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Comparison of the Effect of Inspiratory Muscle Training and Incentive Spirometer on Pulmonary Function, Respiratory Muscle Strength, Dyspnea and Asthma Control in Asthmatic Patients

Rinki Singh[1], Dimple Choudhry[2], Dhruva Chaudhary[3], Anshu Kumari[4]

[1]MPT scholar, College of Physiotherapy, Pt B.D S. PGIMS Rohtak, Haryana, India
[2]Associate Professor, College of Physiotherapy Pt B.D S. PGIMS Rohtak, Haryana, India
[3]Sr. Professor Department of Pulmonary Medicine, Pt B.D S. PGIMS Rohtak, Haryana, India
[4]Clinical Therapist, Department of critical care, Positron Hospital Sec-35, Rohtak, Haryana, India

Corresponding Author: Dimple Choudhry

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ABSTRACT

This study aimed to compare the effects of inspiratory muscle training (IMT) and the incentive spirometer (IS) on pulmonary function, respiratory muscle strength, dyspnea, and asthma control in patients with asthma. 70 asthmatic patients (30–50-year-old) were randomly assigned to two groups: Group 1 (n=35), which received IMT, and Group 2 (n=35), which received IS for a 6-week intervention period. Outcome measurements were performed before and after the intervention, including the spirometry data, Maximal inspiratory and expiratory pressure (MIP and MEP), asthma control test, asthma control questionnaire, dyspnea, were recorded. IMT showed superior improvements in pulmonary function, respiratory muscle strength, and exercise tolerance compared to IS. Significant improvements were observed in FVC (forced vital capacity), FEV1(forced expiratory volume), PEFR (peak expiratory flow rate), MIP, and dyspnea ($p < 0.05$) in the IMT group at 6 weeks. In contrast, IS did not produce similar gains in lung function or respiratory muscle strength. Dyspnea was significantly reduced in the IMT group ($p < 0.05$). No significant differences in oxygen saturation, or heart rate were observed between the two groups. IMT outperformed IS in improving pulmonary function, reducing dyspnea, and enhancing respiratory muscle strength in asthmatic patients. The findings suggest that IMT could be a valuable adjunct therapy in asthma management, given its effectiveness, IMT should be considered a priority intervention alongside traditional asthma treatments to optimize patient outcomes.

Keywords: Asthma, inspiratory muscle training, incentive spirometry, pulmonary function, dyspnea, respiratory muscle strength

INTRODUCTION

Asthma is a chronic inflammatory airway condition marked by airflow obstruction and heightened sensitivity. Globally, over 300 million individuals are affected by asthma, with prevalence rates varying between 1% to 18% across different countries[1]. As per the 2011 census projections, the Indian population aged ≥15 years and ≥35 years is estimated at 845 million and 415 million. Respectively Corresponding to 2.04% population prevalence, nearly people aged ≥15 years have asthma[2]. Consequently, it is essential to investigate cost-effective alternatives of traditional asthma treatments, as well as adjunctive therapies that can enhance existing management strategies and potentially reduce the severity of the disease.

Asthma is characterized by fluctuating symptoms such as wheezing, shortness of breath, chest tightness, and cough, along with varying expiratory airflow limitation. Both the symptoms and the degree of airflow restriction can change over time and in intensity. Common triggers for these variations include exposure to allergens or irritants, changes in weather, and viral respiratory infections. Symptoms and airflow limitations may resolve on their own or in response to medication, and may sometimes be absent for weeks or that months at a time[3]. Patients can also experience acute exacerbations of asthma that may be life-threatening and impose a significant burden to patients and the community[4]. In asthma there is with heightened airway responsiveness to various stimuli and chronic airway inflammation[5]. Incentive spirometer (IS) is a mechanical breathing device designed to encourage patients to take long, slow deep breaths that mimic natural sighing, providing positive visual feedback. It is user-friendly and promotes a prolonged phase of effective inspiration, allowing for more controlled airflow and increased motivation to practice. There are no known side effects associated with the use of an incentive spirometer.[6] It is cost-effective and requires no supervision once the individuals are trained in its use. Incentive spirometers come in two types: volume-oriented, which measures the volume of inspiration, and flow-oriented, which measures the flow rate.

Inspiratory muscle training is a technique designed to enhance the strength and endurance of the diaphragm and accessory muscles used during inspiration. This training works by having the inspiratory muscles adapt to overcome specific resistance[7]. In patients with asthma, the anticipated effects of inspiratory muscle training include increased diaphragm thickness and strength, reduced exertion dyspnea, and a decreased oxygen cost of breathing.[1]Inspiratory muscle training (IMT) enhances both respiratory muscle strength and functional exercise capacity[8,9]. The devices used for IMT primarily include pressure-based and volume-based loading devices. Threshold IMT, a pressure-based loading device, is the most used inspiratory muscle trainer for improving the strength and endurance of respiratory muscles[10].

Breathing exercises serve as a complementary and non-invasive treatment that can positively impact conditions such as insomnia, cardiac autonomic function, depression, anxiety, high blood pressure, and lung diseases[11,12]. These exercises have been shown to enhance both body and brain function, bridging the gap between consciousness and unconsciousness, as well as balancing sympathetic and parasympathetic system activity. As a result, breathing exercises are regarded as an effective tool for promoting relaxation.[13,14]The aim of this study was to help individuals develop a more appropriate breathing pattern characterized by longer exhalations and a slower respiratory rate, thereby reducing hyperventilation and hyperinflation.

MATERIALS & METHODS

The study was a prospective and randomized controlled trial with two arms that compared the incentive spirometer and inspiratory muscle training and ethically approved by institutional ethical committee of Pt. B.D. Sharma University of Health Science, Rohtak with reference to letter No. BREC/23/TH-Physiotherapy 40 dated 20.07.2024 Seventy asthma patients aged between 30 to 50 years who had been diagnosed with asthma for six months were enrolled in study after obtaining consent. Chronic obstructive pulmonary disease or other lung disease, bronchopneumonia and broncho-pulmonary dysplasia, Unstable asthma and history of neurological, musculoskeletal disorder and peripheral vascular diseases were excluded from study. Patient randomly assigned two intervention group (Group A and Group B) with 35 patients in each group by Using Lottery method. Group A: Incentive Spirometer (IS) + Conventional Therapy Group B: Inspiratory Muscle Training (IMT) + Conventional Therapy. Group A (IS group) received 30-min exercise session one times per day,3 days per week, for 6 weeks[15]. The participants were instructed to exhale fully, then inhale slowly through the mouthpiece until the parents can't inhale any further. Goal: Elevated the balls in the IS devices three columns (each representing different levels of inspiratory flow), instruct the patients to hold their breath for 2-3 seconds, then slowly exhale. 10-15 minutes per session, performing 10 repetitions with rest intervals of 30 seconds. After the IS training focused on breathing exercise, these exercises were followed by respiratory exercise and exercise to strengthen the abdomen and diaphragmatic muscles. All of the exercises were associated with diaphragmatic breathing, pursed lip breathing and chest expansion. In pursed-lip breathing, the air is inspired through the nose, causing the abdomen to inflate; then, the air is exhaled through the mouth with semi-open lips. The patients were encouraged to breath out'' the entire air contents of the lungs''.

Group B (IMT group) received 30-min session one times per day, 3 days per week, for 6 weeks [15]. The IMT device is sterilized and the resistance set at 39 cmH20, the participants were instructed to inhale deeply (maximal inspiration), holding for 2-3 seconds at full inspiration, then exhale slowly. The intensity starts at a lower resistance, increasing as the patient adapts, aiming to perform 10 deep breaths at maximal resistance, gradually increasing 20 breaths. This procedure was repeated three times. A nose clip was worn during all breaths, and participants were instructed to maintain a low breathing frequency to avoid hyperventilation. After the IMT training focused on breathing exercise. Participants of both the groups were assessed at baseline, 3rd week and at 6th week for all the parameters. Measurements of pulmonary function was done by PFT (Pulmonary function test)

Forced expiratory volume in one second (FVC1), forced vital capacity (FVC), peak expiratory flow,FVC/FEV1.All the test were repeated three times, from which two sets of data were chosen for this analysis. Asthma control Assessment was done by Asthma Control Test (AST), Asthma Control Questionnaire (ACQ) and Dyspnea-Modified Borg Scale.

Evaluation of respiratory Muscle Strength was measured the Maximal inspiratory pressure or maximal expiratory pressure.

Equations

Model 1: MIP (cmH_2O) = 132.022+6.655 x PEF (L/s) - 102.472 x FEV1/FVC ratio + 11.285 x Sex (female = 0, male=1)

Model 2: MEP (cmH_2O) = 72.989+8.44 x PEF (L/s) = 10.496 x MMEF (L/s) + 17.303 x Sex (female 0, male = 1)

STATISTICAL ANALYSIS

Statistical analysis of data was done by using SPSS software version 21.0. Categorial variables were expressed as frequency and percentages. Continuous variables were presented as mean $\pm$ SD. For within group analysis, repeated measure of ANOVA post hoc analysis by Turkey's were used was to evaluated the effect of treatment. For between group analysis, independent t-test were used. For all statistical test, a p-value < 0.05 was taken as a significant difference.

RESULT

A total of 70 asthmatic patients were included in the study who randomly divided into group 1 and group 2. Both the groups were evaluated for pulmonary function, dyspnea, fatigue, heart rate, oxygen saturation and chest expansion. The table 1.1 shows age wise distribution of participants. The mean age of patients in Group A was 40±9.04 years and 40±8.42 years in Group B. At baseline, no statistically significant difference was found between both groups (p=0.731).

Table 1.1 Age wise distribution of participants both incentive spirometer and inspiratory muscle training

Variable	Group A (IS) (n=30) (Mean ±SD)	Group B (IMT) (n=30) (Mean± SD)	p-value
Age (years)	40±9,04	40±8,42	0.713^{NS}
NS Non significant			

Table 1.2 shows that Turkey's post hoc analysis for multiple comparison of all variable within group in Group A and B at baseline, 3 weeks and 6 weeks.

Table 1.2 show within group analysis of all variable in IS group (Group A) and IMT group (Group B)

Variable	Group A				Group B			
	Mean + SD		Mean difference	P value	Mean + SD		Mean difference	P value
FVC	Baseline 2.79±1.00	3weeks 2.80±1.05	0.009	1.000^{NS}	Baseline 3.10±1.24	3 weeks 3.19 ±1.18	.009	0.050*
	3weeks 2.80±1.05	6weeks 2.84±1.03	0.047	0.081^{NS}	3 weeks 3.19 ±1.18	6 weeks 3.20 ±1.17	.011	0.050*
	Baseline 2.79±1.00	6weeks 2.84±1.03	1.073	1.000^{NS}	Baseline 3.10±1.24	6 weeks 3.20 ±1.17	.101	0.028*
FEV1	Baseline 5.00±12.63	3 weeks 3.93±8.78	1.073	1.000^{NS}	Baseline 2.34±1.06	3 weeks 2.43±1.05	.084	0.013 *
	3 weeks 3.93±8.78	6 weeks 2.03±8.54	1.898	0.648^{NS}	3 weeks 2.43±1.05	6 weeks 2.47±1.01	.048	0.107^{NS}
	Baseline 5.00±12.63	6 weeks 2.03±8.54	2.971	0.536^{NS}	Baseline 2.34±1.06	6 weeks 2.47±1.01	.132	0 .000**
FEV1\FVC	Baseline 59.74±20.79	3 weeks 63.90±17.02	4.159	0.125*	Baseline 68.74±18.84	3 weeks 71.53±16.15	2.79	1.000^{NS}
	3 weeks 63.90±17.02	6 weeks 62.75±18.58	1.151	1.000^{NS}	3 weeks 71.53±16.15	6 weeks 72.98±10.92	4.19	1.000^{NS}
	Baseline 59.74±20.79	6 weeks 62.75±18.58	3.007	0.942^{NS}	Baseline 68.74±18.84	6 weeks 72.98±10.92	3.98	0.648^{NS}
PEFR	Baseline 4.93±2.23	3 weeks 5.15±2.13	0.22	0.320^{NS}	Baseline 5.67±2.49	3 weeks 6.23±2.55	.557	0.028*
	3 weeks	6 weeks	0.71	1.000^{NS}	3 weeks	6 weeks 6.36±2.56	.132	0.230^{NS}

	5.15±2.13	5.86±2.00			6.23±2.55			
	Baseline 4.93±2.23	6 weeks 5.86±2.00	0.93	0.648NS	Baseline 5.67±2.49	6 weeks 6.36±2.56	.689	0.008**
MIP	Baseline 62.57±17.19	3 weeks 58.14±13.82	4.43	0.125*	Baseline 53.68±21.74	3 weeks 54.32±13.86	0.649	1.000NS
	3 weeks 58.14±13.82	6 weeks 60.82±15.54	1.876	0.567NS	3 weeks 54.32±13.86	6 weeks 57.82±12.54	47.805	0.000**
	Baseline 62.57±17.19	6 weeks 60.82±15.54	1,985	1.000NS	Baseline 53.68±21.74	6 weeks 57.82±12.54	3.500	0.000**
MEP	Baseline 33.77±155.74	3 weeks 34.31±155.49	1.021	1.000NS	Baseline 34.95±15.218	3 weeks 40.83±10.759	61.88	1.000NS
	3 weeks 34.31±155.49	6 weeks 40.60±21.50	6.29	1.000NS	3 weeks 40.83±10.759	6 weeks 45.75±18.640	9.92	1.000NS
	Baseline 33.77±155.74	6 weeks 40.60±21.50	7.43	1.000NS	Baseline 34.95±15.218	6 weeks 45.75±18.640	71.8	1.000NS
Dyspnea	Baseline 7.60±1.76	3 weeks 5.05±1.58	2.543	0.000**	Baseline 7.80±.994	3 weeks 5.17±1.29	2.629	0.000**
	3 weeks 5.05±1.58	6 weeks 2.88±1.58	2.171	0.000**	3 weeks 5.17±1.29	6 weeks 3.08±1.12	2.086	0.000**
	Baseline 7.60±1.76	6 weeks 2.88±1.58	4.714	0.000**	Baseline 7.80±.994	6 weeks 3.08±1.12	4.714	0.000**
AST	Baseline 18.08±2.62	3 weeks 14.51±1.48	3.571	0.000**	Baseline 19.74± 12.26	3 weeks 18.88± 12.40	.857	0.004**
	3 weeks 14.51±1.48	6 weeks 14.51±1.48	0.000	1.0NS	3 weeks 18.88± 12.40	6 weeks 18.88± 12.40	.000	1.00NS
	Baseline 18.08±2.62	6 weeks 14.51±1.48	3.571	0.000**	Baseline 19.74± 12.26	6 weeks 18.88± 12.40	.857	0.004**
ASTQ	Baseline 17.02±3.12	3 weeks 9.57±2.25	7.457	0.000**	Baseline 17.77± 13.92	3 weeks 14.25± 14.59	3.514	0.000**
	3 weeks 9.57±2.25	6 weeks 9.57±2.25	0.000	1.00NS	3 weeks 14.25± 14.59	6 weeks 14.25± 14.59	.000	1.00NS
	Baseline 17.02±3.12	6 weeks 9.57±2.25	7.457	0.000**	Baseline 17.77± 13.92	6 weeks 14.25± 14.59	3.514	0.000 **

NS- Non significant, ** Highly Significant

Table 1.3 shows comparison of all variable between incentive spirometer and inspiratory muscle training by using independent t-test at baseline, 3 weeks and 6 weeks.

Table 1.3 show between group analysis of all variable in IS group (Group A) and IMT group (Group B)

Variable	Duration	Group A	Group B	t- value	p-value
FVC	Baseline	2.79±1.00	3.10±1.24	1.160	0.250^{NS}
	3 weeks	2.80±1.05	3.19±1.18	1.473	0.145^{NS}
	6 weeks	2.84±1.03	3.20±1.17	1.358	0.179^{NS}
FEV1	Baseline	5.00± 12.63	2.34± 1.06	1.240	0.219^{NS}
	3 weeks	3.93±8.78	2.43 ± 1.05	1.003	0.319^{NS}
	6 weeks	2.03 ± .854	2.47 ± 1.01	1.994	0.050*
FEV1\FVC	Baseline	59.74± 20.79	68.74± 18.84	1.896	0.062^{NS}
	3 weeks	63.90±17.02	71.53 ± 16.15	1.923	0.05*
	6 weeks	62.75 ± 18.58	72.98 ± 10.92	2.809	0.00**
PEFR	Baseline	4.93± 2.23	5.67± 2.49	1.312	0.194^{NS}
	3 weeks	5.15±2.13	6.23 ± 2.55	1.923	0.05*
	6 weeks	5.86 ± 2.00	6.36 ± 2.59	.915	0.363^{NS}
MIP	Baseline	81.23± 17.327	75.03±17.814	1.498	0.139^{NS}
	3 weeks	91.62±6.626	93.18±10.809	0.739	0.462^{NS}
	6 weeks	95.26 ± 9.315	104.94±7.676	4.811	0.000**
MEP	Baseline	33.77± 15.74	34.95± 15.21	0.009	0.993^{NS}
	3 weeks	34.31 ±15.49	96.83± 10.75	0.937	0.352^{NS}
	6 weeks	96.60± 21.50	10.75± 18.64	2.141	0.036*
Dyspnea	Baseline	7.60± 1.76	7.80± .994	.583	0.562^{NS}
	3 weeks	5.05±1.58	5.17 ± 1.29	.330	0.743^{NS}
	6 weeks	2.88 ± 1.58	3.08 ± 1.12	.609	0.544^{NS}
AST	Baseline	18.08± 2.62	19.74± 12.26	.782	0.437^{NS}
	3 weeks	14.51±1.48	18.88.25 ± 12.40	2.071	0.042*
	6 weeks	14.51±1.48	18.88.25 ± 12.40	2.071	0.042*
ASTQ	Baseline	17.02± 3.12	17.77± 13.92	-.308	0.759^{NS}
	3 weeks	9.57±2.25	14.25 ± 14.59	-1.877	0.065^{NS}
	6 weeks	9.57±2.25	14.25 ± 14.59	-1.877	0.065^{NS}
NS-non significant, ** significant					

DISCUSSION

The current study aimed to analyze the effect of 6 weeks inspiratory muscle training and incentive spirometer in asthmatic Patients. It was hypothesized that inspiratory muscle training and incentive spirometer would affect pulmonary function, dyspnea, fatigue, heart rate, oxygen saturation and chest expansions in asthmatic patients. Inspiratory muscle training shows significant benefits in asthmatic patients. IMT's shows significant effect in increasing forced expiratory volume (FEV1), forced vital capacity (FVC), and peak expiratory flow rate (PEFR) suggest enhanced lung function and airway patency. Additionally, IMT's positive impact on dyspnea and fatigue indicates improved respiratory muscle strength and endurance. In contrast, IS showed minimal improvements in these outcomes, highlighting its limited efficacy in addressing the complex respiratory and physiological needs of asthmatic patients. IMT can enhance inspiratory muscle strength and endurance, leading to improvements in lung volume and airway flow dynamics[1]. IMT may elicit subtle improvements in airway diameter and airflow limitation during exercise, thereby reducing dynamic hyperinflation and increasing exercise capacity. The rising mechanical action on the inspiratory muscles including external intercostals, which affirmatively have an accessory participation in expiration, caused greater thoraco-abdominal mobility, as a result of consequent mechanical reorganization of all of the muscles involved in respiration[16]. IMT involves resistance training on respiratory muscles while BTE is simply to educate patients with appropriate breathing patterns without resistance loads[1]. IMT has been shown to increase diaphragm thickness and increase the proportion of type I fibers and the size of the type II fibers in the accessory inspiratory muscles. Increases in muscle fiber cross-sectional area could reverse or delay the deterioration of inspiratory muscle function and improve inspiratory muscle economy[17]. Consequently, IMT could stimulate hypertrophy of the diaphragm and accessory inspiratory muscles, facilitating more force for a given level of respiratory muscle drive.[1] Significant improvement in dyspnea (measured by the Modified Borg Scale) was observed in both groups after 3 and 6 weeks, with IMT showing a more significant reduction by the 6th week. IMT likely improves inspiratory muscle strength, reducing the sensation of breathlessness during exertion[18]. MIP (Maximal Inspiratory Pressure) showed significant improvement in both groups, with Group B (IMT) showing more pronounced effects at 6 weeks. MEP (Maximal Expiratory Pressure) did not show consistent differences, suggesting that while inspiratory muscle training had a significant effect on inspiratory muscle strength, it did not impact expiratory pressures in the same way. IMT can strengthen the diaphragm and accessory inspiratory muscles, improving MIP and exercise tolerance and inspiratory pressures imposed on the airways may lead to reduced lung hyperinflation, and thus facilitate the action of the inspiratory muscles[18]. Lung hyperinflation, which causes an increase in final expiratory volume, is a characteristic of asthma. It happens because of the premature closing of small-caliber airways that increases the activity of the respiratory muscles at the end of exhalation[19]. In addition, IMT may offset the functional weakening of the inspiratory muscles that arises due to dynamic hyperinflation. Otherwise, that would lead to the recruitment of high-force-generating highly fatiguable accessory muscle fiber, which worsen the development of respiratory muscle fatigue. The reduction of inspiratory muscle fatigue may also have contributed to the improvement in exercise time to the limit of exercise tolerance by delaying the onset of the inspiratory muscle metaboreflex in asthma patients[20]. Both groups showed improvements in Asthma Control (AST) scores, but there were no significant differences between groups at baseline, 3 weeks, or 6 weeks. The Incentive Spirometer group showed a more consistent improvement in asthma control (p=0.04 at 6 weeks). This might be due to the broader focus of breathing exercises included in the IS protocol, which likely has a more immediate effect on improving asthma symptoms, while IMT showed improvements in specific areas like pulmonary function and dyspnea, but not as markedly in asthma control[21].

CONCLUSION

The study concludes that inspiratory muscle training (IMT) is more effective than the incentive spirometer (IS) in improving pulmonary function, reducing dyspnea, and enhancing physiological responses in individuals with asthma. IMT significantly strengthens respiratory muscles and enhances lung function, emphasizing its potential as a valuable adjunct therapy for asthma management. The findings suggest that incorporating IMT into rehabilitation programs can lead to better clinical outcomes, improved quality of life, and greater functional capacity for asthmatic patients. Therefore, IMT should be prioritized as a supplementary intervention alongside traditional treatments to optimize patient care.

Declaration by Authors

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