustani classical vocalists were screened over a period of four weeks. Of these, 12 met the inclusion criteria and were enrolled in the study, resulting in a recruitment rate of 80%. Those excluded primarily did not meet the criteria due to recent respiratory infections or scheduling conflicts with professional performances.

Adherence (%)

Participant adherence to the prescribed IMT protocol was excellent. Adherence was calculated as the percentage of completed training sessions relative to the total number of sessions assigned over the intervention period. The mean adherence rate was 94.2%, with all participants completing at least 90% of the prescribed sessions. This high level of engagement suggests that the training was perceived as highly relevant to their professional vocal practice.

Dropout Rate

There were no dropouts during the course of this study. All 12 participants (100%) who were enrolled successfully completed the entire training protocol and all post-intervention assessments. The 0% dropout rate demonstrates the high acceptability of the IMT intervention and suggests that the training volume and intensity were appropriate for professional vocalists

without causing excessive fatigue or interference with their daily practice.

Participant Feedback

Qualitative feedback collected through post-study exit interviews was overwhelmingly positive. Key observations reported by the participants included:

- **Improved Vocal Sustain:** 100% of participants reported an increased ability to sustain long melodic phrases (alaaps) with greater stability and less perceived effort.
- **Enhanced Breath Support:** Participants noted a subjectively "stronger" breath foundation and better control over their airflow during challenging high-pitch compositions.
- **Practical Integration:** The IMT device was described as portable and easy to use, making it a convenient addition to their traditional "riyaz" (vocal practice) routine.
- **Safety and Tolerability:** No adverse events were reported. While a few participants (n=2) noted mild, transient lightheadedness during the initial sessions, this was successfully managed by refining their breathing technique under supervision.

Table 3: Feasibility Outcomes

Feasibility Metric	Value / Result
Recruitment Rate	80% (12 out of 15 screened)
Adherence Rate	94.20%
Dropout Rate	0%
Completion Rate	100%

Adverse Events	None reported
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Discussion

The findings of this study demonstrate that a targeted Inspiratory Muscle Training (IMT) program yields substantial improvements in both respiratory mechanics and phonatory endurance. The most striking results were observed in Maximal Voluntary Ventilation (MVV) and Maximum Phonation Time (MPT), both of which exhibited large to "huge" effect sizes, suggesting that the intervention effectively enhanced the physiological capacity for sustained airflow and vocal control.

Enhancement of Respiratory Volumes and Capacity

The significant increases in Forced Vital Capacity (FVC) and Forced Expiratory Volume in 1 second (FEV1) indicate that the training regimen successfully increased the volume of air participants could mobilize. While some meta-analyses in clinical populations have suggested that IMT primarily improves muscle strength (Maximal Inspiratory Pressure) rather than static lung volumes (HajGhanbari et al., 2013), the current findings align with studies suggesting that high-intensity training can improve lung compliance and accessory muscle recruitment, thereby increasing FVC and Tidal Volume (TV) (Reyes et al., 2019).

The stability of the FEV1/FVC ratio is a critical clinical finding. Because this ratio remained unchanged despite the increase in absolute volumes, it suggests that the improvements were balanced across both the capacity and flow components of the respiratory system, with no induction of obstructive or restrictive patterns.

Respiratory Muscle Endurance (MVV)

The improvement in MVV ($d = 1.89$) was the most significant respiratory outcome. MVV is a dynamic measure that reflects not only muscle strength but also the endurance and coordination of the entire respiratory pump. The large effect size observed here suggests that participants significantly improved their ability to sustain high-intensity ventilation without fatigue. This is consistent with previous research indicating that IMT specifically targets the diaphragm and external intercostals, leading to delayed metabolic reflex activation and improved ventilatory efficiency (Illi et al., 2012).

Phonatory Performance (MPT)

The "huge" effect size recorded for MPT ($d = 4.48$) represents a transformative clinical outcome. MPT is a direct indicator of the efficiency of the phonatory system and its coordination with respiratory support. The increase of over 6.5 seconds suggests that by strengthening the inspiratory muscles, participants were able to achieve a higher lung volume at the start

of phonation and maintain better subglottal pressure throughout the task.

These results corroborate recent findings by AlDhahi (2025), who reported that even acute inspiratory muscle warm-ups could significantly prolong vocal durations and improve vocal efficiency. Similarly, studies on individuals with respiratory weakness have shown that increasing the "respiratory fuel" through IMT directly translates into longer sustained phonation and better vocal range (Reyes et al., 2019). The magnitude of the change in the current study suggests that IMT may be an exceptionally potent intervention for individuals whose professional or daily life requires sustained vocal output.

Limitations and Trends

While Peak Expiratory Flow Rate (PEFR) showed a medium effect size ($d = 0.55$), it did not reach statistical significance ($p = 0.082$). This is likely a result of the small pilot sample size ($n = 12$). Given the positive trend, it is highly probable that a larger cohort would yield significant results for expiratory flow, as improved inspiratory capacity often leads to better elastic recoil during the initial phase of expiration.

Conclusion

In conclusion, the IMT program used in this study appears to be highly feasible and effective at improving ventilatory endurance and phonatory duration. The integration of improved lung volumes (FVC, TV) and enhanced dynamic endurance (MVV) provides a robust physiological foundation for the dramatic improvements seen in vocal performance. These findings support the use of IMT as a valuable adjunct therapy for both respiratory rehabilitation and vocal training.

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